

## POIKILITIC ALBITE IN THE MICROCLINE OF GRANITIC PEGMATITES<sup>1</sup>

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### ABSTRACT

Small anhedral crystals of albite occur as unoriented and apparently corroded units enclosed in the large perthitic microcline crystals of some granite pegmatites. Such albite is called *poikilitic albite* (PA) because the resulting texture is clearly poikilitic; in similar fashion one may speak of the *perthitic albite* that occurs in microcline perthite. Textural evidence demonstrates that the PA crystals formed more or less contemporaneously with the host microcline crystals, and in some cases definitely earlier. In several deposits PA is cut by later perthitic albite (vein type). Thus not all of the latter can have been formed by a simple, relatively static unmixing process; significant transportation of perthitic albite material has occurred. These relationships deny the statement by Laves and Soldatos (1963) that the PA is developed by the action of later Na-bearing solutions.

### INTRODUCTION

From an extensive study of pegmatite perthites (27 out of 28 samples) made by single-crystal (precession) X-ray techniques, Laves and Soldatos (1963) interpret the relation of the perthitic albite to the host K-feldspar. This involves whether the latter was monoclinic or triclinic at the time of exsolution or recrystallization. They arrive at the following sequence of five stages:

- I. Formation of large monoclinic crystals containing Na-feldspar dissolved in K-feldspar.
- II. With sufficiently slow cooling, unmixing yields chiefly macroperthite (vein or braid) from the monoclinic sanidine host. The growth surfaces of the albite are roughly parallel to  $[c]$ . It is possible that some microperthite (string) forms at this stage, and in some cases as this continues to form it may develop into vein perthite.
- III. With more cooling, at about 500°C, the K-feldspar is converted to "orthoclase," a submicroscopically-twinned material containing triclinic domains. At this stage microperthite (film) is produced, as well as Type I cryptoperthite (perthite from the monoclinic state).

<sup>1</sup> This paper was submitted to another journal in August 1968 while the writer was still at the University of Chicago. It lay buried in Europe 22 months without effective action being taken on it. It was finally returned to the writer only after the threat that extreme measures would be taken to recover it. I am grateful to Philip H. Abelson, Editor of *Science*, for helping me in this matter, and to Richard H. Jahns, Stanford University, for suggestions leading to improvement in this presentation.

- IV. With continued cooling the K-feldspar becomes "more triclinic," and cryptoperthite Type II (perthite from the triclinic state) may develop.
- V. In a final stage plate perthite (Laves and Soldatos, 1962) may form by recrystallization.

No attempt will be made here to repeat the arguments which Laves and Soldatos use to support their theory, but I admit that many of them are cogent. They regard their five stages as the "normal case" of perthite development. But they recognize that replacement phenomena in many cases may modify the results of the unmixing described by them. They list two such possibilities regarded as limits or extremes:

- (a) Albitization by Na-ions, chiefly from outside sources, replacing the K-ions with substantially no change in orientation of the  $AlSi_3O_8$ -structure formed originally as described in Stage I. This process leads to patch perthite and so-called chessboard albite. Many intermediate states and degrees of replacement may occur.
- (b) Formation of "cleavelandite." While the albitization described in a) can proceed to varying degrees without the help of "solutions," the development of "cleavelandite" appears to depend on the action of Na-bearing solutions. Laves and Soldatos state that this process is impressively verified by the observations of Fisher (1942, 1945), Adamson (1942), and Andersen (1928).

#### POIKILITIC ALBITE

The remarks in this paper are primarily concerned with the statement made in (b) above. First let me make clear that the use of the term "cleavelandite" as employed there is not desirable. Typical cleavelandite, which is so commonly present in any but the simplest granitic pegmatite, consists of albite growing in near-parallel platy masses of definite megascopic size. It commonly shows curved lamellae that are generally twinned according to the albite law (Fisher, 1968). Distinctly different are the small, isolated, unoriented crystals called "cleavelandite" by Laves and Soldatos; I prefer to designate these *poikilitic albite*<sup>1</sup> (PA), because the resulting texture is clearly poikilitic (Fisher, 1945). Admittedly this is a minor point, since these PA crystals are commonly platy or almost acicular and generally show albite twinning; some occur in bunched-up masses, but because they are unoriented rather than in near-parallel growths even these are really not the same as typical cleavelandite.

<sup>1</sup> Laves and Soldatos (1963, p. 93) describe two kinds of poikilitic albite. I have not observed their "isometric poikilite." What they designate as "cleavelandite," showing albite twinning as in their Fig. 8, in the present paper is translated as PA (poikilitic albite).

The statement in (b) above cannot be properly attributed to the three cited authors.<sup>2</sup> None of these investigators considers the PA to have formed by the action of Na-bearing solutions, but instead they regard it as a direct precipitate from the pegmatite "magma" in its early stages, with many or all of the crystals antedating the formation of the vein perthitic albite.

Crystals of PA up to about 5 mm in length are known in the K-feldspar (microcline) crystals of granitic pegmatites in three continents. Excellent examples have been described by Laves and Soldatos (1963) as well as the three authors mentioned in paragraph (b) above. Photomicrographs are given by Rogers and Kerr (1942, Fig. 209) and by Drescher-Kaden (1948, Fig. 59; from Southbury, *not* Louthbourn, Conn.; see Cameron *et al.*, 1954, p. 341). Drescher-Kaden states (base p. 75):

Ebenso zweifelsfrei sind Teile des eingeschlossenen Plagioklases vom Bandperthit (oder von den ihm voraufgehenden Lösungen) angefressen und abgelaut.

And in the caption of his figure he refers to the "older plagioclase inclusion in the microcline."

#### CHESSEBOARD ALBITE

What I regard as the clinching argument in this matter is outlined in an earlier report (Fischer, 1945). This publication is relatively inaccessible; hence the gist of the pertinent statements is offered here.

High up on the north wall of the High Climb mine in the Black Hills (Fisher, 1942; Sheridan, 1955) cleavage blocks nearly 30 cm long have been broken off from much larger single crystals of perthitic microcline. These crystals are cut by coarse, vein-like masses of quartz-albite<sup>3</sup> rock. Along contacts with such veins the microcline is completely albitized for a thickness of two to four cm. The albite and microcline are in parallel position as shown by the continuity of the basal cleavage across the faces of specimens. A thin section  $7\frac{1}{2} \times 9$  cm was prepared parallel to the basal cleavage of such a specimen, and from it the photomicrograph shown as Figure 1A was made. Four photomicrographs of selected areas in this section appear as Figures 1B-E. It should be realized that a vein-like mass of quartz and albite formerly extended roughly parallel to (010) just below the base (long side) of Figure 1A.

It is abundantly clear from the field and thin-section evidence that a

<sup>2</sup> In giving an abstract of the Laves and Soldatos (1963) paper, this same erroneous interpretation has been preserved in Tröger (1967).

<sup>3</sup> Earlier termed quartz-cleavelandite rock by Fisher (1942). However this albite probably should not be referred to as cleavelandite, *Sensu strictu* (Fisher, 1968).

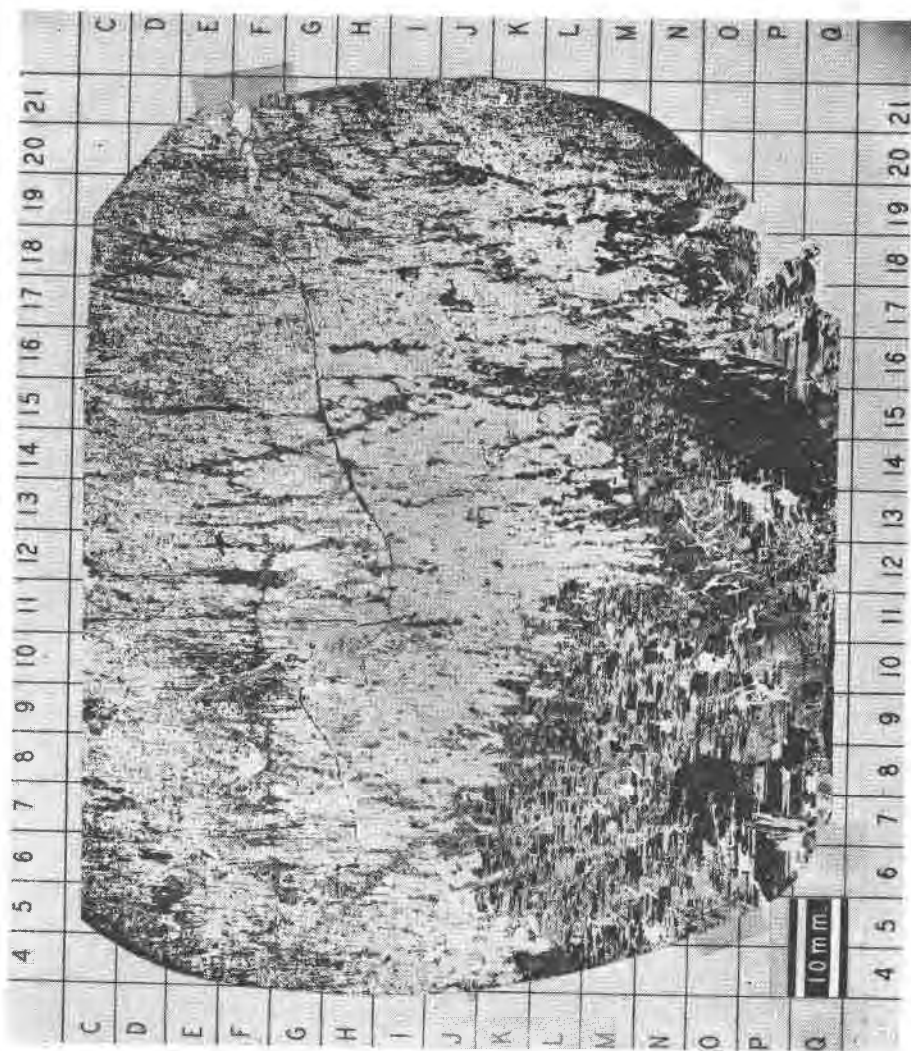
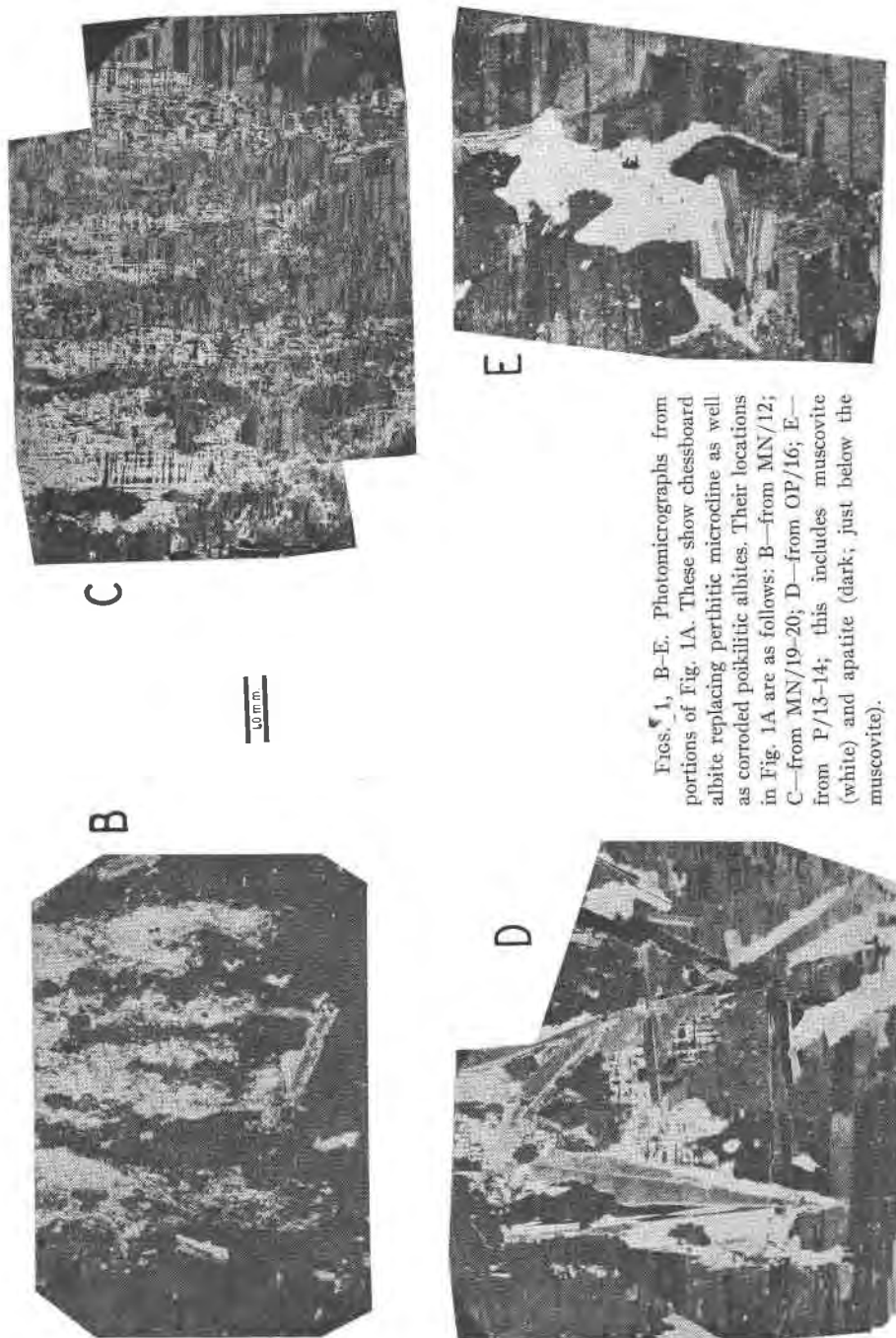


FIG. 1. A. Photomicrograph of a giant thin-section of the basal cleavage surface of a partially albitized crystal of perthitic microcline from the High Climb Lode, Black Hills. The grid lines are 5 mm apart.



Figs. 1, B-E. Photomicrographs from portions of Fig. 1A. These show chessboard albite replacing perthitic microcline as well as corroded poikilitic albites. Their locations in Fig. 1A are as follows: B—from MN/12; C—from MN/19-20; D—from OP/16; E—from P/13-14; this includes muscovite (white) and apatite (dark; just below the muscovite).

"Na-front" invaded the microcline, replaced its K, and yielded this beautiful example of chessboard albite. This was simply a type of ion-exchange reaction involving these two alkali metals, with at most only very slight changes in the  $AlSi_3O_8$ -framework. Some muscovite is present (Fig. 1E), but there is no evidence that it was produced with the aid of the K released in this reaction; certainly this specimen does not show nearly enough muscovite to account for all this K.

The albitization took place starting from the base of Figure 1A and extending upward. It proceeded along surfaces or incipient fissures whose traces were approximately the short side of the figure, producing material like vein perthite. As these albite laminae were extended they broadened somewhat, and where closely-enough spaced they gradually coalesced to form patch perthite. Along their surfaces of juncture the twinning lamellae are offset, giving the typical chessboard texture.

The extremely sinuous character of the boundary between the chessboard albite and the perthitic microcline is made clear in Figures 1A, B, and C. These views also show how individual units of the chessboard albite tend to become coarser with increasing distance from the microcline. But the outstanding feature relative to the present discussion is the presence of PA in all four of the photomicrographs. It is most pronounced in Figure 1D, less so in Figures 1B, E and only two small crystals are visible along the left edge of Figure 1C. The PA has two outstanding characteristics: 1) the crystals are diversely oriented; *i.e.*, poikilitic within the host, with no tendency to line up with any other feldspar, and 2) they are anhedral, and generally appear to be corroded or partially resorbed.

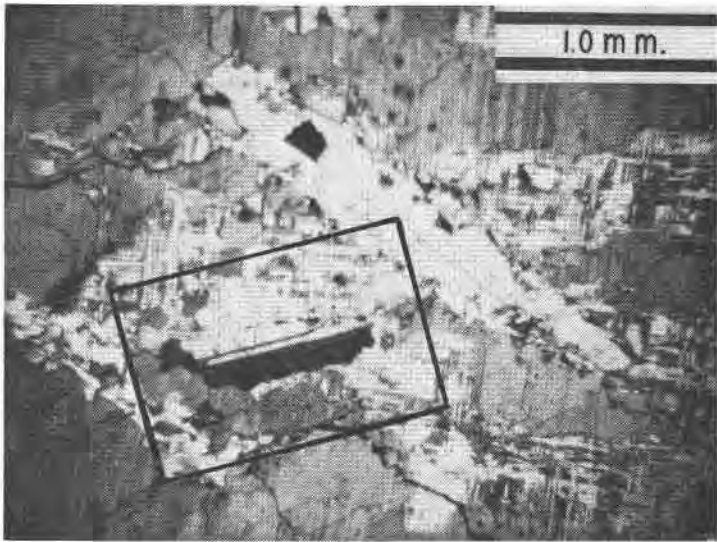
The perthitic albite, the chessboard albite, and the PA all appear to be of essentially the same composition, An 0-5, which is as close as one can determine the composition of albite by optical (U-stage) work, according to the data in Burri *et al.* (1967). I consider it highly unlikely that the occurrence of albite in these three different manifestations can be related to any significant compositional differences. Albite which replaces microcline tends to exist in parallel orientation to it; in fact this is the main criterion for assuming that replacement has occurred. Such albite should not be confused with that PA, or with polycrystalline albite of a later generation that may be fairly common as veins cutting across the perthitic microcline. The relationships shown in Figure 1D indicate that the PA did not replace the chessboard albite. Such PA is common in the perthitic microcline of the pegmatites of the Black Hills and other regions, as is documented herein. A dozen or more PA crystals are present in the upper part of Figure 1A completely surrounded by the perthitic microcline, hence they must have been present in the perthitic microcline

which was replaced by the chessboard albite. It must be concluded that, contrary to the rather involved explanation of Laves and Soldatos (1963), such crystals represent one of the earliest of pegmatite minerals in the K-feldspar unit. Sheridan (1955, p. 87) notes that while "the albite of the matrix appears to replace microcline-perthite in some specimens, in others the microcline replaces and veins the albite of the matrix and poikilitically includes crystals of 'cleavelandite,'" but he says nothing regarding the time of formation of these small poikilitic "cleavelandite" crystals.

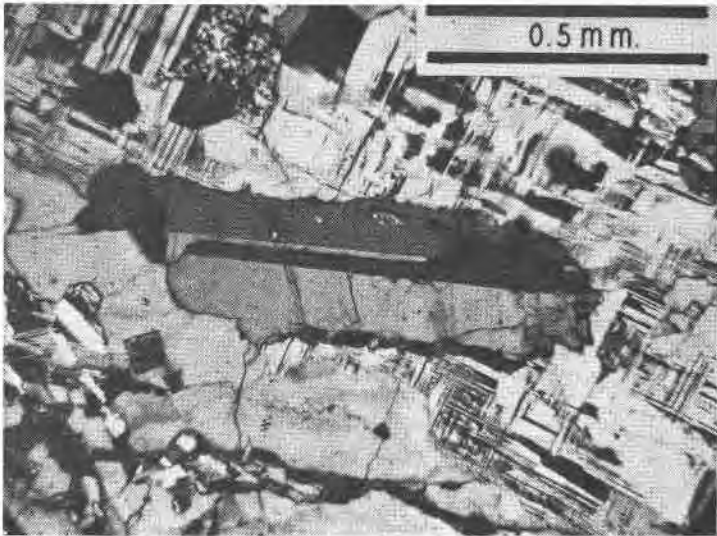
### EXAMPLES

Because the large thin-section from which Figure 1A was made is necessarily of greater than standard thickness, a normal thin section was ground from the same sample and from it the photomicrographs of Figures 2-4 were prepared. The PA crystals shown in Figures 2B and 3B were studied on the U-stage and found to be of composition An 0-5. The crystal shown in Figure 2B is a dual twin after the Carlsbad A law, and that in Figure 3B is polysynthetic according to the albite law. These photomicrographs reveal the anhedral, even corroded, borders of the PA crystals. The discontinuity of individual units of the chessboard albite twins at their contacts with the PA or the perthitic microcline is clearly shown in Figures 3B and 4, fortifying the thesis that the chessboard albite is younger than either of the other two feldspars. The relationships shown in Figure 2B are highly incompatible with the notion that the PA was formed by replacement of the perthitic microcline: why should the introduction of Na (or indeed of all the components of albite) cause the replacement of the microcline lattice in every possible orientation except the one that would involve a minimum rearrangement of the  $AlSi_3O_8$ -groups?

Figure 3 shows the only observed case where a PA crystal is cut in two by the chessboard albite. Note that the larger remnant (on the right) is entirely surrounded by chessboard albite, with the traces of the respective (010) planes nearly perpendicular to each other, whereas the smaller remnant projects into the perthitic microcline. It is clear that the individual units of the chessboard albite are interrupted at the PA except along the tiny tip at the left end of the larger PA remnant. This kind of discontinuity, indicating that the chessboard albite on opposite sides of a remnant of PA or of perthitic microcline grew from different directions and so from different seeds, also is very clear in Figure 4. The lower side of the PA crystal in Figure 4B is spangled with shreds of muscovite, and to the right of this crystal are two linear areas of muscovite shreds that may mark the locations of former PA individuals. However it should be em-



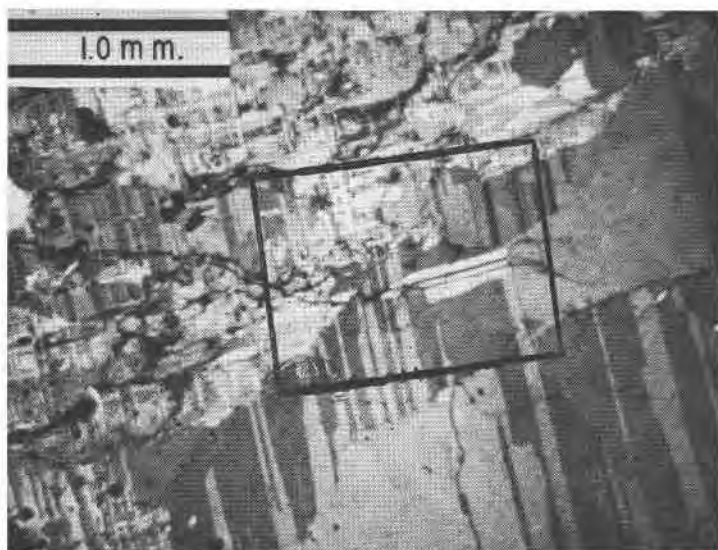
(a)



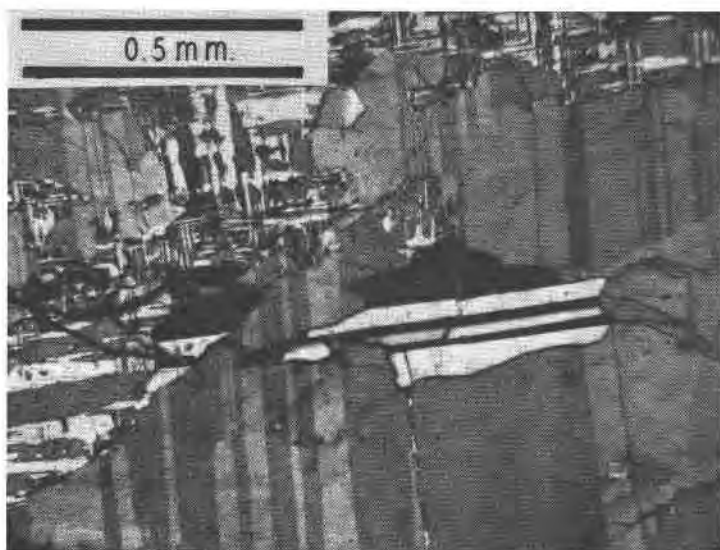
(b)

FIG. 2. Photomicrographs at two scales (A and B) from a standard-size thin-section ground from the same sample as used for Fig. 1. Shows a poikilitic albite (PA) crystal largely in a microcline remnant, but with perthitic albite cutting across its left end. The black band along the lower rim of the PA crystal in Fig. 2B seems to be apatite.



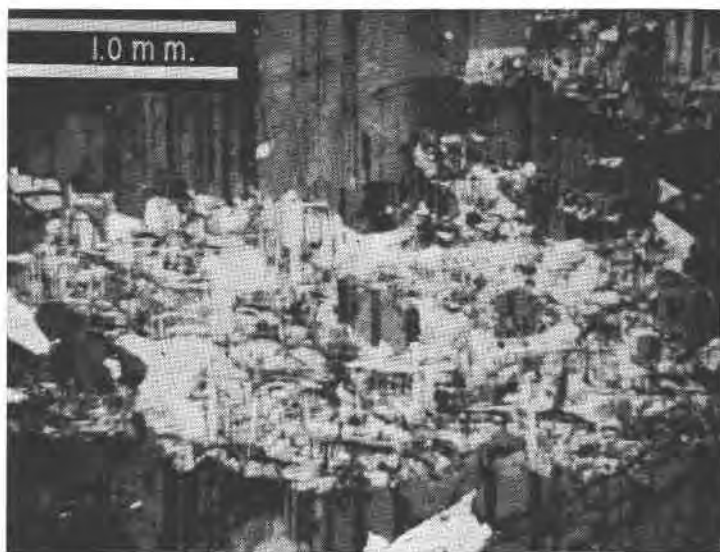


(a)

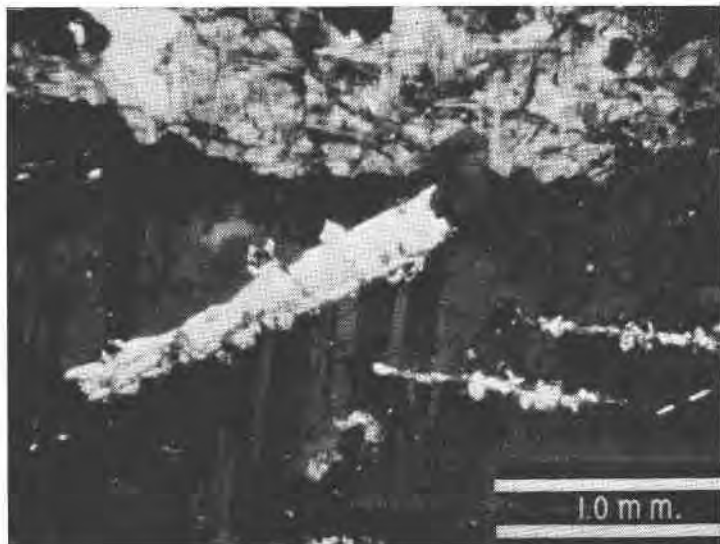


(b)

FIG. 3. Photomicrographs at two scales (A and B) from a standard-size thin-section ground from the same sample as used for Fig. 1. Shows a PA crystal cut in two by chess-board albite; see text for detailed information.



(a)



(b)

FIG. 4. Two photomicrographs from a standard-size thin section ground from the same sample as used for Fig. 1. Fig. 4a shows a remnant of perthitic microcline in chessboard albite. Along the middle of the bottom edge appears the right end of the PA crystal which is shown in the left-center of Fig. 4b. In this view note how the individuals of the chessboard albite are interrupted by the PA. See further discussion in the text.

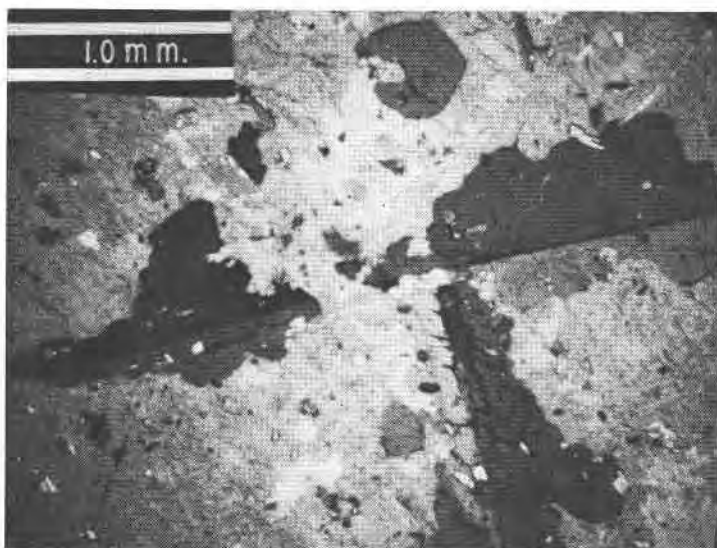
phasized that the association of shreddy muscovite with the borders of the PA crystals (note for example the two crystals crossing the upper right and lower left corners of Fig. 2B; see Fig. 2A) is the exceptional, not the ordinary, occurrence.

Figure 5A shows the only observed case where a PA individual (nearly horizontal across the middle of the view) is divided into two units through partial replacement by microcline. Here one of the PA remnants is very slightly turned from parallel orientation with the other, but the twinning matches up so nicely that there is no doubt that they once constituted a single (twinned) crystal. When looking at this picture one is strongly reminded of Adamson (1942, Fig. 2 on Pl. IV). The lower of the two nearly parallel crystals of PA that extend horizontally across the middle of Figure 5B contains four vein-like stringers of perthitic albite projecting half-way across it.

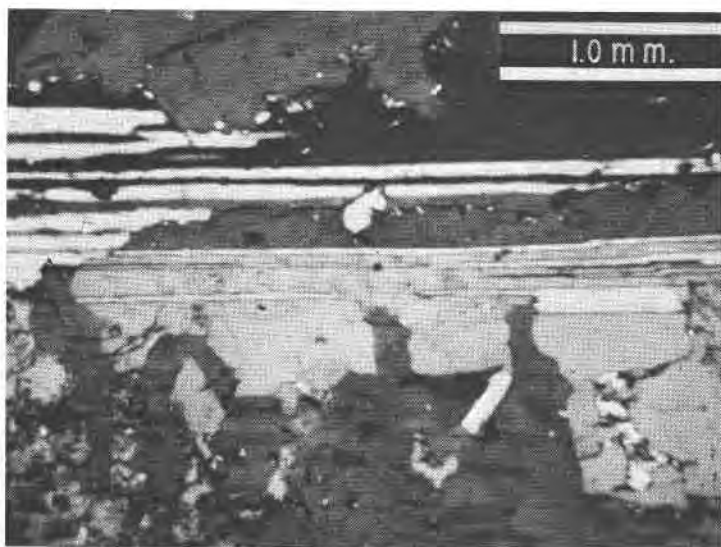
Figure 6 shows corrosion and veining of PA by perthitic albite. This PA is unusual in that it is twinned according to three laws: albite (the polysynthetic twinning in the lower half of the crystal shown on the right side of Fig. 6B), Roc Tourné (the two units shown on the left side of Fig. 6B), and Carlsbad (the light unit in the lower part of the right end of the crystal of Fig. 6B along with its upper part). Both Figure 6 and Figure 7 represent a sample of perthitic feldspar from the Beecher No. 2 pegmatite (Longview mine) in the Black Hills (Fisher, 1942; Page *et al.* 1953). The PA crystal in Figure 7, twinned on the albite law, is not only cut substantially in two by perthitic albite, but its right-hand part is slightly rotated from parallelism with the main left-hand portion. The right edge of the remnant on the right is corroded by another perthitic albite vein.

I have six photomicrographs of microclines from the Custer Mt. Lode (Fisher, 1945; Page *et al.*, 1953) all showing excellent examples of anhedral PA cut by perthitic albite, but here only one is reproduced as Figure 8. This PA is a polysynthetic twin (albite law) that has been corroded and completely severed by the perthitic albite. Clearly the crystal was not broken in two and the two parts shoved away from each other, because the adjacent ends of the two parts do not match. Further, there is no indication of bending or other deformation in the PA. And it seems hardly reasonable to assume that microcline first cut through the PA unit, and that it was later completely replaced by perthitic albite. The perthitic albite cutting the upper part of the PA crystal comprises two units, and the two sets of albite twins are offset from each other as is typical of chessboard albite.

Andersen (1928, p. 153) notes that very often the PA is penetrated by albite of the vein perthite; thus the vein perthite cannot have been formed by exsolution in the solid state, but must have grown from circu-

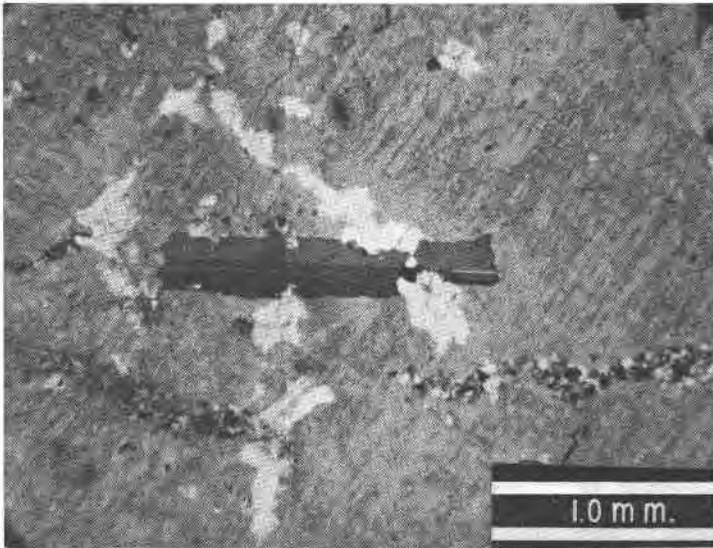


(a)

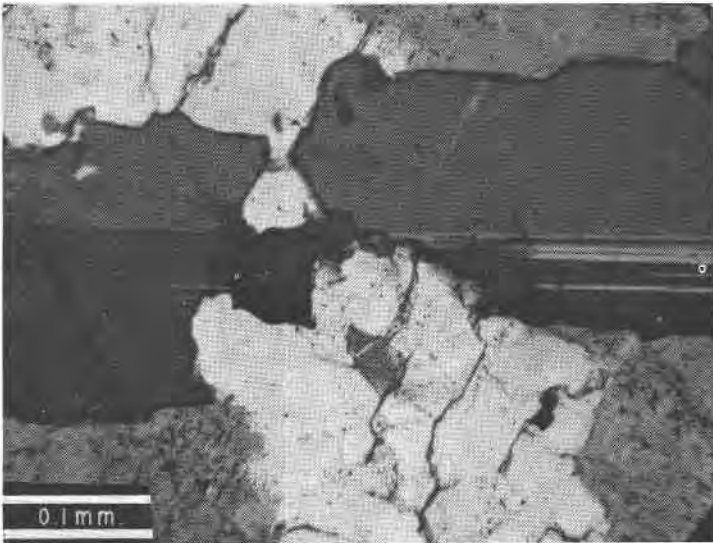


(b)

FIG. 5. Photomicrographs from a perthitic microcline crystal from the High Climb Lode. Fig. 5a shows a PA crystal split into two corroded units by the microcline. The PA crystal of Fig. 5b is cut by four vein-like masses of perthitic albite extending from the perthitic microcline.

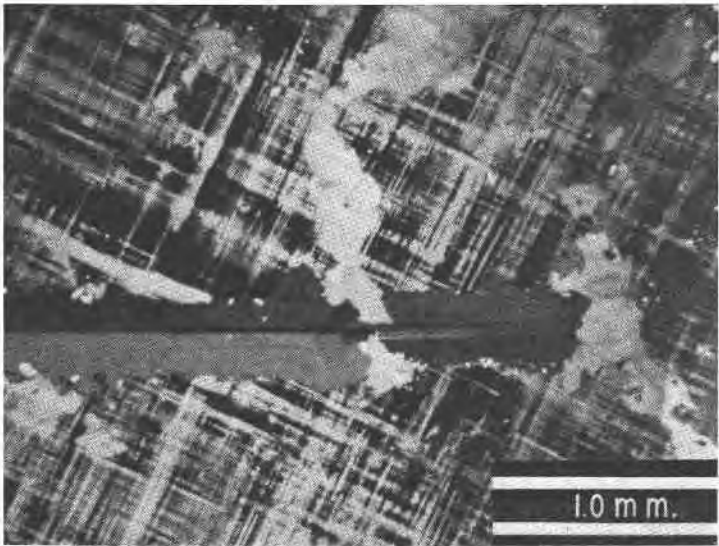


(a)

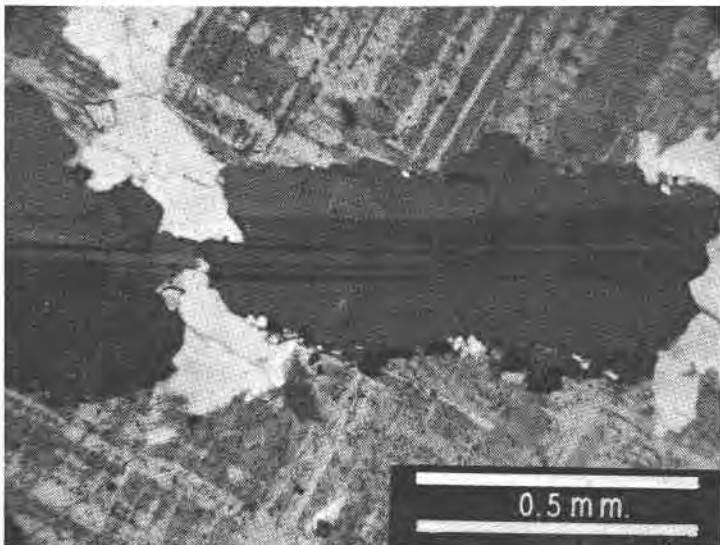


(b)

FIG. 6a. Microcline (light gray) with its perthitic albite (white) cutting across an anhedral crystal of PA twinned according to albite, Carlsbad, and Roc Tourné laws. Fig. 6b shows the enlarged right center part of Fig. 6A Beecher no. 2 pegmatite, Black Hills.



(a)



(b)

FIG. 7. Photomicrographs at two scales (a and b) showing relationships among microcline and two generations of albite. Beecher no. 2 pegmatite, Black Hills.

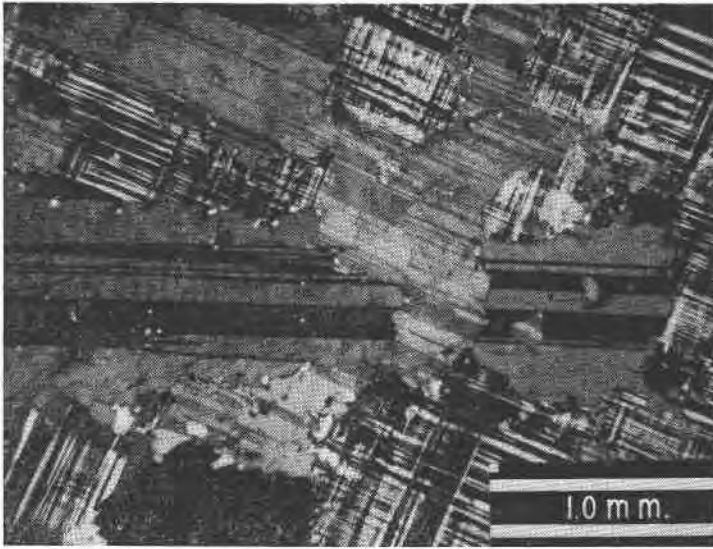


FIG. 8. Perthitic microcline enclosing a corroded crystal of PA that has been cut in two by perthitic albite. Custer Mt. Lode, Black Hills.

lating solutions. Adamson (1942, p. 31) agrees. However it is clear that while this perthitic albite as a result of exsolution may develop initially as tiny specks evenly distributed throughout the microcline, such a condition is not observed during thin-section study. Instead the perthitic albite has aggregated into sheets or vein-like masses through diffusion in the solid state. Thus presumably some transportation of the material of the perthitic albite must have taken place. When perthites which have been homogenized by heating as dry melts are allowed to cool, no exsolution is observed. But according to Richard H. Jahns (personal communication) subsolidus diffusion can occur rapidly over large domains under laboratory conditions if water under pressure is present. Relationships very similar to those here described have been achieved experimentally in only five days.

In the description of the Hugo pegmatite (Norton *et al.*, 1962), the presence of PA in perthite is noted for intermediate zones 3 and 5 (see their fig. 30), and possibly in 6. There also appears to be a crystal of PA in the center of the photomicrograph from zone 5 perthite shown by Orville (1967, Fig. 1).

Through the kindness of Professor T. F. W. Barth, I was able to study one of Andersen's thin sections (A 23-714a) from which he prepared the photomicrograph shown as his Plate VI, Figure 1 (Andersen, 1928E. An

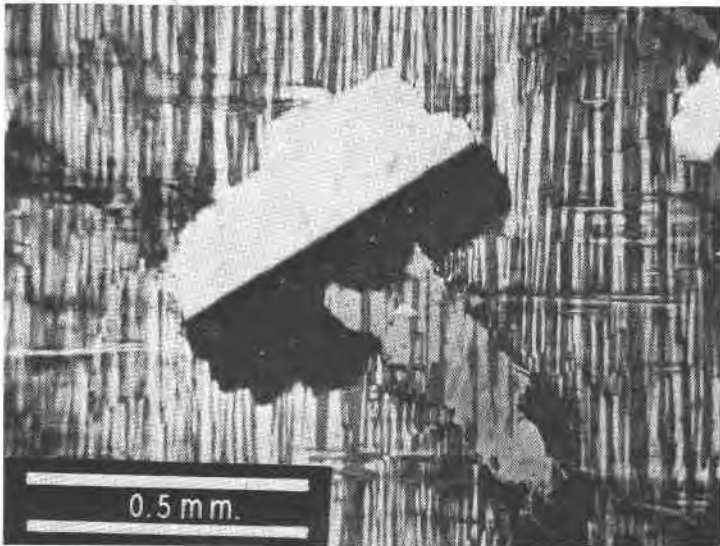


FIG. 9. Perthitic albite invading a corroded crystal of PA in microcline. Tangen, Norway.

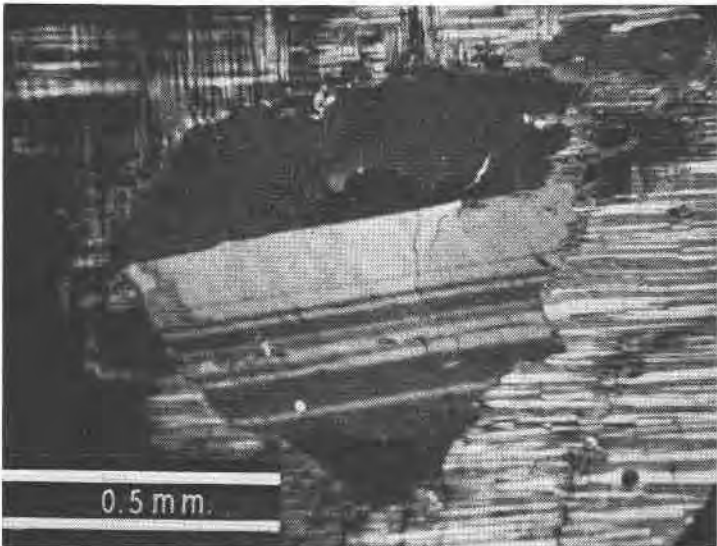


FIG. 10. Corroded poikilitic albite crystal surrounded by microcline. Tangen, Norway.



enlarged view of the PA crystal that appears above the center of his figure is shown here as Figure 9. This corroded crystal (a dual albite twin) lies within microcline and has been invaded by a mass of perthitic albite. Similar relationships appear elsewhere in this same thin-section, which also yielded the photomicrograph reproduced as Figure 10. Here a corroded PA crystal of unusual appearance is completely surrounded by microcline which lacks pericline twinning in the lower part of the view. The lower two-thirds of the PA crystal is a polysynthetic albite twin, whereas the two major parts in its upper half constitute a Carlsbad twin. The dark portion at the top of the crystal and the nearly parallel dark portions in its lower half form a Roc Tourné twin.

#### CONCLUSIONS

In summary, the explanation by Laves and Soldatos (1963) that the PA in granitic pegmatites was introduced by late-stage Na-bearing solutions is here regarded as untenable. They state:

“Na-bearing solutions may enter into the perthitic microcline leading to the solution of K-feldspar and the deposition of Na-feldspar. Since the K-feldspar is especially unstable in the presence of Na-bearing solutions, it is replaced, whereas there is no particular driving force present to cause the replacement of the Na-feldspar of the vein perthite by the Na-feldspar of the PA. Therefore the PA will advance in the microcline, in places growing around the vein perthite present, and the latter will only locally recrystallize in the new PA orientation.”

Each of these three sentences contains statements open to question. Why must “solution of K-feldspar” be inferred? Why not postulate simply an ion-exchange type of reaction with Na replacing K? Regarding the last part of the second sentence, Na-feldspar apparently does replace Na-feldspar, or at least causes it to assume a new orientation, as shown by veins of perthitic albite transecting PA, and by chessboard albite cutting across PA (Fig. 3). But I take particular exception to the final sentence. What actually happens when Na-bearing solutions enter microcline is shown in Figure 1. Not only does the K-feldspar change to Na-feldspar, but the result is non-poikilitic albite—in fact albite in parallel growth, in this case chessboard albite. Emmons and Mann (1953, p. 47) note that in Wisconsin granites where microcline is replaced by plagioclase “it is normal for the ensuing plagioclase to inherit the albite twin lamellae of the microcline almost lamella for lamella.”

Laves and Soldatos (1963) go on to say:

“Andersen noted that the PA crystals are often not bounded by sharp crystal faces, but rather appear to be eaten into or corroded

by the microcline. To this it should be stated that one cannot understand how, during the albitization by vein perthite postulated by Andersen, a development of microcline at the expense of the PA could have taken place."

I would add here that I have never seen a crystal of true PA that was euhedral or even definitely subhedral. If, during the consolidation of a "pegmatite magma", one of the first things to happen during the major microcline stage was the formation of a "shower" of tiny albites (an entirely reasonable hypothesis in terms of what is now known of the physical chemistry of such a system), then these crystals would become engulfed during the development of the much larger microcline crystals. Under these conditions these tiny albites could be expected to 1) suffer some corrosion, and 2) be swallowed poikilitically by the growing microcline. All of this must have occurred while the temperature was such that little or none of the perthitic albite had as yet become unmixed. If Na-solutions were replacing microcline with albite, why should they deposit a little Na-feldspar here and there at widely-spaced distances (considering the tiny sizes of the PA crystals), and with new  $\text{AlSi}_3\text{O}_8$ -structure orientations, rather than building up a non-poikilitic mass near the place of entrance? Andersen's views are not in agreement with the statement in the last sentence of the foregoing quotation.

Laves and Soldatos (1963) continue:

"We are rather inclined to consider the 'corroded' edges of the PA crystals to be merely apparent, and we think they can be better explained as follows: the growth of the PA proceeded most easily where the microcline was most disturbed. The latter was especially the case where the microcline shows 'diffuse' extinction; that is, where there are diffuse twin boundaries; i.e., regions where a disordered and therefore unstable condition existed with respect to the Al/Si distribution."

The corroded nature of the PA crystals seems obvious to me, and this characteristic is well shown by the photomicrographs. It also should be noted that if the PA crystals were engulfed by growing giant microcline crystals, these hosts may have suffered minor and local attacks of indigestion resulting in disturbed border areas. While they may have resorbed some of the PA crystals, clearly there were many that they couldn't finish off!

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