

ALBITE TRENDS IN SOME ROCKS OF THE PIEDMONT.

EARL INGERSON.

ABSTRACT.

There are albite porphyroblasts in most of the rocks of the Piedmont province of southern Pennsylvania and northern Maryland. Many of these albite metacrysts show "trends," that is, they have inclusions that show pronounced alignments. These trends have been interpreted as relict structures indicative of older periods of metamorphism. The present work shows that the albite trends in the Port Deposit granodiorite complex and associated rocks are not relict structures, but are controlled by the lattice of the feldspar grains. They were probably developed by late hydrothermal activity. This does not mean that there has been only one period of metamorphism affecting these rocks, but merely that the albite trends cannot be used as evidence for other periods of metamorphism. Similar studies from the literature are cited. In some of these, the trends appear to be true relict structures. In others, they are related solely to the lattice of the host feldspars.

INTRODUCTION.

In many tectonites, late porphyroblasts contain inclusions of other minerals. Sander¹ has outlined the theoretically possible relations that the orientation of these inclusions may show to that of the same minerals of the "groundmass."² These possibilities may be grouped under three heads:

1. The included minerals may show random orientation.
2. They may have the same preferred orientation as the same minerals of the groundmass.
3. They may have a preferred orientation that is different from the fabric of the groundmass.

Most of the rocks of the Piedmont of southern Pennsylvania and northern Maryland contain porphyroblasts that have other minerals included in them. Of these, albite is the most wide-

¹ Sander, B.: Über Tektonite mit Gürtelgefüge, *Fennia*, 50, No. 14, 1-25, 1928.

² The term "groundmass" is used for convenience and brevity to indicate the part of the rock outside of the porphyroblasts, whether the rock was originally of igneous or sedimentary origin.

spread, although there are also porphyroblasts of muscovite, biotite, tourmaline, and garnet. The albite porphyroblasts occur in all the rocks of Ordovician age and older, being present, for example, in the Conestoga limestone, Vintage dolomite, Antietam quartzite, Peters Creek schist, Wissahickon and Baltimore gneisses, the Port Deposit granodiorite complex, and even in the gabbroic intrusions. In general, the albite in the schists and gneisses has formed by replacement of quartz, mica, and other minerals, whereas that in the igneous rocks has formed at the expense of more calcic plagioclase.

Commonly, the inclusions in the albite porphyroblasts are arranged in more or less well-defined "trends"; that is, the inclusions of quartz, mica, epidote, garnet, and other minerals show definite alignments, which may be either straight or curved.

It can be seen at a glance that the minerals of these trends, especially the micas, have a strong preferred orientation that is different from that of the groundmass (Fig. 10). Therefore, of the possible relations, only case (3) need be considered for these albite trends. Of the several possible origins of an "internal fabric" (Ri) different from that of the groundmass (Re), there are three that should be considered in a study of the Piedmont rocks:

(a) The inclusions may be parts of an older fabric that have been preserved by the protective action of the albite porphyroblasts during the development of a different orientation in the groundmass.

(b) They may be included portions of the existing fabric of the groundmass that have been turned out of position by rotation of the porphyroblasts.

(c) The orientation of the inclusions may be related to the lattice of the individual feldspar crystals and neither to the present nor to an older fabric of the rock as a whole.

PREVIOUS INTERPRETATIONS.

These albite trends in rocks of the Piedmont have been interpreted exclusively as relict structures, but different writers have different ideas as to how they originated. Knopf and Jonas³ describe trends in the Wissahickon that are straight and regular, but show an angular discordance with the struc-

³Knopf, E. B. and Jonas, A. I.: *Geology of the McCalls Ferry-Quarryville District of Pennsylvania*, U. S. Geol. Survey Bull., 799, 29-30, 1929.

tures in the groundmass. This angular discordance is taken as evidence of a rotation of the metacrysts, which involves the assumption that the included minerals are older than the albite porphyroblasts.

There are all gradations between these straight trends and the crumpled ones described by Singewald.⁴ A moderately curved trend from the Antietam is pictured by Cloos.⁵ Singewald pictures trends from the Wissahickon that are slightly crumpled and appear to be approximately parallel to the mica of the groundmass⁶ and also trends that are badly crumpled and whose mica flakes appear to stand at a high angle to those of the groundmass.⁷ Singewald accepts the relict interpretation for these trends, but doubts that rotation has been effective. He believes that the folding of the mica flakes took place before the development of the porphyroblasts and that the apparent angular discordance can be explained by fortuitous development of the metacrysts without any rotation.⁸

STATISTICAL STUDY.

These albite trends are most striking where mica is the included mineral, but many consist of other minerals such as quartz, epidote, or garnet. These trends of other minerals are more difficult to study quantitatively, but where they are present in the same feldspar grain with mica they appear to be parallel to the mica and presumably have the same origin and significance.

I have been unable to find a published suggestion that any of these albite trends in Piedmont rocks may be related to the lattice of the feldspar. However, when I began to study thin sections of the Port Deposit complex and surrounding rocks, I was impressed by the regularity of the albite trends—they are much more regular than the mica orientation in the

⁴ Singewald, J. T., Jr.: Weathering and albitization of the Wissahickon schist at the Prettyboy dam, Baltimore County, Maryland, *Bull. Geol. Soc. Am.*, 43, 449-468, 1932.

⁵ Cloos, E.: The application of recent structural methods in the interpretation of the crystalline rocks of Maryland, *Maryland Geol. Survey*, 13, Pl. 9, 1937.

⁶ *Op. cit.*, Fig. 3.

⁷ *Op. cit.*, Fig. 4.

⁸ *Op. cit.*, p. 461.

groundmass—and it occurred to me that the arrangement might be parallel to important lattice planes of the feldspar grains, even when they show no cleavage. Figures 2, 5, and

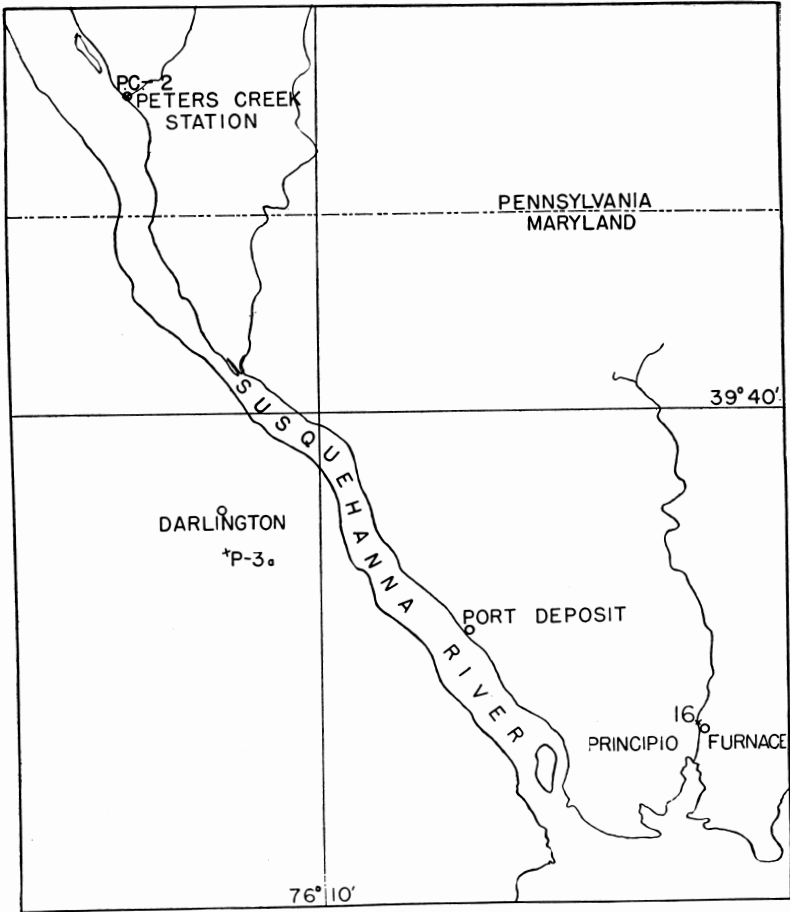


Fig. 1. Index map showing where the specimens whose trends have been analyzed were collected.

10 are photomicrographs of albite porphyroblasts each of which shows one or more trends.

It was a simple matter to test this hypothesis of crystallographic control by making a statistical study of the orientations of all the inclusions in a given albite crystal, and then plotting

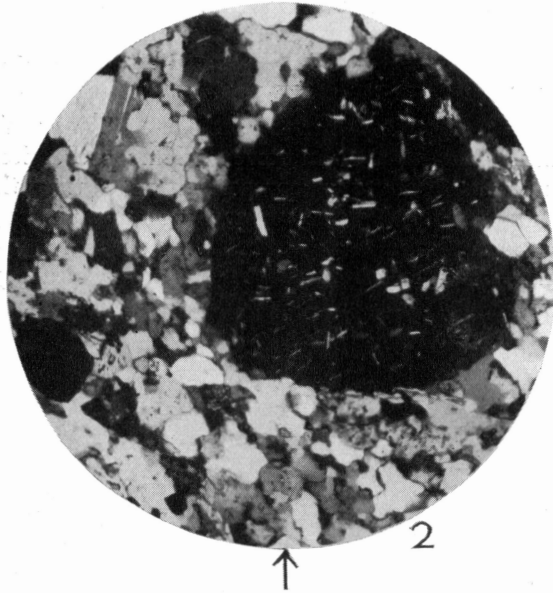


Fig. 2. Photomicrograph of an albite porphyroblast from the granitic facies of the Port Deposit granodiorite at Principio Furnace. Thin section 16. Notice the straightness of the "trends," which are, in this case, included muscovite flakes. Crossed nicols. $\times 65$.

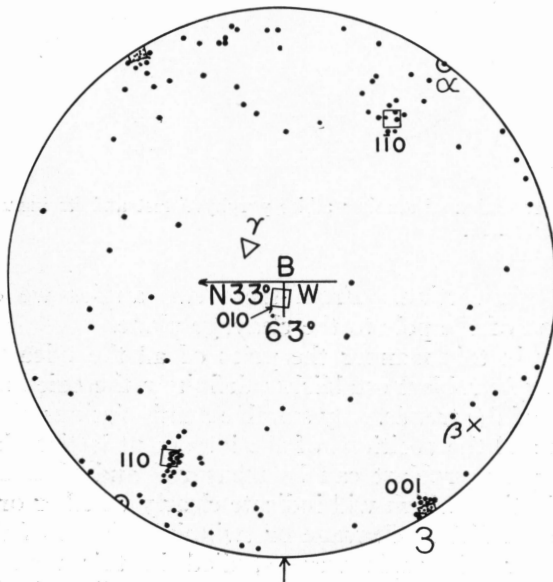


Fig. 3. Equal area projection of the important elements of the crystal shown in Fig. 2 and of the poles of its included mica flakes.

on the same diagram the orientation of the host porphyroblast. These statistical studies were made by plotting the poles of the mica inclusions on an equal area net. The manner of projection is exactly the same as in stereographic projection except that the lower hemisphere is represented rather than the upper one. On the universal stage we can measure the angle that the trace of a cleavage plane makes with the horizontal cross hair, and the angle in space that the plane of the cleavage makes

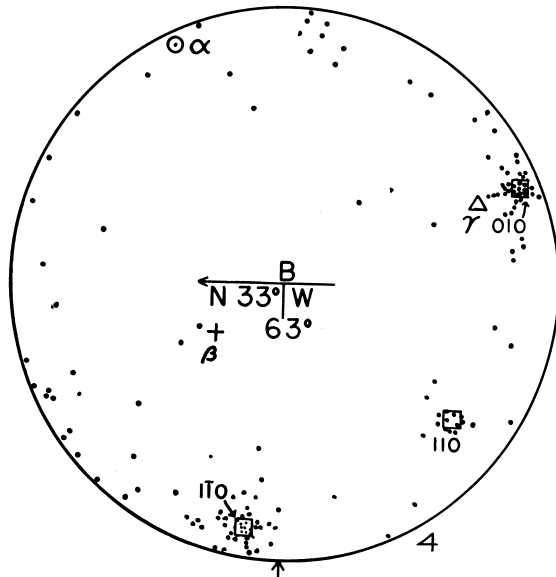


Fig. 4. Projection of another albite porphyroblast and its included mica; from thin section 16.

with the thin section. From these two angles we can plot the position of the pole to the cleavage plane.

Plotting in this manner the poles of all the mica flakes in a given porphyroblast establishes definitely the orientations of the planes of the trends. By suitable manipulations, the optical indicatrix and the positions of the important lattice planes for the same porphyroblast can be measured and plotted on the same projection, which will indicate clearly whether or not the trends lie parallel to cleavage or twinning planes of the host.

A number of trends were studied in this manner, and Fig. 1 indicates where the specimens were collected. Most of the diagrams thus far prepared have been made from specimen

16, collected from a granitic facies of the Port Deposit complex at Principio Furnace, Maryland. Specimen P. C.-2 is from the Peters Creek schist at Peters Creek station, Pennsylvania, and P.-3a is from a granite streamer in gneiss south-east of Darlington, Maryland.

Figure 2 is a photomicrograph of a porphyroblast from specimen 16. Fig. 3 is a projection of the important elements of this crystal, and of the poles of the mica flakes that it

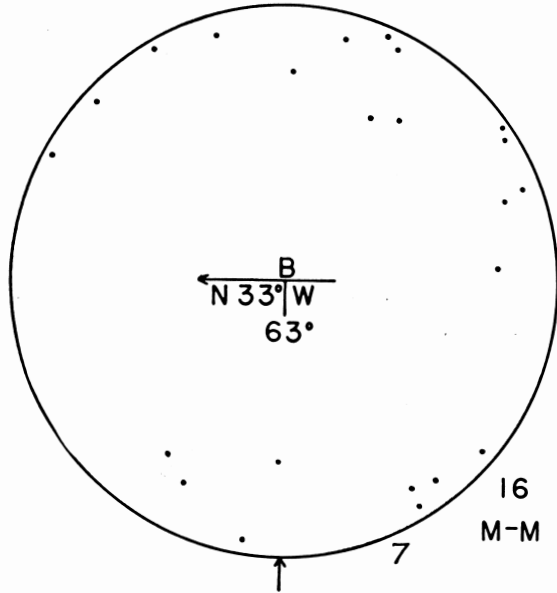


Fig. 7. Poles of twenty-three feldspar lattice planes that control trends of mica inclusions. All are from thin section 16.

includes. There are strong maxima of the poles of the mica flakes corresponding exactly to the (001), (110), and ($1\bar{1}0$) planes of the feldspar, indicating a definite control of the orientation of the inclusions by the lattice of the feldspar. In each example the orientation of the photomicrograph of a crystal and that of its projection are the same, so that the trends in the pictures can be readily correlated with the maxima of the diagrams.

Figure 4 is a similar projection of another albite porphyroblast from the same thin section. It shows strong maxima in (010), (110), and ($1\bar{1}0$) of the feldspar. In each of these

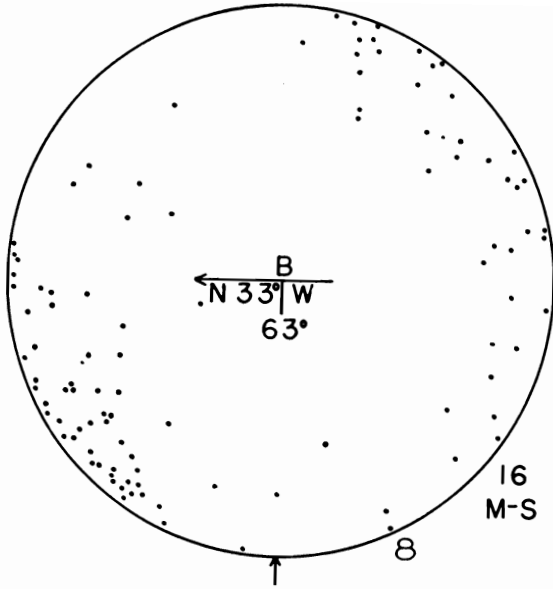


Fig. 8. Poles of 104 mica flakes lying in the s -planes of the groundmass of thin section 16.

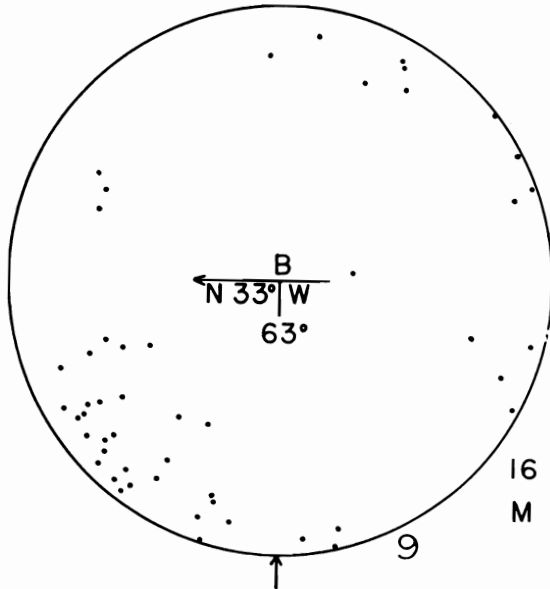


Fig. 9. Poles of 50 mica flakes lying between the s -planes of the groundmass of thin section 16.

projections there are a number of points that do not coincide with the poles of any of the cleavage planes. These are the mica flakes that do not lie in the definite trends. These flakes may (1) show random orientation, (2) be related to the fabric of the groundmass, or (3) be controlled by subordinate planes of the feldspar lattice.

Figure 5 is a photomicrograph of still another albite crystal from specimen 16, and Fig. 6 is a projection of this porphyroblast and the poles of its included muscovite plates. The mica flakes are mostly controlled by (001), (110), and (1 $\bar{1}$ 0). The zones containing these planes have been indicated on the projection and it is evident that *all* the mica flakes lie in or near these zones. This fact suggests that all the mica flakes may be controlled by the lattice of the feldspar, but it is by no means conclusive evidence. The surely established fact is that *the trends are controlled by the important lattice planes of the feldspar.*

Twenty-three such trends were measured from thin section 16, and Fig. 7 is a projection showing their positions. Each point is the pole of a feldspar plane that determines the position of a trend.

In order to see whether there was any relation between these trends and the fabric of the groundmass, diagrams of the muscovite fabric of the groundmass were prepared.

Figure 8 is from the muscovite of the groundmass in the *s*-planes, and Fig. 9 is from the muscovite of the groundmass between the *s*-planes. The maxima of the two diagrams coincide, indicating that the mica fabric of the groundmass is homogeneous. They do not correlate with the maxima from the diagrams of individual feldspar crystals and their inclusions, Fig. 7, except that in both cases the poles tend to form a girdle about the fold axis (= *B*-axis of the fabric), which is the center of each projection.

This indicates an indirect relation of the albite trends to the fabric of the rock in this way—the cleavage planes of each albite grain that were in the zone of the *s*-planes of the rock (i.e. parallel to the axis of folding, or rotation), were the ones that were developed and along which the inclusions grew.

The diagrams from the other specimens show practically the same thing. Figure 10 is a photomicrograph of an albite porphyroblast from the Peters Creek schist. Figure 11 is a projection of this porphyroblast and its included muscovite flakes. The only maximum is in (010). Figure 12 is a dia-

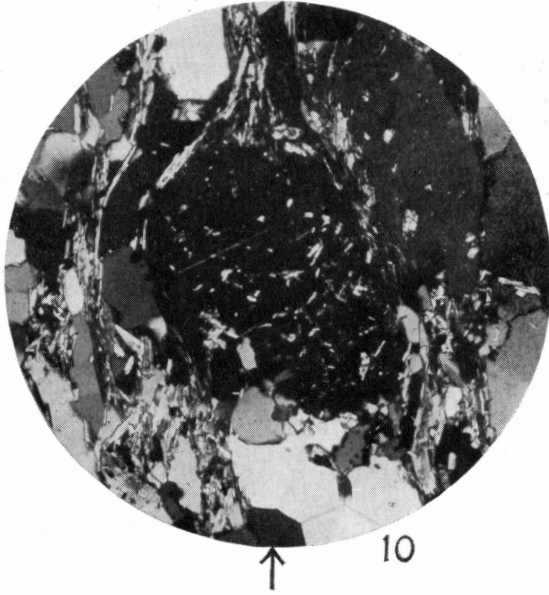


Fig. 10. Photomicrograph of an albite porphyroblast from the Peters Creek schist. Note the high angle that the mica of the trend makes with the mica of the groundmass. Specimen P. C.-2. Crossed nicols. x 85.

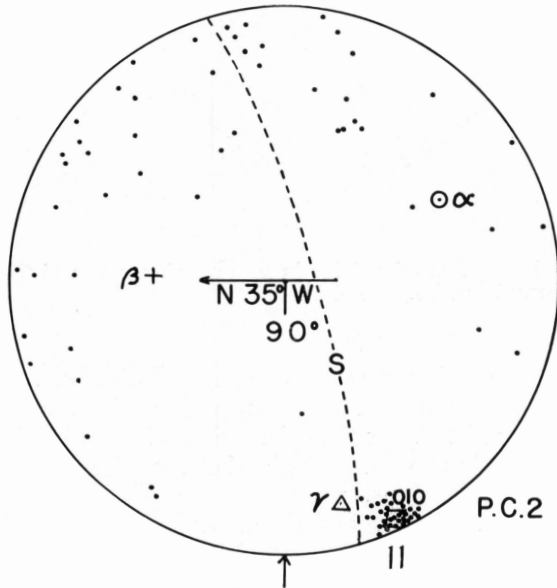


Fig. 11. Projection of the albite crystal shown in Fig. 10 and the poles of its included muscovite flakes.

gram prepared from the mica of the groundmass of this same specimen. It shows that the mica of the trend stands almost normal to that of the groundmass, which can also be seen in the photomicrograph, Fig. 10.

An oligoclase porphyroblast from a specimen of the granite streamer southeast of Darlington, Fig. 13, shows strong maxima in (010) and (001). The mica outside of the porphyroblasts of this specimen is mostly biotite and the crystals

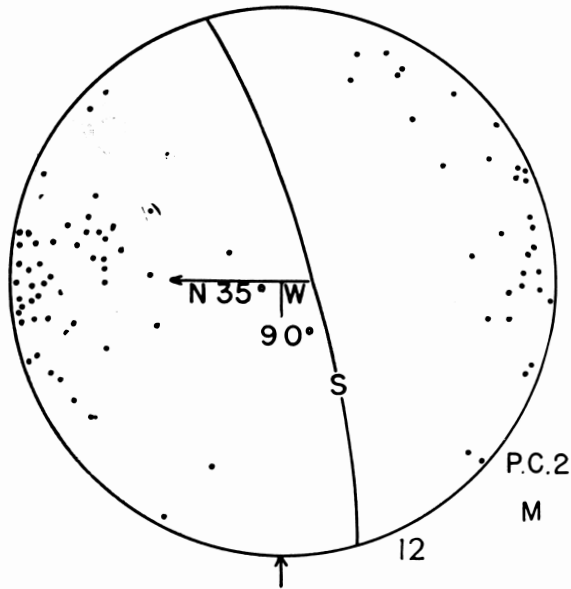


Fig. 12. Poles of 87 mica flakes in the groundmass around the porphyroblast represented in Figs. 10 and 11.

are much larger than are the muscovite inclusions. They are also somewhat crumpled, whereas the inclusions are clear and sharp. Figure 14 shows the orientation of these biotites, which have their maximum concentration between the two maxima of the muscovite inclusions.

This difference in size and character between the mica inside and outside of the plagioclase porphyroblasts is rather common in these rocks and suggests that the inclusions were probably formed later than the host rather than earlier.

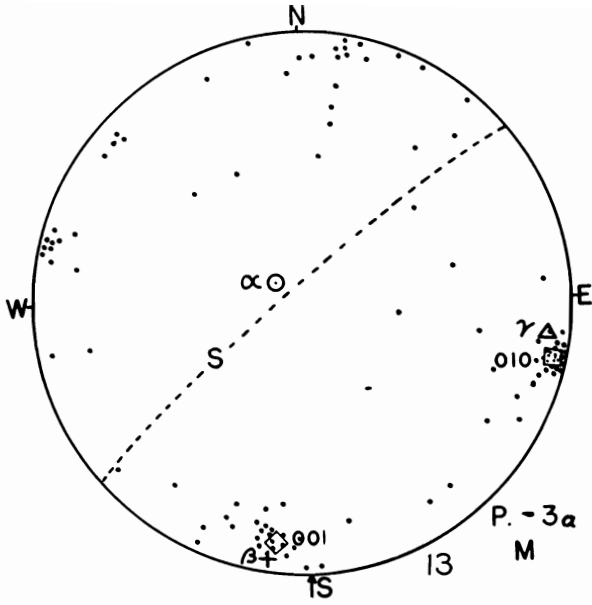


Fig. 13. Projection of an oligoclase porphyroblast from a streamer of granite in gneiss southeast of Darlington. Specimen P.-3a.

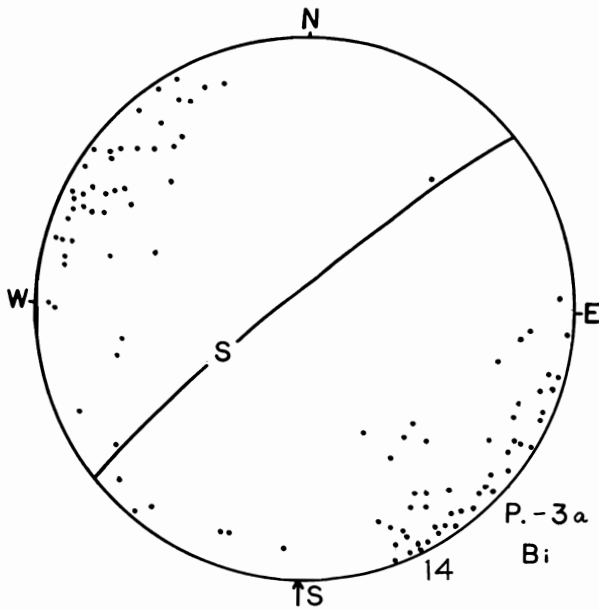


Fig. 14. Poles of 101 biotite flakes from the groundmass of specimen P.-3a.

This control of trends by the lattice of the host should not be applied too generally. There are doubtless some examples of true relict structures. The trends described by Singewald⁹ may be true relict structures, although there is another possible explanation. Cloos¹⁰ observes that the folded trends occur where there is much mica in the groundmass, i.e. in zones that are well lubricated and in which there may have been intense differential movement. If the mica had formed along feldspar cleavages, it conceivably could have been crumpled by later movements.

SIMILAR EUROPEAN OCCURRENCES.

Drescher¹¹ has described what he believes to be true relict structures, although in two of the three diagrams that he gives, the maximum concentration of the microlites is very near to a major cleavage of the feldspar.

Andreatta has done more detailed and extensive work on this problem than anyone else. In intrusive rocks¹² he finds that practically all the mica is controlled by the lattice of the feldspar. The (001) and (010) planes commonly contain most of the mica, but (110) is sometimes effective.

In orthogneiss¹³ he finds that the orientation is less perfect with respect to the lattice of the feldspar, some of the mica flakes apparently being related to the fabric of the rock rather than the host feldspar grains.

From a paragneiss¹⁴ Andreatta describes feldspar porphyroblasts that contain relicts of two older structures that possibly are related to two different periods of metamorphism.

⁹ Op. cit.

¹⁰ Cloos, E.: Personal communication.

¹¹ Drescher, F. K.: Über Mikroklinholoblasten mit Grundgewebeseinschlüssen, Internregelung von Biotit und einige diesbezügliche genetische Erwägungen, Notizbl. des Vereins für Erdkunde u. der Hess. Geol. Landesanstalt zu Darmstadt, 5 Folge, 10 Heft, pp. 246-269, 1927. Also, Zur Genese der Diorite von Fürstenstein, Neues Jahrb. Mineral. Geol., Beilage Band, A, 60, 477-494, 1930.

¹² Andreatta, C.: Disposizione dei microliti micacei in plagioclasti di rocce intrusive (Analisi strutturali di rocce, IV), Periodico mineral. (Rome), 5, 1-21, Plates 1 and 2, 1934.

¹³ Andreatta, C.: Analisi strutturali di rocce metamorfiche, III. La disposizione dei microliti micacei nei plagioclasti di ortogneis, Periodico mineral. (Rome), 4, 1-20, Plates 1-6, 1933.

¹⁴ Andreatta, C.: La formazione gneissico-kinzigitica e le olivinita di Val d'Ultimo, Mem. del Museo di Storia Naturale della Venezia Tridentina, 3, fasc. 2, 31-42, 1935.

CONCLUSIONS.

For the albite trends of the Port Deposit granodiorite complex and surrounding formations, the following conclusions appear to be valid:

1. The mica inclusions are directly related to the lattice of the host feldspar porphyroblasts.
2. They are indirectly related to the present fabric of the rock in that the cleavages controlling the trends have been developed in the zone of the *s*-planes of the rock.
3. These trends are not relict structures and therefore do not indicate more than one period of metamorphism.
4. Since there are similar trends in the plagioclase porphyroblasts in all the rocks of Ordovician age or older, in this region, their presence cannot be used as a criterion of age relations.
5. The inclusions of the trends were probably formed during late hydrothermal activity by solutions permeating the plagioclase along planes of greatest accessibility.