PLAGIOCLASE DETERMINATION BY THE MODIFIED UNIVERSAL STAGE

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ABSTRACT

The modified universal stage having two horizontal east-west axes of rotation is applied to the determinative procedures for plagioclase feldspars and their twin laws, as originally introduced by Fedorov and elaborated more recently by others. The modified universal stage both simplifies and speeds up the procedure by permitting added steps of manipulation. A description is given of the application of this stage to this problem. Appended are necessary diagrams to facilitate calculation by graphical methods. *No graphical construction is required for critically orienting the crystal.* Very little and very simple and elementary construction is required for the determination of the anorthite content of plagioclase. Only slightly more is needed to determine the twin law. The procedure is given as a routine.

INTRODUCTION

The universal stage for which Fedorov is doubtless best known to us, has yielded to foreign petrographers and mineralogists a degree of success in the study of feldspars which has been largely foregone in America, if we may judge from our literature. Since Wright's masterful treatise on petrographic methods, published in 1911 (1), in which he lucidly and adequately outlined the principles of the technique, there has been little active response in applying these resourceful methods to American petrographic problems, due doubtless to the time required for their execution. Recently the writer described a modified universal stage and a simplified and rapid procedure for orienting and determining crystals on it *by immersion methods* (2). It is the intention here to outline the application of this modified stage to the determination *in thin section* of plagioclase feldspars and their twin laws in the hope that the time saving afforded by the modified instrument will encourage its use by some of those who have felt in the past that the results did not justify the time required to obtain them. The time saving is accomplished by executing very simply on the instrument several steps of manipulation which involve graphical

procedure for the operator of the earlier stage: such, for example, as the ready determination of 2V by Berek's method (3), or the change from one critical orientation to another, or the very fundamental step of orienting the crystal itself. In brief, the method consists in relating the orientation of the elements of optic symmetry of plagioclase to the elements of crystallographic symmetry as revealed by the planes, poles and axes of twinning and cleavage. We shall use the extensive data and graphs of feldspar properties compiled by those eminent European and Russian crystallographers who have laid so sound a foundation in recent years for this type of work (4).[1]

EQUIPMENT AND PREPARATION OF THE MOUNT

A thin section is mounted on the universal stage with liquid contacts between the upper hemisphere and the central glass plate. The lower hemisphere is then introduced, also with liquid contact, and the selected crystal is ready for orientation.[2] For feldspar study it is convenient to use hemispheres of index about 1.56 which lessens the corrections to be made for the difference between the indices of the crystal and hemispheres. On the Bausch & Lomb model universal stage are four posts placed on the inner stage in positions similar to those of the upper hemisphere thumb screws. These are intended to aid in the study of grains by immersion methods. Two of these posts may profitably be removed when studying thin sections to permit greater movement of the slide.

[1] The Bausch & Lomb Optical Co. manufactures a stage embodying the modification referred to here; and E. Leitz Co. recently announced an accessory to their stage for this purpose.

[2] The axes of the instrument have been variously named and the names abbreviated to initial letters by foreign writers on the subject with the result that there is no established nomenclature. In view of the prevailing lack of agreement I have deemed it desirable to use an English terminology for the English speaking reader. The initial letters have been used where convenient for abbreviations. The following table gives the correlations of the different nomenclatures. Reference may be had to fig. 1.

Emmons		Reinhard	Berek	Duparc-Reinhard	Fedorov-Nikitin
Inner vertical axis	(I. V.)	N	A_1	N	N
Inner east-west axis	(I. E-W)	—	—	—	—
North-south axis	(N-S)	H	A_2	H	H
Outer vertical axis	(O. V.)	A	A_3	M	M
Outer east-west axis	(O. E-W)	K	A_4	J	J
Microscope axis	(M)	M	A_5	—	—

The illumination should be carefully adjusted in studying plagioclase to obtain accurate results. The purpose is to be sure that the light path is parallel to the axis of the microscope. Direct the beam of the arc lamp or other source squarely onto the plane mirror. Adjust the mirror to give good light in the microscope. Then close down all diaphragms, especially the one below the polarizer[3] and readjust the mirror. The light should be at the center on the cross hairs when viewed through the bertrand lens.

It is not essential to use an objective provided with an iris diaphragm. Such a diaphragm contributes to sharper extinctions
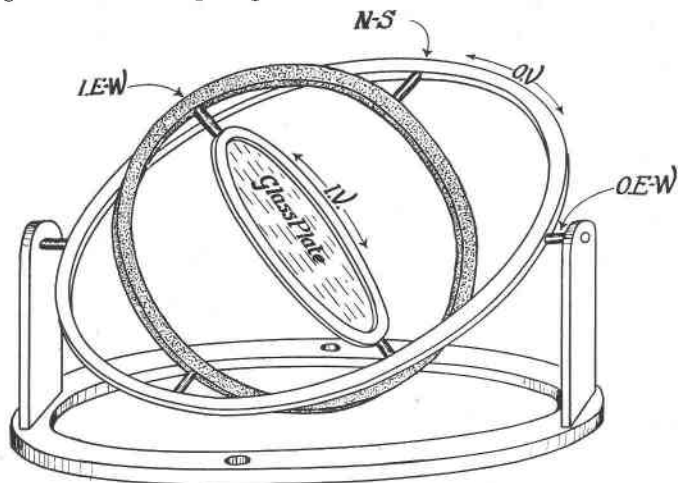

FIG. 1. Showing the five axes of the Bausch & Lomb Universal Stage.

however and is desirable for accurate work. Preliminary or routine procedures may be done with an abundance of light, but the final adjustments, made for accuracy, are done with the several diaphragms cut down.

The many lenses should be tested for strain as a preliminary check. This test is especially desirable for this type of work though it should be made on every petrographic microscope. The most satisfactory test is made with a Berek compensator, by which strain is easily detected as a change from a uniaxial to a biaxial figure. Such strain gives an erroneous orientation and consequently disturbs the results.

[3] This may be obtained as a clamp-on accessory if not embodied in the microscope.

The method of orienting a biaxial crystal is given in two previous papers by the writer and need not be reviewed here (2) (5).

The General Principles of Plagioclase Determination by Rotation

The earlier workers who have accomplished so much in this field have based their determinations on the fact that the orienta-
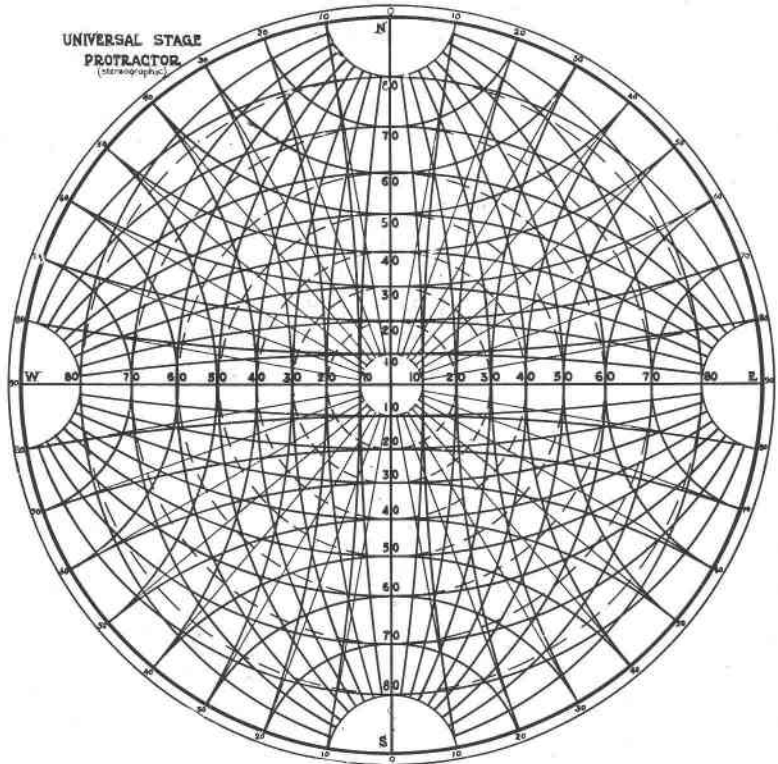

Fig. 2. The Fedorov net. The Wolff net is similar, differing in that it lacks some of the lines of the Fedorov net. The Fedorov net is especially convenient for making the various corrections. A gnomonic net similar to the Fedorov stereographic net is useful for corrections and some find it less confusing.

tion of the optic elements of plagioclase follow a progressive variation with respect to the crystallographic elements, a variation which is as characteristic of the series as are the index changes from albite to anorthite, or the change in 2V, and sign. This orientation variation is graphically illustrated in modern descrip-
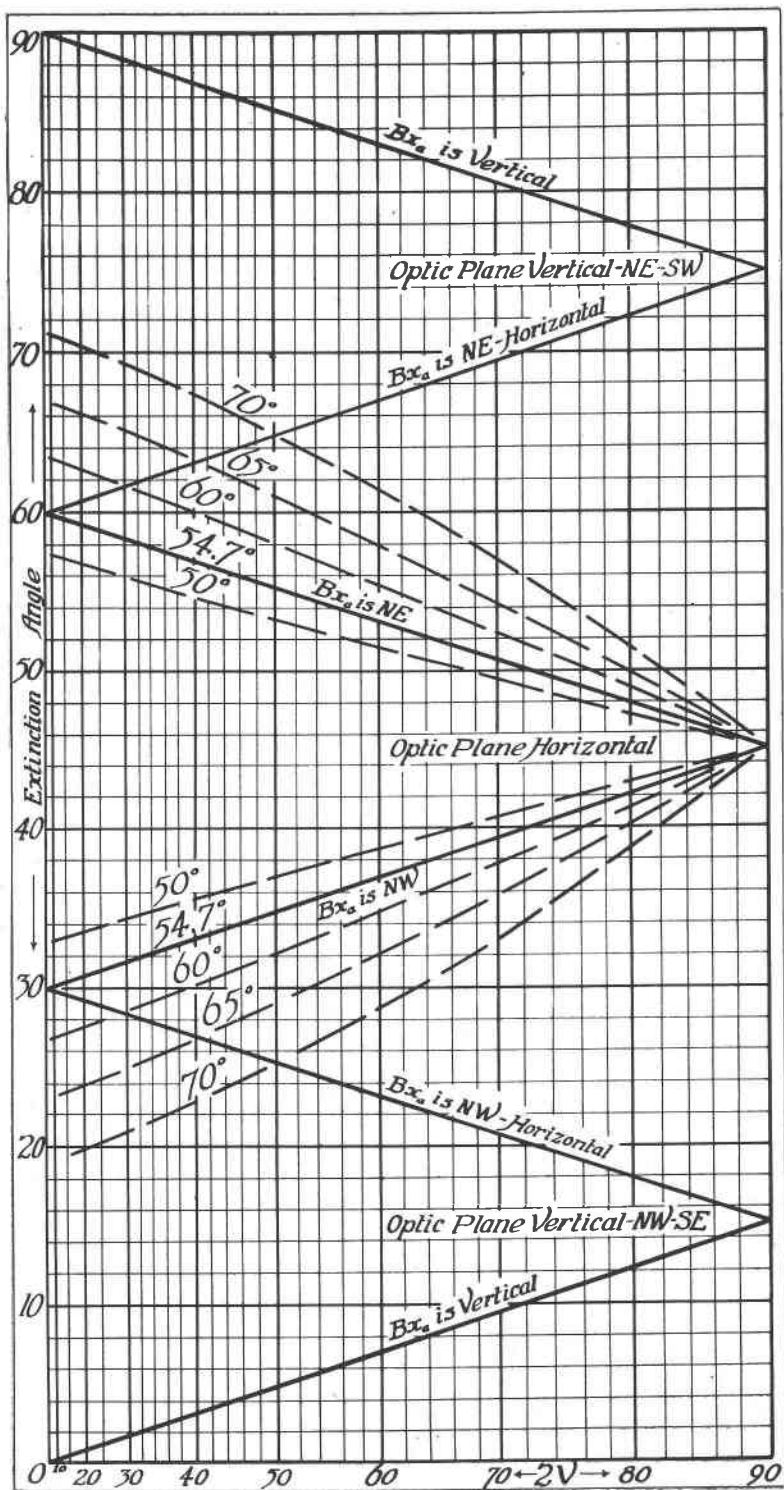
FIG. 3. This diagram is designed for use with feldspars only. It combines Berek's fundamental curves and Dodge's additional curves for the case in which the optic plane is horizontal and 2V may not be read directly. The abscissa scale is arranged to emphasize the inaccuracies of this method when applied to crystals of small 2V.

tive texts on the subject and may be profitably reviewed (6) (7). The original procedure which employs the Fedorov stage with four rotational axes instead of five is in brief as follows,—orient and plot in stereographic projection, one at a time, the optic symmetry planes of each member of a twinned crystal, the composition face or faces, the poles of the planes of cleavage, of crystal faces if present, and any other crystallographic elements which might serve as a means of reference. Then locate on the plot α, β, and γ for each twin member by the intersections of the plotted symmetry planes, and from them the axes of twinning, and hence the type of twinning. α, β, and γ of one of the twin individuals together with one or more of the crystallographic elements are then rotated to a stipulated cardinal position and reference is made to a chart such as those of fig. 6. The points representing the poles and the axes of twinning, etc., indicate by their positions on reference lines, the anorthite content and the twinning law. The new procedure described here is based on the above but eliminates certain steps of graphical construction by executing them directly and more rapidly on the instrument, resulting thereby in a considerable saving of time. The excessive time consumption necessary to the proper execution of the methods of Fedorov is an outstanding limitation, overcoming for many the satisfaction afforded by their revelations. It is felt that a modification designed to help in surmounting this limitation may be welcomed.

The necessary background has long since been worked out for the plagioclase series but the data available do not yet permit interpretation of the influence of the potash molecule present. Fig. 6, which embodies a considerable part of this background, though taken from Nikitin and Reinhard (4) represents the work of many men. Figs. 6b and 6e are the original diagrams, the others are different orientations of them. Their purpose will be brought out later. The Fedorov net, Fig. 2, or the Wulff net are generally used to aid in making the necessary rotations on the stereographic projections. The Fedorov net serves our purpose here more generally and is used exclusively. It is used also in making certain corrections. The procedure recommended is that used in the writer's classes.

EMPIRICAL PROCEDURE

We shall assume that a plagioclase crystal, suitably twinned, (Fig. 4) is chosen and that one of the twin members is oriented so that α, β, or γ is parallel to the axis of the microscope.

(1) First, more should be learned about the details of the orientation. On the outer vertical axis rotate 45° in either direction but bear carefully in mind which way. To avoid confusion it is well to use one direction at all times when possible. This is the reference position for fig. 3. Rotate 54.7° *crystallographically* (i.e., corrected) on the outer E-W axis in whichever direction is more convenient, according to the inclination of the inner stage. If neither direction is convenient, rotate 90° (i.e., to the other 45° position) on the outer vertical axis and then rotate 54.7° on the outer E-W axis. Then rotate on the microscope stage counter-
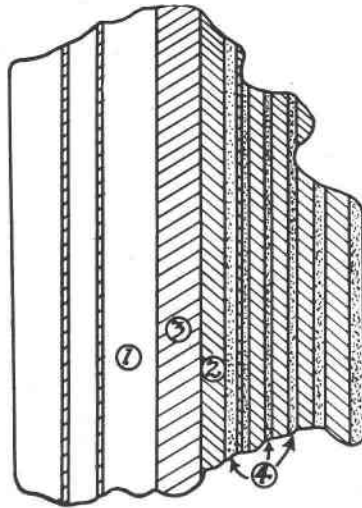

Fig. 4. The twinned feldspar used in the illustration.

clockwise to extinction. Berek's curves (solid black line in fig. 3) now indicate *for the reference position* the attitude of the optic plane and the position of the acute bisectrix. Rotate the microscope stage back to its zero position, return the outer E-W axis to its zero position, and insert the sensitive tint plate bearing in mind the position of the optic plane and the acute bisectrix as determined from fig. 3. The change in interference color of the tint plate gives the sign of the crystal and indicates definitely which direction is α, β, and γ. The sign may remain in doubt if 2V is near 90°, unless the corrections for 54.7° were very carefully made. Record this information as illustrated in table 1. Using a standard

stereographic diagram[4] this information may now be plotted, α, β, and γ being one N-S, one E-W, and one at the center. After a little experience has been acquired, all the information may be

Fig. 5. The four twin units of the crystal illustrated in fig. 4. These diagram[s] show the method of locating points and of rotating most easily to new positions[.] Each was placed over fig. 2 on a light table. (There are some explanatory lines on the drawing which are not made in routine work.)
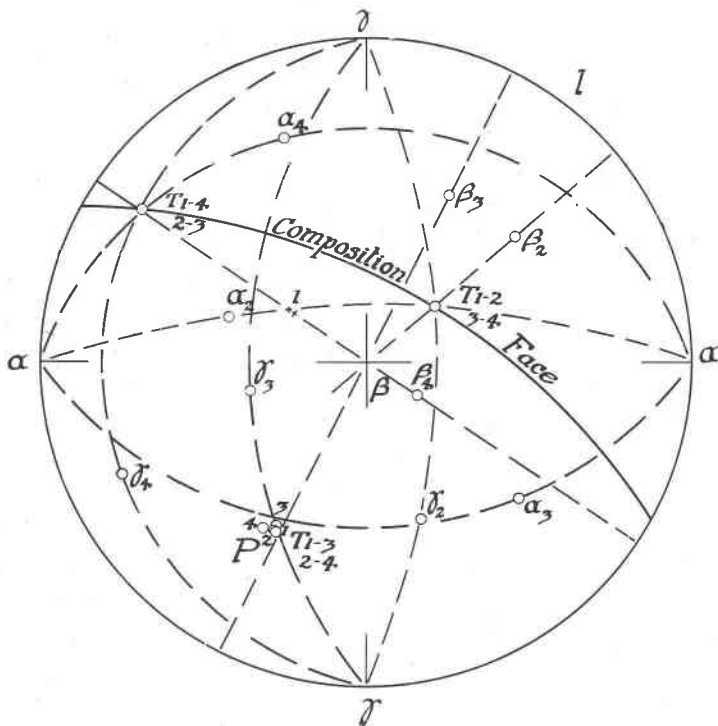

Fig. 5a is the compilation sheet showing the method of locating twinning axes.

assembled on a blank for the purpose and the plotting left till the end.

[4] It is convenient to supply the laboratory with blank charts such as Fig. 2 but the plotting may be done equally well by placing Fig. 2 on a light table and marking on thin paper on which a fundamental circle of the same size has been drawn. The size of circle which has been accepted in Europe is 20 cm. In the writer's laboratory a diameter of 17 cm. has been adopted as better fitting the standard $8\frac{1}{2}'' \times 11''$ page.

(2) If the optic plane is vertical, V or 2V may be read directly in the following manner. Rotate on the stage of the microscope from the oriented position 45° either way. Then using that horizontal axis which is perpendicular to the optic plane (now known), rotate to an extinction position or to both of them if possible. The angle between these positions is apparent 2V, (or apparent V if
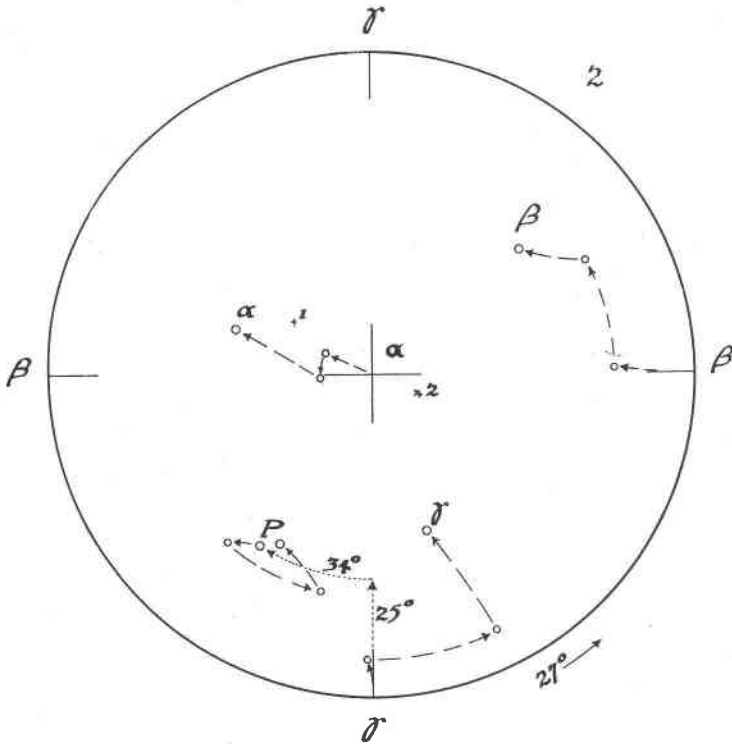

Fig. 5*b*.

measured from α or γ). It is to be corrected for difference in index between crystal and hemispheres as described later. It is almost always possible to measure V or 2V by this direct method in studying plagioclase when the optic plane is vertical, even when the acute bisectrix is horizontal, since 2V is never less than 70°.

If the optic plane is horizontal in the chosen position of orientation it is sometimes possible to obtain a direct reading by rotating on the N-S axis sufficiently to make the optic plane vertical (and parallel with the N-S nicol). In this position V or 2V may be read

as before by turning on a horizontal axis to the proper extinction position. In the event that this rotation is not convenient a more accurate determination of 2V by Berek's method may be made by rotating more than 54.7° on the outer E-W axis. Some additional curves have been added to Berek's diagram (3) for the horizontal position of the optic plane where direct reading of 2V is not possi-
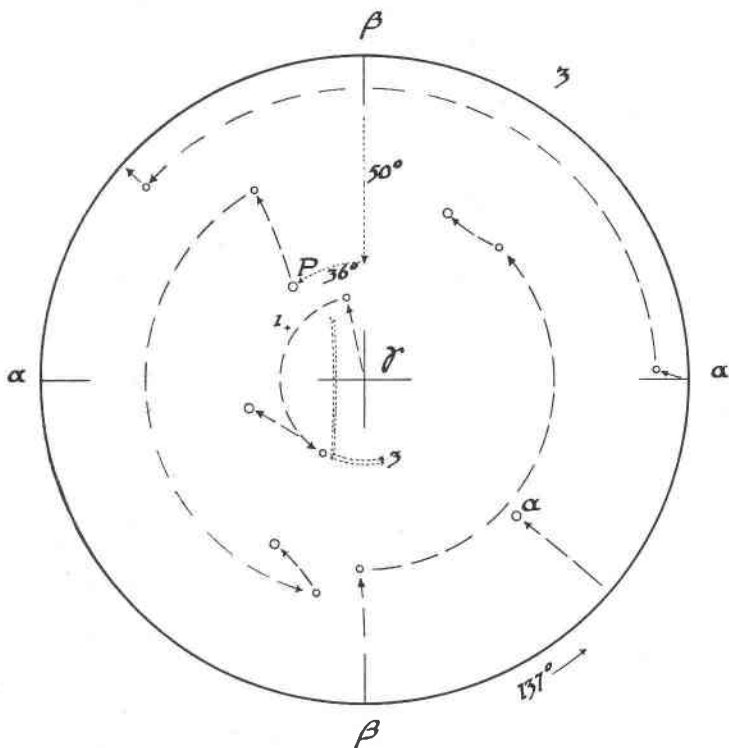
Fig. 5c.

ble. Rotate on the outer E-W axis as much more than 54.7° as is convenient, correct the value of the angle of rotation, determine the counter-clockwise extinction angle and either use the proper curve or interpolate. We now know 2V, and the results for plagioclase (2V = 70°–90°) are quite satisfactorily accurate as may be seen from the curves. Berek's curves as reproduced in fig. 3 are reduced to straight lines thereby expressing in the abscissa scale the variable accuracy of 2V with the size of the angle.

(3) Next search the crystal for traces of cleavage. Make the

cleavage plane vertical and parallel either to the E-W crosshair by rotation on the outer E-W and the outer vertical axes or to the N-S crosshair by rotation on the N-S and outer vertical axes. Record the values. Do the same for the composition faces of the twins. It is by no means easy to make these reference planes *accurately* parallel to the axis of the microscope in sections of standard

Fig. 5*d*.
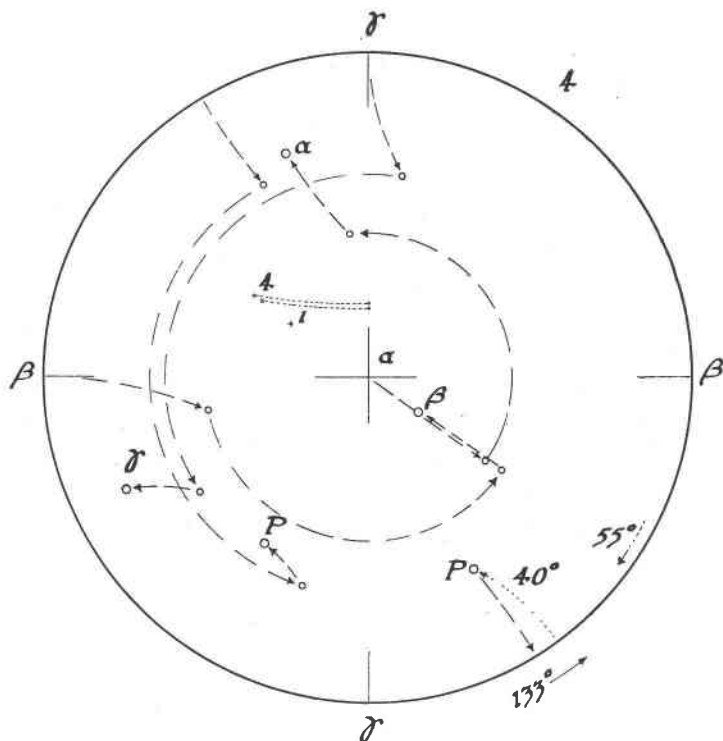
thickness. Nikitin therefore recommends using special sections as much as 0.1 mm. thick. In practice it will be found desirable for accurate work to use sections 0.06–0.10 mm. thick. The thicker the section, the broader must be the lamellae to make orientation possible. This limitation militates against the use of thicker sections than standard. Parallelism to the axis of the microscope is obtained when the line defining the plane is sharpest, that is when the plane is on edge. It is advisable to make several readings and to use an average value for the horizontal axis reading.

(4) Information thus far obtained, enables us to learn where in the crystal is α, β, and γ and where with respect to these directions are the planes of cleavage and the composition faces of the twins.

FIG. 6. Fedorov-Nikitin stereograms. (b) and (e) are the original drawings. The others are different orientations needed for the method described here. The data for the points were taken from Nikitin's recent paper (4).
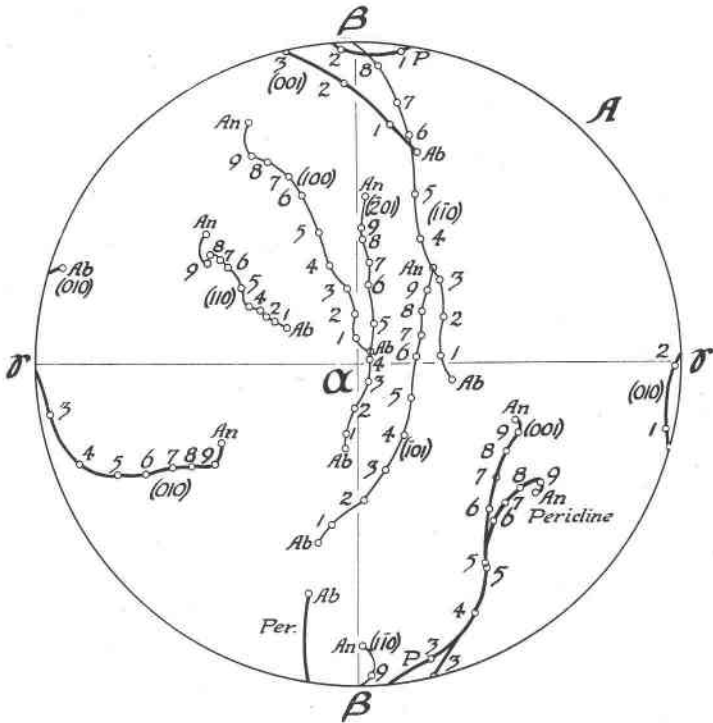
FIG. 6a.

That is, we now have enough information to indicate the relation between the optic orientation and the crystallographic orientation. Therefore on the chart (Fig. 2) on which α, β, and γ have been noted in cardinal positions, plot with corrections as given later the poles of the reference planes, and superimpose the chart on Figs. 6a, 6b or 6c according to whether α, β, or γ is at the center. The positions of the points representing the face poles, on the reference lines of the plot, indicate the anorthite content of the crystal. In actual practice the approximate composition is learned first by

plotting the pole of one face. This value gives the approximate index value, β, of the plagioclase and this is used in correcting the various rotations. In routine work only one plane (cleavage, crystal face or composition face) is used. For a check more than one is plotted.

It will be noticed that four positions of superposition are possible. The correct one is learned by trying each, and choosing that which fits. To do so (1) place the chart over the reference diagram in a position such that α, β, and γ of each properly coincide. Then (2) invert the chart by rotating 180° about one horizontal axis, α for example, assuming β to be at the center; next (3) invert again but about γ in a similar manner, and (4) invert once more about α. (A second rotation about γ would give the original position again.)

The points will not often fall exactly on the reference lines, either because of inaccurate work or because of the potash content of the crystal, or because of strain in the crystal. If a point does not fall exactly on a line, it does not necessarily indicate that potash is present, and if it does fall exactly on a line it does not indicate that potash is absent. The time required to execute the steps thus far taken is surprisingly short for an experienced operator.

An example follows:

TABLE I

UNIVERSAL STAGE DATA SHEET

Rock: *C-15-9*　　　　　Locality: *Hot Point, Lake Superior*
Mineral: *Plagioclase*　　Zero Positions—Mic.　*186.3°*
Hemispheres *1.649*　　　　　　　O.V.　*90°*

Unit 1:—

I.E.W.	17°N	I.V.	22°	Comp. Face	H	26.5°S
N.S. 1	26°W	α	E		V	28.5°
2		β	⊥	Cleavage 1	H	
O.A. 1		γ	N		V	
2		Bx_a		" 2	H	
Ext.B	44°	Sign			V	

Unit 2:—

I.E.W.	7°S	I.V.	49°	Comp. Face	H	24°S
N.S. 1	16°E	α	⊥		V	34° ↰
2		β	E	Cleavage 1	H	
O.A. 1	42°S	γ	N		V	
2	40°N	Bx_a	⊥	" 2	H	
Ext. B		Sign	—		B	

Unit 3:—

I.E.W.	28°S	I.V.	159°	Comp. Face	H	47°N
N.S. 1	7°E	α	E		V	36° ↙
2		β	N	Cleavage 1	H	
O.A. 1	44°W	γ	⊥		V	
2		Bx_a	E	" 2	H	
Ext. B		Sign	—		V	

Unit 4:—

I.E.W.	24°N	I.V.	155°	Comp. Face	H	38°E
N.S. 1	38°W	α	⊥		V	55° ↰
2		β	E	Cleavage 1	H	
O.A. 1	44°S	γ	N		V	
2		Bx_a		" 2	H	
Ext. B		Sign			V	

REMARKS:
    Composition face is (010)
    Twins present—Albite
               Carlsbad
               Albite-Carlsbad Complex
    Composition: 72–75% An.

In fig. 5 the points P represent the pole of the composition face of the twin unit. Note the method of plotting the points—the values were obtained from fig. 2. When these drawings are superposed on fig. 6 it will be found that the points P fall near the line (010) at $\pm 75\%$ An. Adjacent twin lamellae need not have the same composition but are ordinarily close.[5] Since it is intended to point out
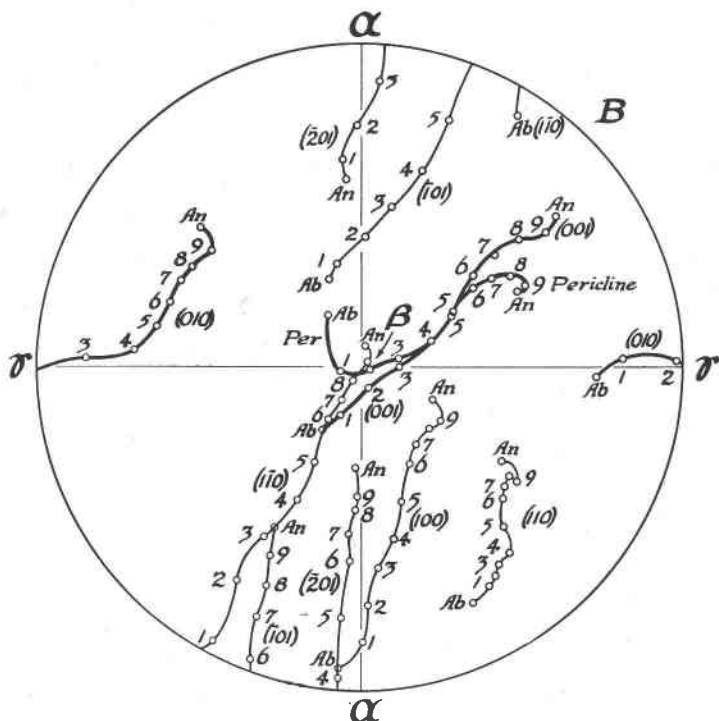

Fig. 6b.

here only the *difference* in the procedure, one example is deemed sufficient. It was selected as a typical one rather than for its completeness or perfection.

Thus far one unit of a twinned plagioclase has been studied and its optic orientation has been related to its crystallographic orientation revealing the anorthite content. We still do not know the type of twin or the position of the twin axis. When this axis is

[5] A. L. Coulson reports differences as high as 17% An. *Rec. Geol. Surv. Ind.*, vol. **65**, p. 163, 1932.

learned it is used in a manner similar to that of the pole of a crystallographic face, to indicate the anorthite content of a plagioclase. It tells us, then, the type of twin by its attitude relative to the composition plane, and by its attitude relative to the optic

FIG. 6c.

orientation it should confirm information already obtained on the anorthite content. The procedure continues:

(5) Having completed the orientational study of one twin unit, attention is similarly turned to another, and a third if a third is present and so on. Each in turn is oriented, the positions of α, β, and γ specifically determined as already outlined for the first, and the cleavage directions and composition planes are related to this optic orientation. Then a stereographic projection blank is filled out in an identical manner for each of these twin units including the placing of the pole of the composition plane (and of the cleavage).

(6) Each member is plotted in an orientation which may be different crystallographically and optically from that of the others. To locate the twin axis all are to be reduced to one crystallographic orientation, that of any one of the plots already constructed, by rotating the points of the others on a stereographic plan. The procedure is this—*first*, choose any one of the plots, locate the
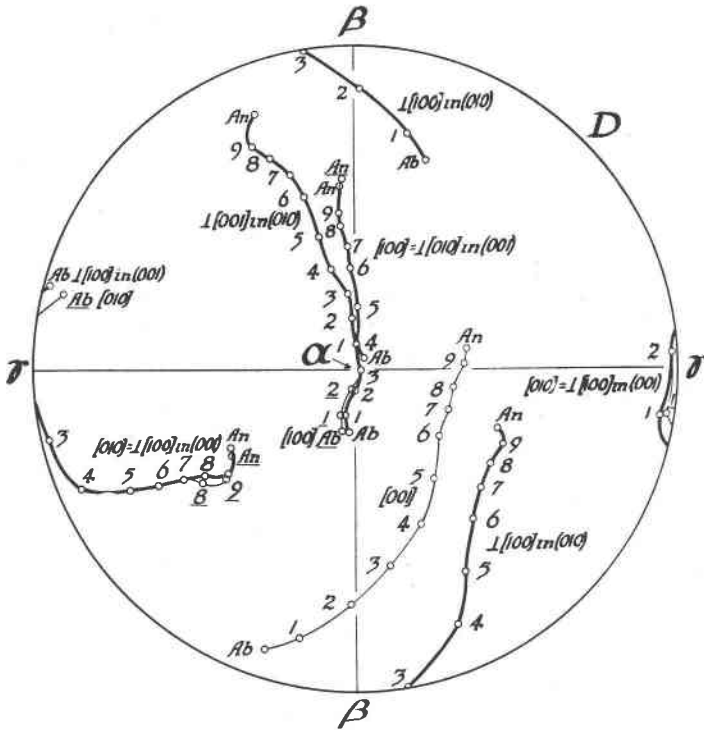

FIG. 6*d*.

perpendicular to the inner stage (for fig. 5*b* it is 7°S, 16°E from the center) and correct the radial angle for difference in index between crystal and hemispheres. The symbols used in the drawings are "×" to indicate an uncorrected point and "+" to indicate a corrected point. The correction is made of course on Fedorov's index diagram reproduced in the earlier paper (2) for sin i $= n$ sin r. Place the chart over a blank one and turn it until the corrected pole of the plane of the inner stage lies on one of the cardinal lines (N-S or E-W) of the blank. Each point is then easily and rapidly

rotated (figs. 5*b*, 5*c*, 5*d*) to its new position, the amount of rotation being that needed to bring to the center the perpendicular to the inner stage. This yields the orientation of the crystal in the horizontal position of the thin section. If there are more than two twin members studied then all but one are so rotated. This one may be arbitrarily selected as unit one.
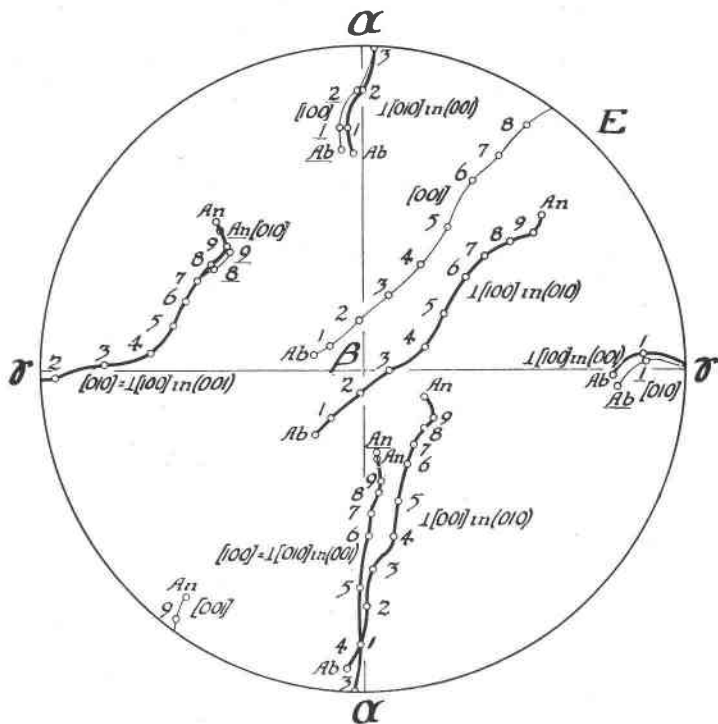

Fig. 6*e*.

Second, each of those so rotated is next turned on an axis perpendicular to the plane of the paper, an amount sufficient to make its orientation, crystallographically identical with that of unit one before its inclination. This amount is read directly from the graduations of the stage,—it is the difference between the inner vertical axis readings of the two units. If the reading for the second unit is less than that for unit one then the points of the second unit are rotated clockwise the proper amount, keeping their radial distance from the center the same,—and *vice versa*.

Third, the second unit is now to be inclined an amount equal to the inclination of unit one. Locate on the unit two chart the corrected position of the perpendicular to the inner stage of unit one. Each point of unit two is then rotated the amount of this radial angle. A simple way to do so is similar to step one above. Superimpose the unit two chart on a blank chart with this new point
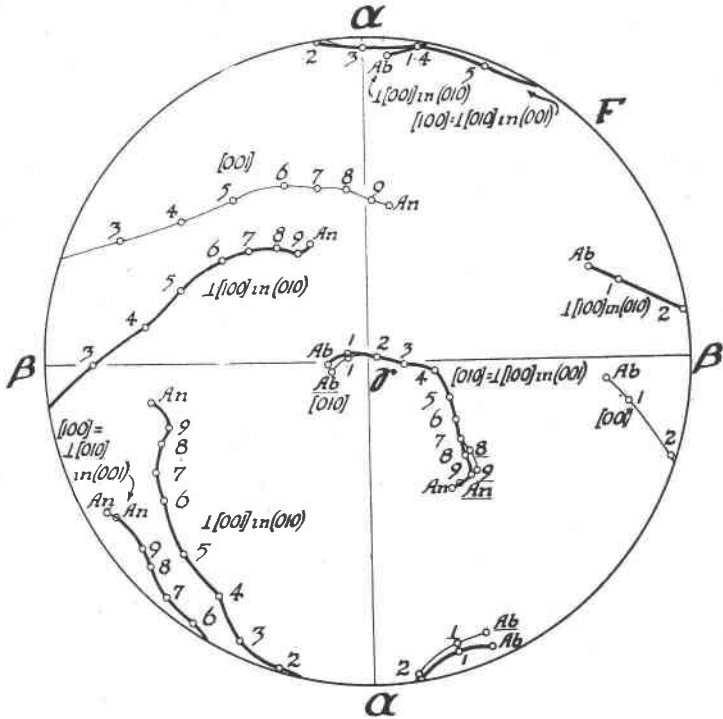

Fig. 6*f*.

on one of the cardinal lines. Then rotate each of the points of interest from their last found position to new positions, an amount sufficient to bring the center to the point transferred from the unit one chart. The points α, β, and γ of unit two are now so placed that this unit is in the position which it occupied when unit one was oriented; these points may now be transferred therefore to the chart of unit one and be properly labelled that there may be no confusion. (i.e., α_2, β_2, γ_2). Other units than the first are similarly treated and transferred to unit one. Fig. 5*a* therefore shows unit

one in critical orientation and units two, three and four in proper relationship to it.

Fourth, if a fundamental circle has been used throughout, as in the example, then superpose in cardinal position the unit one chart to which have now been added α_2, β_2, and γ_2, etc., on fig. 2 and trace the great arcs passing through $\alpha_1-\alpha_2$, $\beta_1-\beta_2$, $\gamma_1-\gamma_2$, $\alpha_1-\alpha_3$, etc. These great arcs will indicate by their points of intersection the twinning axes. They delimit a small triangular area—theoretically a point—at the center of which a point is chosen—it is the twinning axis. Unit 4 is narrow (see fig. 4), a difficult type to orient accurately since large rotations on horizontal axes cannot be made. The orientation of this unit is not so accurate as the others but it illustrates a common difficulty.

The twinning axis lies either in the composition plane or 90° to it. If it is perpendicular to it, coinciding with the pole of the plane, the twin is a normal twin; if it lies within the composition plane the twin is a parallel or complex twin. Seldom does the axis fall ideally in position but it should lie reasonably close to it. Errors of reading, especially of the positions of twin or composition planes, and "errors" due to the presence of K_2O cause discrepancies. The plot is now superimposed over the proper reference plot (figs. 6d, 6e, 6f) and the axis of twinning falls on a line after proper adjustment as was done for the pole of cleavage, indicating thereby the twin law (which the line represents) and the anorthite content (which points on the line represent). Commonly the point representing the twin axis does not fall exactly on the line due to the discrepancies mentioned above.

The corrections are best explained with the aid of an example. In fig. 5c the perpendicular to the inner stage is 28°S and 7°E. These values are to be measured in this order since the axis I.E-W is dependent on the axis N-S. The radial angle is measured next (28°) and corrected for the difference in index of the feldspar (1.57) and the hemisphere (1.649) to 29.7° using Fedorov's diagram. The composition plane of unit three is given as 47°N and 36° clockwise on O.V. from the oriented position. The correction is made on the position of the perpendicular to the inner stage. From both positions "×" and "+" on fig. 5c, measure 36° counter-clockwise. From the new position of "×" measure 47° north along the proper great arc as indicated by the dotted line. Correct the radial angle of

this last found position, and measure the angle south to the corresponding corrected point. It is 50°.[6]

To locate the pole P, measure from the north pole 50° south—the reverse of the original reading,—and 36° counter-clockwise—also the reverse of the original reading. This locates P when the axes O.V. and O.E-W are at their zero readings.

In the readings for the composition face of unit 4 (fig. 5d) the N-S crosshair was used and therefore the axis N-S, which is dependent on the axis O.V. To correct the reading 38°E therefore do not measure 55° counter-clockwise first from the perpendicular to the inner stage (marked "4") but measure 38°E directly as indicated and correct the radial angle. The corrected points indicate a rotational value of 40°E. Note too the difference in locating P. First measure 55° clockwise from the east pole—the reverse direction of the original reading and then measure 40° parallel to the proper arc as indicated by the dotted line. If the positions of the axes are kept in mind there will be no confusion. In general the student's greatest difficulty is encountered in handling the corrections.

SUMMARY OF PROCEDURES

1. Orient a twin unit of a chosen crystal, record the scale readings of the axes I.V., I.E-W and N-S.

2. Orient a cleavage plane, or composition face, etc., and record the scale readings.

3. Determine the positions of the optic plane and acute bisectrix (the sign and 2V).

4. Plot α, β and γ on a suitable chart or preferably on a circle to fit an accompanying Fedorov net. Here they will fall one at the center, one north (and south) and one east (and west).

5. Correct readings made on horizontal axes for the pole of the chosen plane, plot them and fit the plot to the proper reference

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[6] In the references (2) and (5) corrections are made on a stereographic net over which a system of square coordinates was placed instead of following the more accurate, outwardly concave great arcs. For corrections of the type made in those papers an introduced error virtually cancels itself, since only the center of the drawing was used, and the advantage of following straight lines remains. In the writer's laboratory this has been given up for the gnomonic net which also has one set of straight lines. If the Fedorov net is not found confusing, it may be used for all these purposes.

diagram. This is sufficient to give the composition of the plagio-clase.

To determine the twin law:

6. Orient a second unit of the twin and any others present re-cording the values as in table I. Make the necessary corrections and plot the results on separate sheets.

7. Rotate all but unit one through three movements to bring them to the orientation they assumed when unit one was critically oriented.

8. Draw the great circles to locate the twin axes.

It may be noticed that in fig. 5a the great circles through $\alpha_2 - \alpha_3$ $\alpha_2 - \alpha_4$, $\alpha_3 - \alpha_4$ and similarly for β and γ have been omitted to avoid confusion of lines. They indicate the same axes as suggested by the notations on the figure.

It is obvious that the principles underlying this type of study are especially useful in studying feldspars mainly because of the comparative wealth of data available. In principal the technique is equally effective in the study of other minerals, but data are frequently lacking. For those minerals in which optic orientation is a good diagnostic criterion, this is especially well adapted, and there are many such.[7]

[7] When this paper was presented at the Chicago meeting of the Mineralogical Society, Professor E. S. Larsen expressed doubt about the possibility of adjacent twin lamellae being different in composition. Although the writer entertains no such doubts he considers Professor Larsen's comments pertinent. A hurried preliminary test was run on a plagioclase crystal from the anorthosite at Beaver Bay, Lake Superior. This rock was chosen because of the breadth of its twin lamellae. The indices of adjacent lamellae in the crystal studied are:—(1) $\alpha = 1.5666$, $\beta = 1.5718$, $\gamma = 1.5757$; (2) $\alpha = 1.5659$, $\beta = 1.5707$, $\gamma = 1.5759$ ($\pm .0003$). These values are not at all startling but are adequate to indicate a real difference in composition—in this case 2–3% An. It is proposed to study this point thoroughly and to report briefly later.

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