AN INTERACTIVE PROGRAM FOR DETERMINATION OF PLAGIOCLASE CRYSTAL AXES ORIENTATIONS FROM U-STAGE MEASUREMENTS: AN AID FOR PETROFABRIC STUDIES

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Abstract—UNIPLAJ is an interactive program for use on a microcomputer which permits rapid and efficient determination of orientation of plagioclase crystallographic directions from Universal Stage data. The program constructs stereographic projections of Universal Stage data on the computer screen and performs rotations. Orientation data are checked visually and crystallographic direction data are obtained by the program which also creates files. The time necessary for performing complete plagioclase petrofabrics thus is reduced considerably and errors due to the result of manual manipulation of data are eliminated.

Key Words: Mineralogy, Petrofabrics, Petrology structure, Kinematics.

INTRODUCTION

Petrofabric analysis may be performed for a number of reasons including structural and kinematics analysis (Sander, 1970; Nicolas and Poirier, 1976) and calculation of seismic anisotropy (Mainprice and Nicolas, 1989). The least expensive and most accurate method of gathering data for petrofabric analysis involves measurements performed on individual mineral grains in a thin section using a Universal Stage (U-Stage) mounted on a petrographic microscope. Measurement of the optical indicatrix, cleavage planes, or compositional planes of twinning is relatively straightforward (see for instance Phillips, 1971). For kinematic analysis of tectonite rocks and for seismic anisotropy calculations, the information of greatest interest is the preferred orientation of crystallographic directions of minerals in a rock. In orthorhombic minerals such as olivine and orthopyroxene, the optical indicatrix directions Np, Nm, and Ng (or x, y, and z) are parallel to the major crystallographic directions, and thus crystallographic preferred orientations may be inferred directly from the indicatrix measurements. For triclinic minerals, such as plagioclase, none of the principal crystallographic directions may be inferred directly from the indicatrix measurements. For triclinic minerals, such as plagioclase, none of the principal crystallographic directions may be inferred directly from the indicatrix (Fig. 1). Because of its relative abundance in the Earth's crust (> 51%; Ronov and Yaroshevsky, 1969), complete petrofabrics of plagioclase crystallographic directions are of great interest, although rarely reported in the literature. Until recently, most plagioclase petrofabrics have been limited to the optical indicatrix (e.g. Shelley, 1977; Jensen and Starkey, 1985; Olsen and Kohlstedt, 1985; Olesen, 1987), or construction of certain crystallographic directions using indicatrix and cleavage or twinning measurements (e.g. Brothers, 1964; Duffield, 1968; Olesen, 1987). Wenk and others (1986) have introduced a method which allows construction of complete plagioclase crystallographic orientation diagrams from the measured indicatrix and poles to two other measurable planar structural elements, one parallel to (010) [either (010) cleavage or twinning compositional planes], and either (001) cleavage or pericline twinning planes. This method also has been employed by Ji and Mainprice (1988) to produce complete plagioclase petrofabrics. Until now, such crystallographic constructions should have been carried out manually (see following section), a process which has several drawbacks.

1. Manual construction of crystallographic orientations is time consuming and tiring.
2. The construction technique involves several rotations of orientation data, during which errors may be introduced inadvertently.
3. When performing numerous constructions (normally, at least 100 should be performed for a petrofabric analysis), large amounts of tracing paper must be used (at least one sheet per measurement).

We present here an interactive program for use on a microcomputer which performs the tedious work of plotting measurements on a stereographic projection, rotations of data, and obtaining crystallographic orientation data. The program UNIPLAJ also stores data in files which then can be used to plot the results either manually or using a computer. Data obtained using UNIPLAJ are for positive crystallographic directions and the program takes into account whether data are projected in the upper or lower hemisphere. The program is written in Amiga BASIC for use on a Commodore Amiga microcomputer.
Figure 1. Plagioclase crystal of approximately andesine composition with orientations of indicatrix directions and three crystallographic directions [100], *(010), and *(001) indicated. Note that none of crystallographic directions are parallel to indicatrix.

GENERAL CONSTRUCTION METHOD

UNIPLAJ has been developed in such a manner that the operator follows the same general procedure for construction of plagioclase crystallographic orientations as has been described in Wenk and others (1986). Before discussing the program, this construction method now will be outlined briefly.

Manually, the procedure is performed by plotting the U-Stage measurements for the indicatrix, and the poles to the two planar elements measured, on a sheet of tracing paper superposed onto a stereographic net. The data, which is in a lower hemisphere reference frame must be projected into the upper hemisphere and then rotated to bring Nm (fl) into a position perpendicular to the projection. The tracing paper then is superposed onto the Burri, Parker, and Wenk (1967) plagioclase determinative diagram (Fig. 2). The optical directions Np, Nm, and Ng coincide with the Burri diagram in four possible positions, but the poles to the two planes measured will coincide with the migration curves for (010) and either (001) or the pericline twin in only one of these four positions. Once the position where all measurements coincide has been obtained, the required crystallographic directions are located on the respective migration curves of the Burri diagram (see Fig. 2) and marked on the tracing paper. All rotations performed in order to achieve this position, then must be determined in the opposite sense, and the data transferred to the lower hemisphere U-Stage reference frame. The rotation of the required crystallographic directions then may be measured and noted. It is important to take care, when rotating data back to the original position, to note that some data points may change hemisphere as a result of the rotation. This is of absolute importance for plagioclase crystallographic constructions, as positive and negative crystallographic directions must be taken into account. A full sphere is thus necessary for a final representation of plagioclase orientation in stereographic projection (Wenk and others, 1986).

Figure 2. Plagioclase determinative diagram modified from Burri and others (1967). Migration curves give orientations of crystallographic directions with respect to indicatrix for different compositions of plagioclase. An is anorthite end-member, and Ab is albite end-member.

UNIPLAJ

Coordinate systems

UNIPLAJ works with directional data in three coordinate systems which are summarized in Figure 3. These are:

(1) $\Psi/\rho$ — coordinates on a sphere. $\Psi$ corresponds to the azimuth of linear data, and $\rho$ to the complimentary angle of the plunge of linear data.

(2) $X, Y, Z$ — Cartesian coordinates.

(3) $IX, IY$ — screen coordinates.

The spherical coordinate system is the most easily comprehensible for the operator. All rotations of data are performed mathematically using Cartesian coordinates $XYZ$ in a $3 \times 3$ matrix (Noble, 1964). Screen

Figure 3. Three angular reference systems used by UNIPLAJ. Circle represents stereographic projection. $\Psi$ and $\rho$ are spherical coordinates; $X, Y$, and $Z$ are Cartesian coordinates; $IX$ and $IY$ are screen coordinates. “Plunge” is plunge of line projected in sphere.
Determination of plagioclase crystal axes orientations

Migration curve data

When the program UNIPLAJ is charged, two sets of orientation data are stored in arrays which correspond to the migration curves for variations in orientations of plagioclase crystallographic directions with An content (Fig. 2). The crystallographic orientations for 51 compositions of plagioclase (An₀, Anᵢ, Anₓ, ..., An₁₀₀) are present in data lines as Azimuth, Plunge, and first are read directly into arrays. Data for 11 compositions (An₀, Anᵢ₀, Anₓ₀, ..., An₁₀₀) are recalculated then as screen coordinates and stored in arrays which are subsequently used as a source of data for construction of the Burri plagioclase determinative diagram on the computer screen.

Graphics

UNIPLAJ allows the operator to follow essentially the same procedure as outlined previously for constructions of plagioclase orientation diagrams, but more rapidly and more efficiently. Graphics of stereographic projections are created on the screen for the original measurements, and for the new directional data following each rotation. The steps followed for rotations of data are outlined in Figure 4.

The subroutine WNDO defines a high resolution screen which may hold up to eight colors, creates a window in the new screen, and defines a color palette. For each input of orientation data, the screen and window are defined only once, and the LINE statement is used to fill in the window with the background color (palette number 0, in this situation) to efface graphics. The subroutine STEREO creates the outline of a stereonet, a color explanation for data points, plots migration curves for *(010) [the pole to (010)], *(001) [the pole to (001)] and the pole to pericline twinning on the stereonet, and indicates which pos-
Figure 6. General flow chart of UNIPLAJ.
Determination of plagioclase crystal axes orientations

Use of the program

A general flowchart of the program UNIPLAJ is presented in Figure 6. The operator is first prompted for the names of files in which the obtained data will be stored. We have selected to create five separate files for (1) raw U-Stage data, (2) [100], (3) *(010), (4) *(001), and (5) a compilation of [100] and *(001) which may be used subsequently as a data source for a program written by the second author to perform calculations of seismic anisotropy (Mainprice, 1989).

The operator then is prompted for (1) U-Stage indicatrix data, (2) U-Stage data for a first planar element, and (3) for a second planar element. A sample input is presented in Figure 7. The input indicatrix data uses a code which was developed by Bouchez (1977) for treatment of measurements performed on a five-axis U-Stage. This input might be altered for use with another code, or for use with data measured using a four-axis U-Stage (see for example Tocher, 1978). At each input line for U-Stage data, the operator has the option of deleting that line and entering new data. A positive response to the test following the entry of data for the second planar element causes UNIPLAJ to:

1. Calculate Azimuth/Plunge of the three indicatrix axes [subroutine sphere (Bouchez, 1977)].
2. Calculate Azimuth/Plunge of the poles to the two planes measured [subprogram PLAN].
3. Converts these five sets of orientation data to Cartesian coordinates, and converts the data to the upper hemisphere reference frame by changing the sign of the Z coordinate (i.e. \[+Z = -Z\]).

A stereographic projection of the data is created on a new high resolution screen (see previous section). On commands from the operator, UNIPLAJ then performs rotations of data (the different steps are shown in Fig. 4), effacing the previous graphic, and creating a new one with each rotation. Angles for the first two rotations are stored in arrays. After a rotation, the operator may select to abandon the data and repeat the U-Stage measurements. Beginning with position 1, the operator may compare visually the projected data with the migration curves of the Burri diagram, just as when working manually with tracing paper, and then may select to: (1) perform the next rotation, (2) save data, or (3) abandon the measurements. For each position, the screen coordinates are stored in arrays. Once the data is rotated to position 4, the operator may decide to recheck any of the positions 1-4, to save data, or to abandon the data.

When the operator has obtained the position in which the projected data coincides with the Burri diagram and elects to save the data, UNIPLAJ prompts for the composition of the plagioclase (% An content), and searches in the existing arrays for the direction data corresponding to the composition input (subprogram CRYSTALAXIS) for [100], *(010), and *(001). The composition input must be an even number between 0 and 100, as the arrays contain only data corresponding to those compositions. For any given composition of plagioclase, the orientations on migration curves are for negative crystallographic directions for one or two of [100], *(010), and *(001). Depending on the last position shown on the screen, one of the subprograms POSONE, POSTWO, POSTHREE, or POSFOUR then is called. These subprograms correct data for negative crystallographic directions to give corresponding positive directions, and, with the exception of POSONE, bring all data into position 1. These corrections are determined by changing signs of XYZ Cartesian coordinates (Fig. 3). The subprogram LASTROT then is called which, using rotation angles stored in arrays, mathematically rotates data back to the original upper hemisphere orientation. Data are put back into the lower hemisphere U-Stage reference frame, converted to spherical coordinates, and saved in the five separate files. Files are opened and closed each time data are saved, to prevent loss of data between measurements. Negative values for Plunges in final data indicate an orientation in the upper hemisphere. Finally, the operator may choose to stop the program, or to enter a new set of measurements.

**SUMMARY**

UNIPLAJ is an interactive program which allows rapid, efficient, and accurate determination of plagioclase crystallographic orientations from U-Stage measurements. All stereographic projections and
rotations of data are performed by the program and orientation data are checked visually. The program creates files for raw U-Stage data and for the determined crystallographic directions. Final data for crystallographic directions is recorded as Azimuth, Plunge in a lower hemisphere reference frame, negative values for plunges indicating an orientation in the upper hemisphere. Thus, an entire sphere may be employed for plotting the final petrofabric data.

The time necessary for determination of complete plagioclase petrofabrics is reduced considerably; 100 measurements and constructions may be performed per day. Errors which may be introduced during manual elimination of data are eliminated. A version for Apple Macintosh is also available.

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REFERENCES


APPENDIX

******** crystal direction orientation data for different compositions of plagioclase as azimuth/plunge ********

FOR I=0 TO 50
READ DIRAXA(I)
READ PLAXA(I)
READ DIRPOB(I)
READ PLPOB(I)
READ DIRPOC(I)
READ PLPOC(I)
NEXT

******** crystal direction orientation data for different compositions of plagioclase as screen coordinates ********

J=0
FOR I=0 TO 50 STEP 5
CALL ECRAN(DIRPOB(I),PLPOB(I),XPOB(J),YPOB(J))
CALL ECRAN(DIRPOC(I),PLPOC(I),XPOC(J),YPOC(J))
CALL ECRAN(DIRPER(I),PLPER(I),XPER(J),YPER(J))
NEXT

********* MAIN PROGRAM *********
Determination of plagioclase crystal axes orientations

```
PRINT "... and the name for the +A axis file"  
INPUT NOM2
PRINT "... and the name for the pole +0(10) file"  
INPUT NOM13
PRINT "... and the name for the pole +0(001) file"  
INPUT NOM45
PRINT "... and the name for the Seismic Anisotropy file"  
PRINT " (+A and +pole (001))"  
INPUT NOM55

NB=0

10 PRINT
   NB=NB+1
   PRINT "Data line no.";NB
   PRINT "Enter indicatrix data: A,B,J,B,C,IC,KAGY,KAXI"
   INPUT A,B,J,B,C,IC,KAGY,KAXI
   PRINT "Ok? (Y/N)"
   INPUT R$  
   IF R$="N" THEN GOTO 10

   A(1)=A;B(1)=B;J(1)=J;B(1)=B;C(1)=C;IC(1)=IC;KAGY(1)=KAGY;KAXI(1)=KAXI

15 PRINT
   PRINT "First plane: Azimuth (0-180), Dip, Dip Direction (0-E; 1=W)"
   INPUT a2,XINC2,XEO2
   PRINT "Ok? (Y/N)"
   INPUT R2$ 
   IF R2$="N" GOTO 15

   AZPLT(1)=a2;INCPLT(1)=XINC2;INCDIR(1)=XEO2
   CALL PLAN(a2,XEO2,AZPLT)

20 PRINT
   PRINT "Second plane: Azimuth (0-180), Dip, Dip Direction (0-E; 1=W)"
   INPUT a3,XINC3,XEO3
   PRINT "Ok? (Y/N)"
   INPUT R3$  
   IF R3$="N" GOTO 20

   AZPLT(2)=a3;INCPLT(2)=XINC3;INCDIR(2)=XEO3
   CALL PLAN(a3,XEO3,AZPLT)

25 GOSUB sphere
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FOR I=1 TO 5
    CALL ECRAN(AZ(1,1),INC(1,1),IX,1Y) 'projection in +hemisphere (upper)
    LINE (IX-2,1Y-2)-(IX+2,1Y+2),0,BF
NEXT

LOCATE 5,55
PRINT "ORIGINAL POSITION"
LOCATE 39,55
INPUT;"NM VERTICAL Y/N";R1$
IF R1$="N" OR R1$="n" THEN ABORT1
GOTO ROULE1

ABORT1:
SCREEN CLOSE 1
NB=NB-1
GOTO 10

ROULE1:
LINE (0,0)-(0,0),0,BF
GOSUB STEREO

*************** Nm ---> centre of stereonet  ***************

AZC=5:INC=89.5
AZ(1,1)=AZC:INC(1,1)=INC
CALL XYZ(AZ(1,1),INC(1,1),X(1,1),Y(1,1),Z(1,1)) 'coordinateless centre (+z)
IF Z(1,1)<0 THEN Z(1,1)=Z(1,1)

CALL RAXIS(X(1,1),Y(1,1),Z(1,1),RAX(1),RAY(1),RAZ(1),alpha)
ANG(1)=FNRAD(alpha) 'in radians
FOR I=1 TO 5
    CALL ROTATION(RAX(1),RAY(1),RAZ(1),ANG(1),X(1,1),Y(1,1),Z(1,1))
    CALL azimuth(X(2,1),Y(2,1),Z(2,1),AZ(2,1),INC(2,1),hem)
    CALL ECRAN(AZ(2,1),INC(2,1),IX,1Y)
    LINE (IX-2,1Y-2)-(IX+2,1Y+2),0,BF
    IF I=3 OR I=5 THEN
        OPP=AZ(2,1)+180
        CALL ECRAN(OPP,INC(2,1),IX,1Y)
        LINE (IX-2,1Y-2)-(IX+2,1Y+2),0,BF
    END IF
NEXT

LOCATE 5,55
PRINT "NM IS VERTICAL"
LOCATE 36,55
PRINT "NP N-S ?";
LOCATE 38,55
INPUT;"Y/N";R2$
IF R2$="N" OR R2$="n" THEN ABORT2
GOTO ROULE2

ABORT2:
SCREEN CLOSE 1
NB=NB-1
GOTO 10

ROULE2:
LINE (0,0)-(0,0),0,BF
GOSUB STEREO

*************** rotation of Np to position N-S  ***************

gamma=AZ(2,3)
ANG(2)=FNRAD(gamma) ' in radians
RAX(2)=RAY(2)=0:RAZ(2)=1
FOR I=1 TO 5
    CALL ROTATION(RAX(2),RAY(2),RAZ(2),ANG(2),X(2,1),Y(2,1),Z(2,1),X(3,1),Y(3,1),Z(3,1))
    CALL azimuth(X(3,1),Y(3,1),Z(3,1),AZ(3,1),INC(3,1),hem)
    CALL ECRAN(AZ(3,1),INC(3,1),IX(1,1),1Y(1,1))
    LINE (IX(1,1)-J,1Y(1,1)-J)-(IX(1,1)+J,1Y(1,1)+J),0,BF
    IF I=3 THEN
        OPP=AZ(3,1)+180
        CALL ECRAN(OPP,INC(3,1),IX(1,1),1Y(1,1))
        LINE (IX(1,1)-J,1Y(1,1)-J)-(IX(1,1)+J,1Y(1,1)+J),0,BF
    ELSEIF I=5 THEN
        OPP=AZ(3,1)+180
        CALL ECRAN(OPP,INC(3,1),IX(1,1),1Y(1,1))
        LINE (IX(1,1)-J,1Y(1,1)-J)-(IX(1,1)+J,1Y(1,1)+J),0,BF
    END IF
NEXT
Determination of plagioclase crystal axes orientations

PS=1
LOCATE 5.55
PRINT "POSITION":PS
LOCATE 36.55
INPUT: "GO TO POS 2. Y/N":RS$
IF RS$= "N" OR RS$= "n" THEN ENREGISTRER

LINE (0.0)-(xt.yt).0,BF
GOSUB STEREO

"********** rotation 180 about vertical axis to position 2 **********

ANG(3)=ANG(3)-tau in radians
FOR I=1 TO 2
CALL ROTATION(RAX(3),RAY(3),RAZ(3),ANG(3),X(3,1),Y(3,1),Z(3,1),X(4,1),Y(4,1),Z(4,1))
CALL azimuth(X(4,1),Y(4,1),Z(4,1),AZ(4,1),INC(4,1),hem)
CALL ECRAN(AZ(4,1),INC(4,1),X(2,1),Y(2,1))
LINE (X(2,1)-2,Y(2,1)-2)-(X(2,1)+2,Y(2,1)+2),BF
NEXT

FOR I=3 TO 5
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
IF I=3 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
ELSEIF I=5 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
END IF
NEXT

PS=2
LOCATE 5.55
PRINT "POSITION":PS
LOCATE 36.55
INPUT: "GO TO POS 3. Y/N":RS$
IF RS$= "N" OR RS$= "n" THEN ENREGISTRER

LINE (0.0)-(xt.yt).0.BF
GOSUB STEREO

"********** rotation 180 about horizontal N-S axis to position 3 ***

RAX(4)=RAX(4)+tau in radians
FOR I=1 TO 2
CALL ROTATION(RAX(4),RAY(4),RAZ(4),ANG(4),X(4,1),Y(4,1),Z(4,1),X(5,1),Y(5,1),Z(5,1))
CALL azimuth(X(5,1),Y(5,1),Z(5,1),AZ(5,1),INC(5,1),hem)
CALL ECRAN(AZ(5,1),INC(5,1),X(3,1),Y(3,1))
LINE (X(3,1)-2,Y(3,1)-2)-(X(3,1)+2,Y(3,1)+2),BF
NEXT

FOR I=3 TO 5
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
IF I=3 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
ELSEIF I=5 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
END IF
NEXT

PS=3
LOCATE 5.55
PRINT "POSITION":PS
LOCATE 36.55
INPUT: "GO TO POS 4. Y/N":RS$
IF RS$= "N" OR RS$= "n" THEN ENREGISTRER

LINE (0.0)-(xt.yt).0,BF
GOSUB STEREO

"********** rotation 180 about vertical axis to position 4 ****

FOR I=1 TO 2
CALL ROTATION(RAX(3),RAY(3),RAZ(3),ANG(3),X(3,1),Y(3,1),Z(3,1),X(6,1),Y(6,1),Z(6,1))
CALL azimuth(X(6,1),Y(6,1),Z(6,1),AZ(6,1),INC(6,1),hem)
CALL ECRAN(AZ(6,1),INC(6,1),X(4,1),Y(4,1))
LINE (X(4,1)-2,Y(4,1)-2)-(X(4,1)+2,Y(4,1)+2),BF
NEXT

FOR I=3 TO 5
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
IF I=3 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
ELSEIF I=5 THEN
LINE (X(1,1)-2,Y(1,1)-2)-(X(1,1)+2,Y(1,1)+2),BF
END IF
NEXT
BEGIN IF I=5 THEN
LINE ((X(1,7)-2JY(1,7)-2)-(X(1,7)+2JY(1,7)+2),J,BF)
END IF

NEXT

PS=4
LOCATE 5,55
PRINT "POSITION";PS
LOCATE 36,55
IF R$="N" OR R$="n" THEN END
GOTO REVOIR

END1F

ENREGISTRER:
LOCATE 38,55
INPUT: "RECHECK A POS Y/N";R$,
IF R$="N" OR R$="n" THEN ENREGISTRER
GOTO REVOIR

END:
LOCATE 38,55
CALL CRYSTALAXIS(COMP,PS,CP)
IF PS=1 THEN CALL POSONE(CP)
IF PS=2 THEN CALL POSTWO(CP)
IF PS=3 THEN CALL POSTTHREE(CP)
IF PS=4 THEN CALL POSFOUR(CP)

CALL LASTROT

******************************************************************************

This program functions in "upper hemisphere" referential
i.e: +z upwards, to permit comparison with "Burri et al. (1967) diagram"
now convert to lower hemisphere (U-Sage) referential

FOR I=1 TO 3
INCF(I)=INCF(I)
NEXT
******************************************************************************

OPEN NOM1$ FOR APPEND AS #1
OPEN NOM2$ FOR APPEND AS #2
OPEN NOM3$ FOR APPEND AS #3
OPEN NOM4$ FOR APPEND AS #4
OPEN NOM5$ FOR APPEND AS #5
PRINT #1, "NB;A(I);B(I);C(I);KAGY(I);KAXI(I);AZPLT1(I);INCP1(I);INCDIR1(I);AZPLT2(I);INCP2(I);INCDIR2(I)
PRINT #2, "NB;A(I);B(I);C(I);KAXI(I);AZPLT1(I);INCP1(I);INCDIR1(I);AZPLT2(I);INCP2(I); "
PRINT #3, "NB;A(I);B(I);C(I);KAXI(I);AZPLT1(I);INCP1(I);INCDIR1(I);AZPLT2(I);INCP2(I); "
PRINT #4, "NB;A(I);B(I);C(I);KAXI(I);AZPLT1(I);INCP1(I);INCDIR1(I);AZPLT2(I);INCP2(I); "
PRINT #5, "NB;A(I);B(I);C(I);KAXI(I);AZPLT1(I);INCP1(I);INCDIR1(I);AZPLT2(I);INCP2(I); "
CLOSE #1
CLOSE #2
CLOSE #3
CLOSE #4
CLOSE #5

CONTINUE: SCREEN CLOSE 1
PRINT "Do you wish to enter more data? "
PRINT
PRINT
PRINT
PRINT
PRINT
PRINT ENCS$
IF ENCS="N" OR ENCS="n" THEN END
GOTO 10

END 'end of main program

******************************************************************************

********** SUB-PROGRAMS **********

******************************************************************************

SUB circle(alpha) STATIC
THIS SUB PREVENTS ALPHA OVERSHOOTING O-2PI
DPI=x.2831853#
IF alpha<>0! THEN two
one:
alpha=alpha+DPI
F alpha<0! THEN one
GOTO four
Determination of plagioclase crystal axes orientations

two:
IF alpha<DP! THEN four
three:
alpha=alpha-DPI
IF alpha<>DPI THEN three
four:
END SUB

SUB XYZ(AZ,XINC,X,Y,Z) STATIC
'az, inc to x,y,z direction cosines
'Right handed system x=north, y=west,z=vertical
RINC=FRNAD(XINC); RAZ=FRNAD(AZ)
X=COS(RAZ)*COS(RINC)
Y=-SIN(RAZ)*COS(RINC)
Z=SIN(RINC)
END SUB

SUB azimuth(X,Y,Z,AZ,XINC,ZCM) STATIC
'convert cartesian to geographic
'x,y,z direction cosines clockwise +ve right handed
'xinc=90 vertical, xinc=0 horizontal
'convert to upper/lower hemisphere
IF Z<0! THEN xt=-X; yt=-Y; zt=-Z ELSE xt=X; yt=Y; zt=Z
'convert to dir.cos
CALL DRCOS(xt,yt,zt)
'az ant/clockwise +ve
CALL ARCTAN2(xt,yt,AZ)
'convert to clockwise +ve (geographic)−left hand
AZ=360−AZ
'polar angle (vertical to pole)
R=SQR(xt*xt+yt*yt+zt*zt)
IF zt=0 THEN polar=0 ELSE polar=zt/R
CALL arcos(polar,XINC)
'convert to inclination (horizontal to pole)
XINC=90−XINC
'if xinc=1 then distinguishes +ve hemispheres
'if xinc=1 AND Z<0 THEN AZ=AZ+180; XINC=−XINC
IF AZ>360! THEN AZ=AZ−360!
END SUB

SUB arcos(X,ANGLE) STATIC
IF X>1 THEN X=1
IF X<-1 THEN X=-1
IF X=-1 THEN ANGLE=-180
ELSEIF X=0 THEN ANGLE=90
ELSEIF X=1 THEN ANGLE=0
ELSE
ANGLE=(1.5708−ATN(X/SQR(1−X*X)))*57.2958
END IF
END SUB

SUB ARCTAN2(X,Y,ANGLE) STATIC
'arctan(y/x)angle 0−360 degrees ant/clockwise
SMALL=.0001: AX=ABS(X); AY=ABS(Y)
IF AX<SMALL AND AX<SMALL THEN ANGLE=0!GOTO fin
IF AX=SMALL AND AX<SMALL THEN ANGLE=0!GOTO fin
IF AX=SMALL AND AY<SMALL THEN ANGLE=90!GOTO fin
IF AX=SMALL AND AY<SMALL THEN ANGLE=180!GOTO fin
IF AX<SMALL AND AY<SMALL THEN ANGLE=270!GOTO fin
ratio=Y/X
IF ratio>350! THEN ratio=350!
IF ratio<−350! THEN ratio=−350!
ANGLE=FD2DEG(ATN(ratio))
IF X<0! AND Y<0! THEN ANGLE=ANGLE+GOTO fin
IF X<0! AND Y>0! THEN ANGLE=180!+ANGLE+GOTO fin
IF X>0! AND Y<0! THEN ANGLE=180!+ANGLE+GOTO fin
IF X>0! AND Y>0! THEN ANGLE=360!+ANGLE+GOTO fin.
END SUB

SUB DRCOS(X,Y,Z) STATIC
'convert to direction cosines
SMALL=.0001
X=x=SQR(X^2+Y^2+Z^2)

IF ABS(X)>SMALL THEN X=X/XM ELSE X=0!
IF ABS(Y)>SMALL THEN Y=Y/XM ELSE Y=0!
IF ABS(Z)>SMALL THEN Z=Z/XM ELSE Z=0!
END SUB

SUB CROSS(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3) STATIC
'vector cross product |x2|=3 right handed
X3=Y1*Z2-Z1*Y2
Y3=Z1*X2-X1*Z2
Z3=X1*Y2-Y1*X2
END SUB

SUB CANGLE(a1,a2,a3,b1,b2,b3,ANGLE) STATIC
'angle Acubic to Bcubic = angle
G1=SQR(a1*a1+a2*a2+a3*a3)
G2=SQR(b1*b1+b2*b2+b3*b3)
AB=a1*b1+a2*b2+a3*b3
COSAB=AB/G1/G2
CALL arcos(COSAB,ANGLE)
END SUB

SUB RAXIS(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3,pM) STATIC
'defines rotation axis, angle x3,y3,z3 and alpha(degrees)
from axis1 and axis2
'convert 1 and 2 to direction cosines
CALL DIRCOS(X1,Y1,Z1)
CALL DIRCOS(X2,Y2,Z2)
'angle between 1 and 2
CALL CANGLE(X1,Y1,Z1,X2,Y2,Z2,Alpha)
'cross product X1 Y2 Z3
CALL CROSS(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3)
'normalize to dir.cos
CALL DIRCOS(X3,Y3,Z3)
END SUB

SUB ROTATION(R1,R2,R3,beta,X1,Y1,Z1,X2,Y2,Z2) STATIC
'rotates x1,y1,z1 about rotation axis r1,r2,r3 by angle beta to x2,y2,z2
Beta is anticlockwise +ve in radians
sb=SIN(beta)
cb=COS(beta)
s1=R1*cb
s2=R2*cb
s3=R3*sb
ccb=1-cb
c12=R1*R2*ccb
C13=R1*R3*ccb
C23=R2*R3*ccb
X1=(s2-cb-R1*R2*ccb*X1+(c12-s3)*Y1+(c13+s2)*Z1
y1=(c12+s3)*X1+(s2-cb-R2*R3*ccb)*Y1+(c23-s1)*Z1
Z1=(c13-s2)*X1+(c23+s1)*Y1+(s2-R3*R3*ccb)*Z1
X2=X1
Y2=Y1
Z2=Z1
END SUB

SUB PLAN(AZ,DR,AZPL) STATIC
'calculates az pole to plane
IF AZ>90 GOTO more
DIFF=90-AZ
AZPL=90+DIFF
GOTO corr
more:
DIFF=AZ-90
AZPL=90+DIFF
corr:
IF DR=1 THEN
AZPL=AZPL+90
ELSE
AZPL=AZPL-90
END IF
IF AZPL>360 THEN AZPL=0
END SUB

SUB ECRAN(AZ,INCJX.IY) STATIC
SHARED RAYON, COEFF1, IXC, IYC
'INC-->IX, JY screen Schmidt stereonet
THETA=1.5708*FNRAID(INC)
X=2*SN(THETA/2)*SIN(FNRAID(AZ))
Determination of plagioclase crystal axes orientations

\[ Y = 2 \sin(\theta) \cos(\phi) \]
\[ a = \int x^* \cos(\phi) \cos(\theta) + b \cos(\phi) \sin(\theta) + c \sin(\phi) \]
\[ a^* = \int y^* \sin(\phi) \cos(\theta) + b \sin(\phi) \sin(\theta) + c \cos(\phi) \]
\[ a^* = \int z^* \cos(\phi) + b \cos(\phi) \sin(\theta) + c \sin(\phi) \]

\[ \text{SUB CRYSTALAXIS(COMP,PS,CP) STATIC} \]
\[ \text{finds axes crystallographic pole a, pole b, pole c with regards to current position} \]
\[ \text{COMP} = \int (COMP/2) \]
\[ \text{AZA} = \text{DIRAXA(CP), INCA} = \text{PLAXA(CP)} \]
\[ \text{AZB} = \text{DIRPOB(CP), INCB} = \text{PLPOB(CP)} \]
\[ \text{AZC} = \text{DIRPOC(CP), INCC} = \text{PLPOC(CP)} \]
\[ \text{CALL XYZ(AZA,INCA,XYZ1), CALL XYZ(AZB,INCB,XYZ2), CALL XYZ(AZC,INCC,XYZ3)} \]

\[ \text{SUB LASTROT STATIC} \]
\[ \text{axes crystallographic back to original position} \]
\[ \text{conversion cartesian --> az.inc taking into account +ve/-ve hemispheres} \]
\[ \text{ANG(5) = ANG(2), ANG(4) = ANG(1)} \]
\[ \text{NEXT item = 1} \]
\[ \text{CALL ROTATION(RAX1,RAY1,RAZ1,ANG5,XRB1,YRB1,ZRB1,ANG4,XRC1,YRC1,ZRC1)} \]

\[ \text{SUB POSONE(CP) STATIC} \]
\[ \text{axes --> a} \]
\[ \text{IF CP > 16 THEN} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{ELSE} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{END IF} \]
\[ \text{IF CP > 11 THEN} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{ELSE} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{END IF} \]
\[ \text{XR3 = XC3, YR3 = YC3, ZR3 = ZC3} \]

\[ \text{SUB POSTWO(CP) STATIC} \]
\[ \text{rotation position 2 --> position 1} \]
\[ \text{axes --> a} \]
\[ \text{IF CP > 16 THEN} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{ELSE} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{END IF} \]
\[ \text{IF CP > 11 THEN} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{ELSE} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{END IF} \]
\[ \text{XR3 = XC3, YR3 = YC3, ZR3 = ZC3} \]

\[ \text{SUB POSTHREE(CP) STATIC} \]
\[ \text{rotation position 3 --> position 1} \]
\[ \text{axes --> a} \]
\[ \text{IF CP > 16 THEN} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{ELSE} \]
\[ \text{XR1 = XC1, YR1 = YC1, ZR1 = ZC1} \]
\[ \text{END IF} \]
\[ \text{IF CP > 11 THEN} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{ELSE} \]
\[ \text{XR2 = XC2, YR2 = YC2, ZR2 = ZC2} \]
\[ \text{END IF} \]
\[ \text{XR3 = XC3, YR3 = YC3, ZR3 = ZC3} \]
XR(3)=XC(3); YR(3)=YC(3); ZR(3)=ZC(3)  pole c
END SUB

SUB POSFOUR(CP) STATIC
rotation position 4 --> position 1
-axe --> +axe
IF CP>16 THEN
XR(!)=XC(1); YR(!)=YC(1); ZR(!)=ZC(1)  pole a
ELSE
XR(!)=XC(1); YR(!)=YC(1); ZR(!)=ZC(1)
END IF

IF CP>11 THEN
XR(!)=XC(2); YR(!)=YC(2); ZR(!)=ZC(2)  pole b
ELSE
XR(!)=XC(2); YR(!)=YC(2); ZR(!)=ZC(2)
END IF

XR(!)=XC(3); YR(!)=YC(3); ZR(!)=ZC(3)  pole c
END SUB

**********************************************************************
** SUB-Routines ********************************************************
**********************************************************************

***** RECALL ONE OF THE 4 CONSTRUCTIONS **********

REVOIR:
LOCATE 40,55
PRINT "WHICH POSITION ?"
LOCATE 42,55
PRINT "1,2,3 or 4 ".PS
LINE (0,0)-(xt,ys);0,0F
COSUB STEREO
FOR I=1 TO 2
LINE (IX!(PS.I)-2,IY!(PS,I)-2)-(IX!(PS.I)+2,IY!(PS.I)+2);1,1BF
NEXT
FOR I=3 TO 5
LINE (IX!(I,1)-2,IY!(I,1)-2)-(IX!(I,1)+2,IY!(I,1)+2);1,1BF
IF I=5 THEN
LINE (IX!(1,6)-2,IY!(1,6)-2)-(IX!(1,6)+2,IY!(1,6)+2);1,1BF
ELSEIF I=5 THEN
LINE (IX!(1,7)-2,IY!(1,7)-2)-(IX!(1,7)+2,IY!(1,7)+2);1,1BF
END IF
NEXT
LOCATE 5,55
PRINT "POSITION ";PS
LOCATE 36,55
INPUT:"ANOTHER POS Y/N";RT$
IF RT$="N" OR RT$="n" THEN ENREGISTRER
GOTO REVOIR

**********************************************************************
** CONSTRUCT SCHMIDT STEREONET ON SCREEN ****************************
**********************************************************************

WND0:
SCREEN 1,SW,SH,D;SMODE
T="UNIPLAJ by Teceonphysique-Soft"
WINDOW 2,T,(0,0)-(xt,ys);2,1
PALETTE 0,62,62,62
PALETTE 1,0,0,0
PALETTE 3,0,81,18
PALETTE 4,0,31,1
PALETTE 5,0,9,0
PALETTE 6,1,1,1
WINDOW OUTPUT 2
CLS
STEREO:
Plot circle
CLS
X1%=IXC+INT(RAYON*COEFEL+.5)
Y1%=IYC
FOR T%=0 TO 360 STEP 5
TR=T%*.01745
X2%=IXC+INT(RAYON*COS(TR)*COEFEL+.5)
Y2%=IYC+INT(RAYON*3D(TR)*.5)
Determination of plagioclase crystal axes orientations

\[ \begin{align*}
X_1 &= X_2, Y_1 = Y_2 \\
\text{FOR } i = 1 \text{ TO } 3 \\
\text{IF } i = 1 \text{ THEN } \\
\text{AXES} &= "NP" \\
\text{ELSEIF } i = 2 \text{ THEN } \\
\text{AXES} &= "NM" \\
\text{ELSEIF } i = 2 \text{ THEN } \\
\text{AXES} &= "NG" \\
\text{ENDIF} \\
\text{LOCATE } 35 + i, 7 \\
\text{PRINT AXES} \\
\text{IF } i = 1 \text{ THEN } \\
\text{AXE} &= "NI" \\
\text{ELSEIF } i = 2 \text{ THEN } \\
\text{AXE} &= "NM" \\
\text{ELSEIF } i > 2 \text{ THEN } \\
\text{AXE} &= "NG" \\
\text{ENDIF} \\
\text{LOCATE } 39, 7 \\
\text{PRINT "PLANE 1"} \\
\text{KX} &= \text{ INT}(\pi * dx) - 20; KX = \text{ INT}(\pi * dy) - 20 \\
\text{LINE (KX - 2, KY - 2) - (KX + 2, KY + 2), 1, 2, BF} \\
\text{NEXT} \\
\text{LOCATE } 39, 7 \\
\text{PRINT "PLANE 2"} \\
\text{JX} &= \text{ INT}(\pi * dx) - 20; JY = \text{ INT}(\pi * dy) - 20 \\
\text{LINE (JX - 2, JY - 2) - (JX + 2, JY + 2), 1, 2, BF} \\
\text{NEXT} \\
\text{PRINT migration curves pole(010), pole(001), pole pericline twin} \\
\text{FOR } i = 0 \text{ TO } 10 \\
\text{LINE (IXPOB(i), IYPOB(i) - 1) - (IXPOB(i) + 1, IYPOB(i) + 1), 1, BF} \\
\text{LINE (IXPOC(i), IYPOC(i) - 1) - (IXPOC(i) + 1, IYPOC(i) + 1), 1, BF} \\
\text{LINE (IXPER(i), IYPER(i) - 1) - (IXPER(i) + 1, IYPER(i) + 1), 2, BF} \\
\text{NEXT} \\
\text{PX} &= \text{ INT}(\pi * dx) - 20; PY = \text{ INT}(\pi * dy) - 20 \\
\text{LOCATE PX, PY} \\
\text{PRINT "An 100"} \\
\text{PX} &= \text{ INT}(\pi * dx) - 20; PY = \text{ INT}(\pi * dy) - 20 \\
\text{LOCATE PX, PY} \\
\text{PRINT "An 100"} \\
\text{RETURN} \\
\text{********* CONVERSION U-STAGE DATA FOR OPTICAL DIRECTIONS --> RHO-PHI ***} \\
\text{BOUCHEZ (1977) *******************} \\
\text{sphere:} \\
\text{TRANSFORMS MICROSCOPE DATA TO COORDINATES ON A SPHERE} \\
\text{PHI RADIANS RO COSINE} \\
PS2 = 1.570796 \\
PI = 3.141595 \\
RAD = 0.174533 \\
IF A = 90 THEN A = A - 90 ELSE A = A + 270 \\
IF B = 0 THEN B = 5 \\
IF C = 0 THEN C = 5 \\
A = RAD * A + RAD * B * C + RAD * C \\
CC = COS(C) \\
SC = SIN(C) \\
Y1 = COS(PS2) - 1; Y2 = COS(B) * SC; Y3 = COS(B) * CC \\
Y2 = Y2 * Y2 \\
Y3 = Y3 * Y3 \\
CC = CC * CC \\
SC = SC * SC \\
Z1 = 1; Y2 = Y2 * 2 + Z1 + COC2 + Z3 = Z2 + Z1 \\
IF Z3 = 0 THEN Z3 = SQR(Z2 - 1) ELSE Z3 = 0 \\
P = ATN(Z3) \\
Z1 = 1; Y2 = Y2 * 2 + Z1 + SC2 + Z3 = Z2 + Z1 \\
IF Z3 = 0 THEN Z3 = SQR(Z2 - 1) ELSE Z3 = 0 \\
P = ATN(Z3) \\
IF IB = 0 THEN GOTO 30 \\
IF IB = 0 THEN GOTO 40 \\
IF IB = 0 THEN GOTO 50 \\
PHI = A + PS2 + PHI2 + A + PHI3 + A + Q + PI \\
GOTO 60 \\
30 PHI = A + PS2 + PHI2 + A + PHI3 + A + Q + PI \\
GOTO 60
40 PHI1=A.PS2.PHI2=A.P+PL.PHI3=A.P
GOTO 50
50 PHI1=A.PS2.PHI2=A.P+PL.PHI3=A.P
60 CALL circ1(PHI1)
   CALL circ1(PHI2)
   CALL circ1(PHI3)
   IF KAXI=0 THEN GOTO 70
   IF KAXI=1 THEN GOTO 80
   IF KAXI=2 THEN GOTO 90
70 IF KAGY=1 THEN GOTO 75
   ROP=Y1:PHIP=PHI1
   ROM=Y2:PHIM=PHI2
   ROC=Y3:PHIG=PHI3
   GOTO 100
75 ROP=Y3:PHIP=PHI3
   ROM=Y2:PHIM=PHI2
   ROC=Y1:PHIG=PHI1
   GOTO 100
80 IF KAGY=1 THEN GOTO 85
   ROP=Y3:PHIP=PHI3
   ROM=Y1:PHIM=PHI1
   ROC=Y2:PHIG=PHI2
   GOTO 100
85 ROP=Y2:PHIP=PHI2
   ROM=Y1:PHIM=PHI1
   ROC=Y3:PHIG=PHI3
   GOTO 100
90 IF (KAGY+1)>0 THEN GOTO 95
   ROP=Y1:PHIP=PHI1
   ROM=Y3:PHIM=PHI3
   ROC=Y2:PHIG=PHI2
   GOTO 100
95 ROP=Y2:PHIP=PHI2
   ROM=Y3:PHIM=PHI3
   ROC=Y1:PHIG=PHI1
100 RETURN

**************************************************************************
**************************************************************************