DANIEL F. MERRIAM, Editor

FORTRAN IV CDC 6400 COMPUTER PROGRAM TO ANALYZE SUBSURFACE FOLD GEOMETRY

By

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Editor's Remarks

This report, "FORTRAN IV CDC 6400 computer program to analyze subsurface fold geometry", by E. H.T. Whitten, should find many applications. Geologists are interested in the origin of folds and their description. Because of the economic importance of folds in controlling the localization of mineral deposits, they have been studied qualitively for many decades. Now Dr. Whitten has provided a quantitative method of analysis that can readily be used on a computer.

The purpose of the program is to "...describe and map the nature and variability of fold geometry..." in order to predict the occurrence of folded structures. The method has been applied in preliminary trials on "plains-type" folds in the Michigan Basin (Whitten, 1967, Fourier trend-surface analysis in the geometrical analysis of subsurface folds of the Michigan Basin, in Computer applications in the earth sciences: Colloquium on trend analysis: Kansas Geol. Survey Computer Contribution 12, p. 10-11) and in Kansas (described in this paper). In this context petroleum geologists should find the program of considerable interest as both areas are prolific oil producers.

This publication is the thirty-third program made available in two series (COMPUTER CONTRIBUTIONS and Special Distribution Series) by the Geological Survey. Some people have asked why we have published so many programs. The answer is simple.

(1) An investigator is interested in only some of the computer techniques described, and earth scientists represent a diverse group.

(2) Many potentially useful computer methods have been developed in other disciplines and are available; earth scientists should be aware of these.

Earth scientists are the last members of the scientific community to adopt computer methodology. It is imperative that they do this quickly, for self preservation if nothing else. Once they are aware of the "state-of-the-art" and have utilized these methods appropriate to earth studies, the need for published programs will lessen. Hopefully this day is near!

The Geological Survey will make available for a limited time on magnetic tape the program deck with test data and operating instructions for $15.00. An extra charge of $10.00 is made if a punched-card deck is required. An up-to-date list of computer and related publications can be obtained by writing the Editor, COMPUTER CONTRIBUTION Series, Kansas Geological Survey, The University of Kansas, Lawrence, Kansas 66044.

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By

E. H. TIMOTHY WHITTEN

INTRODUCTION

The FORTRAN IV program, prepared for the CDC 6400 computer, is designed principally to permit description and analysis of subsurface folds on the basis of well-log data if dip and strike information is not available. If dip data are available, these can be used directly by the program.

Description of folds may be viewed as an end in itself. If folds in adjacent areas are described in terms of scalars, however, the areal variability may have distinct trends that permit limited extrapolation into neighboring unexplored areas. In addition, if the folds are described in a quantitative manner, it is possible to correlate fold attributes with other geologic variables in an attempt to determine factors controlling development of differing fold geometry (Whitten, 1966a).

OUTLINE OF LOGIC USED IN PROGRAM

In order to describe and map the nature and variability of fold geometry in a quantitative manner, it is useful to use scalar descriptors of fold shape. The basic requirements for the quantitative description of a fold are statements of the size, fold-axis orientation, and summary statements concerning the changing shape of the profile, i.e., section normal to the fold axis (Whitten, 1966a, 1966b). Traditionally, the changing shape has been described qualitatively; however, Loudon (1964) and Whitten (1966a, 1966b) have described a method of developing scalar descriptors.

The method (Loudon, 1964) can be explained easily in relation to the profile of a cylindroidal fold. At i points along a fold profile, the angle θ_i between the normal to bedding and an arbitrary reference axis is measured. The first through fourth statistical moments, skewness, and kurtosis of the array of scalars ($\cos \theta_i$) provide useful descriptors of the fold geometry and can be used to compare and map the geometries of a population of folds. Although comparisons of several folds are possible, the actual shape of the fold profile cannot be retrieved from such statistics because the sequence in which the $\cos \theta_i$ values were obtained is lost in computing them.

In the more general case, if a folded surface is considered in three dimensions, a large number of normals to bedding can be measured and referred to convenient reference axes (e.g., south, east, and vertical up). If p_i, q_i, r_i are the direction cosines of the ith normal referred to south, east, and up, the dispersion matrix $\underset{\sim}{A}$ can be constructed thus

$$\underset{\sim}{A} = \begin{bmatrix} \frac{\Sigma p_i^2}{N} & \frac{\Sigma p_i q_i}{N} & \frac{\Sigma p_i r_i}{N} \\ \frac{\Sigma q_i p_i}{N} & \frac{\Sigma q_i^2}{N} & \frac{\Sigma q_i r_i}{N} \\ \frac{\Sigma r_i p_i}{N} & \frac{\Sigma r_i q_i}{N} & \frac{\Sigma r_i^2}{N} \end{bmatrix}$$

The eigenvectors of $\underset{\sim}{A}$ define the principal axes of the population and the eigenvalues of $\underset{\sim}{A}$ refer to the variance of the normals to bedding with respect to the orthogonal principal axes. If the eigenvectors are

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} = \underset{\sim}{R}^T ,$$

then the eigenvalues can be expressed as

$$\begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} = \underset{\sim}{D} ,$$

where $\underset{\sim}{R}\underset{\sim}{A}\underset{\sim}{R}^T = \underset{\sim}{D}$. If it is arranged that $d_{11} \geqslant d_{22} \geqslant d_{33}$ then b_{11}, b_{21}, b_{31} (the first column of $\underset{\sim}{R}^T$) gives the direction cosines of the principal axis A_I. The second and third columns of $\underset{\sim}{R}^T$ are the direction cosines of A_{II} and A_{III}, respectively. Because d_{33} is the smallest eigenvalue, A_{III} approximates the geometric fold axis (if the folds are cylindroidal or conical). Likewise, A_{II} approximates the normal to the bisecting plane if the folds are of open style; if the folds approach isoclinal form, d_{22} tends to d_{11} and then exceeds d_{11} so that A_I becomes the normal to the bisecting plane of isoclinal folds.

The normals to bedding can be referred to the three orthogonal principal axes instead of the arbitrary cardinal axes, and the four statistical moments, skewness, and kurtosis can be computed for the new direction cosines. These statistics computed with respect to A_{II}, or A_I for isoclinal folds, provide descriptors for the fold profile; those computed with respect to A_{III} provide descriptors for the changing form of the folds parallel to the geometric fold axis.

If folds are observed in the field, actual dip and strike values can be used to build a matrix $\tilde{A}$. In subsurface work, the actual dip at well sites commonly is not determined directly and the only information available consists of the elevation of each folded stratum at a large number of localities. If the folded stratum is reconstructed from such data, the dips and strikes at each well site, or at an arbitrary grid of points, can be calculated and used to generate the scalar descriptors referred to above. Statistics for a single fold, or for the aggregate of all folds in an area, can be computed in this manner. If elevation (X_1) is expressed as a linear or nonlinear function of independent spatial coordinates (U,V), differentiation of the function $X_1 = f(U,V)$ yields the tangent plane (bedding at a point).

In the computer program listed here, it is assumed that the double Fourier series provides an adequate simulation of folded subsurface lithic units. The method, developed by James (1966) for calculating the double Fourier series on the basis of irregularly spaced data, has been used in this program, which permits surfaces up to the complete fifth harmonic to be obtained by the method of least squares. The program is designed to remove the linear polynomial surface, to compute Fourier coefficients with respect to the deviations from the linear surface, and to complete subsequent calculations with the combined linear and Fourier coefficients. Differentiation of the linear plus Fourier function yields normals to the simulated surface at the original data points or at a specified grid of new locations. The combined coefficients also are used to print maps of the folds and von Wulff projections (lower hemisphere, stereographic projections). Computation of the principal axes and scalar statistics has been based on, but represents a considerable modification of, a program originally published by Loudon (1964).

Additional details of the computation are illustrated with data for 200 randomly selected wells cutting top of the Arbuckle Group in Kansas; these data were made available by D.F. Merriam, and are drawn from a more complete set of well data that formed the basis of a published map (Merriam and Smith, 1961).

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RUNNING THE PROGRAM

In addition to the data, a large number of constants and scaling factors must be supplied. It is necessary to provide for operator choice of these constants because raw data for each project tend to differ with respect to scale, orientation, etc. Before setting up the control cards when elevation data are supplied, decisions are required on the following points:

1. Because dips are involved, the horizontal and vertical units of length must be equal, or designed to give a specified vertical exaggeration; commonly, locations are defined in miles or kilometers and elevations in feet below sea level so that considerable scaling is required.

2. The program assumes that orthogonal coordinate axes are used, the origin is at the northwestern corner of the map, the first coordinate (U) has increasing positive values toward the south, and the second coordinate (V) has increasing positive values to the east. Data with axes in other senses commonly can be accommodated by use of a single card, as indicated by a comment card, in subroutine READIN.

3. Provision is made for rotation of the reference orthogonal axes because the commonly used cardinal axes are arbitrary in most projects and geometry of a double Fourier series trend surface depends upon the axes orientation.

4. Computation of the double Fourier series coefficients requires specification of five constants:

   UW - fundamental wavelength in U direction
   VW - fundamental wavelength in V direction
   M - number of terms to be used in the double Fourier series
   UO - wave origin in U direction
   VO - wave origin in V direction.

   UW and VW are chosen empirically: in practice several values somewhat larger than the map dimension must be tested and those yielding the coefficients with smallest absolute values are selected. This statement assumes that the inherent wavelengths of the irregularly spaced data are not known before the analysis begins.

5. Because inclusion of data from the area around the region of principal interest helps eliminate

boundary effects in the computed surface for the region, it is commonly desired to differentiate between the total data array and those data points at which dip values are computed. If a value is assigned to KOUN, dip values will not be computed for the last KOUN data points. Alternatively, use of subroutine SELECT permits assorted subsets of the total data matrix to be used for both surface and dip-value calculations. Both KOUN and SELECT cannot be used in the same problem.

6. To insure better sampling from the Fourier surface, a grid of points (maximum 1500 points) can be specified at which dip values will be calculated. For this purpose, the U,V origin for the grid, the number and magnitude of the increments in the U and the V directions, and the angle that the grid lines make with axes used to compute the Fourier coefficients, must be specified.

7. If a map or maps of the linear plus Fourier function are called, the boundaries of the map frame(s) in terms of U, V coordinates, the smallest contour value required, and the magnitude of the 20 contour increments automatically used, must be specified.

DECK ASSEMBLY

The data deck must comprise the following:

A. 4 title cards
B. 1 master card
C. n factor cards (n can be zero to 6 and is specified by NLIST on master card)
D. data cards (program dimensioned for up to 1600 cards)
E. end of data card
F. subset selection card
G. control card
H. Fourier coefficient specification cards - sufficient cards to specify all coefficients at 25 per card
I. n map control cards (n can be zero or any number as specified by OPB on control card)
J. any number of additional selections can be made by use of different additional subset selection cards here, but each selection card must be followed by a control card (G) and map control cards (I) if specified on the control card.

Title Cards (Format 9A8):

Four cards required; column 1 of first card carries 1 but for next three cards column 1 must be zero. Any alphanumeric descriptive information can be placed on remainder of these four cards.

Master Card:

columns	identification	format	purpose
1-6	ID1	A6	Identification of project
7	NLIN	I1	Leave blank, except use 1 if wish to eliminate subtracting linear before calculating Fourier coefficients
8	IRECT	I1	Leave blank, except use 1 if wish to rotate reference axes clockwise with respect to the map; if blank anticlockwise rotation effected automatically if THETA is greater than 0
9-12	THETA	F4.0	Leave blank, unless axes are to be rotated; THETA is the angle (in degrees) for rotation
13-48	FMT	6A6	Format for reading data cards; if left blank, automatically uses (2A6,3F6.0,2F6.3,6I3)
49-58	COR12	F10.0	Correction factor used to multiply both U and V coordinates (GCOORD (I,1) and GCOORD(I,2))
59-62	COR3	F4.0	Correction factor used to multiply the elevation W coordinate (GCOORD(I,3)) - if no scaling required, must insert 1
63-68	CORAZI	F6.0	Correction factor used to add to directional data (DIRCOS(I,1)) to convert dips to strikes, etc.
69	NLIST	I1	Leave blank if no subset selections required from total data deck; values 1 through 6 are used to correspond with number of factors specified on data cards; if left blank, no factor cards required in data deck
70	NFOLD	I1	Leave blank if directional data supplied as data; use 1 if elevation data supplied
71-74	UTRANS	F4.0	U-axis origin shifted to UTRANS subsequent to use of COR12
75-78	VTRANS	F4.0	V-axis origin shifted to

			VTRANS subsequent to use of COR12

Factor Cards: NLIST cards must be included

1-6	ID1	A6	Identification of project (as on master card)
7-12	ID2	A6	Space not used by program
13-18	NAME (L,1)	A6	Category 1 of Factor L (e.g., SANDST)
19-24	NAME (L,2)	A6	Category 2 of Factor L (e.g., SHALEb)
.			
.			
.			
.			
61-66	NAME (L,9)	A6	Category 9 of Factor L (e.g., CONGLM)

Repeat on L cards, where L = NLIST. An example of the system would be:

FACTOR	1	2	3
CATEGORY	Lithology	Area	Age
1	SANDST	INNERb	PRECMB
2	SHALEb	OUTERb	ORDVCN
3	bbbbbb	bbbbbb	SILURN

Data Cards:

Program is dimensioned for 1600 cards but this can be increased by changing dimensions of DIRCOS, GCOORD, LIST, and IEDIT in the COMMON statements. Any format can be stipulated by master card provided that all variables are accounted for in following list:

1-6	NPROJ	A6	Identification of project (as on master card)
7-12	IPT(I)	A6	Sample point identification
13-18	GCOORD (I,1)	F6.0	U coordinate
19-24	GCOORD (I,2)	F6.0	V coordinate
25-30	GCOORD (I,3)	F6.0	W coordinate
31-36	DIRCOS (I,1)	F6.3	Azimuth of dip direction in degrees E of N
37-42	DIRCOS (I,2)	F6.3	Angle of dip in degrees
43-45	LIND(1)	I3	Category for Factor 1 (e.g., 002 for shale in example given)
46-48	LIND(2)	I3	Category for Factor 2 (e.g., 001 for PRECMB)
.			
.			
58-60	LIND(6)	I3	Category for Factor 6 (blank if no factor 6)

End-of-data Card: (Always needed)

1-6	NPROJ	A6	Identification of project (as in master card)
13-18	999.	F6.0	If variable data-card format specified on master card, 999. must be punched in columns used for GCOORD (I,1) - the U coordinate.

Note: If sense or sequence of U and V are changed as provided for by comment cards in subroutine READIN, this card also will be affected and the value on the card must be modified so that 999. is read into the eventual GCOORD(I,1) location.

Subset Selection Card(s):

If no subset selections required, a card with T in column 78 is required here.

1-6	NPROJ	A6	Identification of project (as in master card)
7-12	ID2	A6	Space not used by program
13-15	KONTROL(1)	I3	If left blank, includes all data cards but if subset required must insert in: Col. 13: 0 include - exclude Col. 14: Factor specification Col. 15: Category specification (e.g. -12 excludes shales on basis of example used)
.			
.			
.			
.			
70-72	KONTROL(20)	I3	subset selection as for columns 13 to 15
75	ISLE	I3	use 2: subroutines SEKSHN, SPIN, and rotated WULFF to be called use 1: subroutines SPIN and WULFF (rotated) to be called use 0: these three subroutines omitted
78	LAST	L3	punch T if this is the last selection card

Control Card:

One card required if NFOLD not zero, i.e., required when elevation data supplied.

1-6	UW	F6.0	Primary wavelength in U direction
7-12	VW	F6.0	Primary wavelength in V direction
13	OPA	F1.0	Leave blank except insert 1 if computed and residual values from linear plus Fourier surface required for each data point
14	OPB	F1.0	0 omits printed map, 1 gives one map, 2 gives two maps, etc. No limit to number, but require one map control card for each map called
15-19	M	I5	Number of terms used in Fourier series (maximum number is 121, or 50 for less than 100000_8 central memory version - see comments cards in subroutine FOLDING)
20-25	UO	F6.0	Wave origin in U direction
26-31	VO	F6.0	Wave origin in V direction
32-37	UMIN	F6.3	Grid origin in U direction
38-43	UINCRM	F6.3	Increment between points in U direction
44-46	JUINS	I3	Number of increments along U
47-52	VMIN	F6.3	Grid origin in V direction
53-58	VINCRM	F6.3	Increment between points in V direction
59-61	JVINS	I3	Number of increments along V
62-64	ANGLE	F3.0	Angle in degrees between grid and map axes measured in clockwise direction from map axes
65-67	KOUN	I3	Number of data cards to be ignored subsequent to calculation of Fourier coefficients - must be zero if subset selections are called.

Note: Leave columns 32 through 64 blank unless dip values are to be read off Fourier surface on a grid (maximum of 1500 grid points).

Fourier Coefficient Specification Cards:

One or more cards required if elevation data supplied, i.e., if NFOLD is not zero. Must designate M coefficients (where M is defined on control card). Format is 75I1 and each coefficient requires three digits (i,j,T) for specification so that 25 coefficients are specified per card. Additional cards are used if more than 25 coefficients are specified.

i refers to the wave frequency in the U direction over the length of one fundamental wavelength
j refers to the wave frequency in the V direction over the length of one fundamental wavelength
T defines the type of double Fourier series term where
T = 1 designates cosUcosV
T = 2 designates cosUsinV
T = 3 designates sinUcosV
T = 4 designates sinUsinV

The subscripts in Figure 1 correspond to the i j values and c and s refer to cos and sin, respectively. To call the coefficient corresponding to ss_{11} and cs_{12} values of 114 and 122 (ijT values) would be inserted on the Fourier coefficient specification cards. Commonly, all terms of the Blocks 0 and I, Blocks 0 through II, Blocks 0 through III, etc. are specified. Other specifications can be made for special purposes.

Map Control Cards:

The number of cards included is defined by OPB on the control card.

1-6	UL	F6.0	Minimum U coordinate for map
7-12	UH	F6.0	Maximum U coordinate for map
13-18	VL	F6.0	Minimum V coordinate for map
19-24	VH	F6.0	Maximum V coordinate for map
25-30	BASE	F6.0	Lowest contour value required
31-36	CINT	F6.0	Contour interval (20 intervals automatically used)

Note: If COR12, UTRANS, and/or VTRANS values specified on master card, UL, UH, VL, VH must be specified in terms of transformed U and V coordinates. If COR3 has been specified, BASE and CINT must be in terms of the transformed W coordinate.

ILLUSTRATIVE EXAMPLE USING SUBSURFACE WELL DATA

To illustrate the manner in which the program works, folds of the upper surface of the Arbuckle Group in Kansas were analyzed using 200 wells selected in a statistically random manner from a much larger target population of wells. Merriam and Smith (1961) demonstrated on the basis of the target population that the surface is complexly folded; obviously, 200 locations in Kansas are inadequate for a detailed analysis of the surface geometry, although they are sufficient to illustrate the technique. In this example, the complete fourth harmonic double Fourier trend surface is used; actual data are listed in Appendix B.

The program lists the original data matrix following the title cards and the variables supplied

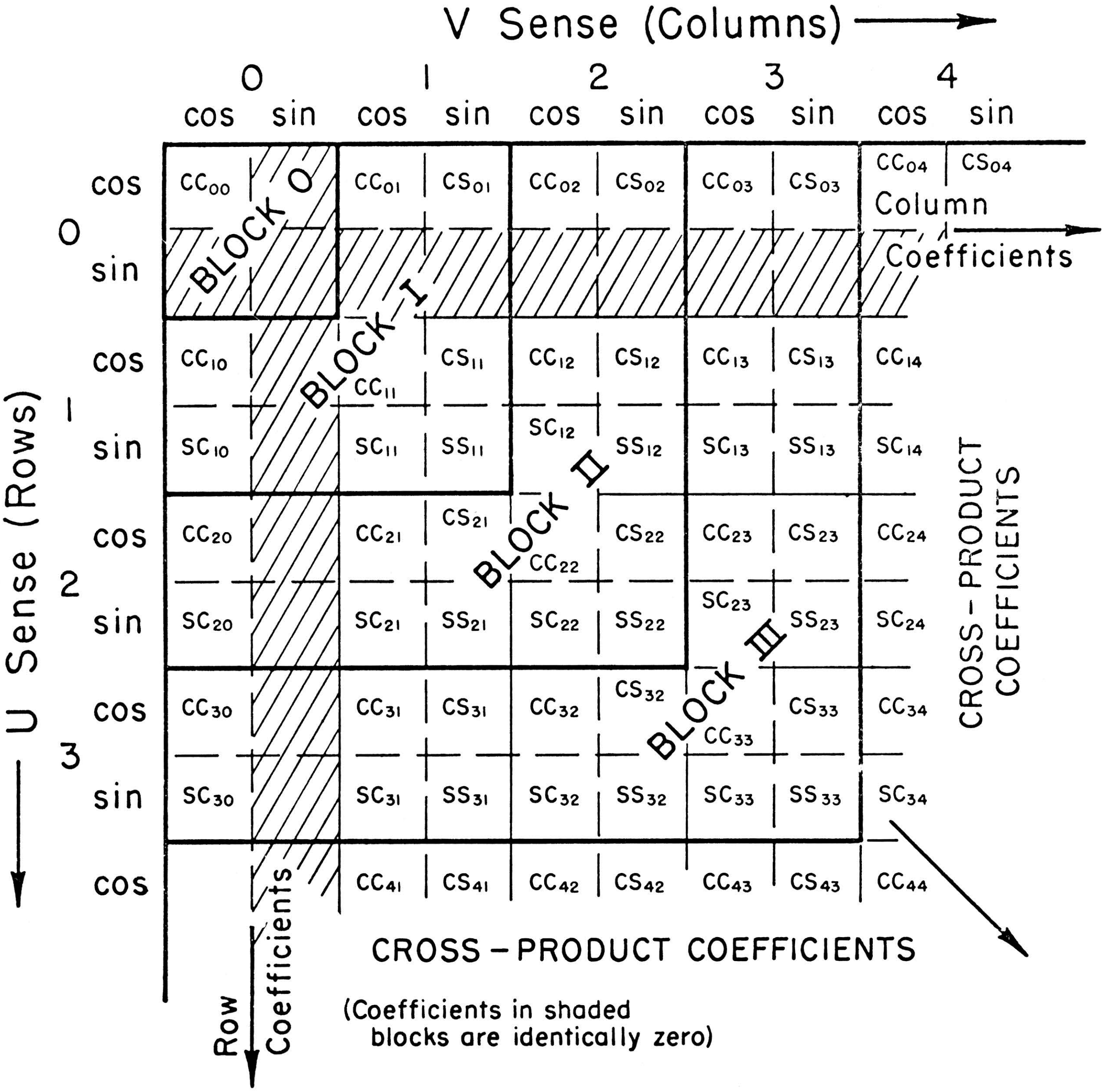


Figure 1.- Diagram displaying grouping of double Fourier series coefficients according to wavelength (after James, 1966).

on the master card (Fig. 2); in the example U and V are in inches measured from the northwestern corner of a 1:500,000 map of Kansas and W is in feet. To give a X10 vertical exaggeration, U and V are multiplied by COR12 = 7.89141414 and W by COR3 = 0.0019. Use of COR12, COR3, UTRANS and/or VTRANS on the master card causes scaling of U, V, and W; the new values are listed by subroutine READIN (Fig. 3); in this example the U,V origin was shifted to U = 110 miles (UTRANS) and V = 210 miles (VTRANS). Irrespective of the site numbers supplied, the program numbers the data points sequentially (left margin, Fig. 2) and this new number is retained as a reference throughout the program. Dip trend and dip values are zero in Figure 2 because elevation rather than dip values were supplied. Subroutine READIN continues to compute the linear polynomial surface and to list the coefficients; from Figure 4 it is seen that the linear polynomial equation for the scaled values of U, V, and W is

$$W = -3.68590935 - 0.013167269U$$
$$+ 0.009480935V$$

and the sum of squares is 38.95 percent. These values are carried in COMMON.

```
 040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

 200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961

 COMPLETE FOURTHHARMONIC N = 200, KOUN = 98

 FWL = 250/500 MILES

PRINT-OUT OF MASTER CARDS
-----------------------

040291    -0 -0  -0.00 (A6,A3,2X,3F15.6,6I1,2F3.0)
          7.891414140          .001900000         -0.000000000   1   1110.000210.0000
040291                INNER    OUTER


                ORIGINAL DATA MATRIX
                --------------------

         PROJ     SAMPLE          U(SOUTH)     V(EAST)        W(UP)     DIP TREND       DIP   CATEGORIES
  1     040287    001               8.6600     16.7500  -1709.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  2     040287    003              22.1000     23.3600  -2961.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  3     040287    004              10.5800     29.8000  -2240.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  4     040287    006              16.2400     22.1800  -1872.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  5     040287    008               3.3600     22.0100  -2584.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  6     040287    009              17.1300     14.1800  -2810.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  7     040287    014              18.5000     15.1000  -3062.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  8     040287    015              10.3000     28.9600  -2540.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -0
  9     040287    017              16.6900     18.9000  -2300.0000      -0.0000     -0.0000  1 -0 -0 -0 -0 -
 10     040287    022              12.2600     21.1100  -1505.0000      -0.0000     -0.0000  1 -0 -0 -
 11     040287    023               4.0000     29.9200  -1921.0000      -0.0000     -0.0000  1 -
 12     040287    025               4.0100     21.8600  -2466.0000      -0.0000     -0.000
 13     040287    027              21.6700     22.7500  -2780.0000      -0.0000     -
 14     040287    028              14.5300     35.9300   -707.0000      -0.00
 15     040287    029              21.1600     21.5900  -2677.0000
 16     040287    030               6.4000     28.2000  -2801
 17     040287    031              19.8300     30.5000
 18     040287    033              17.7400
 19     040287    037              23.9
 20     040287    041
 21     040287
 22
```

Figure 2.- Partial list of data points selected randomly from top Arbuckle Group in Kansas.

On reverting to the main program, the first subset selection card is read and printed out (Fig. 5) with a statement of the groups included and excluded and the number of data remaining after the selection. Because the data consist of elevations, subroutine FOLDING is called and the control card read and listed (Fig. 5). Next, the Fourier coefficient specification card(s) are read and Figure 6 shows the ijT and corresponding coefficient values.

Figure 7 lists the transformed U and V coordinates, deviations from the linear surface (scaled if requested), dip at each U,V-point, and direction cosines of the normal to simulated bedding at each point. If OPA is set to 1 by the control card, computed elevations on the Fourier trend surface and the linear plus Fourier surface are listed (Fig. 8) together with the residuals (both true and scaled) from the linear plus Fourier surface; these values permit calculation of summary statistics (Fig. 8). The percentage of the total sum of squares accounted for by the linear is carried in COMMON from subroutine READIN and TOTAL SS (here 96.58 percent) refers to the total sum of squares accounted for by the linear (in example 38.95 percent) plus 94.3910 percent of the remaining sum of squares (100.00 - 38.95) accounted for by the Fourier surface. If the map-output option is called, the first map control card is read and printed out (Fig. 8) followed by the map (Fig. 9); if more than one map control card is included, the additional specifications and maps follow. It is essential that all variables specified on the map control cards be in transformed units, that is, in units transformed according to the operations performed on the data in response to entries on the master card. The U and V coordinates in Figure 9 are in miles, and as scaled and transformed, the northwestern corner of Kansas (used by Merriam and Smith as the original axes origin) is at coordinates U = - 110 miles, V = -210 miles, so the map is for the central part of the State.

Figure 10 is a von Wulff stereographic projection (lower hemisphere) of the normals to bedding simulated by the linear plus Fourier surface; the points projecting into the area of two digits of the output are summed and printed so that values up to 99 are possible and values less than ten are pre-

```
U AND V VALUES ROTATED, TRANSLATED AND SCALED          SCALED W            CATEGORIES
          1        -41.66035      -77.81881          -3.24710          1  *  *  *  *  *
          2         64.40025      -25.65657          -5.62590          1  *  *  *  *  *
          3        -26.50884       25.16414          -4.25600          1  *  *  *  *  *
          4         18.15657      -34.96843          -3.55680          1  *  *  *  *  *
          5        -83.48485      -36.30997          -4.90960          1  *  *  *  *  *
          6         25.17992      -98.09975          -5.33900          1  *  *  *  *  *
          7         35.99116      -90.83965          -5.81780          1  *  *  *  *  *
          8        -28.71843       18.53535          -4.82600          1  *  *  *  *  *
          9         21.70770      -60.85227          -4.37000          1  *  *  *  *  *
         10        -13.25126      -43.41225          -2.85950          1  *  *  *  *  *
         11        -78.43434       26.11111          -3.64990          1  *  *  *  *  *
         12        -78.35543      -37.49369          -4.68540          1  *  *  *  *  *
         13         61.00694      -30.47033          -5.28200          1  *  *  *  *  *
         14          4.66225       73.53851          -1.34330          1  *  *  *  *  *
         15         56.98232      -39.62437          -5.08630          1  *  *  *  *  *
         16        -59.49495       12.53788          -5.32190          1  *  *  *  *  *
         17         46.48674       30.68813          -5.08820          1  *  *  *  *  *
         18         29.99369       37.63258          -4.16100          1  *  *  *  *  *
         19         78.60480      -18.23864          -6.39730          1  *  *  *  *  *
         20         56.50884      -14.29293          -5.62210          1  *  *  *  *
         21        -22.01073      -30.70707          -2.71890          1  *  *
         22         62.19066      -49.01515          -5.74180          1
         23        -59.25821         -.95644          -4.61890
         24         24.46970       51.36364          -3.404
         25         13.18497      -15.31881
         26         -8.04293       27.53157
         27          3.24179       12.9
         28        -26.50884
         29         24.94318
         30         28
         31
```

Figure 3.- Original data rotated, translated and scaled.

```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961

   REGRESSION MATRIX
       2.00000000E+02    6.68166031E+02   -5.02249054E+03    6.68166031E+02    6.22063851E+05    2.11138293E+0

     -5.02249054E+03    2.11138293E+05    2.28340174E+06

          VECTOR Y
            -7.93597700E+02

            -8.65189268E+03

             3.73811145E+04

         COEFFS DEGREE 1
          -3.68590935        -.01316727         .00948094

              YBAROBS            YBARCOMP           SUM RESIDS

              -3.9680             -3.9680              -.0000

   PER CENT REDUCTION IN SUM OF SQUARES

              38.95

   INTERNAL CHECK ON S

              38.95
```

Figure 4.- Linear polynomial equation values for the scaled values of U, V, and W.

```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961
SELECTION CARD  1 AS FOLLOWS  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0



IN COMPUTING THE NEXT SET OF RESULTS, ONLY MEASUREMENTS IN THE FOLLOWING CATEGORIES WERE USED -
INCLUDED                             EXCLUDED
ALL MEASUREMENTS
  200 CASES IN GROUP AFTER SELECTION


   CONTROL CARD      U WAVELENGTH      250.00           V WAVELENGTH      500.00
         COMPUTED VALUES    1       COSY MAP   1
         NO. COEFFS IN TREND   81      WAVE ORIG    10.00 10.00
```

Figure 5.- First subset selection card.

```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25

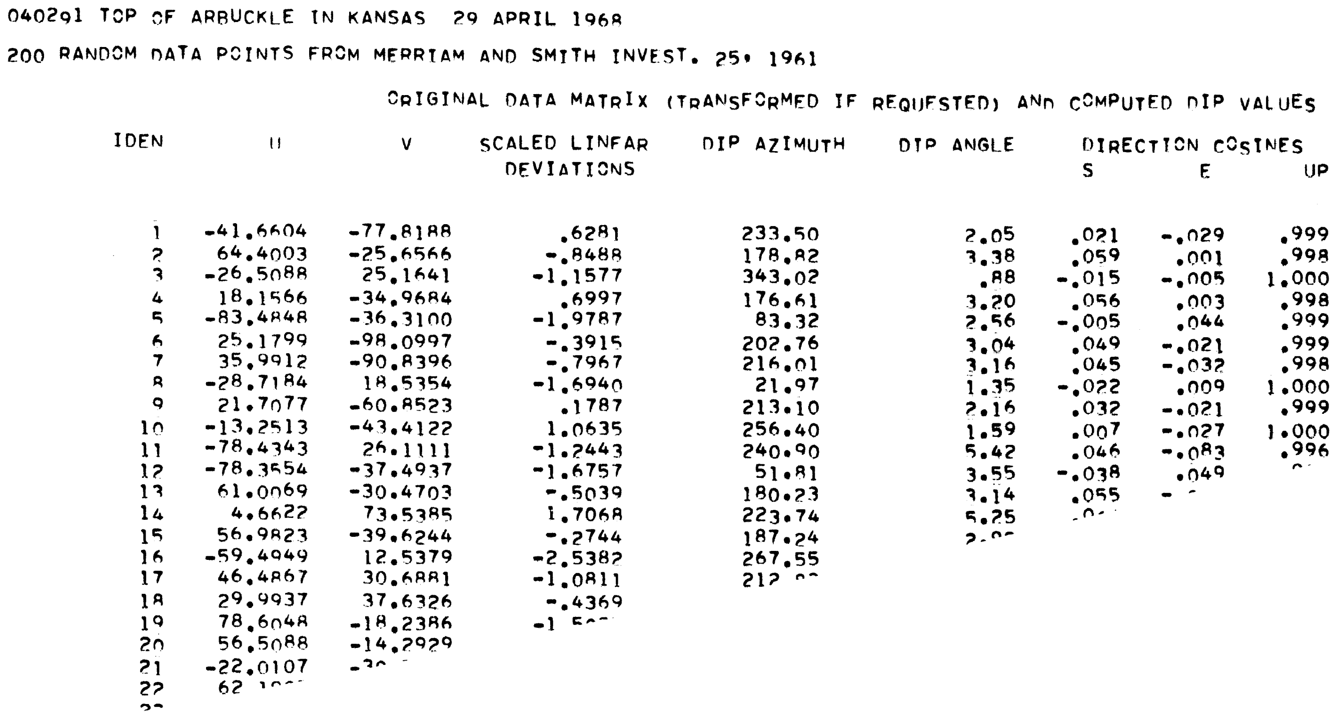
                     COEFFICIENTS
        USUB     VSUB     TYPE     COEFFICIENTS

          0        0        1         .686126
          1        0        1         .974921
          1        0        3        -.745793
          1        1        1         .910933
          1        1        3        1.074180
          1        1        2         .390693
          1        1        4         .837954
          0        1        1       -2.656765
          0        1        2         .879734
          0        2        1         .741559
          0        2        2       -1.446598
          1        2        1        -.229804
          1        2        2         .780832
          1        2        3        -.864118
          1        2        4         .741196
          2        2        1         .213480
          2        2        2        -.460340
          2        2        3        -.530865
          2        2        4         .638317
          2        1        1        -.427467
          2        1        2        -.437818
          2        1        3        1.133400
          2        1        4        -.907968
          2        0        1        -.044411
          2        0        3        -.529332
          0        3        1         .207248
          0        3        2         .394215
          1        3        1        -.813427
          1        3        2         .091102
          1        3        3         .379684
          1        3        4       -1.443484
          2        3        1         .345864
          2        3        2        -.087662
          2        3        3         .022151
          2        3        4         .480699
          3        3        1        -.391465
          3        3        2        -.480543
          3        3        3         .406561
          3        3        4        -.477856
          3        2        1        -.340919
          3        2        2        1.31672*
          3        2        3        -.'-
          3        2        4
          3        1        '
          3        '
          3
```

Figure 6.- Fourier coefficient values.

ceeded by a blank as in Figure 10. In this example only normals to bedding at original data points lying within the map area of Figure 9 are used. This was achieved by setting KOUN = 98 on the control card and insuring that the 98 cards for data points lying outside the limits of Figure 9 are at the end of the data deck. In this manner, the entire data deck is used to compute the linear and Fourier coefficients, etc., but only a specified group of points is used for the von Wulff diagrams and succeeding calculations and output. This option is frequently used - inclusion of data from beyond the geographic limits of immediate interest commonly permits troublesome boundary effects to be eliminated. If subroutine SELECT is utilized to obtain subset selections, the subsets are separated prior to calculation of the Fourier coefficients; the resulting smallness of data sets can introduce troublesome boundary effects and if a subset is drawn from a small geographic area, new primary wavelengths (UW and VW, on control card) must be specified. Use of the subset-selection option is more useful if the subset is to be drawn from points scattered throughout the entire geographic area under investigation.

Figure 11 shows summary statistics for the 102 normals used in Figure 10 (i.e., 200 original points - KOUN = 200 - 98 = 102). These statistics refer to the matrices enumerated at the beginning of this paper. In Figure 11, the covariance matrix is $\underset{\sim}{A}$, $\underset{\sim}{R}^T$ is the following nine values (eigenvectors), and the values 0.99650, 0.00284, and 0.00067 are d_{11}, d_{22}, and d_{33}, respectively. The revised vector matrix gives, in columns, the direction cosines of the principal axes in terms of U, V, and W. The apical angle of the cone, in this example, -0.0 degrees, measures departure from the cylindroidal model; a perfect cylindroidal fold has a zero angle and as the apical angle increases the folds are



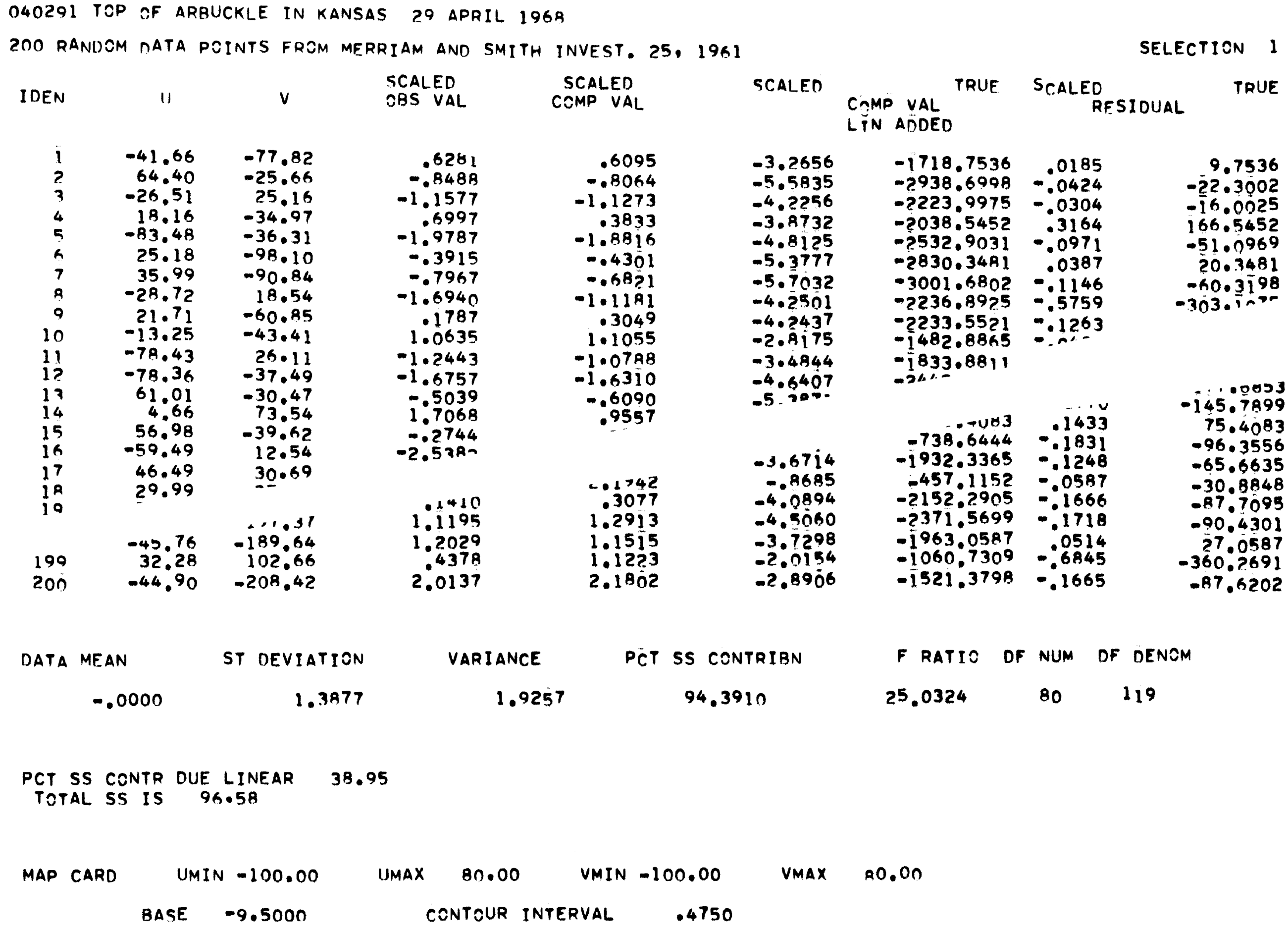
```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961

                         ORIGINAL DATA MATRIX (TRANSFORMED IF REQUESTED) AND COMPUTED DIP VALUES

   IDEN       U          V      SCALED LINEAR   DIP AZIMUTH   DIP ANGLE   DIRECTION COSINES
                                 DEVIATIONS                                S       E       UP

     1   -41.6604   -77.8188        .6281        233.50          2.05    .021   -.029    .999
     2    64.4003   -25.6566       -.8488        178.82          3.38    .059    .001    .998
     3   -26.5088    25.1641     -1.1577         343.02           .88   -.015   -.005   1.000
     4    18.1566   -34.9684        .6997        176.61          3.20    .056    .003    .998
     5   -83.4848   -36.3100     -1.9787          83.32          2.56   -.005    .044    .999
     6    25.1799   -98.0997       -.3915        202.76          3.04    .049   -.021    .999
     7    35.9912   -90.8396       -.7967        216.01          3.16    .045   -.032    .998
     8   -28.7184    18.5354     -1.6940          21.97          1.35   -.022    .009   1.000
     9    21.7077   -60.8523        .1787        213.10          2.16    .032   -.021    .999
    10   -13.2513   -43.4122      1.0635         256.40          1.59    .007   -.027   1.000
    11   -78.4343    26.1111     -1.2443         240.90          5.42    .046   -.083    .996
    12   -78.3554   -37.4937     -1.6757          51.81          3.55   -.038    .049
    13    61.0069   -30.4703       -.5039        180.23          3.14    .055
    14     4.6622    73.5385      1.7068         223.74          5.25
    15    56.9823   -39.6244       -.2744        187.24          2.
    16   -59.4949    12.5379     -2.5382         267.55
    17    46.4867    30.6881     -1.0811         212
    18    29.9937    37.6326       -.4369
    19    78.6048   -18.2386     -1
    20    56.5088   -14.2929
    21   -22.0107   -
    22    62
```

Figure 7.- List of transformed data and computed dip values.



```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961                                 SELECTION  1

                          SCALED        SCALED        SCALED          TRUE    SCALED             TRUE
IDEN      U        V      OBS VAL       COMP VAL              COMP VAL                RESIDUAL
                                                              LIN ADDED

  1    -41.66   -77.82      .6281         .6095       -3.2656   -1718.7536   .0185            9.7536
  2     64.40   -25.66     -.8488        -.8064       -5.5835   -2938.6998  -.0424          -22.3002
  3    -26.51    25.16    -1.1577       -1.1273       -4.2256   -2223.9975  -.0304          -16.0025
  4     18.16   -34.97      .6997         .3833       -3.8732   -2038.5452   .3164          166.5452
  5    -83.48   -36.31    -1.9787       -1.8816       -4.8125   -2532.9031  -.0971          -51.0969
  6     25.18   -98.10     -.3915        -.4301       -5.3777   -2830.3481   .0387           20.3481
  7     35.99   -90.84     -.7967        -.6821       -5.7032   -3001.6802  -.1146          -60.3198
  8    -28.72    18.54    -1.6940       -1.1181       -4.2501   -2236.8925  -.5759         -303.
  9     21.71   -60.85      .1787         .3049       -4.2437   -2233.5521  -.1263
 10    -13.25   -43.41     1.0635        1.1055       -2.8175   -1482.8865  -.
 11    -78.43    26.11    -1.2443       -1.0788       -3.4844   -1833.8811
 12    -78.36   -37.49    -1.6757       -1.6310       -4.6407   -
 13     61.01   -30.47     -.5039        -.6090       -5.                                    .0853
 14      4.66    73.54     1.7068         .9557                                            -145.7899
 15     56.98   -39.62     -.2744                                    083   .1433           75.4083
 16    -59.49    12.54    -2.538                                -738.6444  -.1831          -96.3556
 17     46.49    30.69                                -3.6714   -1932.3365  -.1248          -65.6635
 18     29.99                                 .1742    -.8685    -457.1152  -.0587          -30.8848
 19                            .1410          .3077   -4.0894   -2152.2905  -.1666          -87.7095
                     .37      1.1195         1.2913   -4.5060   -2371.5699  -.1718          -90.4301
         -45.76  -189.64      1.2029         1.1515   -3.7298   -1963.0587   .0514           27.0587
199      32.28   102.66        .4378         1.1223   -2.0154   -1060.7309  -.6845         -360.2691
200     -44.90  -208.42       2.0137         2.1802   -2.8906   -1521.3798  -.1665          -87.6202

DATA MEAN        ST DEVIATION        VARIANCE        PCT SS CONTRIBN        F RATIO  DF NUM  DF DENOM

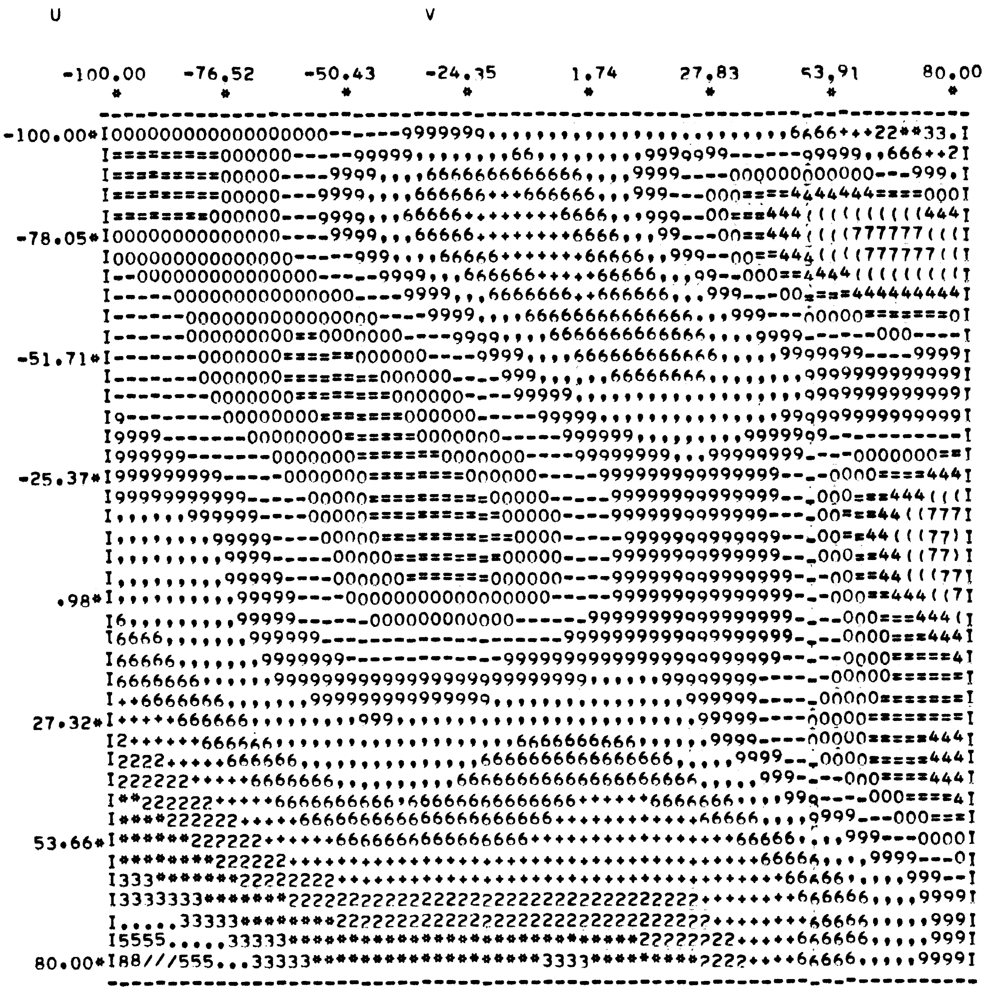
  -.0000             1.3877            1.9257            94.3910            25.0324    80      119


PCT SS CONTR DUE LINEAR    38.95
 TOTAL SS IS    96.58


MAP CARD      UMIN -100.00      UMAX    80.00      VMIN -100.00      VMAX    80.00

         BASE    -9.5000               CONTOUR INTERVAL      .4750
```

Figure 8.- Computed elevations for Fourier trend surface and residual values.



```
SYMBOL   MAX VALUE    MAX VALUE
            TRUE        SCALED
  1       -4750.0       -9.025
  8       -4500.0       -8.550
  /       -4250.0       -8.075
  5       -4000.0       -7.600
  .       -3750.0       -7.125
  3       -3500.0       -6.650
  *       -3250.0       -6.175
  2       -3000.0       -5.700
  +       -2750.0       -5.225
  6       -2500.0       -4.750
  ,       -2250.0       -4.275
  9       -2000.0       -3.800
  -       -1750.0       -3.325
  0       -1500.0       -2.850
  =       -1250.0       -2.375
  4       -1000.0       -1.900
  (        -750.0       -1.425
  7        -500.0        -.950
  )        -250.0        -.475
  $       BEYOND        BEYOND
```

Figure 9. - Linear plus Fourier map of central part of Kansas.

more distinctly conical. The value is based on the least-squares plane fitted to intersections of the bedding normals with the unit sphere (projection sphere); the distance between the center of the spheres and the least-squares plane permits the apical angle to be calculated (Whitten, 1966a). Finally (Fig. 11), the trend and plunge of each principal axis are listed together with the variance (d-value) of the normals about each axis. The A_{III} axis always approximates the geometric fold axis. If d_{22} has the intermediate d-value, A_{II} is the normal to the bisecting plane but, if d_{11} is intermediate, i.e., the folds tend toward isoclinal geometry, then A_I is the normal.

In many runs subroutine SPIN need not be called, but Figure 12 shows the output from this option; the output is useful for redrafting the original data on cross sections in the three orthogonal planes defined by the principal axes. The second through fourth columns are the U, V, and W coordinates of each datum point referred to the principal axes; the next three columns are the direction cosines of the normals to bedding referred to the principal axes. The arithmetic simply involves multiplying the original vectors and scalars by the eigenvectors. Figure 13 shows the stereogram of Figure 10 similarly rotated - the projection plane is now the $A_I A_{II}$-plane so that A_{III} is at the center (for Figure 13, the numerals in parenthesis, rather than the cardinal terms, should be read). Subroutine SEKSHN is also optional and has a use analogous to that of SPIN; the actual inclination of each simulated bedding plane, expressed as tangent of the angle and as the actual angle, with the orthogonal principal-axes planes is given (Fig. 14). The last three columns of SEKSHN output reproduce the same values as those in the second through fourth columns of SPIN output.

Standard output includes a histogram and scalar descriptors with respect to each of the principal axes; these are produced by subroutine MOMENT. As an example, one histogram is shown in Figure 15 together with the first four statistical moments and the skewness and kurtosis values.

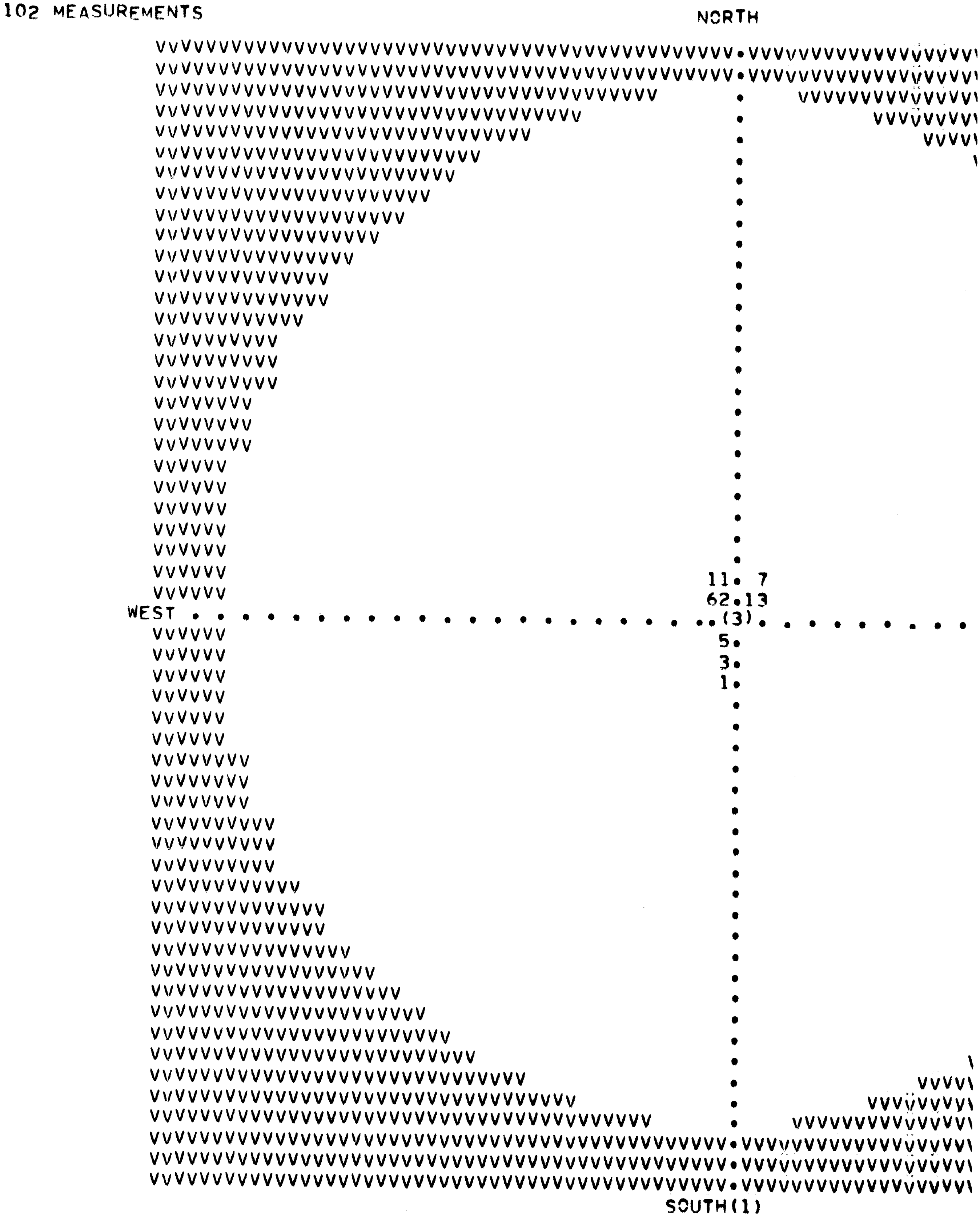


Figure 10. - von Wulff stereographic projection (lower hemisphere) of normals to bedding simulated by linear plus Fourier surface.

```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25



 102 MEASUREMENTS      (SELECTION  1)


COVARIANCE MATRIX
    .00292    -.00066     .01459
   -.00066     .00090    -.01010
    .01459    -.01010     .99618


 EIGENVECTORS AND EIGENVALUES IN COLUMNS
    .01468    -.96984    -.24330
   -.01015     .24317    -.96993
    .99984     .01671    -.00628


    .99650     .00284     .00067

REVISED VECTOR MATRIX USED TO DEFINE NEW REFERENCE AXES
    .01468     .96984     .24330
   -.01015    -.24317     .96993
    .99984    -.01671     .00628


  APICAL ANGLE OF CONE MEASURED FROM 3-AXIS IS
                  -.00


  PRINCIPAL AXES AND ASSOCIATED VARIANCE

TREND (DEGREES E. OF N.) AND PLUNGE OF 1-AXIS
     34.7 AT     89.0
    .99650

TREND (DEGREES E. OF N.) AND PLUNGE OF 2-AXIS
     14.1 AT     -1.0
    .00284

TREND (DEGREES E. OF N.) AND PLUNGE OF 3-AXIS
    284.1 AT      .4
    .00067

         3-AXIS IS APPROXIMATELY B GEOMETRIC FOLD AXIS

         -------------------------------------------
```

Figure 11.- Trend and plunge of each principal axis with variance of normals about each axis.

If specifications for a grid of points are given on the control card, the dip is calculated for each point on the linear plus Fourier surface, together with direction cosines of the normals to bedding (Fig. 16). These values are used to prepare a new von Wulff stereogram (Fig. 17), fold axes (Fig. 18), and histograms and scalar descriptors (Fig. 19).

ILLUSTRATIVE EXAMPLE USING ORIENTATION DATA

Although primarily designed for use with subsurface elevation data, this program can accept orientation data as input. Figure 20 shows the initial output for a small synthetic data matrix in which different categories have been assigned. Factor 1 (lithology) has two categories (sandstone and shale) and factor 2 also has two (first and second). The first subset selection card read
021-21
and Figure 21 shows that, on this basis, only five samples remain; the main program FOLDSTA terminates the selection automatically if less than seven data points remain and moves to the next selection. In this problem the second subset selection card was blank, except for T in column 78, so all points were retained. The resulting stereogram is shown in Figure 22. All succeeding output and options are analogous to those described for the elevation data.

```
 040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

 200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961



  102 MEASUREMENTS      (SELECTION  1)


                         THE MEASUREMENTS BELOW ARE IN TERMS OF THE PRINCIPAL AXES

LIST OF COORDINATES AND DIRECTION COSINES OF MEASUREMENTS TRANSFORMED TO REFER TO PRINCIPAL AXES

SAMPLE      U(SOUTH)      V(EAST)       W(UP)               U(SOUTH)    V(EAST)    W(UP)
    1            .806      -21.491     -85.611                .9998      .0109     -.0165
    2            .357       68.711      -9.222                .9990      .0402      .0218
    3          -1.802      -31.809      17.951                .9996     -.0299     -.0017
    4           1.321       26.101     -29.495                .9991      .0365      .023
    5          -2.836      -72.104     -55.542                .9983     -.0325
    6            .974       48.282     -89.026                .9994
    7            .654       57.008     -79.356
    8          -2.304      -32.331      10.380
    9           1.115       35.847     -5
   10           1.309       -2.31
   11          -2.661
   12          -
```

Figure 12.- List of coordinates and direction cosines of measurements transformed to refer to principal axes.

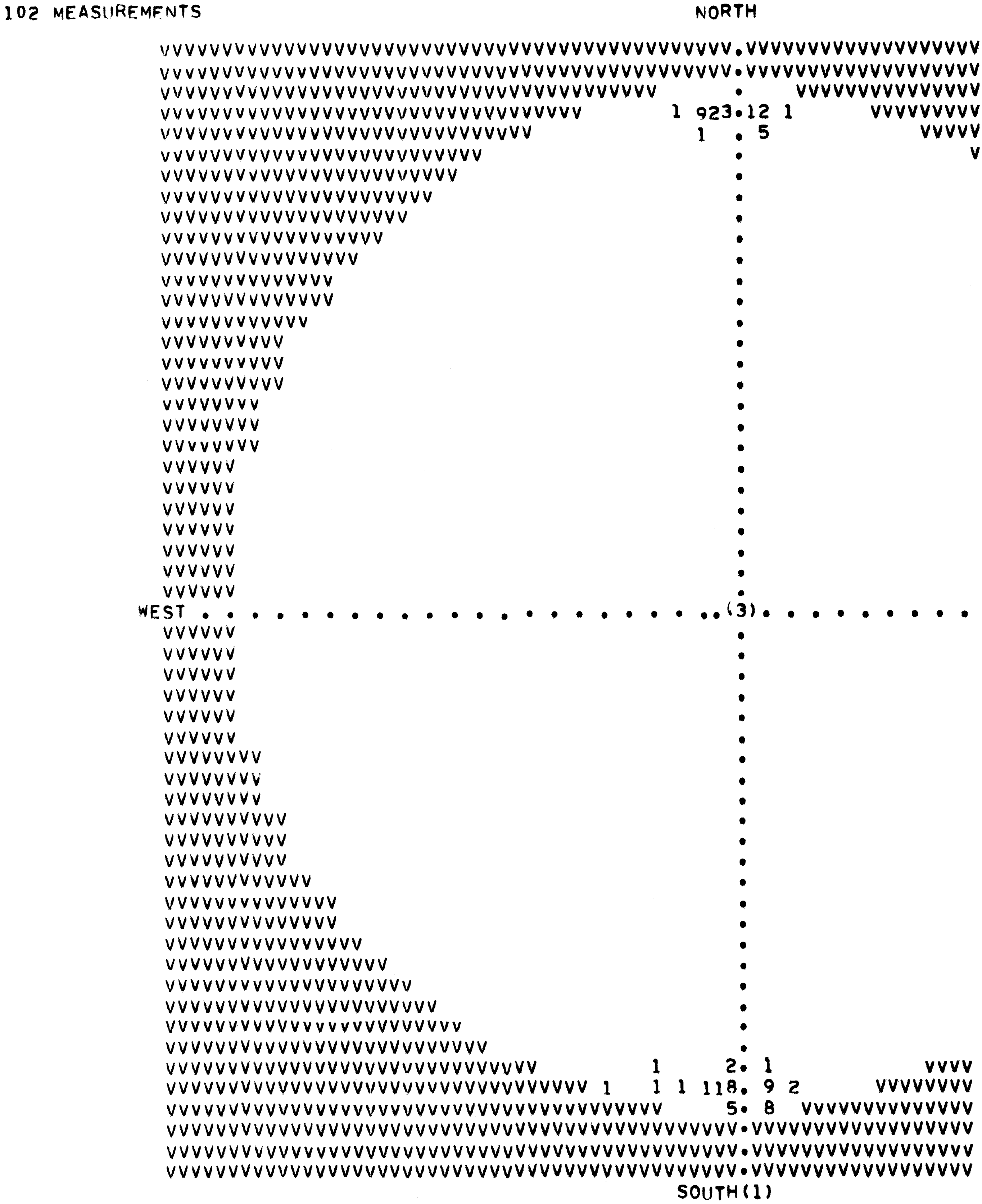
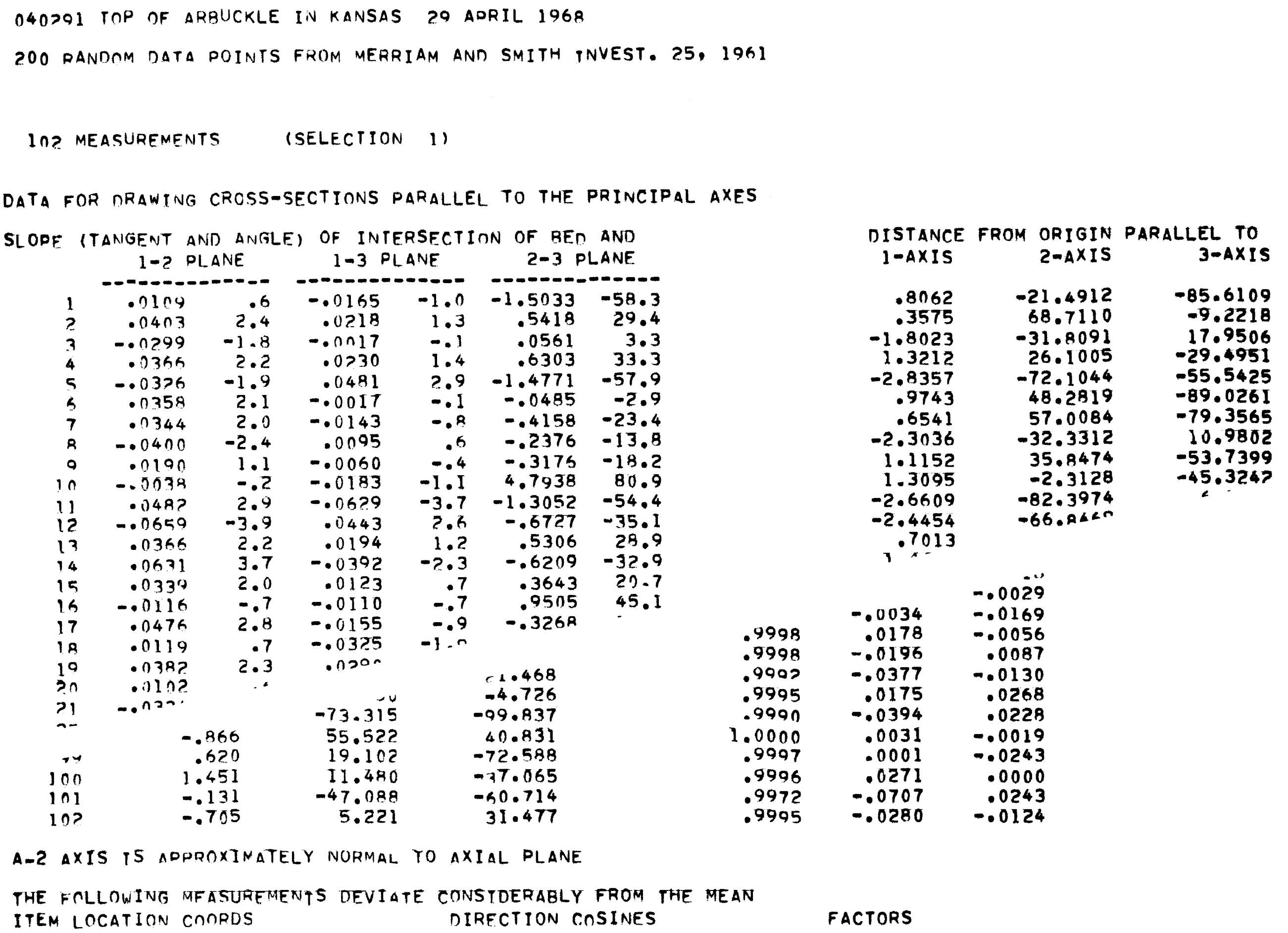


Figure 13.- Rotated stereogram (lower hemisphere) showing distribution of normals to bedding referred to principal axes.



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040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961


 102 MEASUREMENTS      (SELECTION  1)

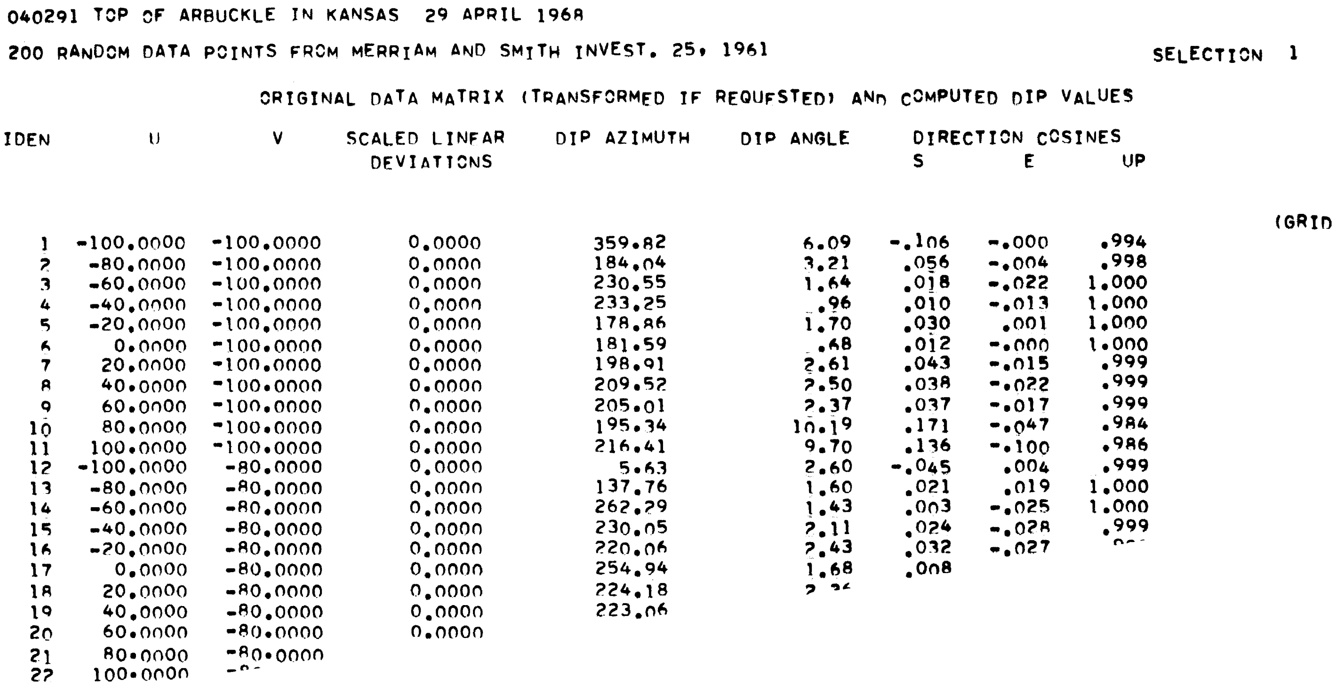
DATA FOR DRAWING CROSS-SECTIONS PARALLEL TO THE PRINCIPAL AXES

SLOPE (TANGENT AND ANGLE) OF INTERSECTION OF BED AND                 DISTANCE FROM ORIGIN PARALLEL TO
        1-2 PLANE         1-3 PLANE          2-3 PLANE                   1-AXIS        2-AXIS        3-AXIS
      --------------   --------------   ----------------
  1     .0109     .6    -.0165   -1.0   -1.5033   -58.3                   .8062      -21.4912      -85.6109
  2     .0403    2.4     .0218    1.3     .5418    29.4                   .3575       68.7110       -9.2218
  3    -.0299   -1.8    -.0017    -.1     .0561     3.3                 -1.8023      -31.8091       17.9506
  4     .0366    2.2     .0230    1.4     .6303    33.3                  1.3212       26.1005      -29.4951
  5    -.0326   -1.9     .0481    2.9   -1.4771   -57.9                 -2.8357      -72.1044      -55.5425
  6     .0358    2.1    -.0017    -.1    -.0485    -2.9                   .9743       48.2819      -89.0261
  7     .0344    2.0    -.0143    -.8    -.4158   -23.4                   .6541       57.0084      -79.3565
  8    -.0400   -2.4     .0095     .6    -.2376   -13.8                 -2.3036      -32.3312       10.9802
  9     .0190    1.1    -.0060    -.4    -.3176   -18.2                  1.1152       35.8474      -53.7399
 10    -.0038    -.2    -.0183   -1.1    4.7938    80.9                  1.3095       -2.3128      -45.3242
 11     .0482    2.9    -.0629   -3.7   -1.3052   -54.4                 -2.6609      -82.3974
 12    -.0659   -3.9     .0443    2.6    -.6727   -35.1                 -2.4454      -66.8
 13     .0366    2.2     .0194    1.2     .5306    28.9                   .7013
 14     .0631    3.7    -.0392   -2.3    -.6209   -32.9
 15     .0339    2.0     .0123     .7     .3643    20.7
 16    -.0116    -.7    -.0110    -.7     .9505    45.1                               -.0029
 17     .0476    2.8    -.0155    -.9    -.3268                          -.0034        -.0169
 18     .0119     .7    -.0325   -1.                          .9998       .0178        -.0056
 19     .0382    2.3     .02                                  .9998      -.0196         .0087
 20     .0102                            1.468                .9992      -.0377        -.0130
 21    -.03                             -4.726                .9995       .0175         .0268
                         -73.315       -99.837                .9990      -.0394         .0228
             -.866        55.522        40.831               1.0000       .0031        -.0019
              .620        19.102       -72.588                .9997       .0001        -.0243
100          1.451        11.480       -37.065                .9996       .0271         .0000
101          -.131       -47.088       -60.714                .9972      -.0707         .0243
102          -.705         5.221        31.477                .9995      -.0280        -.0124

A-2 AXIS IS APPROXIMATELY NORMAL TO AXIAL PLANE

THE FOLLOWING MEASUREMENTS DEVIATE CONSIDERABLY FROM THE MEAN
ITEM LOCATION COORDS                      DIRECTION COSINES                     FACTORS
```

Figure 14.- Data for drawing cross sections parallel to principal axes: Upper figure - SEKSHN output: Lower figure SPIN output (coordinates and direction cosines referred to principal axes).



```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961                                  SELECTION  1

                       ORIGINAL DATA MATRIX (TRANSFORMED IF REQUESTED) AND COMPUTED DIP VALUES

IDEN        U           V       SCALED LINEAR    DIP AZIMUTH     DIP ANGLE     DIRECTION COSINES
                                  DEVIATIONS                                   S         E        UP


                                                                                                              (GRID)
  1  -100.0000  -100.0000         0.0000          359.82            6.09     -.106     -.000      .994
  2   -80.0000  -100.0000         0.0000          184.04            3.21      .056     -.004      .998
  3   -60.0000  -100.0000         0.0000          230.55            1.64      .018     -.022     1.000
  4   -40.0000  -100.0000         0.0000          233.25             .96      .010     -.013     1.000
  5   -20.0000  -100.0000         0.0000          178.86            1.70      .030      .001     1.000
  6     0.0000  -100.0000         0.0000          181.59             .68      .012     -.000     1.000
  7    20.0000  -100.0000         0.0000          198.91            2.61      .043     -.015      .999
  8    40.0000  -100.0000         0.0000          209.52            2.50      .038     -.022      .999
  9    60.0000  -100.0000         0.0000          205.01            2.37      .037     -.017      .999
 10    80.0000  -100.0000         0.0000          195.34           10.19      .171     -.047      .984
 11   100.0000  -100.0000         0.0000          216.41            9.70      .136     -.100      .986
 12  -100.0000   -80.0000         0.0000            5.63            2.60     -.045      .004      .999
 13   -80.0000   -80.0000         0.0000          137.76            1.60      .021      .019     1.000
 14   -60.0000   -80.0000         0.0000          262.29            1.43      .003     -.025     1.000
 15   -40.0000   -80.0000         0.0000          230.05            2.11      .024     -.028      .999
 16   -20.0000   -80.0000         0.0000          220.06            2.43      .032     -.027
 17     0.0000   -80.0000         0.0000          254.94            1.68      .008
 18    20.0000   -80.0000         0.0000          224.18
 19    40.0000   -80.0000         0.0000          223.06
 20    60.0000   -80.0000         0.0000
 21    80.0000   -80.0000
 22   100.0000
```

Figure 16.- Computed dip values and normals to bedding computed for specified new grid of points.

```
 040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

 200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961

DISTRIBUTION OF DIRECTION COSINES ABOUT THE 2-AXIS
  102 MEASUREMENTS     (SELECTION  1)

                      -1.0                 -.5                 0.0
    +   .   .   .   .   +   .   .   .   .   +   .   .   .   .   +   .   .   .
                        000000000000000000000000000000000000000000000000000000
 31                     0
 30                     0
 29                     0
 28                     0
 27                     0
 26                     0                                       *
 25                     0                                       **
 24                     0                                       **
 23                     0                                       **
 22                     0                                       **
 21                     0                                       **
 20                     0                                       **
 19                     0                                       **
 18                     0                                      ***
 17                     0                                      ***
 16                     0                                      ***
 15                     0                                      ***
 14                     0                                     ****
 13                     0                                     ****
 12                     0                                     ****
 11                     0                                     ****
 10                     0                                     ****
  9                     0                                     ****
  8                     0                                     ****
  7                     0                                     ****
  6                     0                                    *****
  5                     0                                    ******
  4                     0                                    ******
  3                     0                                    ******
  2                     0                                    *******
  1                     0                           *   ***  ********
                        000000000000000000000000000000000000000000000000000000
    +   .   .   .   .   +   .   .   .   .   +   .   .   .   .   +   .   .   .
                      -1.0                 -.5                 0.0

                                                    VALUE OF DIRECTION COSINES

PERCENTAGE FREQUENCY PLOTTED VERTICALLY

MOMENTS OF THE ABOVE DISTRIBUTION ARE -
    1      -.0002
    2       .0028
    3      -.0003
    4       .0001

SKEWNESS AND KURTOSIS
 -2.1344      11.3632
A-2 AXIS IS APPROXIMATELY NORMAL TO AXIAL PLANE
```

Figure 15.- Histogram and summary statistics of direction cosines about A_{II}-axis.

```
121 MEASUREMENTS                                              NORTH
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV.VVVVVVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV.VVVVVVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV      .    VVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV            .          VVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVV                .
                   VVVVVVVVVVVVVVVVVVVVVVVVVV                    .
                   VVVVVVVVVVVVVVVVVVVVVVVV                      .
                   VVVVVVVVVVVVVVVVVVVVVV                        .
                   VVVVVVVVVVVVVVVVVVVV                          .
                   VVVVVVVVVVVVVVVVVV                            .
                   VVVVVVVVVVVVVVVV                              .
                   VVVVVVVVVVVVVV                                .
                   VVVVVVVVVVVVVV                                .
                   VVVVVVVVVVVV                                  .
                   VVVVVVVVVV                                    .
                   VVVVVVVVVV                                    .
                   VVVVVVVVVV                                    .
                   VVVVVVVV                                      .
                   VVVVVVVV                                      .
                   VVVVVVVV                                      .
                   VVVVVV                                        .
                   VVVVVV                                        .
                   VVVVVV                                        .
                   VVVVVV                                        .
                   VVVVVV                                       2. 3
                   VVVVVV                                      12. 9 1
                   VVVVVV                                      53.16
                 WEST . . . . . . . . . . . . . . . . . . . . ..(3). . . . . .
                   VVVVVV                                     114. 3
                   VVVVVV                                     1 2.
                   VVVVVV                                     1 3.
                   VVVVVV                                        .
                   VVVVVV                                        .
                   VVVVVV                                        .
                   VVVVVVVV                                      .
                   VVVVVVVV                                      .
                   VVVVVVVV                                      .
                   VVVVVVVVVV                                    .
                   VVVVVVVVVV                                    .
                   VVVVVVVVVV                                    .
                   VVVVVVVVVVVV                                  .
                   VVVVVVVVVVVVVV                                .
                   VVVVVVVVVVVVVV                                .
                   VVVVVVVVVVVVVVVV                              .
                   VVVVVVVVVVVVVVVVVV                            .
                   VVVVVVVVVVVVVVVVVVVV                          .
                   VVVVVVVVVVVVVVVVVVVVVV                        .
                   VVVVVVVVVVVVVVVVVVVVVVVV                      .
                   VVVVVVVVVVVVVVVVVVVVVVVVVV                    .
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVV                .
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV            .          VVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV      .    VVVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV.VVVVVVVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV.VVVVVVVVVVVVVV
                   VVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVVV.VVVVVVVVVVVVVV
                                                            SOUTH(1)
```

Figure 17.- von Wulff stereogram (unrotated) prepared for data at specified new grid points.

```
 040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

 200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961



  121 MEASUREMENTS     (SELECTION  1)


COVARIANCE MATRIX
     .00628   -.00160    .01097
    -.00160    .00174   -.01121
     .01097   -.01121    .99198


 EIGENVECTORS AND EIGENVALUES IN COLUMNS
     .01114    .95899    .28321
    -.01133   -.28309    .95903
     .99987   -.01390    .00771


     .99223    .00660    .00118

REVISED VECTOR MATRIX USED TO DEFINE NEW REFERENCE AXES
     .01114    .95899    .28321
    -.01133   -.28309    .95903
     .99987   -.01390    .00771


  APICAL ANGLE OF CONE MEASURED FROM 3-AXIS IS
                 -.00


  PRINCIPAL AXES AND ASSOCIATED VARIANCE

TREND (DEGREES E. OF N.) AND PLUNGE OF 1-AXIS
     45.5 AT   89.1
     .99223

TREND (DEGREES E. OF N.) AND PLUNGE OF 2-AXIS
     16.4 AT    -.8
     .00660

TREND (DEGREES E. OF N.) AND PLUNGE OF 3-AXIS
    286.5 AT     .4
     .00118
                              3-AXIS IS APPROXIMATELY B GEOMETRIC FOLD AXIS

                              ----------------------------------------
```

Figure 18.- Trend and plunge of each principal axis with variance of normals about each axis prepared for data at specified new grid points.

```
040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968

200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961


DISTRIBUTION OF DIRECTION COSINES ABOUT THE 2-AXIS
  121 MEASUREMENTS      (SELECTION  1)

                     -1.0                 -.5                 0.0
   +   .   .   .   .   +   .   .   .   .   +   .   .   .   .   +   .   .   .   .
                       0000000000000000000000000000000000000000000000000000000000
26                     0
25                     0
24                     0
23                     0
22                     0
21                     0                                       *
20                     0                                       *
19                     0                                       *
18                     0                                       **
17                     0                                       **
16                     0                                       **
15                     0                                       **
14                     0                                       **
13                     0                                      ***
12                     0                                      ***
11                     0                                     ****
10                     0                                     ****
 9                     0                                     ****
 8                     0                                     ****
 7                     0                                     **** *
 6                     0                                     **** *
 5                     0                                    *******
 4                     0                                  * *******
 3                     0                                  **********
 2                     0                                * ************
 1                     0                          ** **** *************
                       0000000000000000000000000000000000000000000000000000000000
   +   .   .   .   .   +   .   .   .   .   +   .   .   .   .   +   .   .   .   .
                     -1.0                 -.5                 0.0

                                                        VALUE OF DIRECTION COSINES

PERCENTAGE FREQUENCY PLOTTED VERTICALLY

MOMENTS OF THE ABOVE DISTRIBUTION ARE -
   1       -.0003
   2        .0066
   3       -.0006
   4        .0002

SKEWNESS AND KURTOSIS
 -1.0316       5.5003


A-2 AXIS IS APPROXIMATELY NORMAL TO AXIAL PLANE
```

Figure 19.- Histogram and summary statistics of direction cosines about A_{11}-axis prepared from data at specified new grid points.

```
 TEST OF FOLD PROGRAM FOR DIRECTIONAL DATA

 MARCH 8 1968        CDC3400

 040281

 WHITTEN

PRINT-OUT OF MASTER CARDS
-------------------------

040281             (2A6,5F6.3,6I3)                                 -0.000     -0.000     -0.000  2 -0
040281             SANSTN    SHALES
040281             FIRST     SECOND


                ORIGINAL DATA MATRIX
                --------------------

             PROJ      SAMPLE          U(SOUTH)      V(EAST)       W(UP)      DIP TREND       DIP   CATEGORIES
  1        040281         1            0.0000        0.0000       0.0000      270.0000     45.0000  1  1 -0 -0 -0 -0
  2        040281         2            0.0000        1.0000       0.0000      270.0000     40.0670  1  1 -0 -0 -0 -0
  3        040281         3            0.0000        2.0000       0.0000      270.0000     22.5570  1  1 -0 -0 -0 -0
  4        040281         4            0.0000        3.0000       0.0000       90.0000      8.1170  1  1 -0 -0 -0 -0
  5        040281         5            0.0000        4.0000       0.0000       90.0000     33.2330  1  1 -0 -0 -0 -0
  6        040281         6            0.0000        5.0000       0.0000       90.0000     43.8170  1  1 -0 -0 -0 -0
  7        040281         7            0.0000        6.0000       0.0000       90.0000     43.8000  1  2 -0 -0 -0 -0
  8        040281         8            0.0000        7.0000       0.0000       90.0000     33.2000  1  2 -0 -0 -0 -0
  9        040281         9            0.0000        8.0000       0.0000       90.0000      8.0500  1  2 -0 -0 -0 -0
 10        040281        10            0.0000        9.0000       0.0000      270.0000     22.6000  1  2 -0 -0 -0 -0
 11        040281        11            0.0000       10.0000       0.0000      270.0000     40.8330  1  2 -0 -0 -0 -0
 12        040281        21            1.0000       -0.0000      -0.0000      271.0000     75.9670  2  2 -0 -0 -0 -0
 13        040281        22            2.0000        1.0000      -0.0000      271.0000     58.9500  2  2 -0 -0 -0 -0
 14        040281        23           -1.0000        2.0000      -0.0000       89.0000     69.1000  2  2 -0 -0 -0 -0
 15        040281        24           -2.0000        3.0000      -0.0000       91.0000     75.4000  2  2 -0 -0 -0 -0
 16        040281        25           -0.0000        4.0000      -0.0000      900.0000     33.6670  2  2 -0 -0 -0 -0
 17        040281        26           -1.0000        5.0000      -0.0000      272.0000     73.4670  1  1 -0 -0 -0 -0
 18        040281        27            1.0000        6.0000      -0.0000      272.0000     73.4330  1  1 -0 -0 -0 -0
 19        040281        28           -0.0000        7.0000      -0.0000       92.0000     29.9000  2  1 -0 -0 -0 -0
 20        040281        29            2.0000        8.0000      -0.0000       92.0000     75.4000  2  1 -0 -0 -0 -0
 21        040281        30           -2.0000        9.0000      -0.0000       85.0000     68.3000  2  1 -0 -0 -0 -0
 22        040281        31           -1.0000       10.0000      -0.0000      272.0000     59.0830  2  1 -0 -0 -0 -0
 23                                  999.0000       -0.0000      -0.0000       -0.0000     -0.0000 -0 -0 -0 -0 -0 -0
  22 MEASUREMENTS
```

Figure 20.- Synthetic data matrix in which dip values and categories have been supplied.

```
 TEST OF FOLD PROGRAM FOR DIRECTIONAL DATA

 MARCH 8 1968        CDC3400

SELECTION CARD  1 AS FOLLOWS  12 -21  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
                                                                                                  SUB. SELECT


IN COMPUTING THE NEXT SET OF RESULTS, ONLY MEASUREMENTS IN THE FOLLOWING CATEGORIES WERE USED -

INCLUDED                              EXCLUDED

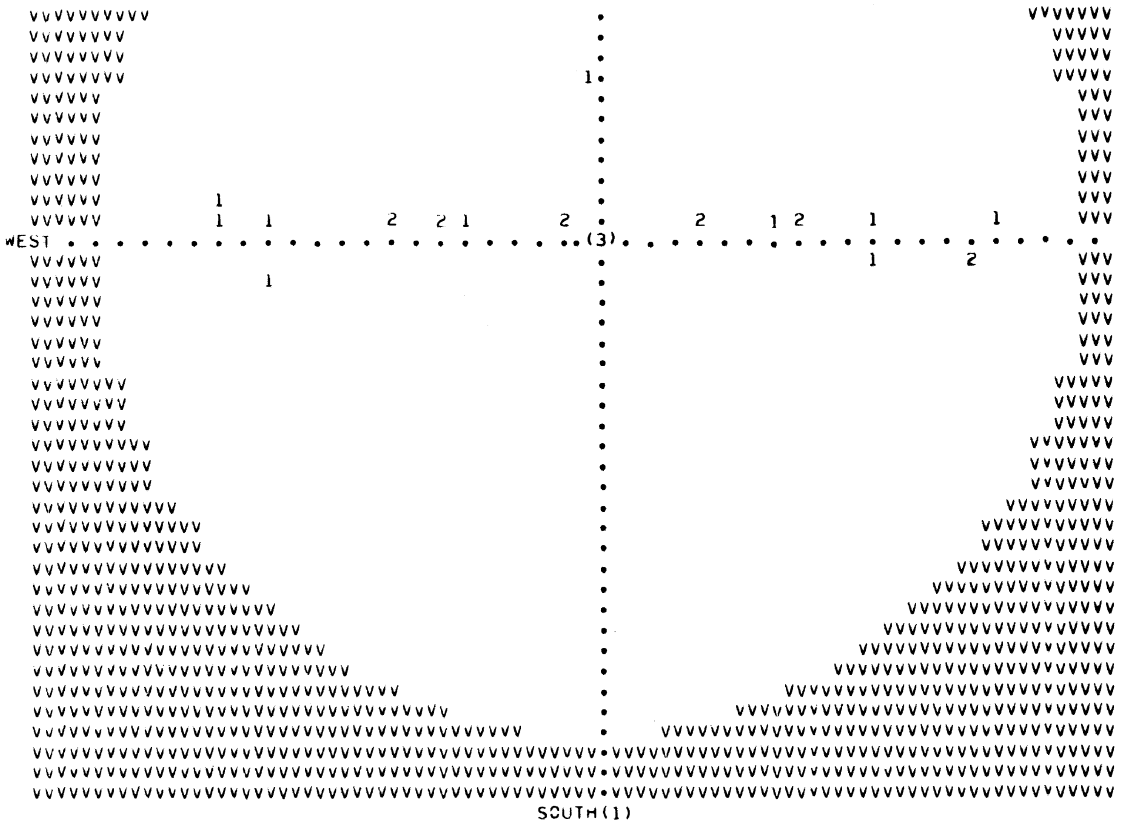

SHALES                                                            SELECTION FIELD  1 USED,VALUE=  12


                                       FIRST                      SELECTION FIELD  2 USED,VALUE= -21

    5 CASES IN GROUP AFTER SELECTION

SELECTED SUBGROUP HAD ONLY  5 DATA ITEMS.  COMPUTATIONS ON SUBGROUP WERE OMITTED.
```

Figure 21.- Selected subgroup has only 5 data items.



22 MEASUREMENTS

STEREOGRAM SHOWING DISTRIBUTION OF POINTS PROJECTED ON LOWER HEMISPHERE OF 20-CENTIMETRE WULFF NET

Figure 22.- von Wulff stereogram for synthetic data matrix of dip values.

REFERENCES

James, W.R., 1966, FORTRAN IV program using double Fourier series for surface fitting of irregularly spaced data: Kansas Geol. Survey Computer Contr. 5, 19 p.

Loudon, T.V., 1964, Computer analysis of orientation data in structural geology: Office of Naval Research, Geography Branch, Tech. Rept. No. 13, ONR Task No. 389-135, 129 p.

Merriam, D.F., and Smith, Polly, 1961, Preliminary regional structural contour map on top of Arbuckle rocks (Cambrian-Ordovician) in Kansas: Kansas Geol. Survey Oil and Gas Invest. 25, map.

Whitten, E.H.T., 1966a, Structural geology of folded rocks: Rand McNally & Co., Chicago, 678 p.

Whitten, E.H.T., 1966b, Sequential multivariate regression methods and scalars in the study of fold-geometry variability: Jour. Geology, v. 74, no. 5, pt. 2, p. 744-763.

APPENDIX A. - Listing of FORTRAN IV program.

```
      PROGRAM FOLDSTA(TAPE51,TAPE52,INPUT,OUTPUT,TAPE6=OUTPUT,
     .TAPE5=INPUT,PUNCH,TAPE53)
C - - - - - -
C     PROGRAM PREPARED BY E. H. TIMOTHY WHITTEN JUNE 1967 FOR CDC 3400
C     AT NORTHWESTERN UNIVERSITY GEOLOGY DEPARTMENT, EVANSTON, ILL 60201
C     WITH PROGRAMMING ASSISTANCE OF MRS BETTY BENSON
C     ADAPTED FROM T. V. LOUDON,S ORIGINAL FORTRAN 4 PROGRAM FOR
C     VECTORAL DATA, COMBINED WITH MODIFIED VERSION OF A
C     DOUBLE FOURIER SURFACE-FITTING PROGRAM IRREGULARLY-SPACED DATA
C     WRITTEN BY W. R. JAMES IN 1966
C     MODIFIED FOR CDC6400 FEBRUARY 1968 BY J. SCHUYLER
C     MAXIMUM 121 FOURIER COEFFICIENTS (ACCOMMODATES COMPLETE 5TH
C     HARMONIC) ALLOWED - REQUIRES CENTRAL MEMORY CDC6400 OF
C     131100 OCTAL  -  CHANGING 2 DIMENSION AND 1 EQUIVALENCE STATEMENT
C     IN SUBROUTINE FOLDING ALLOWS REDUCTION TO 50 COEFFICIENTS WITH
C     ONLY 73600 OCTAL CM REQUIREMENT.
C     *****************************************************************
C     DECK ASSEMBLY REQUIRES
C     4 TITLE CARDS                     READ IN READIN
C     1 MASTER CARD                     READ IN READIN
C     ZERO TO 6 FACTOR CARDS            READ IN READIN
C     UP TO 1600 DATA CARDS             READ IN READIN
C     999. CARD END OF DATA CARDS       READ IN READIN
C     SUBSET SELECTION CARDS            READ IN FOLDSTA
C     CONTROL CARD                      READ IN FOLDING
C     FOURIER COEFF SPECIFICATION CARDS READ IN FOLDING
C     ZERO TO N MAP CONTROL CARDS       READ IN FOLDING
C     ANY NUMBER OF ADDITIONAL SELECT/CONTROL/MAP CARDS READ BY FOLDSTA
C     ****************************************************************)
      COMMON      DIRCOS (1600,3), GCOORD(1600,3)
      COMMON /1/ IEDIT(1600)
      COMMON /7/ KONTROL(20)
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)
      LOGICAL LAST,SAVED
      INTEGER WHSAVE
      DATA (KALF=800)
      REWIND 52  $  REWIND 53
    4 CALL READIN (KOUNT,NFOLD)
      NSEL=0
C WHEN DATA SHOULD BE SAVED ... 2 FOR 2ND HALF OF  ARRAY, 3 FOR TAPES
C KEY INDICATES CURRENT AVAILABILITY OF DATA (1=IN SITU, 2 N 3 AS ABOVE
      KEY=1  $          SAVED=.FALSE.
      WHSAVE=2  $  IF (KOUNT.GT.KALF) WHSAVE=3
C                                   DO THIS SELECTION
    7 READ 100,(KONTROL(I),I=1,20),ISLE,LAST
      NSEL = NSEL+1
      PRINT 110,TITLA,NSEL,KONTROL
C                                RELOAD DATA IF NEED BE
      GO TO (1,2,3) KEY
    3 READ(53) ((GCOORD(I,J),J=1,3),I=1,KOUNT)  $  REWIND 53
      IF (NFOLD.EQ.1) GO TO 9
      READ(52) ((DIRCOS(I,J),J=1,3),I=1,KOUNT)  $  REWIND 52
      GO TO 9
    2 DO 6 I=1,KOUNT
      DO 6 J=1,3
    6 GCOORD(I,J) = GCOORD(I+KALF,J)
      IF (NFOLD.EQ.1) GO TO 9
      DO 8 I=1,KOUNT
```

```
      DO 8 J=1,3
    8 DIRCOS(I,J) = DIRCOS(I+KALF,J)
    9 KEY=1
    1 CONTINUE
      DO 15 I=1,KOUNT
   15 IEDIT(I)=I
      KOUNT2=KOUNT
      CALL SELECT
      IF (KOUNT2 .GT.6)  GO TO 10
      PRINT 109,KOUNT2  $  GO TO 40
   10 KOUNT3=0
      IF (NFOLD.EQ.1) CALL FOLDING (KOUNT3)
      CALL GETCOV
      CALL WULFF
      CALL AXES (NFOLD)
C
C     ISLE = 1 TO SELECT FOR SPIN AND ROTATED WULFF
C     2 FOR SEKSHN IN ADDITION......0 FOR NONE OF THESE
      IF (SAVED) GO TO 28
      GO TO (22,22,20) WHSAVE
   20 IF (ISLE.EQ.0) GO TO 34
C     SPIN HAS BEEN CALLED - THIS DESTROYS STORED DATA UNLESS COPIED
C     SIMILARLY MOMENT WILL DESTROY DIRCOS UNLESS THIS IS COPIED
C     THE  FOLLOWING OPERATIONS EFFECT THE COPYING AUTOMATICALLY
C     SAVED, COPY GCOORD AND DIRCOS
      WRITE (53)  ((GCOORD (I,J), J = 1,3) , I = 1,KOUNT)  $  REWIND 53
      WRITE (52) ((DIRCOS (I,J), J = 1,3), I = 1,KOUNT)  $  REWIND 52
      GO TO 27
   34 IF (LAST) GO TO 30
      WRITE (52) ((DIRCOS (I,J), J = 1,3), I = 1,KOUNT)  $  REWIND 52
      GO TO 27
   22 IF (ISLE.EQ.0) GO TO 35
      DO 25 I = 1,KOUNT
      DO 25  J = 1,3
   25 GCOORD (I + KALF, J) = GCOORD (I,J)
      DO 41  I = 1,KOUNT
      DO 41  J = 1,3
   41 DIRCOS (I + KALF, J) = DIRCOS (I,J)
      GO TO 27
   35 IF (LAST) GO TO 30
      DO 21  I = 1,KOUNT
      DO 21  J = 1,3
   21 DIRCOS (I + KALF, J) = DIRCOS (I,J)
   27 IF (ISLE.EQ.0) GO TO 29  $  SAVED = .TRUE.
   28 KEY = WHSAVE
   29 IF (ISLE.EQ.0) GO TO 30  $  CALL SPIN
      CALL WULFF  $  IF (ISLE.GT.1) CALL SEKSHN
   43 GO TO (30,37,38) WHSAVE
   37 DO 39 I = 1,KOUNT  $  DO 39  J = 1,3
   39 DIRCOS (I,J) = DIRCOS (I+KALF,J)
      GO TO (42,30,30) KEY
   38 READ(52) ((DIRCOS(I,J), J=1,3), I=1,KOUNT)  $  REWIND 52
      IF (KEY.EQ.1) GO TO 42
   30 DO 32  IAXIS = 1,3
   32 CALL MOMENT (IAXIS)
      IF (KEY.EQ.1) GO TO 43
C                                                     GRID
   42 IF (KOUNT3.EQ.0) GO TO 40  $  KOUNT2 = KOUNT3
      CALL DIPAZAN(KOUNT3)
```

```
      CALL GETCOV                                                       FDSTA118
      CALL WULFF                                                        FDSTA119
      CALL AXES (NFOLD)                                                 FDSTA120
      DO 33 IAXIS = 1,3                                                 FDSTA121
   33 CALL MOMENT (IAXIS)                                               FDSTA122
C                            GET READY TO PROCESS NEXT SELECTION        FDSTA123
   40 IF (LAST) 4,7                                                     FDSTA124
  100 FORMAT (12X,2I13,L3)                                              FDSTA125
 109  FORMAT (1H0, 26HSELECTED SUBGROUP HAD ONLY, I3, 52H DATA ITEMS.  CFDSTA126
     1OMPUTATIONS ON SUBGROUP WERE OMITTED.)                            FDSTA127
  110 FORMAT (2(9A8/),*0SELECTION CARD*I3,* AS FOLLOWS*,20I4)           FDSTA128
      END                                                               FDSTA129
      SUBROUTINE AXES (NFOLD)                                           AXES   1
C     - - - - - - - -                                                   AXES   2
C     BASED ON LIBRARY SUBROUTINE HDIAG WRITTEN BY CORBATO AND MERWIN.  AXES   3
C     OF THE M. I. T. COMPUTATION CENTER.                               AXES   4
C     - - - - - - - - -            - - - -                              AXES   5
      COMMON /4/ D(3),COVMAT(3,3)                                       AXES   6
      COMMON /5/ EIGVAL(3),EIGMAT(3,3)                                  AXES   7
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)                        AXES   8
      COMMON /10/ ABC(3)                                                AXES   9
      DIMENSION H(3,3), U(3,3),X(3),IQ(3)                               AXES  10
      DIMENSION DTEMP(3)                                                AXES  11
C                                                                       AXES  12
      PRINT 99,TITLA   $  PRINT 98,KOUNT2,NSEL                          AXES  13
      WRITE(6,103)                                                      AXES  14
      DO 6   J=1,3                                                      AXES  15
      WRITE (6,102)   (COVMAT(J,K), K=1,3)                              AXES  16
      DO 6   K=1,3                                                      AXES  17
 6    H(J,K) = COVMAT(J,K)                                              AXES  18
      N = 3                                                             AXES  19
      IEGEN = 0                                                         AXES  20
      IF (IEGEN) 15,10,15                                               AXES  21
 10   DO 14 I=1,N                                                       AXES  22
      DO 14 J=1,N                                                       AXES  23
      U(I,J) = 0.0                                                      AXES  24
      IF(I.EQ.J)U(I,J)=1.0                                              AXES  25
   14 CONTINUE                                                          AXES  26
 15   NR = 0                                                            AXES  27
      IF (N-1) 1000,1000,17                                             AXES  28
 17   NMI1=N-1                                                          AXES  29
      DO 30 I=1,NMI1                                                    AXES  30
      X(I) = 0.0                                                        AXES  31
      IPL1=I+1                                                          AXES  32
      DO 30 J=IPL1,N                                                    AXES  33
      IF ( X(I) - ABS( H(I,J))) 20,20,30                                AXES  34
 20   X(I)=ABS(H(I,J))                                                  AXES  35
      IQ(I)=J                                                           AXES  36
 30   CONTINUE                                                          AXES  37
C     SET INDICATOR FOR SHUT-OFF.RAP=2**-27,NR=NO. OF ROTATIONS         AXES  38
      RAP=.745058059E-08                                                AXES  39
      HDTEST=1.0E38                                                     AXES  40
 40   DO  70  I=1,NMI1                                                  AXES  41
      IF (I-1) 60,60,45                                                 AXES  42
 45   IF ( XMAX- X(I)) 60,70,70                                         AXES  43
 60   XMAX=X(I)                                                         AXES  44
      IPIV=I                                                            AXES  45
      JPIV=IQ(I)                                                        AXES  46
 70   CONTINUE                                                          AXES  47
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      IF ( XMAX) 1000,1000,80                                           AXES  48
   80 IF (HDTEST) 90,90,85                                              AXES  49
   85 IF (XMAX - HDTEST) 90,90,148                                      AXES  50
   90 HDIMIN = ABS( H(1,1) )                                            AXES  51
      DO 110  I= 2,N                                                    AXES  52
      IF (HDIMIN- ABS( H(I,I))) 110,110,100                             AXES  53
  100 HDIMIN=ABS(H(I,I))                                                AXES  54
  110 CONTINUE                                                          AXES  55
      HDTEST=HDIMIN*RAP                                                 AXES  56
C     RETURN IF MAX.H(I,J)LESS THAN(2**-27)ABSF(H(K,K)-MIN)             AXES  57
      IF (HDTEST- XMAX) 148,1000,1000                                   AXES  58
  148 NR = NR+1                                                         AXES  59
  150 TANG=SIGN(2.0,(H(IPIV,IPIV)-H(JPIV,JPIV)))*H(IPIV,JPIV)/(ABS(H(IPIAXES  60
     1V,IPIV)-H(JPIV,JPIV))+SQRT((H(IPIV,IPIV)-H(JPIV,JPIV))**2+4.0*H(IPAXES  61
     2IV,JPIV)**2))                                                     AXES  62
      COSINE=1.0/SQRT(1.0+TANG**2)                                      AXES  63
      SINE=TANG*COSINE                                                  AXES  64
      HII=H(IPIV,IPIV)                                                  AXES  65
      H(IPIV,IPIV)=COSINE**2*(HII+TANG*(2.0*H(IPIV,JPIV)+TANG*H(JPIV,JPIAXES  66
     1V)))                                                              AXES  67
      H(JPIV,JPIV)=COSINE**2*(H(JPIV,JPIV)-TANG*(2.0*H(IPIV,JPIV)-TANG*HAXES  68
     1 II))                                                             AXES  69
      H(IPIV,JPIV)=0.0                                                  AXES  70
      IF ( H(IPIV,IPIV) -  H(JPIV,JPIV)) 152,153,153                    AXES  71
  152 HTEMP = H(IPIV,IPIV)                                              AXES  72
      H(IPIV,IPIV) = H(JPIV,JPIV)                                       AXES  73
      H(JPIV,JPIV) = HTEMP                                              AXES  74
      HTEMP = SIGN(1.0, -SINE) * COSINE                                 AXES  75
      COSINE = ABS(SINE)                                                AXES  76
      SINE = HTEMP                                                      AXES  77
  153 CONTINUE                                                          AXES  78
      DO 350 I=1,NMI1                                                   AXES  79
      IF(I-IPIV)210,350,200                                             AXES  80
  200 IF(I-JPIV)210,350,210                                             AXES  81
  210 IF(IQ(I)-IPIV)230,240,230                                         AXES  82
  230 IF(IQ(I)-JPIV)350,240,350                                         AXES  83
  240 K=IQ(I)                                                           AXES  84
  250 HTEMP=H(I,K)                                                      AXES  85
      H(I,K)=0.0                                                        AXES  86
      IPL1=I+1                                                          AXES  87
      X(I) =0.0                                                         AXES  88
      DO 320 J=IPL1,N                                                   AXES  89
      IF ( X(I)- ABS( H(I,J)) ) 300,300,320                             AXES  90
  300 X(I) = ABS(H(I,J))                                                AXES  91
      IQ(I)=J                                                           AXES  92
  320 CONTINUE                                                          AXES  93
      H(I,K)=HTEMP                                                      AXES  94
  350 CONTINUE                                                          AXES  95
      X(IPIV) =0.0                                                      AXES  96
      X(JPIV) =0.0                                                      AXES  97
      DO 530 I=1,N                                                      AXES  98
      IF(I-IPIV)370,530,420                                             AXES  99
  370 HTEMP = H(I,IPIV)                                                 AXES 100
      H(I,IPIV) = COSINE*HTEMP + SINE*H(I,JPIV)                         AXES 101
      IF ( X(I) -  ABS( H(I,IPIV)) )380,390,390                         AXES 102
  380 X(I) = ABS(H(I,IPIV))                                             AXES 103
      IQ(I) = IPIV                                                      AXES 104
  390 H(I,JPIV) = -SINE*HTEMP + COSINE*H(I,JPIV)                        AXES 105
      IF ( X(I) -  ABS( H(I,JPIV)) ) 400,530,530                        AXES 106
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 400  X(I) = ABS(H(I,JPIV))                                             AXES 107
      IQ(I) = JPIV                                                      AXES 108
      GO TO 530                                                         AXES 109
 420  IF(I-JPIV)430,530,480                                             AXES 110
 430  HTEMP = H(IPIV,I)                                                 AXES 111
      H(IPIV,I) = COSINE*HTEMP + SINE*H(I,JPIV)                         AXES 112
      IF ( X(IPIV) -  ABS( H(IPIV,I)) ) 440,450,450                     AXES 113
 440  X(IPIV) = ABS(H(IPIV,I))                                          AXES 114
      IQ(IPIV) = I                                                      AXES 115
 450  H(I,JPIV) = -SINE*HTEMP + COSINE*H(I,JPIV)                        AXES 116
      IF ( X(I) -  ABS( H(I,JPIV)) ) 400,530,530                        AXES 117
 480  HTEMP = H(IPIV,I)                                                 AXES 118
      H(IPIV,I) = COSINE*HTEMP + SINE*H(JPIV,I)                         AXES 119
      IF ( X(IPIV) -  ABS( H(IPIV,I)) ) 490,500,500                     AXES 120
 490  X(IPIV) = ABS(H(IPIV,I))                                          AXES 121
      IQ(IPIV) = I                                                      AXES 122
 500  H(JPIV,I) = -SINE*HTEMP + COSINE*H(JPIV,I)                        AXES 123
      IF ( X(JPIV) -  ABS( H(JPIV,I)) ) 510,530,530                     AXES 124
 510  X(JPIV) = ABS(H(JPIV,I))                                          AXES 125
      IQ(JPIV) = I                                                      AXES 126
 530  CONTINUE                                                          AXES 127
C                                                                       AXES 128
C     TEST FOR COMPUTATION OF EIGENVECTORS                              AXES 129
C                                                                       AXES 130
      IF(IEGEN)40,540,40                                                AXES 131
 540  DO 550 I=1,N                                                      AXES 132
      HTEMP=U(I,IPIV)                                                   AXES 133
      U(I,IPIV)=COSINE*HTEMP+SINE*U(I,JPIV)                             AXES 134
 550  U(I,JPIV)=-SINE*HTEMP+COSINE*U(I,JPIV)                            AXES 135
      GO TO 40                                                          AXES 136
 1000 CONTINUE                                                          AXES 137
C                                                                       AXES 138
C     END OF LIBRARY SUBROUTINE HDIAG.                                  AXES 139
C                                                                       AXES 140
      WRITE (6,104)                                                     AXES 141
      DO 8  J = 1,3                                                     AXES 142
      DO 7   K = 1,3                                                    AXES 143
 7    EIGMAT(J,K) = U(J,K)                                              AXES 144
      EIGVAL(J) = H(J,J)                                                AXES 145
 8    WRITE(6,102)   (EIGMAT(J,K), K = 1,3)                             AXES 146
      WRITE (6,106)   (EIGVAL(K), K = 1,3)                              AXES 147
C                                                                       AXES 148
C     IF +VE ENDS OF ANY PRINCIPAL AXIS IN -VE DIRECTION CHANGE         AXES 149
C                                                                       AXES 150
      DO 707 K = 1,3                                                    AXES 151
      E1=ABS(EIGMAT(1,K)) $  E2=ABS(EIGMAT(2,K)) $  E3=ABS(EIGMAT(3,K)) AXES 152
      J=1                                                               AXES 153
      IF (E2.GE. E1) J=2                                                AXES 154
      IF (E3.GE.E1  .AND.  E3.GE.E2) J=3                                AXES 155
      IF (EIGMAT(J,K) .GE.0.0)  GO TO 707                               AXES 156
  704  DO 705   J = 1,3                                                 AXES 157
 705   EIGMAT (J,K) = - EIGMAT (J,K)                                    AXES 158
 707    CONTINUE                                                        AXES 159
       WRITE (6,700)                                                    AXES 160
  711 WRITE(6,102) ((EIGMAT(J,K),K=1,3),J=1,3)                          AXES 161
      IF (NFOLD.NE.1) GO TO 760  $   WRITE (6,701)                      AXES 162
      A4 = 0.0                                                          AXES 163
      DO 76 I = 1,3                                                     AXES 164
      CON = ABC(I)*EIGMAT(I,3)                                          AXES 165
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   76 A4 = A4 + CON                                                     AXES 166
      A4=180.0-ACOS(A4)*360.0/3.14159                                   AXES 167
      WRITE (6,702)  A4                                                 AXES 168
  760 WRITE (6,105)                                                     AXES 169
      DO 1011   J = 1,3                                                 AXES 170
      WRITE (6,107)   J                                                 AXES 171
      DO 1010   I = 1,3                                                 AXES 172
 1010 DTEMP(I)= EIGMAT(I,J)                                             AXES 173
      CALL ENISOC(1,DTEMP)                                              AXES 174
 1011 WRITE(6,102)    EIGVAL(J)                                         AXES 175
      WRITE (6,703)                                                     AXES 176
      RETURN                                                            AXES 177
C                                                                       AXES 178
   98 FORMAT (I6,* MEASUREMENTS*,5X,*(SELECTION*,I3,1H)/)               AXES 179
   99 FORMAT (2(9A8/),1H0,120X*SUB. AXES*//)                            AXES 180
  102 FORMAT (2X3F10.5)                                                 AXES 181
  103 FORMAT(/X,17HCOVARIANCE MATRIX)                                   AXES 182
  104 FORMAT(/1H0,40H EIGENVECTORS AND EIGENVALUES IN COLUMNS)          AXES 183
  105 FORMAT (//3X*PRINCIPAL AXES AND ASSOCIATED VARIANCE*)             AXES 184
  106 FORMAT(//2X,3F10.5)                                               AXES 185
  107 FORMAT(/1H+, 36X, 3HOF , I1, 5H-AXIS)                             AXES 186
  700 FORMAT(*0REVISED VECTOR MATRIX USED TO DEFINE NEW REFERENCE AXES*)AXES 187
  701 FORMAT (//3X*APICAL ANGLE OF CONE MEASURED FROM 3-AXIS IS*)       AXES 188
  702 FORMAT (15X,F6.2)                                                 AXES 189
  703 FORMAT (28X*3-AXIS IS APPROXIMATELY B GEOMETRIC FOLD AXIS*//28X,  AXES 190
     .45(1H-))                                                          AXES 191
      END                                                               AXES 192
      SUBROUTINE ENISOC (LINFOL,DTEMP)                                  ENSOC  1
C     - - - - - - - - -                                                 ENSOC  2
C     THIS SUBROUTINE CONVERTS DIRECTION COSINES TO RADIAL COORDINATES. ENSOC  3
C                                                                       ENSOC  4
      DIMENSION DTEMP(3)                                                ENSOC  5
      D1=DTEMP(1)  $  D2=DTEMP(2)  $  D3=DTEMP(3)                       ENSOC  6
      PRINT 100                                                         ENSOC  7
C                                                                       ENSOC  8
C     CALCULATE THE TREND AND PLUNGE                                    ENSOC  9
      RAD = 180.0/3.141593                                              ENSOC 10
      PLUNGE=90.0- RAD*ACOS(D3) $ FE=D2/D1                              ENSOC 11
      TREND=RAD*ATAN(FE)                                                ENSOC 12
      IF (D2 .LT. 0.0)  31, 32                                          ENSOC 13
   31 IF (FE .LT. 0.0) 33, 34                                           ENSOC 14
   32 IF (FE .LT. 0.0) 34, 35                                           ENSOC 15
   33 TREND = - TREND     $ GO TO 22                                    ENSOC 16
   34 TREND = 180.0 - TREND $ GO TO 22                                  ENSOC 17
   35 TREND = 360.0 - TREND                                             ENSOC 18
   22 PRINT 103, TREND, PLUNGE                                          ENSOC 19
      RETURN                                                            ENSOC 20
C                                                                       ENSOC 21
  100 FORMAT (X,    35HTREND (DEGREES E. OF N.) AND PLUNGE)             ENSOC 22
  103 FORMAT (X,F9.1,4H AT , F6.1)                                      ENSOC 23
      END                                                               ENSOC 24
      SUBROUTINE FOLDING (KOUNT3)                                       FOLDG  1
C                                                                       FOLDG  2
C     THIS SUBROUTINE COMPUTES DOUBLE FOURIER SERIES COEFFICIENTS,      FOLDG  3
C     NORMALS TO LINEAR + FOURIER SURFACE, COMPUTED VALUES ON SURFACE,  FOLDG  4
C     AND PRINTS MAPS OF COMPUTED SURFACES                              FOLDG  5
C                                                                       FOLDG  6
      COMMON      DIRCOS (1600,3), GCOORD(1600,3)                       FOLDG  7
      COMMON /1/ IEDIT(1600)                                            FOLDG  8
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      COMMON /2/ COEFL(3), SSRED                                        FOLDG   9
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)                        FOLDG  10
      COMMON /10/ ABC(3)                                                FOLDG  11
       COMMON /11/COR3                                                  FOLDG  12
C                                                                       FOLDG  13
      DIMENSION CH(20),VPRINT(7),PR(70),CONTOUR(19)                     FOLDG  14
      DIMENSION II(121), JJ(121),IDT(121),C(121),SC(121)                FOLDG  15
      DIMENSION G(121), SSS(121,121)                                    FOLDG  16
      EQUIVALENCE (C,G),   (N,KOUNT2)                                   FOLDG  17
C     DIMENSION PERMIT UP TO COMPLETE 5TH HARMONIC (121 COEFFS) BUT IF  FOLDG  18
C     ONLY 3RD HARMONIC (49 COEFFS) SUFFICIENT USE FOLLOWING 3 CARDS    FOLDG  19
C     INSTEAD OF PRECEEDING THREE.                                      FOLDG  20
C     DIMENSION G(50),SSS(50,50)                                        FOLDG  21
C     DIMENSION II(50),JJ(50),IDT(50),C(50),SC(50)                      FOLDG  22
C     EQUIVALENCE (C,G) , (DIRCOS,SSS) , (DIRCOS(2501),SC) , (N,KOUNT2) FOLDG  23
      LOGICAL GRID                                                      FOLDG  24
      INTEGER PR,CH                                                     FOLDG  25
C                                                                       FOLDG  26
      DATA (CH=1H1,1H8,1H/,1H5,1H.,1H3,1H*,1H2,1H+,1H6,1H,,1H9,1H-,1H0, FOLDG  27
     X1H=,1H4,1H(,1H7,1H),1H$)                                          FOLDG  28
C****************************************                               FOLDG  29
C     READ CONTROL CARD AND FOURIER COEFF SPECIFICATION CARD            FOLDG  30
C****************************************                               FOLDG  31
      READ 107,UW,VW,OPA,OPB,M,UO,VO,UMIN,UINCRM,JUINS,VMIN,VINCRM,JVINSFOLDG  32
     .,ANGLE,KOUN                                                       FOLDG  33
      IF (NSEL.EQ.1) READ 103,(II(L),JJ(L),IDT(L),L=1,M)                FOLDG  34
      PRINT 108,UW, VW, OPA, OPB, M, UO, VO                             FOLDG  35
      IF (JUINS.EQ.0) GO TO 6                                           FOLDG  36
      NUPTS=JUINS+1   $  NVPTS=JVINS+1   $  KOUNT3=NUPTS*NVPTS          FOLDG  37
      ANGLE = (ANGLE)*(3.14159/180.0)                                   FOLDG  38
      CANGL  = COSF(ANGLE) $ SANGL = SINF(ANGLE)                        FOLDG  39
C****************************************                               FOLDG  40
C     COMPUTES SSS, BETA HAT, AND G MATRICES                            FOLDG  41
C****************************************                               FOLDG  42
    6 P=2.0*3.1415926   $  UAC = P/UW  $  VAC=P/VW                      FOLDG  43
      DO 10 I=1,M                                                       FOLDG  44
      G(I)=0.0                                                          FOLDG  45
      DO 10 J=1,M                                                       FOLDG  46
   10  SSS(I,J) = 0.0                                                   FOLDG  47
      DO 11 IE=1,KOUNT2                                                 FOLDG  48
      K=IEDIT(IE)                                                       FOLDG  49
      U=(GCOORD(K,1)-UO) *UAC  $  V=(GCOORD(K,2)-VO) *VAC               FOLDG  50
      DO 19 I=1,M                                                       FOLDG  51
      UII=II(I)*U  $  VII=JJ(I)*V                                       FOLDG  52
      ISKY=IDT(I)                                                       FOLDG  53
      GO TO(13,14,15,16),ISKY                                           FOLDG  54
   13 SC(I) = COS(UII) * COS(VII)  $  GO TO 19                          FOLDG  55
   14 SC(I) = COS(UII)*SIN(VII)  $  GO TO 19                            FOLDG  56
   15 SC(I) = SIN(UII)*COS(VII)  $  GO TO 19                            FOLDG  57
   16 SC(I) = SIN(UII)*SIN(VII)                                         FOLDG  58
   19 CONTINUE                                                          FOLDG  59
      DO 20 I=1,M                                                       FOLDG  60
      G(I) = G(I) + SC(I)*GCOORD(K,3)                                   FOLDG  61
      DO 20 J=1,M                                                       FOLDG  62
   20 SSS(I,J) = SSS(I,J) + SC(I)*SC(J)                                 FOLDG  63
   11 CONTINUE                                                          FOLDG  64
C****************************************                               FOLDG  65
C     SOLVE FOR COEFFICIENTS                                            FOLDG  66
C****************************************                               FOLDG  67
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      K=0                                                               FOLDG 68
   21 CONTINUE                                                          FOLDG 69
      K=K+1                                                             FOLDG 70
      IF(K .EQ. M)25,22                                                 FOLDG 71
   22 DO 23 I=K,M                                                       FOLDG 72
      IF(ABS(SSS(I,K)).LE.0.0001)GOTO 23                                FOLDG 73
      XY = SSS(I,K)                                                     FOLDG 74
      G(I)=G(I)/XY                                                      FOLDG 75
      DO 95 J=K,M                                                       FOLDG 76
   95  SSS(I,J) = SSS(I,J)/XY                                           FOLDG 77
   23 CONTINUE                                                          FOLDG 78
      L=K+1                                                             FOLDG 79
      DO 24 I=L,M                                                       FOLDG 80
      IF (SSS(I,K) .LE. 0.0001) GO TO 24                                FOLDG 81
      G(I)=G(I)-G(K)                                                    FOLDG 82
      DO 29 J=K,M                                                       FOLDG 83
   29 SSS(I,J) = SSS(I,J) - SSS(K,J)                                    FOLDG 84
   24 CONTINUE                                                          FOLDG 85
      GO TO 21                                                          FOLDG 86
C                                                                       FOLDG 87
   25 C(M) = G(M)/SSS(M,M)                                              FOLDG 88
      I=M-1                                                             FOLDG 89
   26 CONTINUE                                                          FOLDG 90
      K=I+1                                                             FOLDG 91
      DO 28 J=K,M                                                       FOLDG 92
   28 C(I) = C(I) - SSS(I,J)*C(J)                                       FOLDG 93
      I=I-1       $  IF (I.GT.0) GO TO 26                               FOLDG 94
      PRINT 999,TITLA,NSEL  $  PRINT 1001                               FOLDG 95
  180 PRINT 1000,(II(K),JJ(K),IDT(K),C(K),K=1,M)                        FOLDG 96
C                                                                       FOLDG 97
      KOUNT2 = KOUNT2 - KOUN                                            FOLDG 98
      GRID=.FALSE.   $  GO TO 66                                        FOLDG 99
C                                                                       FOLDG100
  103 FORMAT (75I1)                                                     FOLDG101
  107 FORMAT (2F6.0,2F1.0,I5,2F6.0,2(2F6.3,I3),1F3.0,I3)                FOLDG102
  108 FORMAT(///4X*CONTROL CARD*,5X*U WAVELENGTH*F11.2,10X*V WAVELENGTH*FOLDG103
     .  F11.2//10X*COMPUTED VALUES*F4.0,5X*COSY MAP*F4.0 //10X*NO. COEFFFOLDG104
     .S IN TREND*I5,5X*WAVE ORIG*,2X,2F6.2)                             FOLDG105
  999 FORMAT (9A8/9A8,40X*SELECTION*I3)                                 FOLDG106
 1000 FORMAT (6X,3I8,F16.6)                                             FOLDG107
 1001 FORMAT (//20X*COEFFICIENTS*//10X*USUB*,4X*VSUB*,4X*TYPE*,4X*COEFFIFOLDG108
     .CIENTS*//)                                                        FOLDG109
C                                                                       FOLDG110
C***************************************                                FOLDG111
C     COMPUTE  DIP AZIMUTHS AND ANGLES                                  FOLDG112
C***************************************                                FOLDG113
.                                                                       FOLDG114
      ENTRY DIPAZAN                                                     FOLDG115
      DO 74  I = 1,KOUNT2                                               FOLDG116
   74 IEDIT(I) = I                                                      FOLDG117
      GRID=.TRUE.                                                       FOLDG118
      VV=VMIN       $   UU=UMIN $ WW=0.0                                FOLDG119
   66 PRINT 999,TITLA,NSEL  $  PRINT 104  $  IF (GRID) PRINT 148        FOLDG120
      ABC(1) = ABC(2) = ABC(3) = 0.0                                    FOLDG121
      DO 8 IE=1,KOUNT2                                                  FOLDG122
      K=IE                                                              FOLDG123
      IF (GRID) GO TO 84                                                FOLDG124
      K=IEDIT(IE)                                                       FOLDG125
      UU=GCOORD(K,1)  $  VV=GCOORD(K,2)  $  WW=GCOORD(K,3)  $ GO TO 85  FOLDG126
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   84 UUT=UU   $    VVT = VV                                                FOLDG127
      UU = UUT*CANGL + VVT*SANGL   $ VV=VVT*CANGL - UUT*SANGL               FOLDG128
   85 U = (UU-UO)*UAC   $   V = (VV-VO)*VAC                                 FOLDG129
        COMPU = 0.0      $ COMPV = 0.0                                      FOLDG130
   86 DO 155 I=1,M                                                          FOLDG131
      UII = II(I)*U    $  UIIC = II(I)*UAC                                  FOLDG132
      VII = JJ(I)*V    $  VIIC = JJ(I)*VAC                                  FOLDG133
      ISKY=IDT(I)                                                           FOLDG134
      GO TO(151,152,153,154),ISKY                                           FOLDG135
  151 COMPU=COMPU-C(I)*SIN(UII)*COS(VII)*UIIC                               FOLDG136
      COMPV=COMPV-C(I)*COS(UII)*SIN(VII)*VIIC                               FOLDG137
      GO TO 155                                                             FOLDG138
  152 COMPU=COMPU-C(I)*SIN(UII)*SIN(VII)*UIIC                               FOLDG139
      COMPV=COMPV+C(I)*COS(UII)*COS(VII)*VIIC                               FOLDG140
      GO TO 155                                                             FOLDG141
  153 COMPU=COMPU+C(I)*COS(UII)*COS(VII)*UIIC                               FOLDG142
      COMPV=COMPV-C(I)*SIN(UII)*SIN(VII)*VIIC                               FOLDG143
      GO TO 155                                                             FOLDG144
  154 COMPU=COMPU+C(I)*COS(UII)*SIN(VII)*UIIC                               FOLDG145
      COMPV=COMPV+C(I)*SIN(UII)*COS(VII)*VIIC                               FOLDG146
  155 CONTINUE                                                              FOLDG147
       COMPU =  COMPU + COEFL(2)                                            FOLDG148
       COMPV = COMPV + COEFL (3)                                            FOLDG149
      H = SQRT (COMPU**2 + COMPV**2 + 1.0)                                  FOLDG150
      A1 = -COMPU/H  $  A2 = -COMPV/H  $  A3= 1.0/H                         FOLDG151
      DIRCOS(K,2)=(360.0/P)*ACOS(A3)                                        FOLDG152
      F=(360.0/P)*ATAN(A2/A1)                                               FOLDG153
      FF = A2/A1                                                            FOLDG154
      IF (A2 .LT. 0.0)  140,141                                             FOLDG155
  140 IF (FF .LT. 0.0) 142,143                                              FOLDG156
  141 IF (FF .LT. 0.0) 144,142                                              FOLDG157
  142 DIRCOS (K,1) = 180.0 - F                                              FOLDG158
      GO TO 145                                                             FOLDG159
  143 DIRCOS (K,1) = 360.0 -F                                               FOLDG160
      GO TO 145                                                             FOLDG161
  144 DIRCOS (K,1) = -F                                                     FOLDG162
      GO TO 145                                                             FOLDG163
  145 CONTINUE                                                              FOLDG164
      PRINT 146,K,UU,VV,WW,(DIRCOS(K,J),J=1,2),A1,A2,A3                     FOLDG165
   30 ABC(1)=ABC(1) + A1   $  ABC(2)=ABC(2)+A2   $  ABC(3)=ABC(3)+A3        FOLDG166
      DIRCOS (K,1) =  A1                                                    FOLDG167
      DIRCOS (K,2) = A2                                                     FOLDG168
      DIRCOS (K,3) = A3                                                     FOLDG169
      IF (.NOT. GRID) GO TO 8                                               FOLDG170
      UU = UUT + UINCRM     $   VV = VVT                                    FOLDG171
      IF (MOD(K,NUPTS) .EQ.0)  7,8                                          FOLDG172
    7 VV=VVT+VINCRM  $  UU=UMIN                                             FOLDG173
    8 CONTINUE                                                              FOLDG174
      DO 9013  I = 1,3                                                      FOLDG175
 9013 ABC(I) = ABC(I)/KOUNT2                                                FOLDG176
  104 FORMAT (1H0,30X,*ORIGINAL DATA MATRIX (TRANSFORMED IF REQUESTED) AFOLDG177
     .ND COMPUTED DIP VALUES*,//10X,                                        FOLDG178
     .*IDEN*,8X,*U*,9X,*V*,5X,*SCALED LINEAR*,4X,*DIP AZIMUTH*,4X,*DIP AFOLDG179
     .NGLE*,5X,*DIRECTION COSINES*,/40X,*DEVIATIONS*,34X,*S*,8X,*E*,7X, FOLDG180
     .*UP*,//)                                                              FOLDG181
  146 FORMAT (8XI6,2F11.4,F13.4,2F15.2,3F8.3)                               FOLDG182
  148 FORMAT (113X,6H(GRID))                                                FOLDG183
      IF (GRID) RETURN                                                      FOLDG184
C***************************************                                    FOLDG185
```

```
C     COMPUTED VALUES AND RESIDUALS FOR LINEAR + FOURIER SURFACE
C
      PRINT 999,TITLA,NSEL  $  IF (OPA.EQ.1) PRINT 110
      SS = TSS = TS = 0.0
      KOUNT2 = KOUNT2 + KOUN
      DO 40 IE=1,KOUNT2  $  K=IEDIT(IE)
      U=(GCOORD(K,1)-UO) *UAC  $  V=(GCOORD(K,2)-VO) *VAC
      COMP=0.0
       DO 2381  I = 1,M
      UII=II(I)*U  $  VII=JJ(I)*V
      ISKY=IDT(I)
      GO TO(34,35,36,37),ISKY
   34 CS = COS(UII) * COS(VII)  $  GO TO 38
   35 CS = COS(UII) * SIN(VII)  $  GO TO 38
   36 CS = SIN(UII) * COS(VII)  $  GO TO 38
   37 CS = SIN(UII) * SIN(VII)
   38 CMMP = COMP + C(I)*CS + COEFL(1) + COEFL(2)*GCOORD(K,1) + COEFL(3)
     .*GCOORD(K,2)
 2381 COMP = COMP + C(I)*CS
      RES = GCOORD(K,3) - COMP
      IF (OPA.EQ.0) GO TO 18
      RESS= RES/COR3   $   CMPS = CMMP/COR3
      PRINT 101,    K ,(GCOORD(K,J),J=1,3),COMP,CMMP,CMPS,RES,RESS
   18 SS = RES**2 + SS
      TS=TS+GCOORD(K,3)
   40 TSS=TSS+GCOORD(K,3)*GCOORD(K,3)
C
      TS=TS/N
      AS=TS*TS*N
      VAR=(TSS-AS)/(N-1)
      ST=VAR**0.5
      ZS=100.0*(1.0-(SS/(TSS-AS)))
      F=((N-M)*(TSS-AS-SS))/((M-1)*SS)
      IDS=M-1
      IDR=N-M
      KOUNT2 = KOUNT2 - KOUN
      PRINT 105
      PRINT 106,TS,ST,VAR,ZS,F,IDS,IDR
      ZZS = (100.0 -SSRED)*ZS    $    ZZS = (ZZS/100.0) + SSRED
      PRINT 1106, SSRED,ZZS
   50 CONTINUE
C
  101 FORMAT (I14,X,2F10.2,F14.4,5F15.4)
  105 FORMAT(///10X,*DATA MEAN*,8X,*ST DEVIATION*,7X,*VARIANCE*,7X,
     X*PCT SS CONTRIBN*,8X,*F RATIO*,2X,*DF NUM*,2X,*DF DENOM*)
  106 FORMAT(/10X,5(F12.4,5X),2(I3,5X))
  110 FORMAT (1H0,40X,*SCALED*,9X*SCALED*,10X*SCALED*,11X*TRUE*,10X,*SCA
     .LED*,11X,*TRUE*,/10X,*IDEN*,8X,*U*,9X,*V*,8X,*OBS VAL*,7X,*COMP VA
     .L*,17X,*COMP VAL*,20X,*RESIDUAL*,/80X,*LIN ADDED*,/)
     X*IDEN*, 8X,*U*,9X,*V*,8X,*OBS VAL*,7X,*COMP VAL*,8X,*COMP VAL*,15X
     .,*RESIDUAL*,/71X,*LIN ADDED*,/)
 1106 FORMAT(///10X,*PCT SS CONTR DUE LINEAR*,F8.2/10X,* TOTAL SS IS*,F8
     ..2)
C
C****************************************
C  MAPPING OPTION FOR COMPUTED SURFACE
C****************************************
      IF (OPB.EQ.0) RETURN
      NMAP=OPB
```

```
      DO 17 MM=1,NMAP                                                   FOLDG245
      READ 102,UL,UH,VL,VH,BASE,CINT                                    FOLDG246
      PRINT 199,UL,UH,VL,VH,BASE,CINT                                   FOLDG247
      DO 135 K=1,19                                                     FOLDG248
  135 CONTOUR(K)=BASE + (CINT*K)                                        FOLDG249
      PRINT 100                                                         FOLDG250
      USTEP=(UH-UL) / 41.0  $  VSTEP = (VH-VL) / 69.0                   FOLDG251
      DO 81 J=10,70,10                                                  FOLDG252
   81 VPRINT(J/10) = VL + (J-1)*VSTEP                                   FOLDG253
      PRINT 111,VL,(VPRINT(J),J=1,7)                                    FOLDG254
      PRINT 112                                                         FOLDG255
      UFIX=(UL-UO)*UAC   $    UTAH=(P*(UH-UL)) / (41.*UW)               FOLDG256
      VFIX=(VL-VO)*VAC   $    VTAH=(P*(VH-VL)) / (69.*VW)               FOLDG257
      DO 80 I=1,42                                                      FOLDG258
      U=UFIX + (I-1)*UTAH                                               FOLDG259
       ULL = UL + (I - 1)*(UH - UL)/41.                                 FOLDG260
      DO 70 J=1,70                                                      FOLDG261
      V = VFIX + (J-1)*VTAH                                             FOLDG262
        VLL = VL + (J - 1)*(VH - VL)/69.                                FOLDG263
      PR(J) = 1H                                                        FOLDG264
        COMP = COEFL(1) + COEFL(2)*ULL + COEFL(3)*VLL                   FOLDG265
      DO 60 L=1,M                                                       FOLDG266
      UII=II(L)*U  $  VII=JJ(L)*V                                       FOLDG267
      LSKY=IDT(L)                                                       FOLDG268
      GO TO(56,57,58,59),LSKY                                           FOLDG269
   56 CS = COS(UII) * COS(VII)  $  GO TO 60                             FOLDG270
   57 CS = COS(UII) * SIN(VII)  $  GO TO 60                             FOLDG271
   58 CS = SIN(UII) * COS(VII)  $  GO TO 60                             FOLDG272
   59 CS = SIN(UII) * SIN(VII)                                          FOLDG273
   60 COMP = COMP + C(L)*CS                                             FOLDG274
      IF (COMP .LT. BASE) GO TO 70                                      FOLDG275
      DO 64 K=1,19                                                      FOLDG276
      IF(COMP.LE.CONTOUR(K))GOTO 65                                     FOLDG277
64    CONTINUE                                                          FOLDG278
      K=20                                                              FOLDG279
   65 PR(J) = CH(K)                                                     FOLDG280
   70 CONTINUE                                                          FOLDG281
      IF (I.EQ.1 .OR. MOD(I,6).EQ.0) 76,77                              FOLDG282
   76 UPRINT=UL + (I-1)*USTEP  $  PRINT 114,UPRINT                      FOLDG283
   77 IF (I-20) 71,72,73                                                FOLDG284
   71 CONTP = CONTOUR(I)/COR3                                           FOLDG285
      PRINT 4001,PR,CH(I),CONTR,CONTOUR(I)     $ GO TO 80               FOLDG286
   72 PRINT 4002                                                        FOLDG287
   73 PRINT 113,PR                                                      FOLDG288
   80 CONTINUE                                                          FOLDG289
      PRINT 115                                                         FOLDG290
   17 CONTINUE                                                          FOLDG291
      RETURN                                                            FOLDG292
C                                                                       FOLDG293
  100 FORMAT (1H1//20X*TREND SURFACE*//19X1HU,30X1HV)                   FOLDG294
  102 FORMAT(6F6.0)                                                     FOLDG295
  111 FORMAT(//20X,F7.2,F9.2,6F10.2/24X1H*,8X1H*,6(9X1H*),2X*SYMBOL*,2X*FOLDG296
     .MAX VALUE*,3X*MAX VALUE*)                                         FOLDG297
  112 FORMAT(23X,72(1H-),11X*TRUE*,7X*SCALED*)                          FOLDG298
  113 FORMAT(23X,1HI,70A1,1HI)                                          FOLDG299
  114 FORMAT (1H+,14XF7.2,1H*)                                          FOLDG300
  115 FORMAT (23X,72(1H-))                                              FOLDG301
  199 FORMAT (///10X*MAP CARD*,5X*UMIN*F8.2,5X*UMAX*F8.2,5X*VMIN*F8.2,  FOLDG302
     .  5X*VMAX*F8.2//20X*BASE*F10.4,10X*CONTOUR INTERVAL*F10.4)        FOLDG303
```

```
 4001 FORMAT (23X1HI,70A1,1HI,4XA1,F12.1,F12.3)
 4002 FORMAT (1H+,98X,1H$,6X6HBEYOND,6X6HBEYOND)
      END
      SUBROUTINE MOMENT (IAXIS)
C     - - - -  - - -
C     A HISTOGRAM AND DESCRIPTIVE STATISTICS ARE CALCULATED FOR A
C     DISTRIBUTION OF DIRECTION COSINES. MEASURED ABOUT THE IAXIS AXIS.
      DIMENSION POWER(4),A(5) ,CT(3)
      COMMON      T(1600,3), S(1600,3)
      COMMON /MISC/ NUMBER(80),IROW(80),DUMMY(2324)
      COMMON /1/ IEDIT(1600)
      COMMON / 5/ EIGVAL(3), EIGMAT(3,3)
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)
      DATA (A = -1.0, -0.5, 0.0, 0.5, 1.0)
      PRINT 99,TITLA   $  PRINT 101,IAXIS   $  PRINT  98,KOUNT2,NSEL
      PRINT 102,A  $  PRINT 103
      COUNT = KOUNT2
      DO 3   J=1,4
 3    POWER(J) = 0.0
      DO 4   M=1,80
 4    NUMBER(M) = 0
      TAB = TRAB = 0.0
C     WRITE TITLES FOR HISTOGRAM
C     CALCULATE SUMS OF FIRST TO FOURTH POWERS OF DATA
      DO 6 IE=1,KOUNT2
      I=IEDIT(IE)
C     CHANGE DIR COS TO REFER TO PRINCIP AXES
      IF (IAXIS.NE.1) GO TO 31
      DO 27 J = 1,3
   27 CT(J) = T(I,1)*EIGMAT(1,J)+T(I,2)*EIGMAT(2,J)+T(I,3)*EIGMAT(3,J)
      ACT = SQRT((CT(1)**2) + (CT(2)**2))
      BCT = SQRT((CT(1)**2) + (CT(3)**2))
      T(I,1) = CT(1)/ACT $ T(I,2) = CT(2)/ACT $ T(I,3) = CT(3)/BCT
      TAB = TAB + ABS (T(I,2))    $   TRAB = TRAB + T(I,2)
      L = 1      $   IF(TRAB.LT.TAB) L = 2
   31 DO 5   J = 1,4
 5    POWER(J) = POWER(J) + (T(I,IAXIS))**J
C     COUNT FREQUENCY OF MEASUREMENTS IN EACH COLUMN OF HISTOGRAM
      M = (T(I,IAXIS) + 1.0)/0.025
 6    NUMBER(M) = NUMBER(M) + 1
C     CONVERT FREQUENCIES TO PERCENTAGES
      DO 7   M = 1, 80
      P = NUMBER(M)
 7    NUMBER(M) =(100.0*P/COUNT) + 0.5
C     FIND LARGEST PERCENTAGE
      MHI=0
       DO 8 M=1,80
    8 MHI =  MAX0 (NUMBER(M),MHI)
C     DRAW HISTOGRAM
      M = MHI + 5
      DO 502 I=1,80
  502 IROW(I)=1R
      PRINT 115
   13 IF (M.GT.MHI) GO TO 503
C     FOR ONE ROW AT A TIME, FIND THE SYMBOL REQUIRED IN EACH COLUMN
      DO 12 I=1,80
      IF(NUMBER(I).GE.M)IROW(I)=1R*
12    CONTINUE
  503 PRINT 108,M,IROW,M
```

```
      M=M-1
      IF (M.GT. 0) GO TO 13
      PRINT 115  $  PRINT 103  $  PRINT 102,A
      PRINT 109
C     COMPUTE AND PRINT THE MOMENTS, SKEWNESS AND KURTOSIS
      WRITE(6,110)
      DO 15   J = 1,4
      POWER(J) = POWER(J)/ COUNT
 15   WRITE (6,111)J, POWER(J)
      B1  =  POWER(3)/(SQRT(POWER(2) ** 3))
      B2   = POWER(4) / (POWER(2)**2)
      PRINT 113,B1,B2
      IF (IAXIS.NE.2) RETURN
      PRINT 100,L
      RETURN
C
   98 FORMAT (I6,* MEASUREMENTS*,5X,*(SELECTION*,I3,1H)/)
   99 FORMAT (2(9A8/),1H0,120X*SUB. MOMENT*/ 1H()
  100 FORMAT(3H0A-,I1,* AXIS IS APPROXIMATELY NORMAL TO AXIAL PLANE*)
  101 FORMAT(*0DISTRIBUTION OF DIRECTION COSINES ABOUT THE*I2,*-AXIS*)
 102  FORMAT (X,5X,5F20.1)
  103 FORMAT (X,  6(3X,1H+,3X,1H.,3X,1H.,3X,1H.,3X,1H.))
  108 FORMAT (XI2,21X,1H0,80R1,1H0,20XI2)
  109 FORMAT (/52X26HVALUE OF DIRECTION COSINES/*0PERCENTAGE FREQUENCY P
     .LOTTED VERTICALLY*)
 110   FORMAT (1H0, 39HMOMENTS OF THE ABOVE DISTRIBUTION ARE -)
  111 FORMAT (I5,F12.4)
  113 FORMAT (*0SKEWNESS AND KURTOSIS*/F9.4,F12.4/1H))
  115 FORMAT (24X,82(1H0))
      END
      SUBROUTINE READIN (KOUNT,NFOLD)
C     - - - - - - - - - -
C     SUBROUTINE READS DATA, SCALES, ROTATES AND TRANSLATES  -
C     IF ELEVATION DATA SUPPLIED COMPUTES LINEAR POLYNOMIAL
C     - - - - - - - - -                   - -
      COMMON      DIRCOS (1600,3), GCOORD(1600,3)
      COMMON /1/ IEDIT(1600)
      COMMON /2/ C(3), SSRED
      COMMON /6/ NLIST,LIST(1600),NAME(6,9),NAMTEMP(6),LIND(6)
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)
       COMMON /11/COR3
      DIMENSION FMT(6), SFMT(6), EM(3),YVECT(3), XMTRX(3,3), A(3,3)
      INTEGER FMT,SFMT,BLANK
      LOGICAL SCALE
      DATA (BLANK=1H    )
      DATA (SFMT=48H  (A6,A6,3F6.0,2F6.3,6I3                          )
      READ 100,TITLA,TITLB
      IF(EOF(5))3,4
    3 STOP
    4 PRINT 100,TITLA,TITLB   $  PRINT 103
      READ 101,ID1,NLIN, IRECT,THETA,FMT,COR12,COR3,CORAZI,NLIST,NFOLD,U
     .TRANS,VTRANS
      PRINT111,ID1,NLIN, IRECT,THETA,FMT,COR12,COR3,CORAZI,NLIST,NFOLD,U
     .TRANS,VTRANS
      IF (NLIST.EQ.0) NAME(1,1) = 5HOMNES
      IF (NLIST.EQ.0) GO TO 40
    6 DO 7 L=1,NLIST
      READ (5,102)   ID1,ID2, (NAME(L,J), J=1,9)
    7 WRITE(6,112)   ID1,ID2, (NAME(L,J), J=1,9)
```

```
C                                                                       READN 30
C     USE STANDARD FORMAT AND NO CORRECTIONS UNLESS ON MASTER CARD      READN 31
   40 SCALE = .FALSE.                                                   READN 32
      IF (COR12 + COR3 .EQ.0.0) GO TO 33                                READN 33
      SCALE = .TRUE.                                                    READN 34
      IF (COR12.EQ.0.0) COR12=1.0                                       READN 35
      IF ( COR3.EQ.0.0)  COR3=1.0                                       READN 36
   33 IF (FMT(1) - BLANK) 8,5,8                                         READN 37
    5 DO 30   J=1,6                                                     READN 38
   30 FMT(J)   = SFMT(J)                                                READN 39
    8 CONTINUE                                                          READN 40
      PRINT 106  $  IF (NLIST.GT.0) PRINT 116   $  PRINT 117            READN 41
      I = 1                                                             READN 42
C STATEMENT 10 FOR SPECIAL FORMAT KANSAS DECK HAD DIRCOS/LIND REVERSED  RDN43-44
   10 READ FMT, NPROJ,IPT, (GCOORD(I,J), J=1,3),(DIRCOS(I,J),J=1,2),    READN 43
     .(LIND(J), J = 1,6)                                                READN 44
C                                                                       READN 45
C     CARD SUCH AS FOLLOWING PERMITS SIGN AND DIRECTION OF U AND V ON A READN 46
C     PUNCHED DECK TO BE CHANGED                                        READN 47
C     GC=-GCOORD(I,2) $ GCOORD(I,2)=GCOORD(I,1) $ GCOORD(I,1)=GC        READN 48
C                                                                       READN 49
      PRINT 114, I,NPROJ,IPT,(GCOORD(I,J),J=1,3),(DIRCOS(I,J),J=1,2)    READN 50
     .,(LIND(J),J=1,6)                                                  READN 51
      IF (GCOORD(I,1) .GT. 998.0) GO TO 12                              READN 52
      DIRCOS(I,1) = DIRCOS(I,1) + CORAZI                                READN 53
   15 IF (.NOT. SCALE) GO TO 19                                         READN 54
      GCOORD(I,1) = GCOORD(I,1) * COR12                                 READN 55
      GCOORD(I,2) = GCOORD(I,2) * COR12                                 READN 56
      GCOORD (I,3) = GCOORD (I,3) * COR3                                READN 57
   19                ENCODE (6,120,LIST(I)) LIND                        READN 58
      I = I+1                                                           READN 59
      GO TO 10                                                          READN 60
   12 KOUNT = I-1   $   PRINT 104,KOUNT                                 READN 61
      IF (NFOLD.NE.1) GO TO 17                                          READN 62
C    ROTATE REFERENCE AXES AND SHIFT AXES ORIGIN IF REQUESTED           READN 63
      IF (THETA .EQ. 0.0) GO TO 22                                      READN 64
      IF ( IRECT - 1)   2,9,2                                           READN 65
    9 A = 1.0    $ GO TO 11                                             READN 66
    2 A = -1.0                                                          READN 67
   11 Z = 0.0174532925 * THETA                                          READN 68
      RCOS = COS (Z)    $   RSIN = SIN (Z)                              READN 69
   22 PRINT 23                                                          READN 70
      DO 24    K = 1,KOUNT                                              READN 71
      DECODE (6,120,LIST(K)) LIND                                       READN 72
      GCOORD (K,1) = GCOORD (K,1) - UTRANS                              READN 73
      GCOORD (K,2) = GCOORD (K,2) - VTRANS                              READN 74
      IF (THETA .EQ. 0.0) GO TO 24                                      READN 75
      GCOORD (K,1) = RCOS * GCOORD (K,1) - A*RSIN*GCOORD(K,2)           READN 76
      GCOORD (K,2) = RCOS*GCOORD(K,2) + A*RSIN*GCOORD(K,1)              READN 77
   24 PRINT 25, K, (GCOORD (K,L), L = 1,3), LIND                        READN 78
C    COMPUTE LINEAR POLYNOMIAL SURFACE, STORE RESIDUALS, COEEFICIENTS   READN 79
C     IF ELEVATIONS SUPPLIED                                            READN 80
      C(1) = C(2) = C(3) = 0.0                                          READN 81
      EM(1) = 1.0                                                       READN 82
      IF (NLIN .NE. 0) GO TO 17                                         READN 83
      DO 110  I = 1,3                                                   READN 84
      YVECT(I) = 0.0                                                    READN 85
      DO 110  J = 1,3                                                   READN 86
  110 XMTRX (I,J) = 0.0    $  SYOBS = SYOBSQ = SYCP = 0.0               READN 87
```

```
      SYCPSQ = SYRES = 0.0
      DO 32   K =1,KOUNT
      EM(2) = GCOORD (K,1)     $   EM(3) = GCOORD (K,2)
      DO 32  I = 1,3
      YVECT(I) = YVECT(I) + EM(I)*GCOORD(K,3)
      DO 32 J = 1,3
   32 XMTRX (I,J) = XMTRX (I,J) + EM(I)*EM(J)    $ COUNT = KOUNT
      PRINT 109, TITLA
      WRITE (6,122)((XMTRX(I,J),J=1,3),I=1,3)
      WRITE (6,105) YVECT
C
C    INVERT X-MATRIX
      MAX = 3
      DO 201 I=1,MAX        $       DO 201 J=1,MAX
  201 A(I,J) = XMTRX(I,J)
      DO 214 K = 1,MAX
      DIV = A(K,K)  $  A(K,K) = 1.0
      DO 211 J = 1,MAX
  211 A(K,J) = A(K,J)/DIV
      DO 214 I = 1,MAX   $   IF (I-K) 212,214,212
  212 DIV = A(I,K)   $   A(I,K) = 0.0
      DO 213 J = 1,MAX
  213 A(I,J) = A(I,J) - DIV*A(K,J)
  214 CONTINUE
      DO 228 I = 1,MAX   $   DO 228 J = 1,MAX
  228 C(I) = C(I) + A(I,J) * YVECT(J)   $   S = 0.0
      DO 229 I = 1,MAX
  229 S = S + YVECT(I) * C(I)
      PRINT 108
      WRITE (6,127) (C(I) , I = 1,MAX)
      DO 60 K = 1,KOUNT    $    YOBS = GCOORD (K,3)
      YCOMP = C(1) + (C(2))*GCOORD(K,1) + (C(3))*GCOORD(K,2)
      YRES = YOBS - YCOMP
      GCOORD (K,3) = YRES        $   SYOBS = SYOBS + YOBS
      SYOBSQ = SYOBSQ + YOBS**2   $   SYCP = SYCP + YCOMP
      SYCPSQ = SYCPSQ + YCOMP**2
   60 SYRES = SYRES + YRES   $   YBAROB = SYOBS/COUNT
      SSYOBS = SYOBSQ - YBAROB*SYOBS
      YBARCP = SYCP/COUNT   $   SSYCP = SYCPSQ - YBARCP*SYCP
      SSYCPS = S - YBAROB*SYOBS   $   SSRED = 100.0 * (SSYCP/SSYOBS)
      PCTRED = 100.0 * (SSYCPS/SSYOBS)
      WRITE (6,133) YBAROB,YBARCP,SYRES
      WRITE (6,135) SSRED
   65 WRITE (6,137) PCTRED
   17 IF (NFOLD.EQ.1) RETURN
C
C     FOLLOWING ONLY USED WHEN DIRECTIONAL DATA SUPPLIED
      WHATZIS=3.14159/180.
      DO 18 I=1,KOUNT
      A = DIRCOS(I,1) * WHATZIS
      B = DIRCOS(I,2) * WHATZIS
      SINB=SIN(B)
      DIRCOS(I,1) = -COS(A) * SINB
      DIRCOS(I,2) =  SIN(A) * SINB
 18   DIRCOS(I,3)= COS(B)
      IF (.NOT. SCALE) GO TO 28
      PRINT 115   $  PRINT 117
      DO 26 I=1,KOUNT
   26 PRINT 113, I, (GCOORD(I,J),J=1,3),(DIRCOS(I,J),J=1,2)
```

```
   28 RETURN                                                            READN147
C                                                                       READN148
   23 FORMAT (///10X,* U AND V VALUES ROTATED, TRANSLATED AND SCALED*,6XREADN149
     .*SCALED W*,11X*CATEGORIES*)                                       READN150
   25 FORMAT (10X,1I15,3F15.5,5X,6(2X,I1))                              READN151
  100 FORMAT (9A8)                                                      READN152
C FOR KANSAS DECK HERE USE (A6,2I1,F4.0,6A6,F10.0,2F5.0,2I1,2F4.0)      READN153
  101 FORMAT     (A6,2I1,F4.0,6A6,F10.0,F4.0,F6.0,2I1,2F4.0)            READN154
 102  FORMAT (12A6)                                                     READN155
  103 FORMAT (1H0,25HPRINT-OUT OF MASTER CARDS / X,25(1H-)/)            READN156
 104  FORMAT (X,I6,X,12HMEASUREMENTS)                                   READN157
  105 FORMAT (//12X8HVECTOR Y,  (/10XE20.8))                            READN158
  106 FORMAT (//15X*ORIGINAL DATA MATRIX*/15X,20(1H-)/)                 READN159
  108 FORMAT (/10X,* COEFFS DEGREE 1*)                                  READN160
  109 FORMAT (9A8/9A8)                                                  READN161
  111 FORMAT   (X,A6,3X,I2,1X,I2,1X,F6.2,1X,6A6,/2X,3F19.9,2I4,2F8.4)   READN162
 112  FORMAT (X,12(A6,3X))                                              READN163
  113 FORMAT (20XI6,3X,5F12.4)                                          READN164
  114 FORMAT (I6,5X,2(A6,3X),5F12.4,6I3)                                READN165
  115 FORMAT (//15X*SCALED DATA MATRIX*/15X,18(1H-)/)                   READN166
  116 FORMAT (1H+,89X10HCATEGORIES)                                     READN167
  117 FORMAT(12X4HPROJ,4X6HSAMPLE,8X8HU(SOUTH),5X7HV(EAST),6X5HW(UP),   READN168
     .  4X9HDIP TREND,6X3HDIP)                                          READN169
  120 FORMAT (6R1)                                                      READN170
  122 FORMAT (//5X17HREGRESSION MATRIX,  (/5X6E18.8))                   READN171
  127 FORMAT (5X6F18.8)                                                 READN172
  133 FORMAT (//18X,7HYBAROBS,12X8HYBARCOMP,10X10HSUM RESIDS//5X,3F20.4)READN173
  135 FORMAT (//5X36HPER CENT REDUCTION IN SUM OF SQUARES//10XF12.2)    READN174
  137 FORMAT (//5X19HINTERNAL CHECK ON S// 10XF12.2)                    READN175
      END                                                               READN176
      SUBROUTINE SEKSHN                                                 SEKSH  1
C     - - - - - - - - - -                                               SEKSH  2
C     COMPUTES SLOPE AND LOCATION OF INTERSECTION OF MEASURED PLANES    SEKSH  3
C       WITH PRINCIPAL PLANES.                                          SEKSH  4
C                                                                       SEKSH  5
      COMMON /1/ IEDIT(1600)                                            SEKSH  6
      COMMON     T(1600,3), S(1600,3)                                   SEKSH  7
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)                        SEKSH  8
      DIMENSION KRIS(3)                                                 SEKSH  9
      DATA (KRIS=8H     1-2,8H     1-3,8H     2-3)                      SEKSH 10
      PRINT 99,TITLA   $  PRINT 98,KOUNT2,NSEL                          SEKSH 11
C                                                                       SEKSH 12
      PRINT 103  $  PRINT 100                                           SEKSH 13
      PRINT 101,KRIS,(J,J=1,3)                                          SEKSH 14
C                                                                       SEKSH 15
      F=59.2957                                                         SEKSH 16
      DO 1 IE=1,KOUNT2                                                  SEKSH 17
      I=IEDIT(IE)                                                       SEKSH 18
      A = T(I,2) / T(I,1)                                               SEKSH 19
      B = T(I,3) / T(I,1)                                               SEKSH 20
      C = T(I,3) / T(I,2)                                               SEKSH 21
      AA=F * ATAN(A)  $  BB=F*ATAN(B)  $  CC=F*ATAN(C)                  SEKSH 22
    1 PRINT 102,    I ,A,AA,B,BB,C,CC,(S(I,J),J=1,3)                    SEKSH 23
      RETURN                                                            SEKSH 24
C                                                                       SEKSH 25
   98 FORMAT (I6,* MEASUREMENTS*,5X,*(SELECTION*,I3,1H)/)               SEKSH 26
   99 FORMAT ( 2(9A8/),1H0,120X*SUB. SEKSHN*/)                          SEKSH 27
 100  FORMAT ( 1H0,52HSLOPE (TANGENT AND ANGLE) OF INTERSECTION OF BED ASEKSH 28
     1ND, 19X, 33HDISTANCE FROM ORIGIN PARALLEL TO )                    SEKSH 29
```

```
  101 FORMAT (7X,3(A8,6H PLANE,2X), 11X,3(I8,5H-AXIS) /              SEKSH 30
     .9X,14H--------       ,2X,14H--------*     ,2X,14H--------- ----)/) SEKSH 31
  102 FORMAT (XI6,3(F9.4,F7.1), 11X,3F13.4)                          SEKSH 32
  103 FORMAT (*0DATA FOR DRAWING CROSS-SECTIONS PARALLEL TO THE PRINCIPASEKSH 33
     .L AXES*)                                                        SEKSH 34
      END                                                             SEKSH 35
      SUBROUTINE SELECT                                               SELCT  1
C     - - - - - - - - - -                                             SELCT  2
C        KONTROL IS A 3-DIGIT INTEGER,                                SELCT  3
C        THE SECOND DIGIT IS THE FACTOR CODE NUMBER (KLASS),          SELCT  4
C        THE THIRD DIGIT IS THE CATEGORY CODE NUMBER (KAT).           SELCT  5
C                                                                     SELCT  6
      COMMON       DIRCOS (1600,3), GCOORD(1600,3)                    SELCT  7
      COMMON /1/ IEDIT(1600)                                          SELCT  8
      COMMON /4/ D(3),COVMAT(3,3)                                     SELCT  9
      COMMON /6/ NLIST,LIST(1600),NAME(6,9),NAMTEMP(6),LIND(6)        SELCT 10
      COMMON /7/ KONTROL(20)                                          SELCT 11
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)                      SELCT 12
C                                                                     SELCT 13
      PRINT 99  $  PRINT 100                                          SELCT 14
      IF (KONTROL(1) .NE.0) GO TO 3                                   SELCT 15
      PRINT 105  $  GO TO 30                                          SELCT 16
    3 DO 20 K=1,20                                                    SELCT 17
      IF (KONTROL(K) .EQ.0) GO TO 30                                  SELCT 18
      PRINT 109,K,KONTROL(K)                                          SELCT 19
      INGA = IABS(KONTROL(K))                                         SELCT 20
      KVAR = INGA/10                                                  SELCT 21
      KAT= MOD(INGA,10)                                               SELCT 22
      IF (KVAR .GT. NLIST) 13,15                                      SELCT 23
   13 PRINT 104  $  STOP                                              SELCT 24
   15 NEW=0                                                           SELCT 25
      IF (KONTROL(K)) 17,16,16                                        SELCT 26
   16 PRINT 103,NAME(KVAR,KAT)     $  GO TO 18                        SELCT 27
   17 PRINT 102,NAME(KVAR,KAT)                                        SELCT 28
   18 DO 2 IE=1,KOUNT2                                                SELCT 29
      I=IEDIT(IE)                                                     SELCT 30
      DECODE (6,120,LIST(I)) LIND                                     SELCT 31
      IF (KONTROL(K)) 5,4,4                                           SELCT 32
C     'KONTRL' WAS POSITIVE, SPECIFIED CATEGORY ONLY IS TO BE RETAINED. SELCT 33
    4 IF (LIND(KVAR) .EQ. KAT) 6,2                                    SELCT 34
C     KONTROL WAS -VE, EVERYTHING EXCEPT SPECIFIED CAT RETAINED       SELCT 35
    5 IF (LIND(KVAR) .EQ. KAT) 2,6                                    SELCT 36
    6 NEW=NEW+1                                                       SELCT 37
      IEDIT(NEW) = I                                                  SELCT 38
    2 CONTINUE                                                        SELCT 39
   20 KOUNT2 = NEW                                                    SELCT 40
   30 PRINT 107,KOUNT2                                                SELCT 41
      RETURN                                                          SELCT 42
C                                                                     SELCT 43
C   ****************************************************              SELCT 44
                             ENTRY GETCOV                             SELCT 45
C   ****************************************************              SELCT 46
C                                                                     SELCT 47
    7 DO 31 J=1,3                                                     SELCT 48
      D(J) = 0.0                                                      SELCT 49
      DO 31 K=1,3                                                     SELCT 50
   31 COVMAT(J,K)=0.0                                                 SELCT 51
      DO 28 IE=1,KOUNT2                                               SELCT 52
      I = IEDIT(IE)                                                   SELCT 53
```

```
      DO 28   J=1,3
      D(J) = D(J) + DIRCOS(I,J)
      DO 28   K=1,3
   28 COVMAT(J,K) = COVMAT(J,K) + DIRCOS(I,J)*DIRCOS(I,K)
      COUNT = KOUNT2
      DO 29   J=1,3
      D(J) = D(J) / COUNT
      DO 29   K=1,3
 29   COVMAT(J,K) = COVMAT(J,K)/COUNT
      RETURN
C
   99 FORMAT (1H0,120X,*SUB. SELECT*///)
  100 FORMAT(*0IN COMPUTING THE NEXT SET OF RESULTS, ONLY MEASUREMENTS I
     .N THE FOLLOWING CATEGORIES WERE USED -*/9H0INCLUDED,30X8HEXCLUDED)
  102 FORMAT (40X,A6)
  103 FORMAT (X,A6)
  104 FORMAT (1H1,63HSELECTION ERROR. PLEASE CHECK CONTROL CARDS AT END
     1OF DATA DECK)
  105 FORMAT (1H0, 16HALL MEASUREMENTS)
  107 FORMAT (/I6,* CASES IN GROUP AFTER SELECTION*)
  109 FORMAT (//1H+,99X,*SELECTION FIELD*I3,* USED,VALUE=*,I4)
  120 FORMAT (6R1)
      END
      SUBROUTINE SPIN
C     - - - -   - - -           - - -
      COMMON /1/ IEDIT(1600)
      COMMON     T(1600,3), S(1600,3)
      COMMON /5/ EIGVAL(3),EIGMAT(3,3)
      COMMON /6/ NLIST,LIST(1600),NAME(6,9),NAMTEMP(6),LIND(6)
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)
      DIMENSION GCO(3),DIRC(3)
C
      PRINT 99,TITLA   $  PRINT 98,KOUNT2,NSEL
      PRINT 105
      DO 40 IE=1,KOUNT2
      I=IEDIT(IE)
      DO 38 J=1,3
      DIRC(J) = T(I,J)
   38 T(I,J) = 0.0
      DO 39 J=1,3
      DO 39 K=1,3
   39 T(I,J) = T(I,J) + DIRC(K) * EIGMAT(K,J)
   40 CONTINUE
      DO 50 IE=1,KOUNT2
      I=IEDIT(IE)
      DO 48 J=1,3
      GCO(J) = S(I,J)
   48 S(I,J)=0.0
      DO 49 J=1,3
      DO 49 K=1,3
   49 S(I,J) = S(I,J) + GCO(K) * EIGMAT(K,J)
   50 CONTINUE
C
      PRINT 106  $  TAB=TRAB=0.0
      DO 6 IE=1,KOUNT2
      I=IEDIT(IE)
      PRINT 107,     I  ,(S(I,J),J=1,3),(T(I,J),J=1,3)
      TAB=TAB + ABS (T(I,2) )
    6 TRAB = TRAB + T(I,2)
```

```
C                                                                       SPIN  37
      L=1  $  IF (TRAB.LT.TAB) L=2                                      SPIN  38
      PRINT 100,L                                                       SPIN  39
      PRINT 109                                                         SPIN  40
      E = SQRT((EIGVAL(1))**2+ (EIGVAL(2))**2 + (EIGVAL(3))**2)         SPIN  41
      DO 20 IE=1,KOUNT2                                                 SPIN  42
      I=IEDIT(IE)                                                       SPIN  43
      TSUM = SQRT (T(I,1)**2 + T(I,2)**2 + T(I,3)**2)                   SPIN  44
      IF (TSUM.LT. 1.5*E) GO TO 20                                      SPIN  45
      DECODE(6,120,LIST(I)) LIND                                        SPIN  46
      DO 21 L=1,NLIST                                                   SPIN  47
      KAT=LIND(L)                                                       SPIN  48
   21 NAMTEMP(L) = NAME(L,KAT)                                          SPIN  49
      PRINT 111,I,(S(I,J),J=1,3),(T(I,J),J=1,3),(NAMTEMP(L),L=1,NLIST)  SPIN  50
 20   CONTINUE                                                          SPIN  51
      PRINT 112                                                         SPIN  52
      RETURN                                                            SPIN  53
C                                                                       SPIN  54
   98 FORMAT (I6,* MEASUREMENTS*,5X,*(SELECTION*,I3,1H)/)               SPIN  55
   99 FORMAT ( 2(9A8/),1H0,120X*SUB. SPIN*/)                            SPIN  56
  100 FORMAT (3H0A-,I1,* AXIS IS APPROXIMATELY NORMAL TO AXIAL PLANE*)  SPIN  57
 105  FORMAT (1H0, 25X, 57HTHE MEASUREMENTS BELOW ARE IN TERMS OF THE PRSPIN  58
     1INCIPAL AXES)                                                     SPIN  59
  106 FORMAT(*0LIST OF COORDINATES AND DIRECTION COSINES OF MEASUREMENTSSPIN  60
     . TRANSFORMED TO REFER TO PRINCIPAL AXES*/7H0SAMPLE,4X8HU(SOUTH),5XSPIN  61
     .7HV(EAST),8X5HW(UP),14X8HU(SOUTH),2X8H V(EAST),3X5HW(UP))         SPIN  62
  107 FORMAT (XI6,3F13.3,10X,3F10.4)                                    SPIN  63
  109 FORMAT(*0THE FOLLOWING MEASUREMENTS DEVIATE CONSIDERABLY FROM THE SPIN  64
     .MEAN*/* ITEM LOCATION COORDS*,16X*DIRECTION COSINES*14X7HFACTORS/)SPIN  65
 111  FORMAT (X,I6,X,3E10.3,3X,3F7.4,3X,6(A6,X))                        SPIN  66
  112 FORMAT (//25X,45(1H-))                                            SPIN  67
  120 FORMAT (6R1)                                                      SPIN  68
      END                                                               SPIN  69
      SUBROUTINE WULFF                                                  WULFF  1
C     - - - - - - - - -                                                 WULFF  2
C     SUBROUTINE PRODUCES LOWER HEMISPHERE VON WULFF STEREOGRAM OF      WULFF  3
C     APPROXIMATELY 20 CMS DIAMETER.                                    WULFF  4
C                                                                       WULFF  5
      COMMON       T(1600,3), S(1600,3)                                 WULFF  6
      COMMON /1/ IEDIT(1600)                                            WULFF  7
      COMMON /9/ KOUNT2,NSEL,TITLA(18),TITLB(18)                        WULFF  8
      COMMON /MISC/ IROW(54,46)                                         WULFF  9
      WRITE (6,105)                                                     WULFF 10
      R6 = 6.0 * 3.937   $  P= 1.0/R6                                   WULFF 11
      R5 = 5.0 * 3.937   $  Q= 1.0/R5                                   WULFF 12
C   FOR POINTS ON THE CIRCUMFERENCE OF THE PRIMITIVE CIRCLE,            WULFF 13
C     (MP/2)**2 + (NQ/2)**2 = 1, BY THE THEOREM OF PYTHAGORAS.          WULFF 14
      DO 2 M=1,54  $  DO 2 N=1,46                                       WULFF 15
 2    IROW(M,N) = 0                                                     WULFF 16
      DO 3 IE=1,KOUNT2                                                  WULFF 17
      I=IEDIT(IE)                                                       WULFF 18
      T3 =  T(I,3)  $  F = SIGN(1.0,T3)                                 WULFF 19
      T1 =  T(I,1) * F                                                  WULFF 20
      T2 =  T(I,2) * F                                                  WULFF 21
      A=ABS(T3) + 1.0                                                   WULFF 22
C                                                                       WULFF 23
C     IN THE NEXT TWO EXPRESSIONS, 3.937 IS THE RADIUS OF THE NET, IN   WULFF 24
C     INCHES, 6.0 IS THE NUMBER OF LINES OF OUTPUT PER INCH, 5.0 IS THE WULFF 25
C     NUMBER OF TWO-DIGIT CHARACTERS PER INCH, 0.5 IS A ROUNDING FACTOR.WULFF 26
```

```
      M = T1/A *(-R6) +1.0 +R6                                          WULFF 27
      N = T2/A *(-R5) + 1.0+R5                                          WULFF 28
      M=M+3  $  N=N+3                                                   WULFF 29
 3    IROW(M,N) = IROW(M,N) + 1                                         WULFF 30
C                                                                       WULFF 31
C     FILL IN BACKGROUND EXCEPT WHERE PLOTTED                           WULFF 32
      QSQ=Q**2                                                          WULFF 33
      DO 6 M=1,54                                                       WULFF 34
      R = ABS (M-27.0)                                                  WULFF 35
      X = (1.05- (R*P)**2) / QSQ                                        WULFF 36
      IF (X.GT.0) 31,32                                                 WULFF 37
   31 N2=SQRT(X) + 0.5  $  GO TO 33                                     WULFF 38
   32 N2=0                                                              WULFF 39
   33 NA=23 - N2  $  NB=23 + N2                                         WULFF 40
      DO 7 N=1,NA                                                       WULFF 41
      IF(IROW(M,N).EQ.0)IROW(M,N)=-9                                    WULFF 42
7     CONTINUE                                                          WULFF 43
      DO 6 N=NB,46                                                      WULFF 44
      IF(IROW(M,N).EQ.0)IROW(M,N)=-9                                    WULFF 45
6     CONTINUE                                                          WULFF 46
      DO 40 M=1,54                                                      WULFF 47
      DO 40 N=1,46                                                      WULFF 48
      IF (IROW(M,N)) 37,38,35                                           WULFF 49
   37 IROW(M,N) = 2RVV                                                  WULFF 50
      GO TO 40                                                          WULFF 51
   38 IROW(M,N) = 2R                                                    WULFF 52
      GO TO 40                                                          WULFF 53
   35 IF (IROW(M,N) .LE.9) GO TO 39                                     WULFF 54
      ITEMP=IROW(M,N)                                                   WULFF 55
      ENCODE(10,102,IROW(M,N)) ITEMP                                    WULFF 56
      GO TO 40                                                          WULFF 57
   39 IROW(M,N) = IROW(M,N) + 2R 0                                      WULFF 58
   40 CONTINUE                                                          WULFF 59
C                                                                       WULFF 60
C     PRINT THE RESULTS.                                                WULFF 61
      DO 4 M=1,54                                                       WULFF 62
      IF (M.EQ.28) PRINT 104                                            WULFF 63
    4 PRINT 100,(IROW(M,N),N=1,46)                                      WULFF 64
      PRINT 101,KOUNT2  $  PRINT 103                                    WULFF 65
      RETURN                                                            WULFF 66
C                                                                       WULFF 67
  100 FORMAT (21X,23R2,1H.,23R2)                                        WULFF 68
  101 FORMAT (62X8HSOUTH(1)//I5,* MEASUREMENTS*)                        WULFF 69
  102 FORMAT (8XI2)                                                     WULFF 70
 103  FORMAT (1H0, 98HSTEREOGRAM SHOWING DISTRIBUTION OF POINTS PROJECTEWULFF 71
     .D ON LOWER HEMISPHERE OF 20-CENTIMETRE WULFF NET/1H))             WULFF 72
  104 FORMAT (19X4HWEST,21(2H .),1H.,3H(3),20(2H. ),7HEAST(2))          WULFF 73
  105 FORMAT (1H1,63X,5HNORTH / 1H()                                    WULFF 74
C  NOTE THAT LEFT PAREN OF FORMAT 105 KNOCKS OUT NORMAL PAGE OVERFLOW,  WULFF 75
C  RIGHT PAREN OF FORMAT 103 RESTORES IT.)                              WULFF 76
      END                                                               WULFF 77
                   001171 CARDS
```

APPENDIX B. - Listing of assembled data deck used to generate results illustrated.

Note: To accommodate format and axes sense used in data deck supplied by Kansas Geological Survey, subroutine READIN was modified as follows:
- (a) Statement 10: sequence altered as noted on comment card,
- (b) Format 101: changed to read scaling factors needed - see comment card, and
- (c) Card labelled READIN 48 was actually used.

```
1 040291 TOP OF ARBUCKLE IN KANSAS  29 APRIL 1968
0 200 RANDOM DATA POINTS FROM MERRIAM AND SMITH INVEST. 25, 1961
0 COMPLETE FOURTHHARMONIC N = 200, KOUN = 98
0 FWL = 250/500 MILES
040291       (A6,A3,2X,3F15.6,6I1,2F3.0)           7.89141414.0019      11 110 210
040291        INNER OUTER
040287001          16.750000      -8.660000   -1709.0000001
040287003          23.360000     -22.100000   -2961.0000001
040287004          29.800000     -10.580000   -2240.0000001
040287006          22.180000     -16.240000   -1872.0000001
040287008          22.010000      -3.360000   -2584.0000001
040287009          14.180000     -17.130000   -2810.0000001
040287014          15.100000     -18.500000   -3062.0000001
040287015          28.960000     -10.300000   -2540.0000001
040287017          18.900000     -16.690000   -2300.0000001
040287022          21.110000     -12.260000   -1505.0000001
040287023          29.920000      -4.000000   -1921.0000001
040287025          21.860000      -4.010000   -2466.0000001
040287027          22.750000     -21.670000   -2780.0000001
040287028          35.930000     -14.530000    -707.0000001
040287029          21.590000     -21.160000   -2677.0000001
040287030          28.200000      -6.400000   -2801.0000001
040287031          30.500000     -19.830000   -2678.0000001
040287033          31.380000     -17.740000   -2190.0000001
040287037          24.300000     -23.900000   -3367.0000001
040287041          24.800000     -21.100000   -2959.0000001
040287043          22.720000     -11.150000   -1431.0000001
040287044          20.400000     -21.820000   -3022.0000001
040287046          26.490000      -6.430000   -2431.0000001
040287051          33.120000     -17.040000   -1792.0000001
040287052          24.670000     -15.610000   -2146.0000001
040287053          30.100000     -12.920000   -2131.0000001
040287056          28.250000     -14.350000   -2421.0000001
040287059          27.210000     -10.580000   -2204.0000001
040287060          14.310000     -17.100000   -2810.0000001
040287062          19.380000     -17.600000   -2348.0000001
040287066          32.480000      -2.240000   -1618.0000001
040287068          18.960000     -14.540000   -1834.0000001
040287069          32.970000     -11.790000   -1884.0000001
040287070          23.500000      -1.570000   -2308.0000001
040287072          31.400000     -12.200000   -2058.0000001
040287073          31.600000     -22.820000   -2711.0000001
040287074          35.900000      -9.900000   -1537.0000001
040287077          21.540000     -14.900000   -1667.0000001
040287078          33.460000     -12.310000   -1694.0000001
040287080          19.400000     -16.570000   -2300.0000001
040287082          35.180000     -19.790000   -1465.0000001
040287084          21.200000      -3.500000   -2349.0000001
040287085          23.500000     -13.020000   -1564.0000001
040287087          34.450000     -19.450000   -1257.0000001
040287088          25.600000     -17.180000   -2337.0000001
040287090          29.320000     -11.480000   -2109.0000001
```

040287093	25.900000	-19.050000	-2607.0000001
040287095	20.120000	-19.800000	-2751.0000001
040287098	33.870000	-23.970000	-1626.0000001
040287100	14.780000	-20.580000	-3431.0000001
040287104	34.280000	-1.780000	-2305.0000001
040287111	24.600000	-20.450000	-2483.0000001
040287112	25.100000	-22.840000	-3095.0000001
040287114	26.470000	-13.190000	-1490.0000001
040287115	20.230000	-17.580000	-2307.0000001
040287116	35.270000	-19.230000	-1037.0000001
040287118	25.000000	-9.200000	-1407.0000001
040287119	22.950000	-8.420000	-2133.0000001
040287120	35.000000	-23.130000	-3090.0000001
040287121	30.070000	-15.180000	-1890.0000001
040287125	18.450000	-9.010000	-1651.0000001
040287127	29.050000	-21.080000	-2998.0000001
040287128	35.400000	-20.900000	-1902.0000001
040287130	26.700000	-12.800000	-1785.0000001
040287131	15.580000	-4.630000	-1593.0000001
040287132	20.700000	-20.390000	-2722.0000001
040287134	20.800000	-11.500000	-1477.0000001
040287137	22.110000	-21.000000	-2598.0000001
040287138	26.860000	-21.170000	-2951.0000001
040287139	29.930000	-16.800000	-2435.0000001
040287140	24.620000	-23.120000	-3177.0000001
040287141	26.040000	-16.520000	-2241.0000001
040287143	32.860000	-13.520000	-1775.0000001
040287150	22.400000	-13.230000	-1500.0000001
040287151	27.910000	-16.480000	-2481.0000001
040287154	19.920000	-11.100000	-1599.0000001
040287155	29.620000	-20.270000	-2875.0000001
040287156	36.500000	-10.210000	-1353.0000001
040287157	16.580000	-5.120000	-1608.0000001
040287159	34.450000	-6.220000	-1499.0000001
040287161	30.260000	-22.270000	-3029.0000001
040287162	35.600000	-20.950000	-1860.0000001
040287164	23.230000	-11.590000	-1412.0000001
040287165	27.020000	-17.010000	-2407.0000001
040287166	20.940000	-22.900000	-3044.0000001
040287169	17.530000	-10.020000	-1657.0000001
040287170	28.270000	-8.160000	-2540.0000001
040287172	13.920000	-2.200000	-1313.0000001
040287173	32.580000	-19.860000	-2140.0000001
040287174	35.450000	-17.030000	-883.0000001
040287175	21.210000	-14.570000	-1695.0000001
040287176	36.200000	-16.250000	-1746.0000001
040287180	28.520000	-17.200000	-2440.0000001
040287181	29.800000	-13.960000	-2346.0000001
040287182	30.400000	-10.020000	-2182.0000001
040287184	25.020000	-17.820000	-2063.0000001
040287186	16.600000	-1.850000	-1583.0000001
040287190	29.920000	-22.020000	-3061.0000001
040287191	17.100000	-14.050000	-2402.0000001
040287194	21.700000	-14.210000	-1608.0000001
040287196	20.600000	-6.280000	-1613.0000001
040287198	30.320000	-15.550000	-2195.0000001
040287002	12.130000	-18.020000	-2934.0000002
040287005	13.180000	-3.920000	-1478.0000002
040287007	12.340000	-4.810000	-1826.0000002
040287010	10.850000	-1.320000	-1477.0000002

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040287011       39.330000     -21.140000    -1119.0000002
040287012       49.300000     -14.850000     -125.0000002
040287013       46.000000      -2.150000    -1891.0000002
040287016        4.310000      -8.150000    -1800.0000002
040287018        5.900000      -8.960000    -2017.0000002
040287019        7.800000      -1.780000    -1578.0000002
040287020        5.960000      -1.500000    -1693.0000002
040287021        2.100000      -2.650000    -1800.0000002
040287024       41.990000      -5.310000    -2056.0000002
040287026       41.300000     -16.380000    -1077.0000002
040287032       41.200000      -3.500000    -2586.0000002
040287034         .300000       -.400000    -2029.0000002
040287035        3.900000     -15.650000    -2208.0000002
040287036        2.400000     -24.000000    -3167.0000002
040287038       43.100000     -15.340000     -399.0000002
040287039        8.900000     -21.000000    -3603.0000002
040287040       47.300000      -4.920000    -1400.0000002
040287042       12.600000     -14.830000    -2545.0000002
040287045        1.150000     -25.850000    -1923.0000002
040287047       45.900000     -13.250000     -638.0000002
040287048         .850000      -4.200000    -1803.0000002
040287049       10.500000      -5.500000    -1907.0000002
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040287054       10.000000     -26.100000    -6242.0000002
040287055       26.120000       -.500000    -2295.0000002
040287057       49.860000     -18.600000       -1.0000002
040287058       10.480000     -19.500000    -3256.0000002
040287061       42.000000     -17.900000     -885.0000002
040287063       12.710000      -1.760000    -1313.0000002
040287064        7.500000     -11.000000    -2270.0000002
040287065       47.320000     -19.580000     -210.0000002
040287067        4.990000     -18.580000    -2446.0000002
040287071       41.890000     -15.250000    -1108.0000002
040287075       11.000000     -21.500000    -3561.0000002
040287076        4.620000     -13.550000    -2256.0000002
040287079       44.080000     -10.860000     -978.0000002
040287081        4.390000     -23.100000    -3782.0000002
040287083        2.800000      -6.200000    -1867.0000002
040287086       19.090000     -24.400000    -3657.0000002
040287089       28.600000     -26.150000    -4373.0000002
040287091       43.100000     -19.000000        1.0000002
040287092       32.600000     -24.150000    -2923.0000002
040287094       12.320000     -20.650000    -3292.0000002
040287096       12.420000     -14.050000    -2435.0000002
040287097        4.000000     -16.500000    -2333.0000002
040287099        7.820000     -24.100000    -4272.0000002
040287101       50.650000     -20.980000      145.0000002
040287102        7.210000      -4.020000    -1634.0000002
040287103        4.710000      -6.130000    -1844.0000002
040287105        1.930000     -20.480000    -3075.0000002
040287106       39.600000     -19.400000    -1135.0000002
040287107        1.200000     -18.880000    -2802.0000002
040287108       49.000000     -15.000000      125.0000002
040287109       39.010000      -9.930000    -1971.0000002
040287110       44.410000      -8.570000    -1293.0000002
040287113       24.480000     -24.450000    -3589.0000002
040287117        8.200000     -14.200000    -2133.0000002
040287122       40.000000     -16.820000    -1366.0000002
040287123       10.820000     -21.420000    -3609.0000002
040287124        8.200000     -12.920000    -2280.0000002
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040287126      38.010000   -26.050000  -1857.0000002
040287129      41.180000   -20.140000   -998.0000002
040287133       9.790000    -9.950000  -1835.0000002
040287135      41.110000    -5.220000  -2274.0000002
040287136       6.600000   -19.680000  -2853.0000002
040287142      11.120000    -9.500000  -2012.0000002
040287144       7.500000    -6.620000  -1937.0000002
040287145       2.000000   -20.430000  -3075.0000002
040287146       9.010000   -13.890000  -2101.0000002
040287147      15.100000   -25.850000  -5400.0000002
040287148      45.020000   -25.080000   -485.0000002
040287149      36.990000   -25.280000  -1852.0000002
040287152       7.000000   -15.680000  -2489.0000002
040287153      12.610000   -14.770000  -2545.0000002
040287158      42.860000   -23.480000   -792.0000002
040287160       3.880000    -1.060000  -1860.0000002
040287163        .100000   -16.610000  -2382.0000002
040287167       9.000000   -26.120000  -5211.0000002
040287168       1.660000    -7.430000  -1819.0000002
040287171      17.830000     -.100000  -1647.0000002
040287177      11.870000    -2.520000  -1392.0000002
040287178      13.190000   -13.100000  -2344.0000002
040287179      49.700000   -25.900000    563.0000002
040287183      37.450000    -7.180000  -1934.0000002
040287185      34.200000   -26.200000  -2834.0000002
040287187      17.400000    -1.100000  -1521.0000002
040287188      41.120000   -19.860000   -835.0000002
040287189       7.910000    -8.010000  -1998.0000002
040287192      44.080000   -20.520000   -488.0000002
040287193      12.580000   -10.680000  -2240.0000002
040287195       1.600000   -16.250000  -2462.0000002
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040291                                                            2  T
   250   50011   81     10     10 -100.    20. 10 -100.    20. 10     98
001101103111113112114011012021022121122123124221222223224211212213214201203
031032131132133134231232233234331332333334321322323324311312313314301303041
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411412413414401403
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-  END OF INFORMATION
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KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN IV CDC 6400 computer program to analyze subsurface fold geometry.

Date: June 12, 1968

Author, organization: E.H. Timothy Whitten

Northwestern University

Direct inquiries to: Author or

Name: D.F. Merriam

Address: Kansas Geological Survey
University of Kansas
Lawrence, Kansas 66044

Purpose/description: To permit description and analysis of subsurface folds using well-log data if strike and dip information not available, or direct use of dip and strike.

Mathematical method: Scalar descriptors are used to describe and map fold geometry.

Restrictions, range:

Computer manufacturer: CDC

Model: 6400

Programming language: FORTRAN IV

Memory required: 74 to 132* K

Approximate running time: **

Special peripheral equipment required:

Remarks (special compilers or operating systems, required word lengths, number of successful runs, other machine versions, additional information useful for operation or modification of program)

This program has been successfully tested and run on the CDC 6400 for numerous data sets.

*according to number of Fourier coefficients called.

**Example used here: central process. 136 sec., peripheral process. 51 sec. Time differs widely according to number of coefficients and particularly printed maps.

COMPUTER CONTRIBUTIONS

Kansas Geological Survey
University of Kansas
Lawrence, Kansas

Computer Contribution

1.	Mathematical simulation of marine sedimentation with IBM 7090/7094 computers, by J.W. Harbaugh, 1966	$1.00
2.	A generalized two-dimensional regression procedure, by J.R. Dempsey, 1966	$0.50
3.	FORTRAN IV and MAP program for computation and plotting of trend surfaces for degrees 1 through 6, by Mont O'Leary, R.H. Lippert, and O.T. Spitz, 1966	$0.75
4.	FORTRAN II program for multivariate discriminant analysis using an IBM 1620 computer, by J.C. Davis and R.J. Sampson, 1966	$0.50
5.	FORTRAN IV program using double Fourier series for surface fitting of irregularly spaced data, by W.R. James, 1966	$0.75
6.	FORTRAN IV program for estimation of cladistic relationships using the IBM 7040, by R.L. Bartcher, 1966	$1.00
7.	Computer applications in the earth sciences: Colloquium on Classification procedures, edited by D.F. Merriam, 1966.	$1.00
8.	Prediction of the performance of a solution gas drive reservoir by Muskat's Equation, by Apolonio Baca, 1967	$1.00
9.	FORTRAN IV program for mathematical simulation of marine sedimentation with IBM 7040 or 7094 computers, by J.W. Harbaugh and W.J. Wahlstedt, 1967	$1.00
10.	Three-dimensional response surface program in FORTRAN II for the IBM 1620 computer, by R.J. Sampson and J.C. Davis, 1967	$0.75
11.	FORTRAN IV program for vector trend analyses of directional data, by W.T. Fox, 1967	$1.00
12.	Computer applications in the earth sciences: Colloquium on trend analysis, edited by D.F. Merriam and N.C. Cocke, 1967	$1.00
13.	FORTRAN IV computer programs for Markov chain experiments in geology, by W.C. Krumbein, 1967	$1.00
14.	FORTRAN IV programs to determine surface roughness in topography for the CDC 3400 computer, by R.D. Hobson, 1967	$1.00
15.	FORTRAN II program for progressive linear fit of surfaces on a quadratic base using an IBM 1620 computer, by A.J. Cole, C. Jordan, and D.F. Merriam, 1967.	$1.00
16.	FORTRAN IV program for the GE 625 to compute the power spectrum of geological surfaces, by J.E. Esler and F.W. Preston, 1967.	$0.75
17.	FORTRAN IV program for Q-mode cluster analysis of nonquantitative data using IBM 7090/7094 computers, by G.F. Bonham-Carter, 1967	$1.00
18.	Computer applications in the earth sciences: Colloquium on time-series analysis, D.F. Merriam, editor, 1967	$1.00
19.	FORTRAN II time-trend package for the IBM 1620 computer, by J.C. Davis and R.J. Sampson, 1967	$1.00
20.	Computer programs for multivariate analysis in geology, D.F. Merriam, editor, 1968	$1.00
21.	FORTRAN IV program for computation and display of principal components, by W.J. Wahlstedt and J.C. Davis, 1968	$1.00
22.	Computer applications in the earth sciences: Colloquium on simulation, edited by D.F. Merriam and N.C. Cocke, 1968	$1.00
23.	Computer programs for automatic contouring, by D.B. McIntyre, D.D. Pollard, and R. Smith, 1968	$1.50
24.	Mathematical Model and FORTRAN IV program for computer simulation of deltaic sedimentation, by G.F. Bonham-Carter and A.J. Sutherland, 1968	$1.00
25.	FORTRAN IV CDC 6400 computer program to analyze subsurface fold geometry, by E.H. T. Whitten, 1968	$1.00