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A Computer Programme for Analysing Directional Data designed for use on A CDC3600

by

B. G. Jones

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Contents

ABSTRACT

A computer programme has been developed to correct three dimensional directional data for the effects of regional tilt. The data may be presented either as a strike and dip measurement using a single cardinal point for the dip direction, or as an azimuth and dip measurement. After correcting each measurement back to an assumed original horizontal attitude arithmetic and two and three dimensional vectorial analysis of the data may be undertaken (optional) at three hierarchial levels to provide mean vector directions, vector magnitudes, and confidence limits about the vector mean.

INTRODUCTION

This report describes a programme developed to correct cross-bed data for regional tilt and to produce a vectorial analysis for current direction studies. The effect of regional tilt on directional features is quite pronounced even at dips as low as 20°. In any study of paleocurrent trends the first consideration is, therefore, to apply tilt corrections to directional structures such as cross-bedding so as to calculate the original attitude of the cross-strata. The second step involves vectorial analysis of the corrected azimuths so as to calculate a mean azimuthal trend. The programme is designed to handle three dimensional data such as cross-stratification as well as two dimensional directional or linear data.

Each individual entry specifies 'locality' and 'stratigraphic' references as well as orientation of regional tilt and the directional feature. A separate card is required for each directional feature. The 'locality' parameter controls the third level of grouping and may be alpha-numerical. The 'stratigraphic' reference parameter is numerical and changes in its value trigger the first and second levels of grouping.

The programme output may be varied according to the requirements of the operator. The calculated parameters are grouped according to the information which they contain. They are stored in the computer until all calculations are completed and they are then printed out in tabular form. The tables, in order of output, contain original and corrected individual cross-bed measurements; number and percentage frequency distributions of individuals per group; calculated means for groups of beds; calculated means for specified group intervals; and calculated means for each locality.

TILT CORRECTION

Each directional feature is corrected for regional tilt by a trigonometric solution using lower hemisphere projections. The method only corrects for simple unidirectional tilting of the beds about a horizontal axis. Where plunge of the beds is also important the programme would have to be run twice - once to correct for the plunge and then again for the tilting. Plunge correction is only necessary where the plunge of a bed is greater than about 20°. With high plunges care would also have to be taken to ensure that other tectonic deformation has not affected the beds and produced further anomalies.

ANALYSIS OF DIRECTIONAL FEATURES

Corrected cross-bed trends may be studied in terms of direction analysis as may other two and three dimensional data. Direction analysis may be visual or vectorial and data for both options is available as output from the programme, although current roses are not plotted and are just provided in numerical form.

Vectorial analysis of the data is undertaken at three hierarchical levels of grouping. The lowest level of grouping that can be specified groups individual data measurements from one bed, stratigraphic level, or geographic locality depending upon the type of analysis being conducted. The second level of grouping yields two values, the first based on the mean of all individual readings and the second based on the vectorial means of lower level groups. The highest level of grouping uses the same data as the second level of grouping but groups the beds, stratigraphic intervals, or localities to provide an overall analysis of all the data in one set. The method of grouping data is illustrated in the flow diagram in Figure 1 .

Two Dimensional Analysis

The procedure for analysing the directional data follows Potter and Pettijohn (1963). Analysis may be simply visual and this is accomplished by plotting number or percentage frequency distributions for each grouping as a histogram or current rose. Numerical results for these distributions are given in the second table of output. The distribution is recorded in 30° intervals from 0° to 29.99° etc.

The first level of data grouping utilized in this programme is controlled by the number given as the group reference parameter, (second entry on all data cards). Any change in this number initiates the calculation of vector means for the preceeding set of directional features where the group reference parameter remained constant. Any number of individuals can be included in a group although no output will result when attempting to group one sample. When only two individuals are grouped various three dimensional parameters are not calculated, but for groups of three or more individuals, all parameters are calculated.

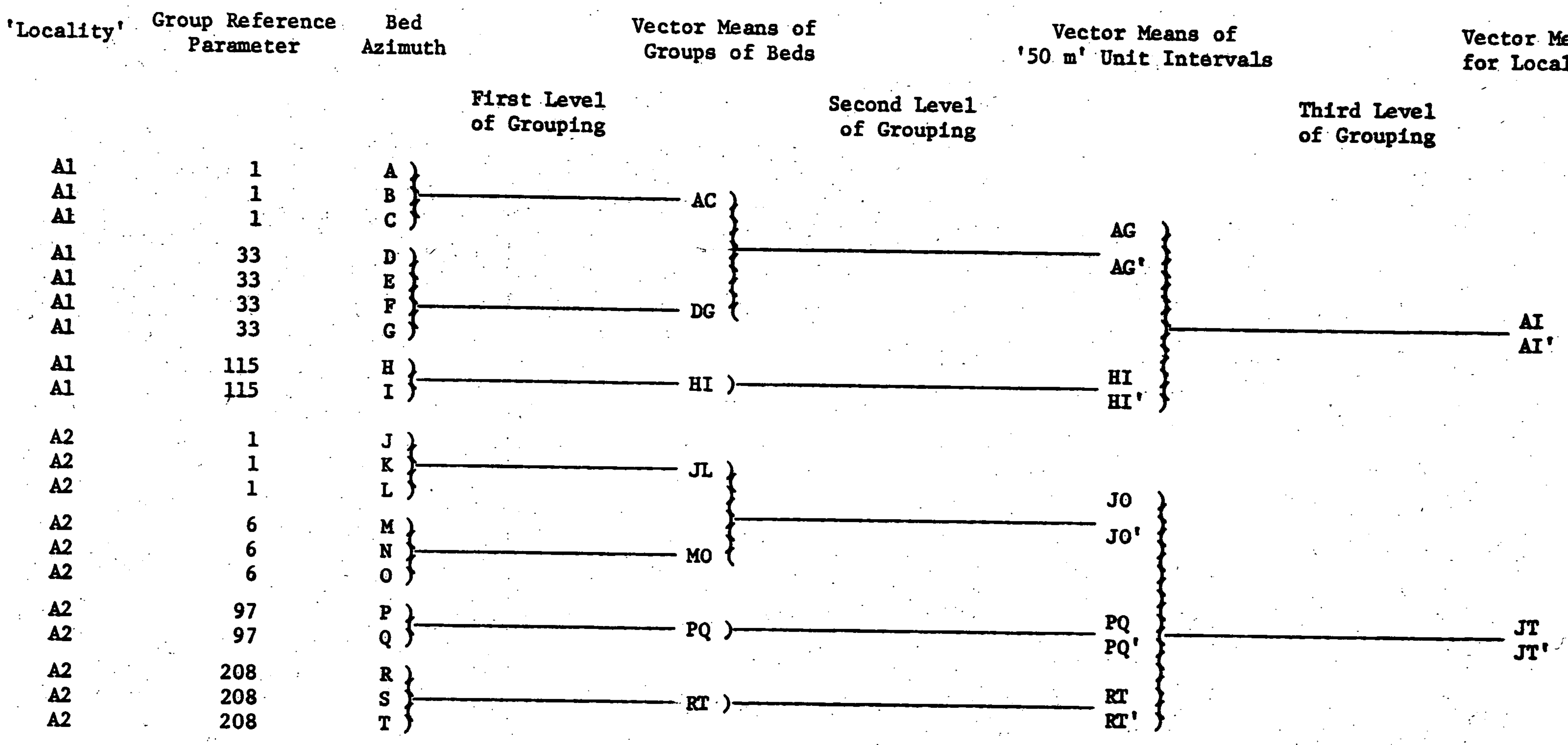

Figure 1 A flow diagram illustrating the methods of grouping data into three hierarchical levels. The second and third levels of grouping each produce two vector means - one utilizes the individual data measurements and is thus weighted by the number of readings in a group while the second uses unweighted vector means of the group to give a normally distributed resultant vector.

Averages calculated at the first level of grouping include arithmetic, vectorial and three dimensional parameters while at higher levels of data grouping only vectorial analyses are presented. The arithmetic mean is calculated for each sample although it is not a good measure of central tendency (Potter and Pettijohn, 1963). The average cross-bed dip and thickness (where measured) are also determined arithmetically but no statistical measures of consistency are calculated for them. Vectorial analysis is the simplest and most reliable method of determining the mean direction from data with a relatively wide scatter about the dominant direction. The use of vectorial analysis has been described in Potter and Pettijohn (1963). The programme is designed so that the following parameters, as defined in Potter and Pettijohn (1963), are calculated: - vector trend, vector magnitude and vector magnitude expressed as a percentage of the possible unidirectional magnitude, the variance and standard deviation about the vector trend, the Rayleigh probability of randomness and its equivalent significance level.

The magnitude percent gives an indication of the consistency of the vector direction with higher percentages indicating greater consistency. The magnitude percent negatively correlates with variance (Curray, 1956) and is a useful method of representing directional consistency. The variance and standard deviation both give estimates of the spread of the data and the variance can be used to statistically test the data for randomness by means of an F ratio. The variance of a random data spread (Su^2) in a 360° field is $Su^2 = 10,800$ (Griffiths and Rosenfeld, 1953).

The F-ratio is obtained from the expression $F = Su^2/Sd^2$ where Sd^2 is the observed variance and it is compared with tables of the F-distribution using the same number of degrees of freedom for the numerator and denominator (e.g. Pearson and Hartley, 1962, Table 31, p.179). If the F-ratio is less than the tabled value the data does not differ significantly from a random distribution.

The Rayleigh test of significance is also a test of randomness. A modified version of the test (Durand and Greenwood, 1958) was used in this programme and it provides a statistic of randomness for samples of more than five individuals. The comparable five percent confidence level is also calculated for each sample and if this is larger than the associated Rayleigh probability then the sample can be considered to be randomly distributed.

Both the F-ratio and Rayleigh tests only test for randomness of distribution. If they indicate that the distribution is not random this cannot be taken as a statistical proof that the data is oriented (Griffith and Rosenfeld, 1953).

The second level of grouping is controlled by IC on Control Card 1. The unit interval (IP) over which averages are produced may be selected by the operator, but for any set of data under the same control cards the interval is constant. The arithmetic average thickness and dip is computed from every individual cross-bed measurement in the specified interval. Likewise, the average two dimensional vector trend and associated vector magnitude and magnitude percent is calculated from every individual cross-bed in the specified interval. In addition, the vector means obtained for groups of individuals are analysed without weighting, and the resultant average group vectors and group vector magnitude percent are recorded. The latter parameters give a better representation of overall current direction if each group, from a single stratigraphic horizon, is considered to represent a sample of a normal population of current trends at the sampling locality.

The third level of grouping is controlled by a change in locality identity in the data deck. It initiates a similar set of calculations to the above with two dimensional vectorial analysis of every individual in the locality as well as analysis of the unweighted group vectors.

Three Dimensional Vector Analysis

A three dimensional vector analysis is included at the first level of grouping to enable the programme to handle three dimensional data such as paleomagnetic measurements, imbrication of grains or clasts, as well as providing a three dimensional approach to determining cross-bed azimuth directions.

The method follows Steinmetz (1962) who reviewed much of the earlier relevant literature. He suggested that a three dimensional analysis of three dimensional data gives a more accurate indication of vectorial direction and also enables confidence limits to be calculated about the resultant. Azimuth and dip values of cross-beds, corrected for regional tilt, are used in the programme as the basic data for vectorial analysis, and the following parameters are calculated: -

$\bar{A}$ = average vector direction of dip which may be interpreted as the mean direction of current, etc.

$= \arctan(\Sigma(\sin A.\cos D) \;/\; \Sigma(\cos A.\cos D))$

R = magnitude of resultant three dimensional vector

$= ((\Sigma(\sin A.\cos D))^2 + (\Sigma(\cos A.\cos D))^2 + (\Sigma(\sin D))^2)^{\frac{1}{2}}$

$\overline{D}$ = inclination of resultant vector. Does not equal average dip of cross-beds

$= \arcsin (\Sigma(\sin D)/R)$

$\theta_{.05}$ = spherical radius of circle of 95 percent confidence around the resultant vector

$= \arccos (1 - ((N-R)((\frac{1}{P})^{1/(N-1)} - 1)/R))$

κ = estimate of precision with 2(N-1) degrees of freedom

$= (N-1)/(N-R)$

where A = azimuth direction

D = dip of azimuth

N = number of readings

P = probability level required

The resultant three dimensional vector magnitudes can be tested for randomness by simply determining their length and comparing this with the tables of five percent and one percent values of significant randomness (Watson, 1956, p.161) for sample sizes up to 20. For groups with between 20 and 100 samples the five percent significance points may be estimated by evaluating $N\chi_3^2/3$ where $\chi_3^2 = 7.815$. The values obtained are all 0.04 above the true value. One percent significance points can be approximated to within 0.15 above true values from $N\chi_3^2/3$ where $\chi_3^2 = 11.345$. Provided the resultant vector length is greater than the equivalent significance value the vector direction can be considered reasonably reliable i.e. significantly different from a random distribution.

The meaning of $\theta_{.05}$ is that there is a five percent probability that the true azimuth direction of the data deviates by more than θ°

in any direction from the calculated resultant vector direction.

κ values from various groups of data may be used to test whether the resultant vector means are significantly different from each other. The same number of samples are required in each group (i.e. $v = N-1$) for the test to be correct. An approximate test can be made using the mean values of N and v, but for more accurate work an M test of variance should be used (Pearson and Hartley, 1962, p.61).

PROGRAMME OPERATION

Data Control Variables

The first two variables on each data card are parameters which control and initiate various functions in the programme. Both are usually required for the successful running of the programme and they may be true or dummy variables. The first variable controls the third grouping level and an individual run is terminated if this field is left blank. The variable may be any combination of eight or fewer alpha-numeric characters except zero and any change in any of the characters initiates averaging of all data since the preceeding change of the characters. This variable is usually used to represent a location or subregion in which a variable number of readings have been taken.

The second variable, the group reference parameter, is a numerical floating point variable which controls the averaging of data in groups and over specified intervals. Any change in the number initiates averaging of all individuals within the group denoted by the preceeding number. Averaging over a specified unit interval is controlled by the change of the second variable number from one group interval to the next. An example of the use of the second variable follows. If the specified unit interval (IP on Control Card 1) equals 100, unit interval averages will be calculated when the second variable changes from the range 0-99.9 to 100-199.9 etc, and the group averages will be calculated at any change in the second variable e.g. 1 to 1.5, or 10 to 60, or 5 to 287 etc. The second variable may be used to conveniently represent stratigraphic height at a locality or it may be a dummy variable used to represent individual sampling localities.

For large programmes requiring more hierarchical levels of grouping the programme would have to be run more than once with the second run requiring vectorial analysis only. Provision is made for punching the result at the first grouping level (controlled by IB = 2).

The third, fourth and fifth variables are used to record the regional tilt. The third variable may be used to give either the regional strike or the azimuth of the regional dip. The fourth variable gives the regional dip while the fifth variable is <u>only</u> used when the regional strike is given in the third variable. In this case the fifth variable must be given in terms of the cardinal points N, E, S or W. If the strike, or its reciprocal, is the same as the cardinal direction given for the dip the reading is rejected from the analysis (e.g. strike 270 dip 17°E).

The sixth, seventh and eighth variables give the equivalent information for the cross-bed reading. However, when the dip of the cross-bed is zero put the azimuth or strike of the cross-bed equal to the azimuth or strike of the regional dip.

In the case of two dimensional data, such as current lineation, no correction for regional tilt is provided. However, the vectorial analysis of such data may be carried out using this programme. Provision is made for analysing such data in two forms, one when the sense of the directional feature is known and the other when the sense is unknown. However, these two cases cannot be run concurrently. In both cases the only information required for the programme operation is the first two variables and the strike or direction of the sense of the structure being analysed. Provision has to be made on the data card, however, for the third, fourth and fifth variables (e.g. three blanks on the data card and equivalent formats 2F1.0, R1).

The ninth to twelfth variables are optional and they are not necessary for the functioning of the programme. The ninth variable is numerical and is averaged in the first level of grouping. It may be used for bed thickness or similar information. The following three variables may be alpha-numeric and they are simply copied onto the output.

Deck Structure

The complete deck is composed of the standard operation control cards together with the programme deck in fortran or binary. This is followed by three control cards, the data deck and either a blank card or, at the end of a run, by an end of file card.

Fortran Programme Deck

1. Job card: - Column 1 *JOB, Charge Code, DIRECT, time limit
2. Fortran card: - Column 1 *FTN, L, X
3. Programme deck in Fortran
4. Scope card: - Column 10 SCOPE
5. Load card: - Column 1 *LOAD
6. Run card: - Column 1 *RUN, time, maximum lines of print.

Binary Programme Deck

1. Job card: - Column 1 *JOB, Charge code, DIRECT, time limit
2. Binary object programme
3. Run card: - Column 1 *RUN, time, maximum lines of print.

Data Deck(s)

One or more separate data decks can be run at a time and each is preceeded by three control cards.

Control Card 1 (analysis specification)

Controls method of data analysis and output specifications.

Column 5 IA = 0 Do not print individual bed corrections
= 1 Print individual bed corrections
= 2 END PROGRAMME EXECUTION

Column 10 IB = 0 Do not analyse or print groups of beds
= 1 Analyse and print groups of beds
= 2 Analyse, print and punch groups of beds

Column 15 IC = 0 Do not analyse or print unit intervals
= 1 Analyse and print unit intervals
specified by control IP

Column 20 ID = 0 Do not analyse or print locality averages
= 1 Analyse and print locality averages

Column 25 IE = 0 Do not analyse or print 30° quadrant measures
= 1 Analyse and print 30° quadrant measures

Column 30 IG = 0 Analyse as three directional data e.g. x-beds
= 1 Analyse as two dimensional data with sense e.g. flute casts
= 2 Analyse as two dimensional data without sense e.g. current lineation.

Columns 31-35 IP = x required when IC = 1 to specify unit interval, x, over which averages are required. e.g. 100 for 100m intervals as from 100 to 199, 200 to 299 etc. Operates on data supplied in second statement on input card. May be omitted when IC = 0

Columns 36-40 AMAG = correction factor for magnetic deviation if required. Read in F5.1 format and if correction factor is negative it must be written here as such. May be omitted if no correction is necessary.

Control Card 2 (Format statement)

The second control card contains the format statement for data input. It is variable but has the following limitations. The entries must be in the following order unless statement number 80 in the Fortran programme deck is altered: -

1.	'Locality'	A format	
2.	'Group'	F format	
3.	Regional strike or azimuth of regional dip	F format	
4.	Regional dip	F format	
5.	Regional dip direction (only required if regional strike used)	R1 format	
6.	Cross-bed strike or azimuth of cross-bed dip	F format	
7.	Cross-bed dip	F format	
8.	Cross-bed dip direction (only required if cross-bed strike used)	R1 format	
9.	Cross-bed thickness	F format	presence of data optional
10.	Additional information to be copied onto output	3A formats	presence of data optional

The F formats are of free size while the first and last 3A formats are variable up to a maximum of eight characters. If the last 3 A formats are eight characters each, the information they contain will be copied, without breaks, onto the output and may be used for any information that the programmer desires. The restricted formats are the R1 formats following the bedding and cross-bedding dip measurements. A suggested data sheet layout and appropriate format statement is given in Table 1, line numbers (1) and (2). If the thickness and comment columns are not required the format may remain as in (2) or be altered to (3).

<u>Control Card 3</u> (title card)

Any information that the programmer requires can be written on all 80 columns of the title card and it will be simply copied

CSIRO DATA SHEET

PROGRAM	NAME	JOB	DATE	PAGE NO.
DIRECT.	TABLE 1			

```
  COMPUTER RUN CONTROL CARDS

*JØB,CBDMRCTQ,DIRECT,4
*FTN,L,X
OR *FTN,L,X,P                                 {PRINTS OUT BINARY DECK}
         SCØPE
*LØAD
*RUN,4,5000


  SUGGESTED DATA LAYOUT AND FORMATS FOR PROGRAMME DIRECT

                       BEDDING      CROSS-BED
(1) LOCATION  GROUP     TREND DIP E  TREND DIP G   THICK  SHAPE  GRAIN  OTHERS
(2) (A8,F7.0,1X,2(4X,2F5.0,R1),F9.0,1X,3A8)
(3) (A8,F7.0,1X,2(4X,2F5.0,R1),I1,3A1)        {MAY BE USED WHEN THERE IS NO DATA
                                                          IN COLUMNS 51-80}
```

out as a heading. If centred on the card it will be centred on the output.

Data Deck follows immediately after the control cards and is terminated by blank card. Any number of data sets may be included in a single run of the programme and the run is terminated by a card with 2 in column 5 (i.e. by reading Control Card 1 with IA = 2 followed by an end of deck card, *EOD from column 1-4.

Programme Size

The number of individual readings that can be analysed is limited only by the time required for analysis and print-out. However, data grouping levels are restricted in the present programme by the available memory in the computer. The programme as dimensioned here is very close to the maximum available size and it can handle up to 375 first level groups, 250 second level groups and 100 third level groups in any single data set and the number of consecutive data sets that it can handle is limited only by the time required for analysis.

The programme takes about seven minutes to complete a full analysis of 4000 directional features using about 80 percent of the first, second, and third level groupings.

Output

The output begins with a copy of the information on the three control cards and this is followed by the original and calculated data values.

The data from this programme is printed in tabular format under the appropriate headings for each table. The tables, in order of output, contain (1) original and corrected individual cross-bed measurements, (2) number and percentage frequency distribution of individual per group, (3) calculated means for groups of beds, (4) calculated means for specified group intervals, and (5) averages per locality. Any of the five tables may be requested with the parameters on Control Card 1 and the tables are printed on separate pages. Examples of headings and data print-outs are given in Table 2 . The headings are all largely self explanatory but the following abbreviations have been used.

APPROX	=	approximate
ARITH	=	arithmetic
AV	=	average
CONFID	=	confidence
MAGN(IT)	=	magnitude
PC	=	percent
PRECIS	=	precision
PROB	=	probability
RAYLE	=	Rayleigh
RAY SIG	=	Rayleigh significance
STAT	=	statistic
STD	=	standard deviation (vectorial)
THICK	=	thickness
VAR	=	variance (vectorial)
VECT(S)	=	vector(s)
X	=	cross
3D	=	three dimensional

TABLE 2 EXAMPLES OF OUTPUT LAYOUT AND HEADINGS.

LOCATION	STRATIGRAPHIC INTERVAL	BEDDING DIP TREND	BEDDING DIP	X-BEDDING DIR TREND	X-BEDDING DIP	RESULTANT X-BED TREND	RESULTANT X-BED DIP	THICKNESS	OBSERVATIONS SHAPE	GRAIN	OTHERS
NHERM H8	40	194	77	173	79	112,29	20,63	30,00	O	M-C	
		194	77	181	83	132,87	14,13	50,00	A	M-C	
		194	77	166	75	101,42	27,22	40,00	A	M-C	
		194	77	193	95	202,22	18,03	65,00	O	C	OU
		194	77	175	84	127,71	19,99	25,00	O	M-C	
		194	77	186	90	167,00	15,23	30,00	O	M-C	
		194	77	187	92	224,34	16,53	30,00	A	M-C	RU
		194	77	163	76	103,44	30,14	15,00	O	M-C	RU
		194	77	188	88	170,14	12,50	45,00	O	C	OU
		194	77	197	93	188,25	16,28	50,00	O	C	
		194	77	175	82	122,10	19,33	40,00	O	M-C	RU
		194	77	164	79	109,62	29,40	20,00	A	M-C	
		194	77	170	84	123,22	24,66	35,00	A	M-C	
NHERM H8	240	196	75	163	74	104,72	31,78	15,00	A	M	
		196	75	175	80	122,25	21,09	25,00	A	M	

PERCENTAGE FREQUENCY DISTRIBUTION

LOCATION	GROUP INTERVAL	CLASS 0	30	60	90	120	150	180	210	240	270	300	330	360
NHERM H8	40	0,0	0.0	0,0	30,8	30,8	15,4	15,4	7,7	0,0	0.0	0,0	0,0	
NHERM H8	240	0,0	0.0	0,0	36,4	27,3	9,1	27,3	0,0	0,0	0.0	0,0	0,0	
NHERM H8	400	0,0	0.0	0,0	12,5	0,0	6,3	12,5	25,0	18,8	25.0	0,0	0,0	
NHERM H8	600	0.0	0.0	0,0	11,8	17,6	17.6	17,6	0,0	5,9	23.5	5,9	0,0	
GLENH H9	10	0,0	0.0	0,0	25,0	25,0	0.0	25,0	0,0	25,0	0.0	0,0	0,0	
GLENH H9	120	0,0	0.0	0,0	9,1	18,2	18,2	9,1	0,0	27,3	18,2	0,0	0,0	
GLENH H9	140	0,0	0.0	0,0	30,0	20,0	0.0	20,0	20,0	0,0	10.0	0,0	0,0	
GLENH H9	300	0.0	0.0	0,0	0,0	25,0	12,5	12,5	12,5	12,5	25,0	0,0	0,0	
GLENH H9	385	0.0	0,0	0,0	22,2	22,2	22,2	11,1	11,1	11,1	0,0	0,0	0,0	
GLENH H9	700	0,0	0.0	0,0	5,9	11,8	11.8	11,8	5,9	29,4	17,6	5,9	0,0	
GLENH H9	880	0.0	0.0	0,0	0,0	10,0	20.0	20,0	20,0	10,0	20.0	0,0	0,0	

NUMBER FREQUENCY DISTRIBUTION

LOCATION	GROUP INTERVAL	CLASS 0	30	60	90	120	150	180	210	240	270	300	330	360
NHERM H8	40	0,0	0.0	0.0	4,0	4,0	2,0	2,0	1,0	0,0	0.0	0,0	0,0	
NHERM H8	240	0,0	0.0	0,0	4,0	3,0	1.0	3,0	0,0	0,0	0.0	0,0	0.0	
NHERM H8	400	0,0	0.0	0.0	2,0	0,0	1,0	2,0	4,0	3,0	4.0	0,0	0,0	
NHERM H8	600	0,0	0.0	0,0	2,0	3,0	3.0	3,0	0,0	1,0	4.0	1,0	0,0	
GLENH H9	10	0,0	0.0	0,0	1,0	1,0	0,0	1,0	0,0	1,0	0.0	0,0	0,0	
GLENH H9	120	0.0	0.0	0,0	1,0	2,0	2.0	1,0	0,0	3,0	2.0	0,0	0,0	
GLENH H9	140	0,0	0,0	0.0	3,0	2,0	0.0	2,0	2,0	0,0	1.0	0,0	0,0	
GLENH H9	300	0.0	0.0	0,0	0,0	2,0	1.0	1,0	1,0	1,0	2.0	0,0	0,0	
GLENH H9	385	0.0	0.0	0,0	2,0	2,0	2.0	1.0	1,0	1,0	0.0	0,0	0.0	
GLENH H9	700	0,0	0.0	0,0	1.0	2,0	2.0	2,0	1,0	5,0	3.0	1,0	0,0	
GLENH H9	880	0.0	0.0	0,0	0,0	1,0	2.0	2,0	2,0	1,0	2.0	0,0	0.0	

TABLE 2 (cont.)

AVERAGES FOR BEDS IN ONE GROUP INTERVAL

LOCATION	GROUP	BEDS	ARITH TREND	VECT TREND	VECT MAGN	VECT MAGRC	VECT VAR	VECT STD	RAYLE PROB	RAYSIG STAT	AV DIP	AV THICK	3D TREND	3D AVDIP	VECT MAGNIT	CONFID CIRCLE	APPROX PRECIS
NHERM H8	40	13	144.97	142.58	10.21	78.52	1668.6	40.85	8.0156	2.9384	20.31	36.54	143.75	25.25	10.53	21.04	4.85
NHERM H8	240	11	140.95	139.15	8.85	80.47	1517.4	38.95	7.1232	2.9279	20.39	23.00	140.33	24.81	9.09	22.10	5.23
NHERM H8	400	16	222.04	231.75	10.08	63.00	3439.5	58.65	6.3514	2.9491	16.39	39.38	232.52	24.79	10.73	26.94	2.85
NHERM H8	600	17	201.56	194.33	6.64	39.08	5187.7	72.03	2.5965	2.9519	17.53	77.35	195.64	38.79	8.14	39.13	1.81
GLENH H9	10	4	176.63	173.36	1.91	47.72	5461.4	73.90	0.9107	2.8093	16.60	10.75	174.18	32.08	2.14	119.27	1.61
GLENH H9	120	11	203.69	201.78	5.19	47.14	4450.6	66.71	2.4441	2.9279	20.03	22.55	200.03	37.48	6.18	43.31	2.08
GLENH H9	140	10	172.79	166.53	5.57	55.72	8799.4	93.81	3.1048	2.9212	19.82	33.50	165.08	32.43	6.30	39.80	2.43
GLENH H9	300	8	213.14	212.78	4.74	59.21	3419.6	58.48	2.8047	2.9025	18.84	56.88	212.46	29.86	5.18	44.79	2.49
GLENH H9	385	9	162.55	157.84	5.89	65.48	5977.1	77.31	3.8591	2.9129	15.86	63.89	159.05	23.46	6.15	37.89	2.80
GLENH H9	700	17	220.68	230.10	8.40	49.40	4369.3	66.10	4.1481	2.9519	15.68	23.76	229.28	29.64	9.27	34.09	2.07
GLENH H9	880	10	211.22	209.80	6.85	68.50	2567.3	50.67	4.6922	2.9212	17.59	54.00	209.42	24.78	7.20	32.16	3.22

AVERAGES FOR BEDS IN 100 UNIT INTERVALS

LOCATION	100 INTERVAL	AV TREND	MAGNIT	MAGNPC	NO.XBEDS	AV DIP	AV THICK	AV GROUP VECTS	MAGN AGV PC
NHERM H8	0- 99	142.58	10.21	78.52	13	20.31	36.54	142.58	100.00
NHERM H8	200- 299	139.15	8.85	80.47	11	20.39	23.00	139.15	100.00
NHERM H8	400- 499	231.75	10.08	63.00	16	16.39	39.38	231.75	100.00
NHERM H8	600- 699	194.33	6.64	39.08	17	17.53	77.35	194.33	100.00
GLENH H9	0- 99	173.36	1.91	47.72	4	16.60	10.75	173.36	100.00
GLENH H9	100- 199	183.50	10.25	48.82	21	19.93	27.76	184.15	95.31
GLENH H9	300- 399	182.07	9.45	55.57	17	17.26	60.59	185.31	88.72
GLENH H9	700- 799	230.10	8.40	49.40	17	15.68	23.76	230.10	100.00
GLENH H9	800- 899	209.80	6.85	68.50	10	17.59	54.00	209.80	100.00

AVERAGES FOR BEDS IN EACH LOCATION

LOCATION	AV VECT TREND	MAGNIT	MAGNPC	NO XBEDS	AV DIP	AV THICK	AV GROUP VECTS	MAGN AGV PC
NHERM H8	174.94	27.59	48.40	57	18.40	46.89	175.83	78.67
GLENH H9	197.85	34.56	50.09	69	17.69	37.68	193.23	90.55

Subroutines

The programme DIRECT uses the subroutines AZIMUTH and ROTATE (given) and calls on the following standard computer functions SINF, ASINF, COSF, ACOSF, ATANF, and ASQRTF.

REFERENCES

CURRAY, J.R., 1956: The analysis of two-dimensional orientation data. *J. Geol.*, *64*, pp. 117-131.

DURAND, D., and GREENWOOD, J.A., 1958: Modifications of the Rayleigh test for uniformity in analysis of two-dimensional orientation data. *J. Geol.*, *66*, pp. 229-238.

GRIFFITHS, J.C., and ROSENFELD, M.A., 1953: A further test of dimensional orientation of quartz grains in Bradford Sand. *Amer. J. Sci.*, *251*, pp. 192-214.

PEARSON, E.S., and HARTLEY, H.O., (eds), 1962: *Biometrica Tables for Statisticians, Volume 1.* Univ. Press, Cambridge, 240 pp.

POTTER, P.E., and PETTIJOHN, F.J., 1963: *Paleocurrents and Basin Analysis.* Springer-Verlag, Berlin, 296 pp.

STEINMETZ, R., 1962: Analysis of vectorial data. *J. sediment. Petrol.*, *32*, pp. 801-812.

WATSON, G.S., 1956: A test for randomness of directions. *Mon. Not. R. astr. Soc. geophys. Suppl.*, *7*, pp. 160-161.

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      PROGRAM DIRECT
C     PROGRAMME CROSS-BED ANALYSIS
C     PROGRAMME TO CORRECT CROSS-BED MEASUREMENTS FOR TECTONIC TILT
C     AND TO DETERMINE VECTOR MEAN AZIMUTHAL DIRECTIONS AND AVERAGE
C     CROSS-BED DIP AND THICKNESS FOR EACH STRATIGRAPHIC INTERVAL
C     THIS PROGRAMME FOLLOWS P.J.COOK (BMR RECORD 1966/1) AND
C     J.CURRAY,1956 (J.GEOL.64,117)
C     INPUT TERMINOLOGY
C       STRAT  = STRATIGRAPHIC INTERVAL, F FORMAT
C       LOC    = LOCALITY, A8 FORMAT
C       TP     = TREND OF BEDDING DIP, F FORMAT
C       P      = DIP OF BEDDING, F FORMAT
C       TQ     = TREND OF CROSS-BEDDING DIP, F FORMAT
C       Q      = DIP OF CROSS-BED, F FORMAT
C       AMAG   = MAGNETIC DEVIATION CORRECTION FACTOR, F FORMAT
C       XST    = NUMBER OF CROSS-BED UNITS IN ONE STRATIGRAPHIC INTERVAL
C       CS     = COSINE
C       TN     = TANGENT
C       SN     = SINE
C       AF     = FUNCTION FOR EXPRESSING ANGLES IN RADIANS
C       STDA   = ARITHMETIC STANDARD DEVIATION OF CROSS-BED TREND
C       TAA    = ARITHMETIC MEAN CROSS-BED TREND
C       3DTREND = TREND OF RESULTANT SPHERICAL VECTOR (STEINMETZ,1962)
C       3DAVDIP = DIP OF RESULTANT SPHERICAL VECTOR
C       WO5    = SPHERICAL RADIUS OF CONFIDENCE CIRCLE ABOUT 3D VECTOR
C      OK      = ESTIMATE OF PRECISION FOR F-RATIO (STEINMETZ,1962,JSP)
C
C       RPP    = MAGNITUDE OF RESULTANT PLANAR VECTOR - POTTER + PETTIJOHN
C       LPP    = PLANAR VECTOR MAGNITUDE IN PERCENT              1963
C       SUBSCRIPT O = ORIGINAL
C       SUBSCRIPT 1 = RESULTANT
C       SUBSCRIPT A = AVERAGE
C       SUBSCRIPT I = 100M INTERVAL
C       SUBSCRIPT T = LOCALITY INTERVAL
C
C       GRAIN = GRAIN SIZE, FREE A5 FORMAT, NOT AVERAGE
C       SHAPE = SHAPE OF CROSS-BED (ALLEN,1963),FREE A5 FORMAT
C       OTHERS = FREE A8 FORMAT
C       THK    = THICKNESS OF CROSS-BED UNIT, F FORMAT, AVERAGE CALCULATED
C       THE ABOVE 4 PARAMETERS MAY BE USED FOR ANY INFORMATION UNDER THE
C       NOTED FORMATS BUT THE OUTPUT IS UNDER THESE HEADINGS IN STATEMENTS
C       70,840,880,920
C
C
C       NOTE  WHEN QO = 0  PUT TQO = TPO
C
C
      INTEGER E,G,LOC,LOC1,TLOC,SLOC,ALOC
 31   DIMENSION TLOC(375),STR(375),QA(375),TH(375),TAA(375),VAR(375),
     1TA(375),RPP(375),OLPP(375),TSQ(375),TSQD(375),R(375),WO5(375),
     2OK(375),TXS(375),VSD(375),RAY(375),Z(375)
 33   DIMENSION SLOC(250),NA(250),NB(250),XSI(250),TI(250),QI(250),
     1PQI(250),PPI(250),TKI(250),AVL(250),AVR(250)
 35   DIMENSION ALOC(100),TOTT(100),TOX(100),RTOT(100),OLT(100),
     1TTQA(100),TTKA(100),ALR(100),ALL(100)
 37   DIMENSION V(375,12),X(12),TV(200),FMT(10),TITLE(10)
       PI    = 3.1416
       HPI   = 1.5708
       HPI3  = 4.7124
       PI2   = 6.2832
       ZP    = 2.99573
       ZQ    = -0.74574
       AF    = PI/180.
 38    LOC=STRAT=J=K=L=JJ=0.
      READ 10, IA,IB,IC,ID,IE,IQ,IP,AMAG
 10   FORMAT(7I5,F5.1)
      IF (IA.EQ.2) GO TO 945
      READ 20,FMT
```

```
 20    FORMAT(10A8)
       READ 30, TITLE
 30    FORMAT(10A8)
 39    PRINT 40, TITLE,FMT,IA,IB,IC,ID,IE,IG,IP,AMAG
 40    FORMAT(1H1* CROSS-BED PROGRAMME - B,G,JONES, 1970*/10A8/10A8/7I5
      1,F5.1)
       PRINT 50, TITLE
 50    FORMAT(1H1///30X*PROGRAMME TO CORRECT CROSS-BED MEASUREMENT FOR TE
      1CTONIC TILT*//20X10A8/////)
       IF (IA) 60,80
 60    PRINT 70
 70    FORMAT(*  LOCATION STRATIGRAPHIC  BEDDING  BEDDING X-BEDDING X-BED
      1DING  RESULTANT  RESULTANT  THICKNESS         OBSERVATIONS*/
      213X*INTERVAL      DIP TREND    DIP    DIP TREND     DIP*
      3*      X-BED TREND X-BED DIP                    SHAPE  GRAIN    OTHERS*/)
 80    READ FMT, LOC1,STRAT1,TPO,PO,E,TQO,QO,G,THICK,SHAPE,GRAIN,OTHERS
 81    IF (LOC1.EQ.LOC) GO TO 90
       IF (LOC.EQ.0.) GO TO 365
        GO TO 100
 90    IF (STRAT1.EQ.STRAT) GO TO 402
C
C COMPUTING VECTOR MEAN AND AVERAGE THICKNESS AND DIP
C
 100    TOXX = TOXX+XST
        TOTS = TOTS+SNQT
        TOTC = TOTC+CSQT
        SNI  = SNI+SNQT
        CSI  = CSI+CSQT
        TTK  = TTK+THKT
        TTQ  = TTQ+QT
        THKI = THKI+THKT
        QII  = QII+QT
        XSII = XSII+XST
        JJ   = JJ+1
       DO 105KK=1,12
 105    V(JJ,KK) = X(KK)
       IF (IB) 108,250
C
C      AVERAGING OF STRATIGRAPHIC GROURS
C
 108    K     = K+1
        TXS(K)= XST
        QA(K) = QT/XST
        TH(K) = THKT/XST

       IF (XSQ.EQ.0.) GO TO 110
        ATQ  = STQ/XSQ
 110   IF (XSP.EQ.0.) GO TO 120
        ATP  = STP/XSP
 120    XPQ  = ATP-ATQ
       IF (XPQ.LT.180.) GO TO 130
        ATQ  = ATQ+360.
        TAA(K)=(ATQ*XSQ+ATP*XSP)/(XSQ+XSP)
       IF (TAA(K).LT.360.) GO TO 140
        TAA(K)= TAA(K)-360.
        GO TO 140
 130    TAA(K)= (STQ+STP)/(XSP+XSQ)
 140    SNQT2= SNQT*SNQT
        CSQT2= CSQT*CSQT
        RPP(K)= SQRTF(SNQT2+CSQT2)
        OLPP(K)= RPP(K)*100./XST
        TSAB2= TSAB*TSAB
        TCAB2= TCAB*TCAB
        TSB2 = TSB*TSB
        R(K) = SQRTF(TSAB2+TCAB2+TSB2)
        ONR  = XST-R(K)
        TSQ(K) = ATANF(TSAB/TCAB)/AF
        TSD  = TSB/R(K)
        TSQD(K) = ASINF(TSD)/AF
```

```
      IF (XST.LT.3.) GO TO 150
       XQ    = 1./(XST-1.)
       YQ    = 20.**XQ-1.
       CSW05= 1.-ONR*YQ/R(K)
       IF (ABS(CSW05).GT.1.) GO TO 150
       W05(K) = ACOSF(CSW05)/AF
      GO TO 160
150    W05(K) = (BH           )
160    OK(K) = (XST-1.)/ONR
       TA(K) = ATANF(SNQT/CSQT)/AF
      CALL ROTATE (TA(K),SNQT,CSQT)
       NXST = XST
       DO 230 IT=1,NXST
       TZ    =  ABSF(TA(K)-TV(IT))
      IF (TZ.LE.180.) GO TO 220
       TZ    = TZ-360.
220    TTV   = TTV+TZ*TZ
230   CONTINUE
       VAR(K) = TTV/(XST-1.)
       VSD(K) = SQRTF(VAR(K))
      CALL ROTATE (TSQ(K),TSAB,TCAB)
       TLOC(K)= LOC
        STR(K)= STRAT
       AB    = TA(K)*AF
       AA1   = AA1+SINF(AB)
       AA4   = AA4+SINF(AB)
       AA2   = AA2+COSF(AB)
       AA5   = AA5+COSF(AB)
       AA3   = AA3+1.
       AA6   = AA6+1.
       RAY(K)= (RPP(K)**2)/XST
       Z(K)  = ZP+ZQ/XST

      IF (IG.NE.2) GO TO 250
240    TA(K)= TA(K)/2.
       VAR(K)= VAR(K)/4.
       VSD(K)=VSD(K)/2.
       TSQ(K) =TSQ(K)/2.
250   IF (IC) 260,310
C
C     AVERAGES FOR 100 UNIT INTERVALS
C
260    II    = STRAT1/IP
      IF (LOC1.NE.LOC) GO TO 265
       IF (II.EQ.I) GO TO 390
265    J     = J+1
       NA(J) = I*IP
       NB(J) = NA(J)+IP-1
       I     = II
       TI(J) = ATANF(SNI/CSI)/AF
       QI(J)= QII/XSII
       TKI(J)= THKI/XSII
       POI(J)= SQRTF(SNI*SNI+CSI*CSI)
       PPI(J)= POI(J)*100./XSII
       XSI(J)= XSII
       SLOC(J)= LOC
      CALL ROTATE (TI(J),SNI,CSI)
      IF (IB) 270,280
270    AVLL = SQRTF(AA1*AA1+AA2*AA2)
       AVL(J)= AVLL*100./AA3
       AVR(J) = ATANF(AA1/AA2)/AF
      CALL ROTATE (AVR(J),AA1,AA2)
       GO TO 300
280    AVL(J)=AVR(J)=0.
300   IF (IG.NE.2) GO TO 310
       TI(J) = TI(J)/2.
       AVR(J) = AVR(J)/2.
310   IF (ID) 320,380
```

```
C
C     LOCALITY AVERAGES
C
 320  IF (LOC1.EQ.LOC) GO TO 380
       L     = L+1
       TTQA(L)= TTQ/TOXX
       TTKA(L)= TTK/TOXX
       TOX(L)= TOXX
       ALOC(L)= LOC
       TS2   = TOTS*TOTS
       TC2   = TOTC*TOTC
       RTOT(L)= SQRTF(TS2+TC2)
       OLT(L)= RTOT(L)*100./TOXX
       TOTT(L) = ATANF(TOTS/TOTC)/AF
      CALL ROTATE (TOTT(L),TOTS,TOTC)
      IF (IB) 340,350
 340   ALLT = SQRTF(AA5*AA5+AA4*AA4)
       ALL(L) = ALLT*100./AA6
       ALR(L) = (ATANF(AA4/AA5))/AF
      CALL ROTATE (ALR(L),AA4,AA5)
       GO TO 360
 350   ALL(L)=ALR(L)=0.
 360  IF (IG.NE.2) GO TO 370
       TOTT(L) = TOTT(L)/2.
       ALR(L) = ALR(L)/2.
       GO TO 370
C
C     END OF AVERAGES
C
 365   I = STRAT1/IP
 370   TOTS=TOTC=TTK=TTQ=TOXX=AA4=AA5=AA6=0.
 380   SNI=CSI=THKI=XSII=QII=AA1=AA2=AA3=TTV=0.
 390  IF (LOC1.EQ.8H         ) GO TO 750
       LOC  = LOC1
       STRAT= STRAT1
       XST=THKT=QT=TSAB=TCAB=TSB=SNQT=CSQT=STQ=XSQ=STP=XSP=ATP=ATQ=0
       SDP=SDQ=Y=0.
       DO 391 M=1,12
 391   X(M) = 0.
 402  IF (IG) 685,403
 403  IF (E.EQ.60B) GO TO 404
      CALL AZIMUTH (E,TPO,ZZ)
      IF (ZZ) 80,404
 404  IF (G.EQ.60B) GO TO 405
      CALL AZIMUTH (G,TQO,ZZ)
      IF(ZZ) 80,405
C
C     CORRECTION FOR X-BED AZIMUTH AND DIP
C
 405   XST   = XST+1.
       TP    = TPO+AMAG
       TQ1   = TQO+AMAG
       TPQ   = TP-TQ1
C
C  CORRECTION FOR TILT IF TRENDS 180 APART OR EQUAL
C
      IF (ABS(TPQ).NE.180.) GO TO 410
       Q1    = QO+PO
       GO TO 630
 410  IF (TPQ.NE.0.) GO TO 420
       Q1    = QO-PO
      IF (Q1.GT.0.) GO TO 630
       Q1    = -Q1
       TQ1   = TQ1+180.
      IF (TQ1.LT.360.) GO TO 630
       TQ1   = TQ1-360.
       GO TO 630
```

```
C
C NORMAL BEDDING PLANES HORIZONTAL
C
 420    P     = (90.-PO)*AF
        SNP   = SINF(P)
       IF (SNP.NE.1.) GO TO 425
        Q1    = QO
        GO TO 630
C
C NORMAL TILT CORRECTIONS
C CONVERTING TREND AND DIP READINGS TO LOWER HEMISPHERE
C
 425   IF (TP.LT.180.) GO TO 430
        TP    = TP-180.
        GO TO 440
 430    TP    = TP+180.
 440   IF (TQ1.LT.180.) GO TO 450
        TQ1   = TQ1-180.
        GO TO 460
 450    TQ1   = TQ1+180.
C
C      INCLINED BEDDING PLANES
C
 460    CSP   = COSF(P)
        Q     = (90.-QO)*AF
        TP    = TP*AF
        TQ    = TQ1*AF
        SNQ   = SINF(Q)
        CSQ   = COSF(Q)
        T     = TQ-TP
        S1=S2=S3=0.
       IF (T.GE.0.) GO TO 480
        T     = T+PI2
 480    S1    = T
       IF (Q.GE.0.) GO TO 500
       IF((S1.GT.HPI3).OR.(S1.LT.HPI)) GO TO 490
        GO TO 500
 490    SNQ   = -SNQ
        CSQ   = -CSQ
 500   IF (PI.GE.T) GO TO 510
        T     = PI2-T
 510    CST   = COSF(T)
C
C DIP CORRECTION FACTOR
C
        SNQ1 = SNP*SNQ + CSP*CSQ*CST
       IF (Q.GE.0.) GO TO 530
        S2    = PI
       IF (SNQ1.LT.0.) GO TO 520
         SNQ   = -SNQ
        GO TO 530
 520    SNQ1 = -SNQ1
 530    Q1    = ASINF(SNQ1)
        CSQ1 = COSF(Q1)
C
C CORRECTION FOR TREND DIRECTION
C
       IF (S2.GE.PI) GO TO 540
        FN    = SNQ-(SNP*SNQ1)
       IF (FN.GE.0) GO TO 550
        FN    = -FN
        S3    = PI
        GO TO 550
 540    FN    = SNQ+(SNP*SNQ1)
 550    CSZ   = FN/(CSP*CSQ1)
        W     = ASINF(CSZ)
```

```
      IF (S3.GE.PI) GO TO 560
       T1    = HPI+W
       GO TO 570
 560   T1    = HPI-W
 570  IF (S1.LT.PI) GO TO 580
       T1    = PI2-T1
 580   TQ1   = T1+TP+S2
      IF (PI2.GE.TQ1) GO TO 590
       TQ1   = TQ1-PI2
 590   Q1    = Q1/AF
       TQ1   = TQ1/AF
C
C REVERSE OF STEPS 420 TO 460 RETURNING READINGS TO UPPER HEMISPHERE
C
      IF (Q1.LT.0.) GO TO 620
      IF (TQ1.GT.180.) GO TO 600
       TQ1   = TQ1+180.
       GO TO 610
 600   TQ1   = TQ1-180.
 610   Q1    = 90.-Q1
       GO TO 630
 620   Q1    = -Q1
 630  IF (IA) 640,690
 640  IF (XST.GT.1.) GO TO 660
      PRINT 650, LOC1,STRAT1,TPO,PO,TQO,QO,TQ1,Q1,THICK,SHAPE,GRAIN,OTHE
     1RS
 650  FORMAT(1H ,1X,A8,F10.0,4X,2F8.0,F9.0,F10.0,2F12.2,F10.2,4X,3A8)
      GO TO 680
 660  PRINT 670, TPO,PO,TQO,QO,TQ1,Q1,THICK,SHAPE,GRAIN,OTHERS
 670  FORMAT(1H ,23X,2F8.0,F9.0,F10.0,2F12.2,F10.2,4X,3A8)
 680  IF (IB.EQ.0.AND.IC.EQ.0.AND.ID.EQ.0.AND.IE.EQ.0.AND.IG.EQ.0) GO TO
     1 80
       GO TO 690
 685   Q1    = QO
       XST = XST+1.
      IF (IG.EQ.1) GO TO 687
      IF (TQO.LT.180.) GO TO 686
       TQO   = TQO-180.
 686   TQ1   = TQO*2
       GO TO 690
 687   TQ1 = TQO
C
C      DATA FOR AVERAGES
C
 690  IF (TQ1.GE.180.) GO TO 700
       XSQ   = XSQ+1.
       STQ   = STQ+TQ1
       GO TO 710
 700   XSP   = XSP+1.
       STP   = STP+TQ1
 710   TV(XST)= TQ1
       TQ2   = TQ1*AF
       SNTQ1= SINF(TQ2)
       CSTQ1= COSF(TQ2)
       THKT  = THKT+THICK
       QT    = QT+Q1
       SNQT  = SNQT+SNTQ1
       CSQT  = CSQT+CSTQ1
       Q1    = Q1*AF
       CB    = COSF(Q1)
       TSAB  = TSAB+SNTQ1*CB
       TCAB  = TCAB+CSTQ1*CB
       TSB   = TSB+SINF(Q1)
      IF (IE) 720,80
 720   MI    = (TQ1+30.)/30.
       X(MI)= X(MI)+1
       GO TO 80
```

```
C
C     PRINT OUTS
C
 750  IF (IE) 760,820
 760  PRINT 770
 770  FORMAT(1H1//45X*NUMBER FREQUENCY DISTRIBUTION*///* LOCATION   GROU
     1P INTERVAL    CLASS 0     30     60     90     120     150     180    2
     210    240    270    300    330    360*/)
      DO 790 JK=1,JJ
      PRINT 780, (TLOC(JK),STR(JK),(V(JK,KK),KK=1,12))
 780  FORMAT(1H ,R8,F12.0,15X,4F6.1,8F7.1)
 790  CONTINUE
      PRINT 800
 800  FORMAT(1H1//43X*PERCENTAGE FREQUENCY DISTRIBUTION*///* LOCATION
     1 GROUP INTERVAL    CLASS 0    30     60     90     120     150     180
     2   210    240     270    300     330     360*/)
      DO 810 JK=1,JJ
       Y = 0.
      DO 805 KK=1,12
 805   Y = Y+V(JK,KK)
      DO 806 KK=1,12
 806   V(JK,KK) =V(JK,KK)*100./Y
      PRINT 780, (TLOC(JK),STR(JK),(V(JK,KK),KK=1,12))
 810  CONTINUE
 820  IF (IB) 830,860
 830  PRINT 840
 840  FORMAT(1H1//36X*AVERAGES FOR BEDS IN ONE GROUP INTERVAL*
     1//* LOCATION GROUP  BEDS  ARITH   VECT  VECT  VECT  VECT  VECT  R
     2AYLE  RAYSIG    AV     AV      SD     SD    VECT  CONFID APPROX*/
     323X*TREND  TREND  MAGN MAGPC   VAR   STD    PROB   STAT    DIP  TH
     4ICK  TREND AVDIP MAGNIT CIRCLE PRECIS*/)
      PRINT 850,(TLOC(M),STR(M),TXS(M),TAA(M),TA(M),RPP(M),OLPP(M),VAR(M
     1),VSD(M),RAY(M),Z(M),QA(M),TH(M),TSQ(M),TSQD(M),R(M),WD5(M),OK(M),
     2 M=1,K)
 850  FORMAT(1H ,R8,F6.0,F5.0,1X,2F7.2,2F6.2,F8.1,F6.2,2F7.4,F6.2,2F7.2,
     1F6.2,3F7.2)
      IF (IB.NE.2) GO TO 860
      PUNCH 845, (TLOC(M),STR(M),TA(M),QA(M),TH(M), M=1,K)
 845  FORMAT(A8,F7.0,19X,2F5.1,F10.2)
 860  IF (IC) 870,900
 870  PRINT 880, IP,IP
 880  FORMAT(1H1//13X*AVERAGES FOR BEDS IN*I5* UNIT INTERVALS*//*  LOCAT
     1ION *I5 * INTERVAL    AV TREND     MAGNIT     MAGNPC    NO.XBEDS    AV D
     2IP    AV THICK  AV GROUP VECTS  MAGN AGV PC*/)
      PRINT 890,(SLOC(M),NA(M),NB(M),TI(M),PQI(M),PPI(M),XSI(M),QI(M),
     1TKI(M),AVR(M),AVL(M),M=1,J)
 890  FORMAT(1H ,1XR8,I8,*-*I4,F12.2,F11.2, F9.2,F8.0,F12.2,F10.2,
     12F14.2)
 900  IF (ID) 910,940
 910  PRINT 920
 920  FORMAT(1H1//22X*AVERAGES FOR BEDS IN EACH LOCATION*//*  LOCATION
     1 AV VECT TREND    MAGNIT     MAGNPC    NO XBEDS    AV DIP    AV THICK
     2AV GROUP VECTS  MAGN AGV PC*/)
      PRINT 930,(ALOC(M),TOTT(M),RTOT(M),OLT(M),TOX(M),TTQA(M),TTKA(M)
     1,ALR(M),ALL(M), M=1,L)
 930  FORMAT(1H ,1XR8,F12.2,F13.2,F9.2,F8.0,F12.2,F10.2,2F14.2)
C
 940   GO TO 38
 945  PRINT 950
 950  FORMAT(1H1)
      END
```

```
      SUBROUTINE AZIMUTH (G,TPO,ZZ)
C
C     CORRECTION FOR X-BED STRIKE AND DIP
C
      INTEGER G
      IF (G.NE.8H0000000N) GO TO 392
      IF (TPO.EQ.0.) GO TO 400
      IF (TPO-180.)396,400,395
 392  IF (G.NE.8H0000000S) GO TO 393
      IF (TPO.EQ.0.) GO TO 400
      IF (TPO-180.)395,400,396
 393  IF (G.NE.8H0000000E) GO TO 394
      IF (TPO.LT.90.OR.TPO.GT.270.) GO TO 395
      IF (TPO.EQ.90.OR.TPO.EQ.270.) GO TO 400
       GO TO 396
 394  IF (TPO.LT.90.OR.TPO.GT.270.) GO TO 396
      IF (TPO.EQ.90.OR.TPO.EQ.270.) GO TO 400
 395   TPO  = TPO+90.
       GO TO 397
 396   TPO  = TPO-90.
 397  IF (TPO.GE.0.) GO TO  398
       TPO  = TPO+360
       GO TO 399
 398  IF(TPO.LT.360.) GO TO 399
       TPO  = TPO-360.
 399   ZZ = 0.
      GO TO 401
 400   ZZ = 1.
 401  RETURN
      END
      SUBROUTINE ROTATE (T,S,C)
C
      IF (T.NE.0.) GO TO 961
      IF (C.LT.0.) GO TO 960
       T     = 0.
       GO TO 964
 960   T     = 180.
       GO TO 964
 961  IF (T.GE.0.) GO TO 962
      IF (S.GE.0.) GO TO 963
       T     = T+360.
       GO TO 964
 962  IF (S.GE.0.) GO TO 964
 963   T     = T+180.
 964  RETURN
      END
```