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SEDAN - *A Computer Program for Sediment Particle-Size Analysis*

J.P. COAKLEY and G.S. BEAL

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SEDAN - *A Computer Program for Sediment Particle-Size Analysis*

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INLAND WATERS DIRECTORATE
DEPARTMENT OF THE ENVIRONMENT
OTTAWA, CANADA, 1972

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Acknowledgments

The computer program described here was developed by the authors and makes wide use of programs existing in the literature. The line-printer plot of the cumulative frequency curve and the moment measure calculations were taken from a program written by Kramer and Williams (PROBAB) in 1969. Textural labels for the sample materials, based on Shepard's (1954) nomenclature, were derived from parts of Schlee and Webster's (1965) program.

Abstract

SEDAN is a computer program written in FORTRAN IV to calculate the mean and the first three moments about the mean (variance, skewness measure and kurtosis measure) for a sediment particle-size distribution using the method of moments (Krumbein, 1936). A line-printer probability plot of the cumulative per cent versus size class and of the frequency histogram is included in the output from the program. In addition, the standard deviation, mode, percentages of sand, silt and clay, and the amount of sample finer than 9 phi (2 microns) are calculated and the sediment type is labelled using the Shepard (1954) textural nomenclature.

Résumé

SEDAN - Un programme pour ordinateur permettant l'analyse granulométrique d'un sédiment.

SEDAN est un programme pour ordinateur écrit en Fortran IV. Il permet de calculer la moyenne et les trois premiers "moments autour de la moyenne" (variance, mesure asymétrique et mesure de kurtosis), lors des études de distribution granulométrique d'un sédiment par la méthode des "moments" (Krumbein, 1936). Une représentation graphique du "pourcentage cumulé" reporté comme fonction de "classe granulométrique" ainsi que celle d'un histogramme de fréquence ont été incluses dans le "système de sortie" (output) du programme. Par ailleurs, la déviation standard et le mode, les pourcentages du sable, du silt et de l'argile, ainsi que la fraction de l'échantillon dont les grains possèdent un diamètre inférieur à 9 phi (2 microns) ont été calculés. Le nom de type du sédiment à été attribué selon la nomenclature texturale de Shepard (1954).

SEDAN - *A Computer Program for Sediment Particle-Size Analysis*

J.P. COAKLEY and G.S. BEAL

INTRODUCTION

The use of moment measures to describe the particle-size distributions of sediments dates back to Krumbein (1936). Application of this method is now almost universal, due primarily to the popularization of the digital computer which vastly reduces the long and rather tedious computation previously associated with moment measure calculations. To date, several computer programs have been published for this purpose.

The SEDAN computer program described here uses a number of adaptations of algorithms and subroutines contained in these programs, e.g., Schlee and Webster (1965) and Pierce and Good (1966), and is believed to offer considerably greater flexibility and conveniance of output compared to the programs described in the literature. The program is easy to use and the benefits which this offers to researchers and technicians will be apparent from the description of the program.

SEDAN COMPUTER PROGRAM

SEDAN is a computer program written in FORTRAN IV to calculate the mean particle size and the first three moments about the mean (variance, skewness and kurtosis) for a sediment particle-size analysis, using the method of moments. In addition, the standard deviation, mode, percentages of sand, silt and clay and the amount of the sample finer than 2 microns (9 phi) are calculated. Finally, the sample is labelled using Shepard's (1954) textural nomenclature. Line-printer plots of the frequency histogram and the cumulative frequency ogive are also constructed.

SEDAN is presently in use at the Canada Centre for Inland Waters and accepts input data from the following methods of analysis:

1. Sieve
2. Pipette
3. Sieve/pipette combination
4. Settling tube
5. Settling tube/pipette combination
6. Automated sedimentometer methods

Some of the above methods of analysis require slight modification of the program steps and/or further data preparation prior to computation.

For example:

1. Light or X-ray absorption methods (method 6 in the above list). Data from this source are in the form of solution turbidity or density versus time graphs, showing the cumulative amount finer than the size settling out at the time recorded. These methods are thus analogous to the pipette method and the data can be entered in the form required by SEDAN for pipette data input.

2. Settling-tube analysis of sands (method 4 above). As this method measures cumulative heights in a column beginning at zero and ending at 100 per cent at the end of the analysis, data thus obtained cannot be accepted by SEDAN in this form. It is suggested, therefore, that size class frequencies be extracted from the curve of cumulative heights and input to the program be made in a manner similar to that for sieve fractions. The total sample weight should be the final column height in the tube. This would make no difference to the statistical parameters calculated, as the units used for the frequencies are not considered.

3. Pipette data (method 2 above). These data can be handled most conveniently if two dummy sieve values are read in. If these values are both very low (e.g., 0.001) and the starting-size class is adjusted accordingly, there will be no change in the results. In other words, for pipette data alone, the computer analysis must be treated as if it were a combination of sieve and pipette data.

THEORETICAL CONSIDERATIONS

The essential assumptions made in the use of moment statistics to describe size frequency distributions are as follows:

1. The distribution is not open-ended, i.e., the sum of the size frequencies is equal to the total weight of the sample.

2. The distribution is normal when the class intervals are expressed in phi (Ø) units (Krumbein and Pettijohn, 1938). The phi transform (phi = $-\log_2$ diameter in mm) is necessary to compress the large range of grain diameters found in a natural sediment, and offers the added advantage of making the plot of grain size versus frequency fall along a straight line in cases of perfect normality.

The moment statistics concept still involves some controversy, as expressed by Inman (1952), McCammon (1962), and Spencer (1963). However, it represents the most convenient method of routine sediment-size analysis.

The formulae used in this computer program to calculate moment measure comprise the standard G-statistics (Fisher, 1970; p. 74), as expressed by Kramer and Williams (1969). They are:

1. Mean phi size:

$$\overline{X} = \frac{1}{N} \sum_{i=1}^{K} f(X_i) \cdot X_i$$

where $f(X_i)$ = frequency of a size class; X_i = class mid-point; N = total of frequencies $\sum_{i=1}^{K} f(X_i)$; and K = number of class intervals.

2. Standard deviation:

$$S = \sqrt{\frac{X_2}{N - 1}}$$

3. Measure of skewness:

$$M_3 = \frac{X_3}{2(N-2)S^3}$$

4. Measure of kurtosis:

$$M_4 = \frac{X_4}{(N-4)S^4} - 3$$

where $X_n = \sum_{i=1}^{K} (X_i - \overline{X})^n \cdot f(X_i)$

The above statistics are standardized values and give values of zero for skewness and kurtosis for a perfectly normal distribution. This is not always the case for other moment measure calculations; e.g., the value for kurtosis in a perfectly normal distribution is sometimes given as 3.0 in general statistical formulae (Krumbein and Pettijohn, 1938). In general, the sediment moment measures of skewness and kurtosis can be compared with results from different studies only if care is taken to ensure that the formulae used are rendered compatible.

DESCRIPTION OF PROGRAM

SEDAN consists of twelve subroutines driven by the main program MAINLINE. The memory core size required to compile the program is roughly 40 K words on the CDC 6400 using a SCOPE 3.1.2 system. One hundred samples can be run in approximately 30 seconds. Figures 1 and 2 show the sequence of operations. The functions carried out by the various subroutines can be briefly stated as follows:

1. MAINLINE is the vehicle for data input and for computing sand, silt and clay percentages. It reduces the input data to frequencies which are passed into subroutines PROBPLT, MODE and BRESLAU.

FIGURE I

FLOW CHART: SEDAN

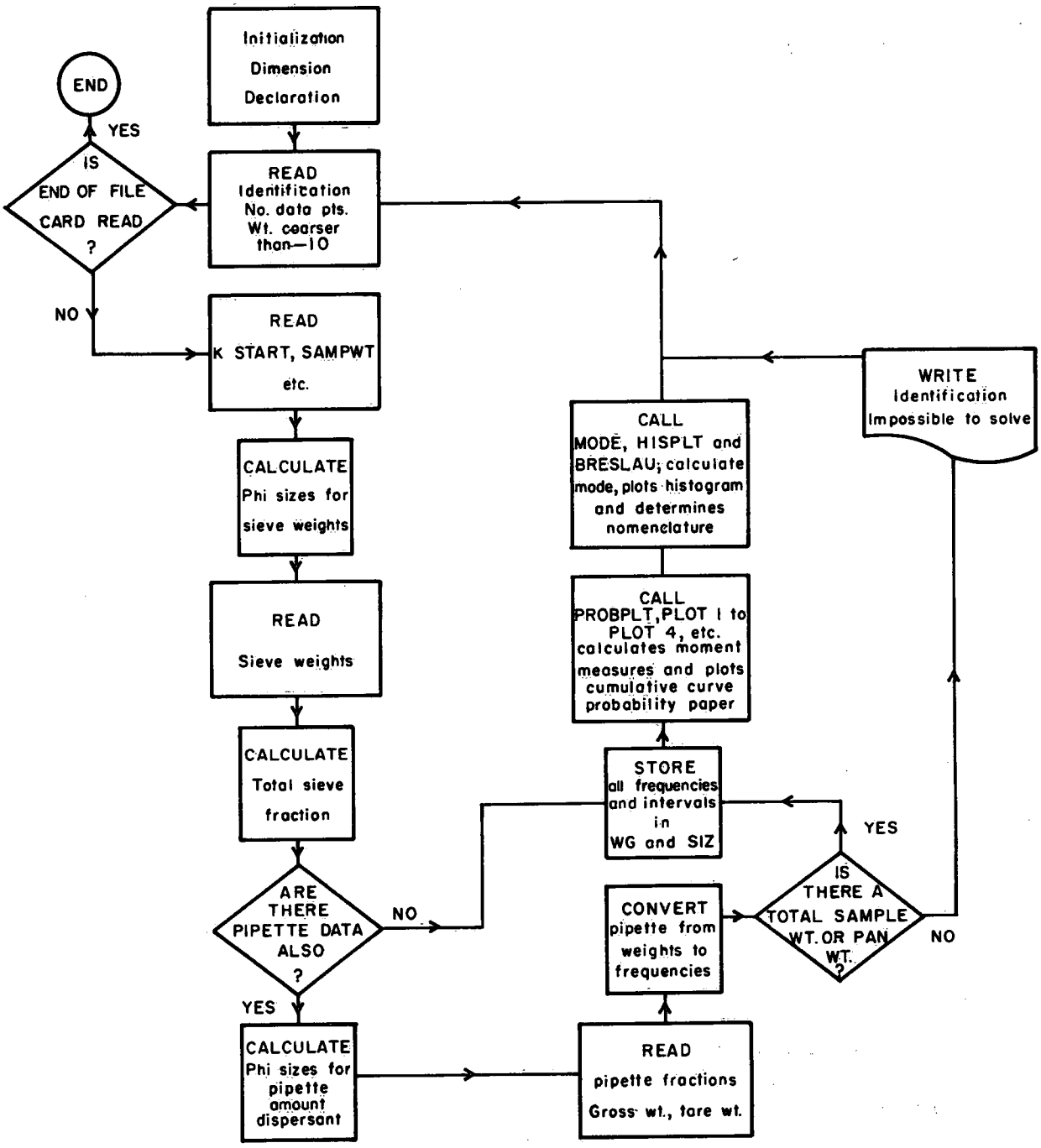
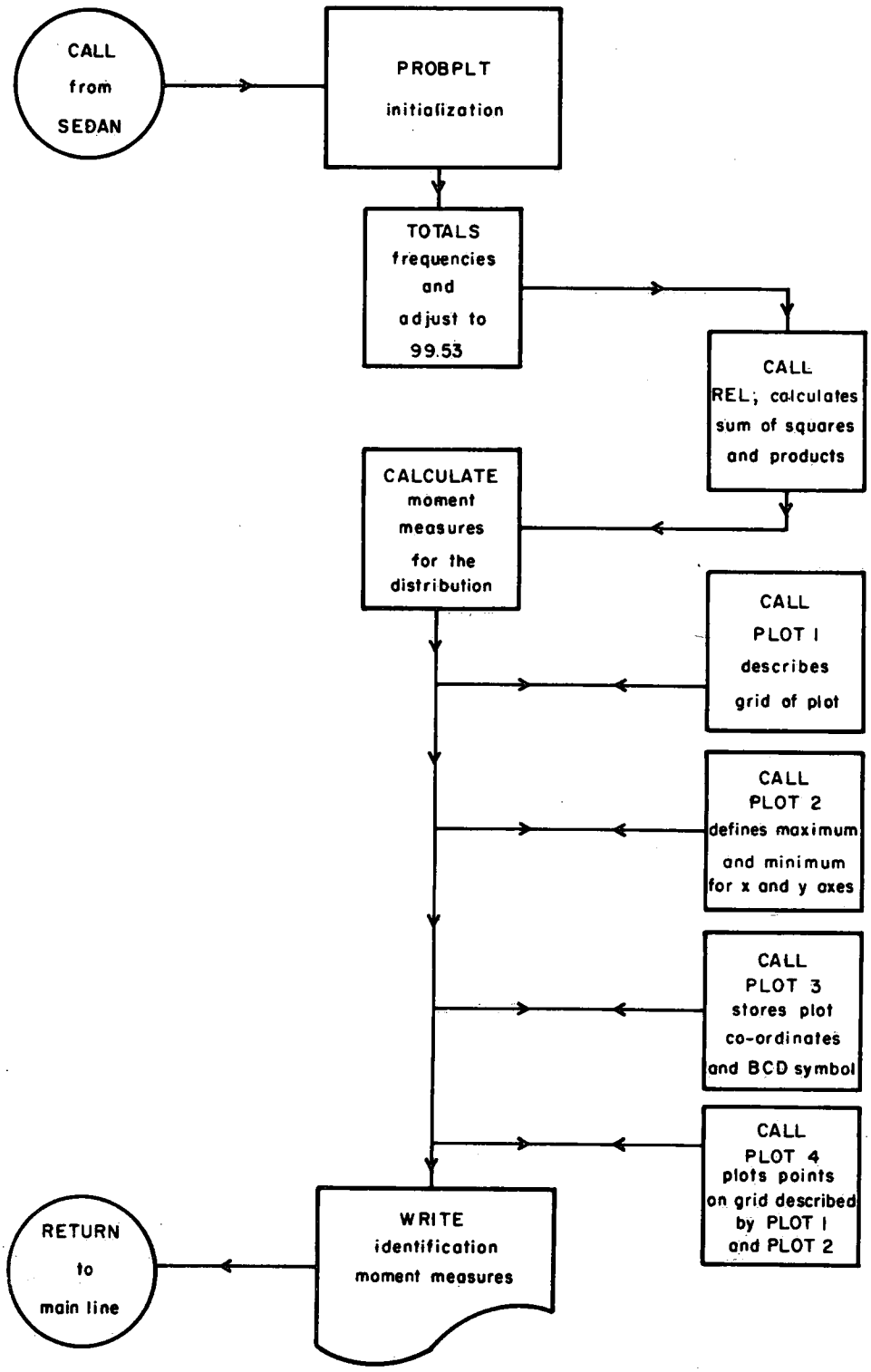


FIGURE 2

FLOW CHART for PROBPLT and PLOT SUBROUTINES



2. PROBPLT is the most important functional subroutine in the program. It uses as input the frequency and class interval information transferred from MAINLINE and calculates the first three moments around the mean. It then plots the cumulative frequency on a probability scale. In order to do this, it calls, in sequence, the subroutines OMIT, REL, PLOT 1, PLOT 2, PLOT 3 and PLOT 4.

3. Subroutine REL calculates the sum of squares and products for distribution and returns these values to PROBPLT.

4. The PLOT subroutines, PLOT 1 to PLOT 4 inclusive, comprise the printer plot subroutine package:

   a) PLOT 1 defines and plots the grid co-ordinates of the plot (see comment cards at the beginning of the list for PLOT 1 in Appendix A.

   b) PLOT 2 sets maximum and minimum values for the x- and y- axes.

   c) PLOT 3 collects and stores the x and y co-ordinates and the BCD character to be printed at these points.

   d) PLOT 4 plots the points collected by PLOT 3 and prints them on the graph described by PLOT 1 and PLOT 2. PLOT 4 also calls subroutines LONGPAG, UNLONG and SETLOG.

5. Subroutine MODE computes the modal class of the distribution. In the case of polymodal distributions, only those classes in which there is a value change of at least 1 per cent are used. MODE calls HISPLT.

6. HISPLT plots a histogram of raw weight frequencies for the sample distribution.

7. Subroutine BRESLAU was taken from a subroutine written by Lloyd Breslau as part of Pierce and Good's (1966) program. It uses the Shepard (1954) method for sediment textural nomenclature which assigns a name to the sediment based on percentages of sand, silt and clay. Gravel is included in the sand percentages in this operation.

PROGRAM SEQUENCE

Variable names used in the MAIN program are explained in Table 1. In order of processing, the various data values are read in as follows:

1. <u>Initialization</u>

   a) Statement 100 reads in the sample identification (TITLE), the total number of data points (NO) and the weight of material coarser than -1 phi (2 mm) diameter (GRAVEL). This is the Wentworth scale boundary between sand and gravel.

   b. Statement 110 reads in the number of sieve points (K), the phi value for the coarsest class (START), the total dry sample weight in grams (SAMPWT), the total weight in grams of dispersant used if pipette readings are taken (DISP), the weight of the pan fraction (PANWT), the phi interval used (PHINT) and the volume of the graduated cylinder used if pipette analysis is included. If no pipette analysis was carried out, the corresponding data variables can be left blank.

TABLE 1

List of Variable Names

The variables used are coded as follows:

TITLE	- Identifiers desired by the user. Twenty-four spaces are reserved for this input.
NO	- Total number of data points.
GRAVEL	- Weight of material coarser than -1 phi (2 mm).
ENDFILE	- A computer function code indicating end of a job.
K	- Number of sieve points.
START	- Phi value of the first size interval, or in other words, that of the coarsest fraction.
SAMPWT	- Total sample weight when dry.
DISP	- Weight of dispersant used, in grams.
PHINT	- Phi intervals used for sieve fraction, i.e., 0.5 phi or 1.0 phi.
M	- Calculated number of pipette data points, including extrapolated points.
SIZE	- Vector containing sieve size intervals corresponding to the weight fractions.
FLOAT	- Computer library function that converts integers to decimal numbers.
SIEVE	- Vector containing weights of sieve fractions only.
PSAMPWT	- Calculated total of all sieve fraction weights.
CYLSIZE	- Volume in ml of graduated cylinder used in pipette analysis.
PIPFRA	- Conversion factor of pipette residue weights to frequency weights.
GROSS	- Weight of pipette draw-off plus container.
TARE	- Weight of container alone.
DIF	- Vector containing weight of draw-off corresponding to a size class.
WEIGHT	- Pipette residue weights converted to weight frequency.
SIZ	- Vector containing all size classes (in phi units).
WG	- Vector containing all size frequencies expressed as weight in grams.

All the above data should be supplied to the program, if possible. However, if due to analytical considerations a pan fraction weight is not available, its absence is not critical. The program will calculate the weight of material finer than 4 phi. Similarly, if a pan weight is supplied but no dry sample weight was recorded, the total weight of frequencies will be calculated. Input of either a pan weight or a total dry sample weight or both is required for the operation of the program.

2. Data Input

The specified number of sieve data values are then read in (SIEVE(I), I = 1,K).

If the total number of data points (NO) is not equal to the number of sieve points (K), then pipette or other values are expected. If such is the case, pipette values are read in next as follows:

Gross weight (residue + tare)

Tare weight (weight of container)

until the number of data points specified by NO is reached.

The value of the multiplication factor PIPFRA that converts pipette residue weights to real cumulative weights, is entered in a data statement at the beginning and can be changed to suit the particular analysis technique used.

The interval used for pipette analysis is 1 phi.

Formats for both initialization and data entry are shown in Figures 3 and 4 and test data are included in Appendix A.

3. Data Output

The program output Appendix B consists of the following:

a) A line-printer plot on probability paper showing the cumulative per cent frequency ogive of the size distribution of the sediment sample analyzed. The upper limit is set at 99.53 per cent due to paper-size considerations.

b) The sample identification and the labelled statistical parameters printed out below the cumulative frequency plot.

c) A reference histogram of raw weights, followed by the major mode or modes of the distribution.

d) Percentages of gravel, sand, silt and clay, followed by the appropriate textural nomenclature.

e) A print-out of the residue finer than 9 phi for pipette analysis. This gives some idea of the reliability of the analysis by indicating how much open-endedness is present in the distribution. It also illustrates the approximate percentage of mineral clay in the sample (Thomas, 1969).

FIGURE 3

PARTICLE SIZE ANALSIS CODING FORM

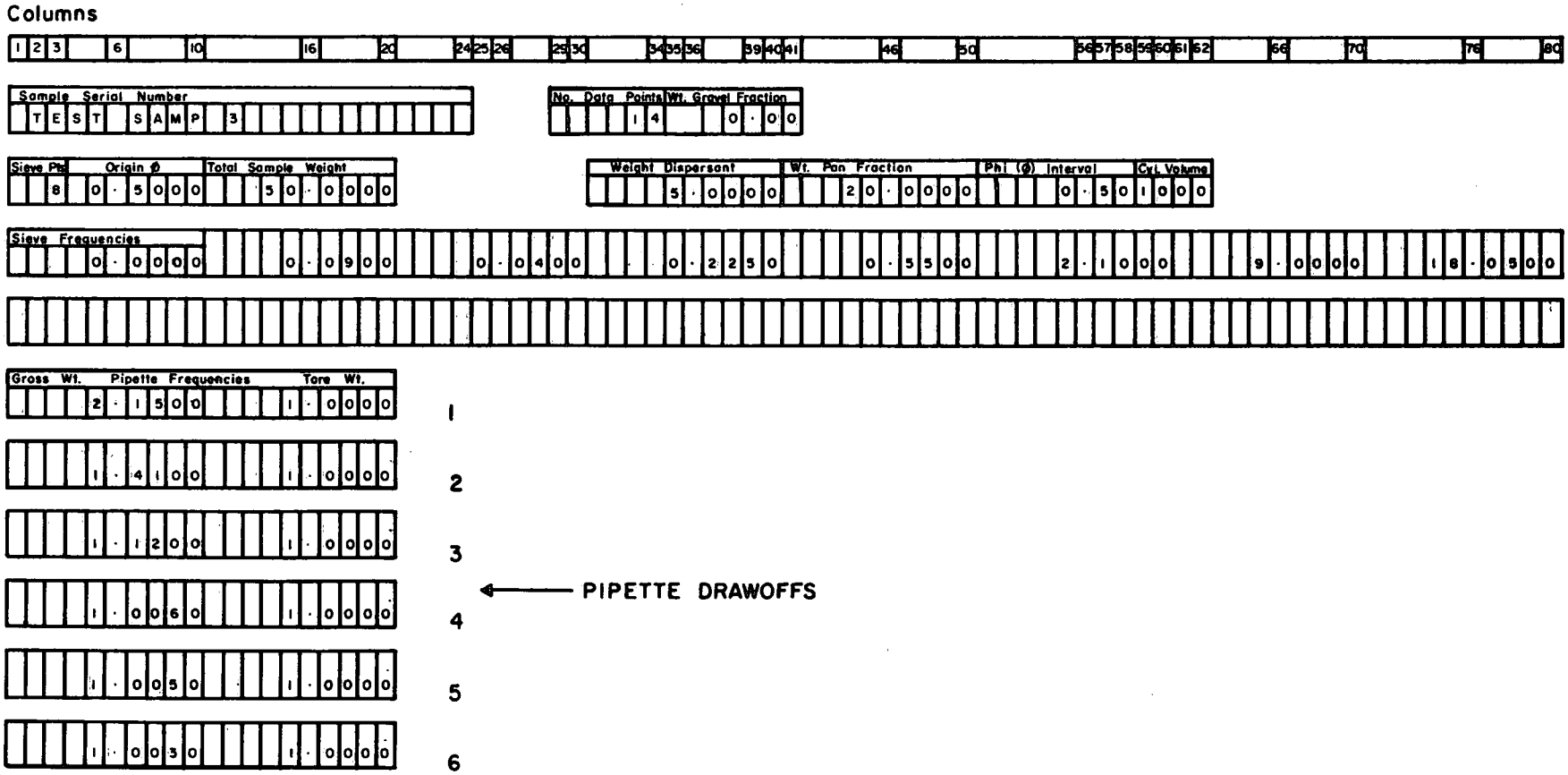


FIGURE 4

SEDIMENTOLOGY LABORATORY

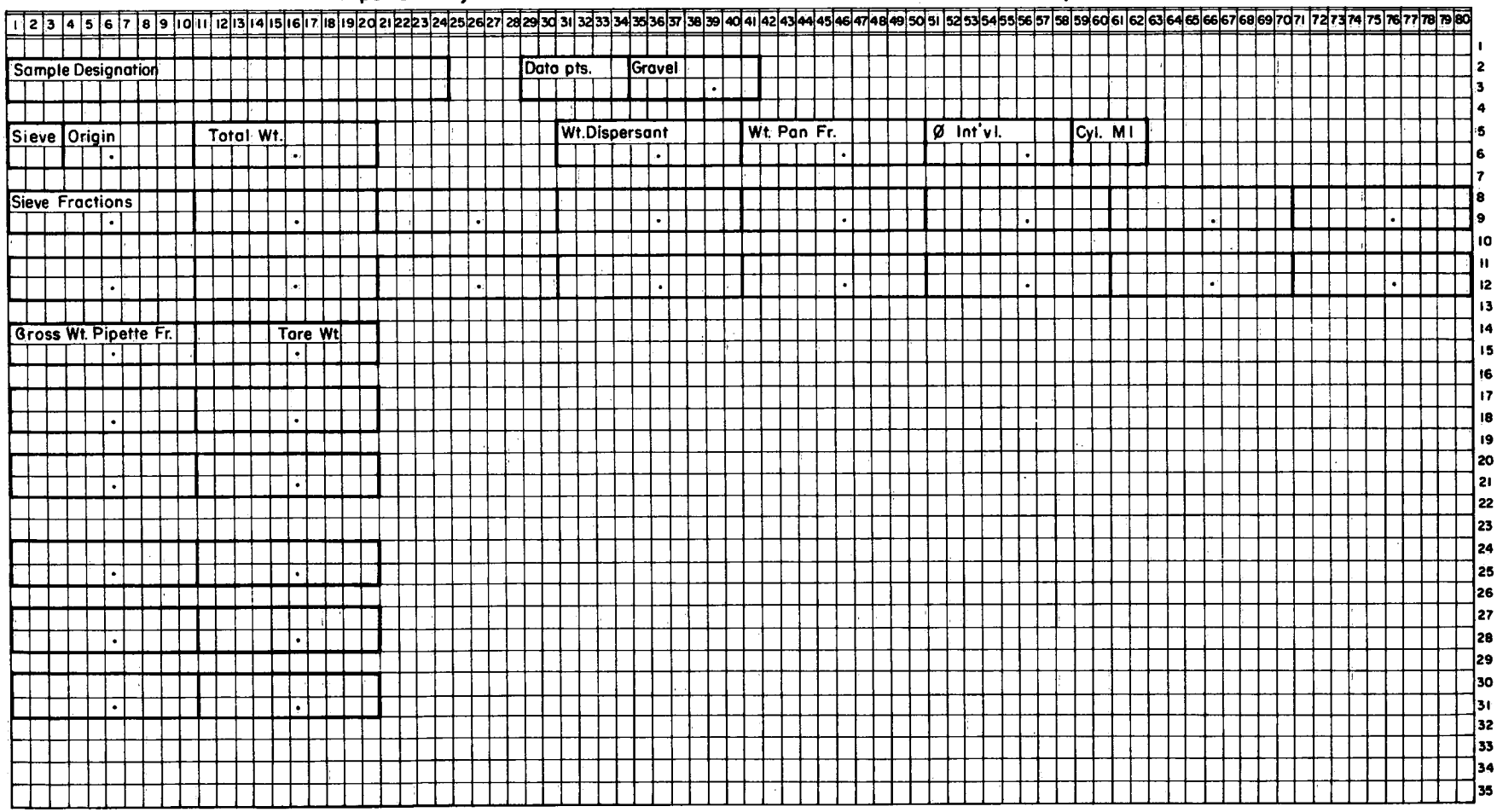
SIEVE AND PIPETTE SIZE ANALYSIS

CODING FORM

Analyst: _____ Sample No. _____

Date _____ Page ___ of ___ pages ___

Pipette Trays — Sieve Trays



SUMMARY

The program, SEDAN, provides an automated and comprehensive description of the texture of sediment samples. It has been in active use at the Canada Centre for Inland Waters for over three years and, in its present form, incorporates considerable refinements taken from other size analysis programs in the literature. Examples of the treatment of both sieve and sieve/pipette analysis data are shown in Appendix B. Test sample 1 was taken from Folk (1968, p. 50), test sample 2 from Krumbein and Pettijohn (1938, p. 251), and test sample 3 from an arbitrary distribution. The resulting statistical parameters (Appendix B) compare satisfactorily with those obtained by the authors (Table 2). Test sample 3 was checked by hand.

TABLE 2

COMPARISON OF RESULTS

PARAMETER	TEST SAMP. 1		TEST SAMP. 2		TEST SAMP. 3	
	FOLK	SEDAN	KRUMBEIN & PETTIJOHN	SEDAN	ARBITRARY	SEDAN
MEAN	2.680	2.638	1.815	1.809	4.03	4.049
ST. DEVIATION	1.060	0.995	0.563	0.568	0.84	0.852
SKEWNESS			-0.011	-0.016	0.462	0.202
KURTOSIS			-0.5	-0.517	0.769	0.759

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Folk, R.L., 1968. Petrology of sedimentary rocks. Univ. Texas Geology Manual, Hemphill's, Austin, Texas, 159 p.

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Krumbein, W.C., and F.J. Pettijohn, 1938. Manual of sedimentary petrography. Appleton-Century-Crofts Inc., Division of Meredith Corp., New York, 549 p.

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Pierce, J.W., and D.I. Good, 1966. Fortran II program for standard size analysis of unconsolidated sediments using an IBM 1620 computer. Kansas State Geological Survey, University of Kansas, Lawrence, Special Dist., Publ. 28, 19 p.

Schlee, J., and J. Webster, 1965. A computer program for grain-size data. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, Tech. Report, ref. no. 65-42, 21 p.

Shepard, F.P., 1954. Nomenclature based on sand-silt-clay ratios. J. Sed. Petr., 24 (3), pp. 151-158.

Spencer, D.W., 1963. The interpretation of grain-size distribution curves of clastic sediments. J. Sed. Petr., 33 (1), pp. 180-190.

Thomas, R.L., 1969. A note on the relationship of grain size, clay content, quartz and organic carbon in some Lake Erie and Lake Ontario sediments. J. Sed. Petr., 39 (2), pp. 803-809.

Appendix A

```
                                P R O G R A M    S E D A N
            1        (INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7=PUNCH)
      C                                                                          A   2
      C  PROGRAM SEDAN IS DESIGNED TO CALCULATE MOMENT MEASURES AND OTHER
      C  STATISTICAL PARAMETERS FOR PARTICLE SIZE DISTRIBUTIONS.  IT ALSO
      C  PLOTS A CUMULATIVE CURVE AND A HISTOGRAM FOR VISUAL APPRAISAL.
      C
000003        DIMENSION SIZE(60), WEIGHT(60), PIPET(6), SIEVE(40), GROSS(6), TAR  A   5
             IE(6),DIF(40),SIZ(60,10),WG(60,10),TP(60)
000003        INTEGER CYLSIZE                                                    A   9
000003        INTEGER TITLE(12,10)                                               A  10
000003        DIMENSION FREQ(50)                                                 A   7
      C THE VALUE OF PIPFRA MUST BE ASSIGNED AND IS THE RATIO OF PIPETTE
      C DRAW-OFF SIZE (VOLUME) TO THAT OF THE GRADUATED CYLINDER USED.
      C
000003        DATA PIPFRA/0.025/
      C                                                                          A   8
      C                                                                          A  11
      C       NO IS THE TOTAL NUMBER OF POINTS  IE SIEVE PTS + 6 IF PIPET ALSO   A  12
      C                                                                          A  13
000003  100   READ (5,470) (TITLE(I,1),I=1,12),NO,GRAVEL                         A  14
000021        IF(EOF,5)430,110
      C                                                                          A  15
      C       READ NO OF SIEVES,STARTING PHI VALUE SAMPLE WEIGHT AMNT OF         A  16
      C       DISPERSANT                                                         A  17
      C       PAN FRACTION WEIGHT  PHI INTERVAL  AND CYLINDER SIZE               A  18
      C                                                                          A  19
000024  110   READ (5,480) K,START,SAMPWT,DISP,PANWT,PHINT,CYLSIZE               A  21
      C                                                                          A  22
      C       THIS LOOP SETS INTO ≠SIZE≠ THE PHI VALUES FOR THE SIEVE SECTION    A  23
      C       NOTE :  IT DOES IT ONLY FOR THE SIEVE SECTION NOW                  A  24
      C                                                                          A  25
000046        M=NO-K                                                             A  26
000050        IL=K+1                                                             A  27
000052        DO 120 I=1,K                                                       A  28
000053        SIZE(I)=(START+(FLOAT(I-1)*PHINT)-0.00499)
000061  120   CONTINUE                                                           A  30
      C                                                                          A  31
000063        PSAMPWT=0.                                                         A  32
      C                                                                          A  33
      C       WE NOW READ IN THE K VALUES FOR THE SIEVE WEIGHTS                  A  34
      C                                                                          A  35
000064        READ (5,490) (SIEVE(I),I=1,K)                                      A  36
000076        SLAST=SIEVE(K)                                                     A  37
      C                                                                          A  38
      C       TOTAL THE SIEVE WEIGHTS                                            A  39
      C                                                                          A  40
000100        DO 130 I=1,K                                                       A  41
000102        PSAMPWT=PSAMPWT+SIEVE(I)                                           A  42
000104  130   CONTINUE                                                           A  43
      C                                                                          A  44
      C  DECIDE IF THERE ARE PIPETTE VALUES ALSO, IF NOT GO TO 140
      C
000106        IF (K.NE.NO) GO TO 140                                             A  46
000110        PIPTOT=0.0                                                         A  47
000111        DIFTOT=0.0                                                         A  48
000112        DEM=0.0
000113        COFAC=1.0
000114        GO TO 280
000115  140   CONTINUE                                                           A  49
000115        IF (K.NE.NO) 150,280                                               A  50
000122  150   PIPTOT=0.                                                          A  51
      C                                                                          A  52
      C                                                                          A  53
      C       THIS LOOP SHOULD CALCULATE THE PHI VALUES FOR THE PIPET SECTION    A  54
      C                                                                          A  55
                                                                                 A  56
```

```
000123          DO 160 I=1,6                                              A  57
000125          IQ=K+I                                                    A  58
000127          SIZE(IQ)=SIZE(K)+FLOAT(I)                                 A  59
000132    160   CONTINUE                                                  A  60
          C
          C     FIGURE AMOUNT OF DISPERSANT ADDED TO EACH SAMPLE          A  61
          C                                                               A  62
000133          IF (DISP.GT.0.0) 180,170                                  A  64
000140    170   DISP=((FLOAT(CYLSIZE))*0.0050)                            A  65
000143    180   ACTDISP=DISP*PIPFRA                                       A  66
          C                                                               A  67
          C  FIND INDIVIDUAL PIPETTE FREQUENCIES AND TOTAL WEIGHT OF PIPETTE
          C  FRACTIONS (DIF AND DIFTOT RESPECTIVELY)
          C                                                               A  69
000145          DO 190 I=1,6                                              A  70
000147          READ (5,490) GROSS(I),TARE(I)                             A  71
000156          PIPET(I)=GROSS(I)-TARE(I)                                 A  72
000161          PIPTOT=PIPTOT+PIPET(I)                                    A  73
000163    190   CONTINUE                                                  A  74
          C                                                               A  75
          C     GET THE DIFFRENCES                                        A  76
          C                                                               A  77
000165          DO 210 I=1,5                                              A  78
000166          J=I+1                                                     A  79
000170          DIF(I)=PIPET(I)-PIPET(J)                                  A  80
000173          DEM=PIPET(J)/PIPFRA
000175          IF (DIF(I)) 230,200,200                                   A  81
000176    200   CONTINUE                                                  A  82
000176    210   CONTINUE                                                  A  83
000200          DIFTOT=0.                                                 A  84
000201          DO 220 I=1,5                                              A  85
000203          DIF(I)=DIF(I)/PIPFRA                                      A  86
000205          DIFTOT=DIFTOT+DIF(I)                                      A  87
000207    220   CONTINUE                                                  A  88
          C
          C CHECK TO SEE IF EITHER PAN WEIGHT OR SAMPLE WEIGHT IS MISSING
          C AND CALCULATE TOTAL WEIGHT BASED ON SUM OF FREQUENCIES.
          C
000211          JMP=1                                                     A  99
000212          IF (SAMPWT.GT.0.0) JMP=3                                  A 100
000214          IF (PANWT.GT.0.0) JMP=4                                   A 101
000217          IF (SAMPWT.GT.0.0.AND.PANWT.GT.0.0) JMP=2                 A 102
000230          GO TO (230,260,240,250), JMP                              A 103
000240    230   WRITE (6,500) (TITLE(I,1),I=1,12)                         A 104
000252          GO TO 100                                                 A 105
000253    240   PANWT=SAMPWT-PSAMPWT                                      A 106
000255          GO TO 260                                                 A 107
000256    250   SAMPWT=PANWT+PSAMPWT                                      A 108
000260    260   CONTINUE                                                  A 109
000260          COFAC=PANWT/(PIPET(1)/PIPFRA)
          C
          C     ADJUST PIPETTE FRACTIONS TO TOTAL UP TO PAN WEIGHT.
          C
000263          DO 270 I=1,M                                              A 110
000264          L=I+K                                                     A 111
000266          WEIGHT(L)=DIF(I)                                          A 112
000270    270   CONTINUE                                                  A 113
000272    280   DO 290 I=1,K                                              A 114
000274          SIZ(I,1)=SIZE(I)$WG(I,1)=SIEVE(I)                         A 115
000277    290   CONTINUE                                                  A 116
000301          JO=NO                                                     A 117
000303          IF (K.NE.NO) 300,320                                      A 118
000306    300   CONTINUE                                                  A 119
000306          JO=NO-1                                                   A 120
000310          DO 310 I=IL,JO                                            A 121
000312          SIZ(I,1)=SIZE(I) $ WG(1,1)=WEIGHT(I)*COFAC
```

```
000316   310   CONTINUE                                                    A 123
         C
         C  NOW ALL SIZE CLASSES AND CORRESPONDING FREQUENCIES ARE STORED IN
         C  THESE ARRAYS AND READY FOR TRANSFER TO SUBROUTINE PROBPLT.
         C
000320   320   CONTINUE                                                    A 124
000320         GRAV=0.0                                                    A 125
000321         XSTART=START                                                A 126
000323         I=1                                                         A 127
000324   330   IF (XSTART.GT.-1.0) GO TO 340                               A 128
000330         GRAV=GRAV+SIEVE(I)                                          A 129
000332         XSTART=XSTART+PHINT                                         A 130
000334         I=I+1                                                       A 131
000335         GO TO 330                                                   A 132
000335   340   CONTINUE                                                    A 133
000335         SAMPLE=PSAMPWT+PANWT                                        A 134
000337         FINES=PANWT                                                 A 135
000340         XXTOT=SAMPLE                                                A 136
000342         GRAV=(GRAV/XXTOT)*100.0                                     A 137
000344         XSAND=((PSAMPWT/XXTOT)*100.0)-GRAV                          A 138
000346         MO=JO+1$MV=1                                                A 139
000351         DEM=(DEM*COFAC)/(SAMPLE*0.01)
000355   350   REM=FINES-DIFTOT                                           A 141
000357         IF (REM.LE.0.0) GO TO 380                                   A 142
000361         XY=(REM/SAMPLE)*100.0                                       A 143
         C
         C  IF MORE THAN 10% OF THE FINES ARE UNACCOUNTED FOR BY THE PIPETTE
         C  ANALYSIS, THEN THE REMAINDER IS ASSIGNED TO THE END OF THE DISTRIB-
         C  UTION BY THE FOLLOWING METHOD.
         C
000364         IF (XY-10.0) 370,370,360                                    A 144
000366   360   WG(MO,1)=REM/2.0                                            A 145
000371         SIZ(MO,1)=SIZE(JO)+FLOAT(MV)                                A 146
000374         DIFTOT=DIFTOT+WG(MO,1)                                      A 147
000376         MV=MV+1                                                     A 148
000377         MO=MO+1                                                     A 149
000400         GO TO 350                                                   A 150
000400   370   CONTINUE                                                    A 151
000400         MOL=MO-JO                                                   A 152
000402         IF (MOL.EQ.1) GO TO 380                                     A 153
000404         IF (MOL.GE.2) JO=MO-1                                       A 154
000407   380   CONTINUE                                                    A 155
000407         IF (K.NE.NO) GO TO 390                                      A 156
000411         SILT=FINES                                                  A 157
000413         CLAY=0.0                                                    A 158
000414         GO TO 400                                                   A 159
000414   390   CONTINUE                                                    A 160
000414         SILCL=PANWT/(SAMPLE* 0.01)
000417         CLAY=((PIPET(5)/PIPFRA)*COFAC)/(SAMPLE*0.01)
000425         SILT=SILCL-CLAY
000427   400   CONTINUE                                                    A 164
000427         CALL PROBPLT(SIZ,WG,JO,0,0,1,0,TITLE,TP)
000440         WRITE (6,440)                                               A 169
000444         DO 410 J=2,JO
000446         JPC=J-1
000450         FREQ(JPC)=TP(J)
000452     410 CONTINUE
000454         CALL MODE(SIZ,FREQ,TITLE,JO,PHINT)                          A 170
000460         WRITE (6,450) GRAV,XSAND,SILT,CLAY                          A 171
000474         CALL BRESLAU (GRAV,XSAND,SILT,CLAY)                         A 172
000477         IF (K.EQ.NO) GO TO 420                                      A 173
000501         WRITE (6,460) DEM                                           A 174
000507   420   CONTINUE                                                    A 175
000507         GO TO 100                                                   A 176
000510   430   CALL EXIT                                                   A 177
         C     THE FOLLOWING ARE THE FORMATS USED                          A 178
         C                                                                 A 179
```

```
000511   440    FORMAT (///)                                                    A 180
000511   450    FORMAT (//*    GRAVEL*,*       SAND*,*       SILT*,*       CLAY*,//4F  A 181
               110.2)                                                          A 182
000511   460    FORMAT (1H0,*THE RESIDUAL LESS THAN 9 PHI IS *,F10.4,* PERCENT*)  A 183
000511   470    FORMAT (12A2,4X,I6,F7.2)                                        A 184
000511   480    FORMAT (I3,F5.2,2X,F10.4,12X,2F10.4,F8.2,I4)                    A 185
000511   490    FORMAT (8F10.4)                                                 A 186
000511   500    FORMAT (*                    DATA SET  *12A2*  IMPOSSIBLE TO SOLVE*//  A 187
               1* *10X,*NIETHER SAMPLE WEIGHT OR PAN WEIGHT GIVEN     */*1*)   A 188
000511          END                                                            A 189-

UNUSED COMPILER SPACE
021100


                SUBROUTINE PROBPLT(SIZ,WG,NO,IPR,IPHI,IRTN,ICL,TIT,TP)
         C      PROGRAM PLOTS (PHI IF DESIRED) DATA ON PROB. SCALE.  LINEAR     B   2
         C      REGRESSION PLOT TO SHOW GOODNESS OF FIT TO NORMAL DISTRIBUTION,  B   3
         C      CALCULATES 1, 2, 3 MOMENTS.                                     B   4
         C                                                                      B   5
000014          DIMENSION          SIZ(60,10), WG(60,10), TIT(12,10), X(27), Y(60,2  B   6
               10), N(5),          BCD(13),          XX(60), YY(60), RC(10), S(10),  B   7
               2 AA(10), XM(60), XMO(30,12), TP(60)                             B   8
000014          DATA BCD/1HX,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0/               B   9
000014          DATA X/50.,53.98,57.93,61.79,65.54,69.15,72.57,75.80,78.81,81.59,8  B  10
               14.13,86.43,88.49,90.32,91.92,93.32,94.52,95.54,96.41,97.13,97.72,9  B  11
               28.21,98.61,98.93,99.18,99.38,99.53/                             B  12
000014          ND=1                                                            B  13
000015          DO 20 I=1,ND                                                    B  14
000016          TOT=0.                                                          B  15
000017          DO 10 K=1,NO                                                    B  16
000021          TOT=TOT+WG(K,I)                                                 B  17
000026   10     CONTINUE                                                        B  18
000030          A=99.53/TOT                                                     B  19
000032          SUM=0.                                                          B  20
000033          DO 20 K=1,NO                                                    B  21
000034          SUM=SUM+WG(K,I)*A                                               B  22
000042          WG(K,I)=SUM                                                     B  23
000046   20     CONTINUE                                                        B  24
000052          DO 90 I=1,ND                                                    B  25
000053          DO 90 K=1,NO                                                    B  26
000054          IF (WG(K,I)-50.) 30,50,40                                       B  27
000062   30     VAL=99.53-WG(K,I)                                               B  28
000070          XL=-1.                                                          B  29
000071          GO TO 60                                                        B  30
000072   40     VAL=WG(K,I)                                                     B  31
000077          XL=1.                                                           B  32
000100          GO TO 60                                                        B  33
000101   50     Y(K,I)=0.                                                       B  34
000105          GO TO 90                                                        B  35
000105   60     DO 80 L=1,27                                                    B  36
000107          IF (X(L)-VAL) 80,70,70                                          B  37
000112   70     XK=L-2                                                          B  38
000115          IF (L.EQ.1) GO TO 50                                            B  39
000117          Y(K,I)=(XK+(VAL-X(L-1))/(X(L)-X(L-1)))*XL                       B  40
000132          GO TO 90                                                        B  41
000133   80     CONTINUE                                                        B  42
000135          Y(K,I)=26.00                                                    B  43
000141   90     CONTINUE                                                        B  44
000146          DO 110 I=1,ND                                                   B  45
000150          DO 100 K=1,NO                                                   B  46
000151          XX(K)=Y(K,I)                                                    B  47
000155          YY(K)=SIZ(K,I)                                                  B  48
000161   100    CONTINUE                                                        B  49
000163          CALL REL (XX,YY,NO,R,SL,A)                                      B  50
000166          RC(I)=R                                                         B  51
000170          S(I)=SL                                                         B  52
000172          AA(I)=A                                                         B  53
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```
000173   110   CONTINUE                                                B  54
000201         DO 150 I=1,ND                                           B  55
000203         FAC=1./(99.53-WG(1,I))                                  B  56
000210         FACO=98.53-WG(1,I)                                      B  57
000214         FACT=97.53-WG(1,I)                                      B  58
000220         FACH=96.53-WG(1,I)                                      B  59
000224         DO 120 K=1,6                                            B  60
000225         XMO(I,K)=0.                                             B  61
000231   120   CONTINUE                                                B  62
000233         DO 130 K=2,NO                                           B  63
000234         XM(K)=(SIZ(K,I)+SIZ(K-1,I))*.5                          B  64
000245         TP(K)=WG(K,I)-WG(K-1,I)                                 B  65
000252         XMO(I,1)=XMO(I,1)+TP(K)*XM(K)                           B  66
000260   130   CONTINUE                                                B  67
000262         XMO(I,1)=XMO(I,1)*FAC                                   B  68
000264         DO 140 K=2,NO                                           B  69
000266         XMO(I,3)=XMO(I,3)+TP(K)*(XM(K)-XMO(I,1))                B  70
000275         XMO(I,4)=XMO(I,4)+TP(K)*(XM(K)-XMO(I,1))**2             B  71
000306         XMO(I,5)=XMO(I,5)+TP(K)*(XM(K)-XMO(I,1))**3             B  72
000317         XMO(I,6)=XMO(I,6)+TP(K)*(XM(K)-XMO(I,1))**4             B  73
000330   140   CONTINUE                                                B  74
000332         XMO(I,4)=XMO(I,4)/FACO                                  B  75
000334         XMO(I,2)=SQRT(XMO(I,4))                                 B  76
000342         XMO(I,5)=XMO(I,5)/(FACT*XMO(I,4)*XMO(I,2)*2.)           B  77
000347         XMO(I,6)=XMO(I,6)/(FACH*XMO(I,4)**2)-3.                 B  78
000353         XMO(I,3)=XMO(I,3)*FAC                                   B  79
000355   150   CONTINUE                                                B  80
000363         N(1)=1                                                  B  81
000364         N(2)=0                                                  B  82
000365         N(3)=2                                                  B  83
000366         N(4)=0                                                  B  84
000367         N(5)=1                                                  B  85
000370         SIMA=SIZ(1,1)                                           B  86
000371         SIMI=SIZ(1,1)                                           B  87
000372         DO 190 I=1,ND                                           B  88
000374         DO 190 K=1,NO                                           B  89
000375         IF (SIZ(K,I)-SIMA) 170,190,160                          B  90
000403   160   SIMA=SIZ(K,I)                                           B  91
000410         GO TO 190                                               B  92
000410   170   IF (SIZ(K,I)-SIMI) 180,190,190                          B  93
000416   180   SIMI=SIZ(K,I)                                           B  94
000423   190   CONTINUE                                                B  95
000430         L=SIMI                                                  B  96
000432         IF (L) 200,210,210                                      B  97
000434   200   L=L-1                                                   B  98
000436   210   SI=L                                                    B  99
000440         L=SIMA                                                  B 100
000442         IF (L) 220,230,230                                      B 101
000443   220   SA=L                                                    B 102
000445         GO TO 240                                               B 103
000445   230   SA=L+1                                                  B 104
000450   240   L=SA-SI+1                                               B 105
000455         LC=9                                                    B 106
000456         IF (L.GT.6) LC=4                                        B 107
000461         CALL PLOT1 (N,L,LC,104,0)                               B 108
000465         CALL PLOT2 (26.,-26.,SA,SI)                             B 109
000470         DO 260 I=1,ND                                           B 110
000475         DO 250 J=1,NO                                           B 111
000476         XX(J)=Y(J,I)                                            B 112
000502         YY(J)=SIZ(J,I)                                          B 113
000506   250   CONTINUE                                                B 114
000510         CALL PLOT3 (BCD(I),XX,YY,NO)                            B 115
000516   260   CONTINUE                                                B 116
000524         WRITE (6,300)                                           B 117
000530         CALL OMIT (0,1,0,1)                                     B 118
000533         CALL PLOT3 (1H1,-23.3,SA,1)                             B 119
000536         CALL PLOT3 (1H1,-23.3,SI,1)                             B 120
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000541          CALL PLOT3 (1H9,23.3,SI,1)                                      B 121
000544          CALL PLOT3 (1H9,23.3,SA,1)                                      B 122
000547          CALL PLOT3 (1H5,16.45,SA,1)                                     B 123
000552          CALL PLOT3 (1H5,16.45,SI,1)                                     B 124
000555          CALL PLOT3 (1H5,-16.45,SI,1)                                    B 125
000560          CALL PLOT3 (1H5,-16.45,SA,1)                                    B 126
000563          CALL PLOT3 (1H9,12.83,SA,1)                                     B 127
000566          CALL PLOT3 (1H9,12.83,SI,1)                                     B 128
000571          CALL PLOT3 (1H1,-12.83,SI,1)                                    B 129
000574          CALL PLOT3 (1H1,-12.83,SA,1)                                    B 130
000577          CALL PLOT3 (1H2,-8.44,SA,1)                                     B 131
000602          CALL PLOT3 (1H2,-8.44,SI,1)                                     B 132
000605          CALL PLOT3 (1H8,8.44,SI,1)                                      B 133
000610          CALL PLOT3 (1H8,8.44,SA,1)                                      B 134
000613          CALL PLOT3 (1H3,-5.244,SA,1)                                    B 135
000616          CALL PLOT3 (1H3,-5.244,SI,1)                                    B 136
000621          CALL PLOT3 (1H7,5.244,SI,1)                                     B 137
000624          CALL PLOT3 (1H7,5.244,SA,1)                                     B 138
000627          CALL PLOT3 (1H4,-2.533,SA,1)                                    B 139
000632          CALL PLOT3 (1H4,-2.533,SI,1)                                    B 140
000635          CALL PLOT3 (1H6,2.533,SI,1)                                     B 141
000640          CALL PLOT3 (1H6,2.533,SA,1)                                     B 142
000643          CALL PLOT3 (1H5,0.,SA,1)                                        B 143
000646          CALL PLOT3 (1H5,0.,SI,1)                                        B 144
000651          CALL PLOT4 (34,34H                                PHI)          B 145
000653          WRITE (6,310)                                                   B 146
000657          DO 270 I=1,ND                                                   B 147
000664          WRITE (6,320)    (TIT(K,I),K=1,12),(XMO(I,K),K=1,6)             B 148
000706    270   CONTINUE                                                        B 149
000714          IF (IRTN) 280,290,280                                           B 150
000715    280   RETURN                                                          B 151
000716    290   STOP                                                            B 152
          C                                                                     B 153
000720    300   FORMAT (1H1,27X,80HCUMULATIVE PLOT VS PHI (PROBABILITY SCALE).  GR B 154
               1APH ENDS = 99.53 AND 0.47 PERCENT)                              B 155
000720      310 FORMAT(1H0,103X,26H    MOMENT       MEASURES  ,/6X,
               122H SAMPLE IDENTIFICATION,55X,17HMEAN   STD DEV   ,3X,1H1,
               28X,1H2,8X,1H3,8X,1H4//)
000720    320   FORMAT (1H ,3X,2X,12A2,48X,6F9.3)                               B 158
000720          END                                                             B 159-

UNUSED COMPILER SPACE
017700


                SUBROUTINE REL (XX,YY,NO,R,SL,A)                                C   1
000011          DIMENSION XX(60), YY(60)                                        C   2
000011          SXY=0.                                                          C   3
000011          SX=0.                                                           C   4
000012          SY=0.                                                           C   5
000013          SXX=0.                                                          C   6
000014          SYY=0.                                                          C   7
000015          ANO=NO                                                          C   8
000017          DO 10 M=1,NO                                                    C   9
000021          SX=SX+XX(M)                                                     C  10
000023          SY=SY+YY(M)                                                     C  11
000025          SXY=SXY+XX(M)*YY(M)                                             C  12
000031          SXX=SXX+XX(M)**2                                                C  13
000033          SYY=SYY+YY(M)**2                                                C  14
000036    10    CONTINUE                                                        C  15
000040          R=(ANO*SXY-SX*SY)/SQRT((ANO*SXX-SX*SX)*(ANO*SYY-SY*SY))         C  16
000057          SL=(SXY-SX*SY/ANO)/(SXX-SX*SX/ANO)                              C  17
000066          RETURN                                                          C  18
000067          END                                                             C  19-

UNUSED COMPILER SPACE
023200
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                SUBROUTINE PLOT1 (NSCALE,NLH,NSBH,NLV,NSBV)                     D   1
          C     PRINTER PLOT SUBROUTINE PACKAGE      FEBRARY 24,1969        FGW  D   2
          C     THIS SUBROUTINE PACKAGE WILL PRODUCE PLOTS ON THE PRINTER OF THE  D   3
          C     CDC 6400.  PACKAGE CONSISTS OF 4 BASIC SUBROUTINES AND OTHERS     D   4
          C     WHICH ALLOW FOR VARIOUS OPTIONS                                   D   5
          C     USUAL CALLING SEQUENCE IS PLOT1, PLOT2, PLOT3, PLOT4 FOR EACH PLOT D   6
          C     PLOT1 DESCRIBES GRID OF PLOT.  IF PLOT1 IS NOT CALLED, DEFAULT    D   7
          C     VALUES ARE ASSIGNED - N(1)=0, LH=6, NPH=9, LV=12, NPV=9           D   8
          C     IF ARGUEMENTS FOR PLOT1 ARE TO BE THE SAME AS FOR PREVIOUS PLOT,  D   9
          C     PLOT1 NEED NOT BE CALLED.                                         D  10
          C     N IS AN INTEGER ARRAY (5).  IF N(1)=0, N(2)=N(4)=0 AND N(3)=N(5)=3 D  11
          C        N(2) = J VALUES PRINTED FOR Y ARE 10**J TIMES THEIR TRUE VALUE. D  12
          C        N(3) - NUMBER OF DECIMAL PLACES PRINTED FOR VALUES ON Y - AXIS D  13
          C        N(4) AND N(5) ARE FOR X AS N(2) AND N(3) ARE FOR Y.            D  14
          C     LH - NUMBER OF HORIZONTAL LINES (LH NUMBERS ARE PRINTED ON Y-AXIS) D  15
          C     NPH - NUMBER OF POSITIONS BETWEEN HORIZONTAL LINES                D  16
          C     LV AND NPV ARE FOR X AS LH AND NPH ARE FOR Y                      D  17
000010          COMMON /P14/ N,LH,NPH,LV,NPV/P13S/ILOG/P140/OMIT/P1234/LC1,LC2,LC3 D  18
000010          DIMENSION OMIT(4), N(5), NSCALE(5)                                D  19
000010          INTEGER OMIT                                                      D  20
000010          DO 10 I=1,5                                                       D  21
000011          N(I)=NSCALE(I)                                                    D  22
000013    10    CONTINUE                                                          D  23
000015          LH=NLH                                                            D  24
000015          NPH=NSBH                                                          D  25
000016          LV=NLV                                                            D  26
000017          NPV=NSBV                                                          D  27
000020          IF (N(1)) 30,20,30                                                D  28
000022    20    N(2)=N(4)=0                                                       D  29
000026          N(3)=N(5)=3                                                       D  30
          C     INITIALIZATION                                                    D  31
000032    30    ILOG=1                                                            D  32
000033          OMIT(1)=OMIT(2)=OMIT(3)=OMIT(4)=1                                 D  33
000045          LC1=999                                                           D  34
000046          RETURN                                                            D  35
000047          END                                                               D  36-

UNUSED COMPILER SPACE
023200


                SUBROUTINE PLOT2 (XMAXI,XMINI,YMAXI,YMINI)                      E   1
          C     PLOT2 SETS MAXIMUM AND MINIMUM VALUES FOR X AND Y                 E   2
          C     IF PLOT1 HAS NOT BEEN CALLED, PLOT2 ASSIGNS DEFAULT VALUES FOR    E   3
          C        PLOT1 PARAMETERS                                               E   4
000007          COMMON /P234/ XMAX,XMIN,YMAX,YMIN,IC/P1234/LC1,LC2,LC3            E   5
000007          DIMENSION N(5)                                                    E   6
000007          XMAX=XMAXI                                                        E   7
000007          XMIN=XMINI                                                        E   8
000010          YMAX=YMAXI                                                        E   9
000011          YMIN=YMINI                                                        E  10
          C     INITIALIZATION                                                    E  11
000012          IF ((LC1.EQ.999).OR.(LC1.EQ.888)) GO TO 10                        E  12
000022          N(1)=0                                                            E  13
000023          CALL PLOT1 (N,6,9,12,9)                                           E  14
000026    10    IC=0                                                              E  15
000027          LC2=999                                                           E  16
000030          RETURN                                                            E  17
000031          END                                                               E  18-

UNUSED COMPILER SPACE
023300
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                SUBROUTINE PLOT3 (GBCD,GX,GY,N)                                 F   1
        C       PLOT3 COLLECTS THE X AND Y CORDINATES AND THE BCD CHARACTER TO BE  F   2
        C       PRINTED AT THESE POINTS.                                        F   3
        C       PLOT3 MAY BE CALLED ANY NUMBER OF TIMES BEFORE PLOT4 FOR ONE PLOT  F   4
000007          DIMENSION GX(N), GY(N), X(1000), Y(1000), BCD(1000)             F   5
000007          COMMON /P13S/ ILOG/P234/XMAX,XMIN,YMAX,YMIN,IC/P34/X,Y,BCD/P1234/L  F   6
               1C1,LC2,LC3                                                      F   7
000007          DO 80 I=1,N                                                     F   8
000010          J=IC+I                                                          F   9
000011          BCD(J)=GBCD                                                     F  10
000013          X(J)=GX(I)                                                      F  11
000015          Y(J)=GY(I)                                                      F  12
000017          IF (LC2.NE.999) GO TO 30                                        F  13
        C       CHECK IF X AND Y ARE WITHIN STATED RANGE, IF NOT, IGNORE.       F  14
000022          BX=XMAX                                                         F  15
000023          SX=XMIN                                                         F  16
000024          BY=YMAX                                                         F  17
000026          SY=YMIN                                                         F  18
000027          IF (BX.GT.SX) GO TO 10                                          F  19
000033          BX=XMIN                                                         F  20
000033          SX=XMAX                                                         F  21
000034   10     IF (BY.GT.SY) GO TO 20                                          F  22
000040          BY=YMIN                                                         F  23
000040          SY=YMAX                                                         F  24
000042   20     IF ((X(J).LE.BX.AND.X(J).GE.SX).AND.(Y(J).LE.BY.AND.Y(J).GE.SY)) G  F  25
               10 TO 30                                                         F  26
000066          IC=IC-1                                                         F  27
000070          GO TO 80                                                        F  28
000070   30     GO TO (80,40,50,60), ILOG                                       F  29
000100   40     IF (X(J).LE.0) GO TO 70                                         F  30
000102          X(J)=ALOG10(X(J))                                               F  31
000106          GO TO 80                                                        F  32
000111   50     IF (Y(J).LE.0) GO TO 70                                         F  33
000113          Y(J)=ALOG10(Y(J))                                               F  34
000117          GO TO 80                                                        F  35
000122   60     IF (X(J).LE.0.OR.Y(J).LE.0) GO TO 70                            F  36
000133          X(J)=ALOG10(X(J))                                               F  37
000136          Y(J)=ALOG10(Y(J))                                               F  38
000146          GO TO 80                                                        F  39
000151   70     WRITE (6,90) GX(I),GY(I),GBCD                                   F  40
000171          IC=IC-1                                                         F  41
000173   80     CONTINUE                                                        F  42
000200          IC=IC+N                                                         F  43
000201          LC3=999                                                         F  44
000202          RETURN                                                          F  45
        C                                                                       F  46
000202   90     FORMAT (49H ATTEMPT TO FIND LOG OF ZERO OR A NEGATIVE NUMBER,2F20.  F  47
               18,12HTHIS POINT (,A1,21H) WILL NOT BE PLOTTED)                  F  48
000202          END                                                             F  49-

UNUSED COMPILER SPACE
022500


                SUBROUTINE PLOT4 (NC,LABEL)                                     G   1
        C       PLOT4 PLOTS POINTS COLLECTED BY PLOT3 AND PRINTS THEM ON A GRAPH   G   2
        C       DESCRIBED BY PLOT1 AND PLOT2.                                   G   3
000005          INTEGER OMIT                                                    G  11
000005          DIMENSION LABEL(NC), YLINE(125), XAXIS(125), FMT1(2), FMT2(2), FMT  G   4
               13(5), FMT4(2), OMIT(4), N(5), X(1000), Y(1000), BCD(1000), XSCALE(  G   5
               2100)                                                            G   6
000005          COMMON /P14/ N,LH,NPH,LV,NPV/P140/OMIT/P234/XMAX,XMIN,YMAX,YMIN,IC  G   7
               1/P34/X,Y,BCD/P13S/ILOG/P1234/LC1,LC2,LC3/P1A4/XINC,YINC         G   8
000005          DATA AST/1H*/,BLANK/1H /,PLUS/1H+/,FMT3(2)/10H,5H=XMIN,F/,FMT3(5)/  G   9
               110HH=XINC)    /                                                 G  10
000005          IF (LC2.EQ.999.AND.LC3.EQ.999) GO TO 30                         G  12
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000013          IF ((LC3.EQ.999).AND.(IC.GT.0)) GO TO 10                G  13
000022          IF (LC2.EQ.999) GO TO 20                                G  14
000023          WRITE (6,420)                                           G  15
000027          GO TO 390                                               G  16
000031    10    WRITE (6,430) (X(I),Y(I),BCD(I),I=1,IC)                 G  17
000055          GO TO 390                                               G  18
000057    20    WRITE (6,440)                                           G  19
000063          GO TO 390                                               G  20
          C     ARRANGE X,Y, AND BCD IN DESCENDING ORDER OF Y           G  21
000065    30    ICOUNT=IC-1                                             G  22
000067          DO 60 I=1,ICOUNT                                        G  23
000071          TY=Y(I)                                                 G  24
000072          TX=X(I)                                                 G  25
000074          TBCD=BCD(I)                                             G  26
000075          JI=I+1                                                  G  27
000077          DO 60 J=JI,IC                                           G  28
000100          IF (YMAX.GT.YMIN) GO TO 40                              G  29
000103          IF (Y(J).GE.TY) GO TO 60                                G  30
000106          GO TO 50                                                G  31
000106    40    IF (Y(J).LE.TY) GO TO 60                                G  32
000111    50    Y(I)=Y(J)                                               G  33
000114          Y(J)=TY                                                 G  34
000115          TY=Y(I)                                                 G  35
000116          X(I)=X(J)                                               G  36
000120          X(J)=TX                                                 G  37
000122          TX=X(I)                                                 G  38
000123          BCD(I)=BCD(J)                                           G  39
000125          BCD(J)=TBCD                                             G  40
000126          TBCD=BCD(I)                                             G  41
000127    60    CONTINUE                                                G  42
          C     CENTER GRAPH ON PAGE                                    G  43
000134          IF (LC1.EQ.999) GO TO 70                                G  45
000136          LH=ABS(YMAX-YMIN)/(YINC*(NPH+1))+1                      G  46
000147          LV=ABS(XMAX-XMIN)/(XINC*(NPV+1))+1                      G  47
000161    70    JJJ=(LH-1)*(NPH+1)+1                                    G  48
000165          RJJ=JJJ                                                 G  49
000166          IF (JJJ.GE.58) GO TO 90                                 G  50
000171          LSKIP=(60.-RJJ)/2.                                      G  51
000175          DO 80 L=1,LSKIP                                         G  52
000177          WRITE (6,450)                                           G  53
000202    80    CONTINUE                                                G  54
000206    90    KKK=(LV-1)*(NPV+1)+1                                    G  55
000212          RKK=KKK                                                 G  56
000213          MMM=(136.-RKK)/2.                                       G  57
000217          LLL=MMM-10                                              G  58
000221          GO TO (130,100,110,120), ILOG                           G  59
000231    100   XMAX=ALOG10(XMAX)                                       G  60
000233          XMIN=ALOG10(XMIN)                                       G  61
000236          GO TO 130                                               G  62
000240    110   YMAX=ALOG10(YMAX)                                       G  63
000242          YMIN=ALOG10(YMIN)                                       G  64
000245          GO TO 130                                               G  65
000247    120   XMAX=ALOG10(XMAX)                                       G  66
000251          XMIN=ALOG10(XMIN)                                       G  67
000253          YMAX=ALOG10(YMAX)                                       G  68
000255          YMIN=ALOG10(YMIN)                                       G  69
000260    130   IF (LC1.EQ.888) GO TO 140                               G  70
000264          XINC=ABS(XMAX-XMIN)/(RKK-1.)                            G  71
000270          YINC=ABS(YMAX-YMIN)/(RJJ-1.)                            G  72
000275    140   J=1                                                     G  73
000276          NY=N(3)                                                 G  74
000277          NX=N(4)                                                 G  75
          C     OBJECT TIME FORMATS ENCODED                             G  76
000301          ENCODE (10,460,FMT1(1) )LLL                             G  77
000312          ENCODE (10,470,FMT1(2) )NY                              G  78
000324          ENCODE (10,480,FMT2(1) )MMM                             G  79
000336          ENCODE (10,490,FMT2(2) )KKK                             G  80
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000350          ENCODE (10,500,FMT3(1) )NX                                  G  81
000362          ENCODE (10,510,FMT3(3) )NX                                  G  82
000374          ENCODE (10,520,FMT3(4) )NX                                  G  83
        C       PRINT PLOT - ONE LINE AT A TIME                             G  84
000406          PY=YMAX+YINC                                                G  85
000410          NY=NY+4                                                     G  86
000412          PPY=YMAX                                                    G  87
000413          DO 150 I=1,KKK                                              G  88
000416          YLINE(I)=1H                                                 G  89
000420          XAXIS(I)=1H*                                                G  90
000421   150    CONTINUE                                                    G  91
000423          NPVC=NPV+1                                                  G  92
000425          DO 160 I=1,KKK,NPVC                                         G  93
000427          XAXIS(I)=1H+                                                G  94
000431   160    CONTINUE                                                    G  95
000433          IF (OMIT(1).EQ.0) GO TO 180                                 G  96
000434          DO 170 I=1,KKK                                              G  97
000435          YLINE(I)=XAXIS(I)                                           G  98
000437   170    CONTINUE                                                    G  99
000441   180    PY=PY-YINC                                                  G 100
000443          IF (YMAX.GT.YMIN) GO TO 190                                 G 101
000447          IF (PY.LT.PPY) GO TO 220                                    G 102
000451          GO TO 200                                                   G 103
000451   190    IF (PY.GT.PPY) GO TO 220                                    G 104
000455   200    IF (OMIT(4)) 210,220,210                                    G 105
000456   210    WRITE (6,FMT1) PPY                                          G 106
000464          RNPH=NPH+1                                                  G 107
000466          PPY=PPY-RNPH*YINC                                           G 108
000472   220    IF (.NOT.((PY.GT.(YMIN-YINC/2.)).AND.(PY.LT.(YMIN+YINC/2.)))) GO T  G 109
               10 250                                                       G 110
000507          IF (OMIT(3)) 230,250,230                                    G 111
000510   230    DO 240 I=1,KKK                                              G 112
000512          YLINE(I)=XAXIS(I)                                           G 113
000514   240    CONTINUE                                                    G 114
000516          GO TO 310                                                   G 115
000516   250    IF (PY.EQ.YMAX) GO TO 270                                   G 116
000520          DO 260 I=1,125                                              G 117
000522          YLINE(I)=1H                                                 G 118
000524   260    CONTINUE                                                    G 119
000525   270    CONTINUE                                                    G 120
000525          IF (OMIT(4)) 280,290,280                                    G 121
000526   280    YLINE(1)=1H*                                                G 122
000527          IF (ABS(PY-PPY+RNPH*YINC).LE.1.*10**(-8)) YLINE(1)=1H+      G 123
000546   290    IF (OMIT(2)) 300,310,300                                    G 124
000547   300    YLINE(KKK)=YLINE(1)                                         G 125
000551   310    IF (J.GT.IC) GO TO 320                                      G 126
000555          IF (Y(J).LT.(PY+YINC/2.).AND.(Y(J).GE.(PY-YINC/2.))) GO TO 400  G 127
000571   320    WRITE (6,FMT2) (YLINE(K),K=1,KKK)                           G 128
000605          IF ((YMAX.GT.YMIN).AND.(PY.GT.YMIN)) GO TO 180              G 129
000620          IF ((YMIN.GT.YMAX).AND.(PY.LT.YMIN)) GO TO 180              G 130
        C       PRINT SCALE FOR X-AXIS                                      G 131
000627          IF (OMIT(3).EQ.0) GO TO 380                                 G 132
000630          DO 330 J=1,10                                               G 133
000631          J1=J                                                        G 134
000632          IF (XMAX.LT.10.**J) GO TO 340                               G 135
000637   330    CONTINUE                                                    G 137
000641          GO TO 360                                                   G 138
000641   340    NP=NX+J1+1                                                  G 139
000643          IF (NX.EQ.0) NP=J1                                          G 140
000646          RNPV=NPV+1                                                  G 141
000650          XSPACE=RNPV*XINC                                            G 142
000652          DO 350 J=1,LV                                               G 143
000653          R=J-1                                                       G 144
000655          XSCALE(J)=XMIN+R*XSPACE                                     G 145
000660   350    CONTINUE                                                    G 146
000663          NS=NPV-NP+1                                                 G 147
000665          IF (NS.LE.0) GO TO 360
```

```
000667          IF ((MMM+LV*(NP+NS)).LE.136) GO TO 370                          G 148
000674    360   CONTINUE                                                        G 149
000674          GO TO 380                                                       G 150
000675    370   ENCODE (10,530,FMT4(1) )MMM,LV                                  G 151
000710          ENCODE (10,540,FMT4(2) )NP,NX,NS                                G 152
000726          WRITE (6,FMT4) (XSCALE(J),J=1,LV)                               G 153
000743    380   IF (N(2).EQ.0.AND.N(4).EQ.0) GO TO 390                          G 154
000752          WRITE (6,550) N(2),N(4)                                         G 155
000763    390   IC=0                                                            G 156
000764          RETURN                                                          G 158
          C     PLOT (X,Y) IN YLINE                                             G 159
000765    400   PX=XMIN-XINC                                                    G 160
000767          DO 410 I=1,KKK                                                  G 161
000772          PX=PX+XINC                                                      G 162
000774          IF (X(J).GE.(PX+XINC/2.).OR.(X(J).LT.(PX-XINC/2.))) GO TO 410   G 163
001011          YLINE(I)=BCD(J)                                                 G 164
001014          J=J+1                                                           G 165
001015          GO TO 310                                                       G 166
001016    410   CONTINUE                                                        G 167
001021          WRITE (6,560) X(J),Y(J),BCD(J)                                  G 168
001040          J=J+1                                                           G 169
001042          GO TO 310                                                       G 170
          C                                                                     G 171
001044    420   FORMAT (56H PLOT2 AND PLOT3 ARE NOT ENTERED. PLOT4 CAN NOT PROCEDE G 172
               1.)                                                              G 173
001044    430   FORMAT (79H PLOT2 IS NOT ENTERED. PLOT4 CAN NOT PROCEDE. X-Y VALUE G 174
               1S COLLECTED IN PLOT3 ARE/(1H ,5(2F10.5,2X,A1,3X)))              G 175
001044    440   FORMAT (45H PLOT3 IS NOT ENTERED. PLOT4 CAN NOT PROCEDE.)       G 176
001044    450   FORMAT (1H )                                                    G 177
001044    460   FORMAT (5H(1H+,,I3,2HX,)                                        G 178
001044    470   FORMAT (4HF10.,I1,5H)     )                                     G 179
001044    480   FORMAT (5H(1H ,,I3,2HX,)                                        G 180
001044    490   FORMAT (I3,7HA1)     )                                          G 181
001044    500   FORMAT (9H(1H0,F40.,I1)                                         G 182
001044    510   FORMAT (3H40.,I1,6H,5H=XM)                                      G 183
001044    520   FORMAT (7HAX,F40.,I1,2H,5)                                      G 184
001044    530   FORMAT (1H(,I2,2HX,,I3,2H(F)                                    G 185
001044    540   FORMAT (I2,1H.,I1,1H,,I2,3HX)))                                 G 186
001044    550   FORMAT (16H Y-SCALE FACTOR=,I10,15X,15HX-SCALE FACROR=,I10)     G 187
001044    560   FORMAT (11H ERROR IN X,2F15.8,A1)                               G 188
001044          END                                                             G 189-

UNUSED COMPILER SPACE
017400

                SUBROUTINE HISPLT (Y,R)                                         A   1
000005          DIMENSION R(100)                                                A   2
000005          DATA BL/1H /,STAR/1H*/                                          A   3
000005          DO 10 J=1,100                                                   A   4
000006          R(J)=BL                                                         A   5
000010    10    CONTINUE                                                        A   6
000012          IF (Y.LT.0.5) GO TO 50                                          A   7
000014          IF (Y.LT.100.0) GO TO 30                                        A   8
000017          DO 20 J=1,100                                                   A   9
000020          R(J)=STAR                                                       A  10
000022    20    CONTINUE                                                        A  11
000024          GO TO 50                                                        A  12
000024    30    CONTINUE                                                        A  13
000024          IY=Y+0.5                                                        A  14
000027          DO 40 J=1,IY                                                    A  15
000031          R(J)=STAR                                                       A  16
000033    40    CONTINUE                                                        A  17
000035    50    CONTINUE                                                        A  18
000035          RETURN                                                          A  19
000036          END                                                             A  20-

UNUSED COMPILER SPACE
023300
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                SUBROUTINE BRESLAU (GRAV,XSAND,SILT,CLAY)                B   1
          C     THIS IS LLOYD BRESLAUS SEDIMENT CLASS PROGRAM            B   2
000007          IF (XSAND) 20,10,20                                      B   3
000010    10    XSAND=.001                                               B   4
000011    20    IF (SILT) 40,30,40                                       B   5
000012    30    SILT=.001                                                B   6
000013    40    IF (CLAY) 60,50,60                                       B   7
000014    50    CLAY=.001                                                B   8
000015    60    SAND=XSAND+GRAV                                          B   9
000016          IF (SAND-75.) 70,180,180                                 B  10
000021    70    IF (SILT-75.) 80,190,190                                 B  11
000024    80    IF (CLAY-75.) 90,200,200                                 B  12
000027    90    SANSIL=SAND/SILT                                         B  13
000030          CLYSND=ABS(CLAY/SAND)                                    B  14
000032          SILCLY=ABS(SILT/CLAY)                                    B  15
000034          IF (SAND-20.) 100,100,130                                B  16
000037   100    IF (SANSIL-1.) 110,110,210                               B  17
000042   110    IF (SILCLY-1.) 220,120,120                               B  18
000045   120    IF (CLYSND-1.) 240,240,230                               B  19
000050   130    IF (CLAY-20.) 140,140,160                                B  20
000053   140    IF (SANSIL-1.) 240,150,150                               B  21
000056   150    IF (SILCLY-1.) 260,260,250                               B  22
000061   160    IF (SILT-20.) 170,170,270                                B  23
000064   170    IF (CLYSND-1.) 260,260,210                               B  24
000067   180    PRINT 380                                                B  25
000073          GO TO 280                                                B  26
000076   190    PRINT 370                                                B  27
000102          GO TO 280                                                B  28
000105   200    PRINT 360                                                B  29
000111          GO TO 280                                                B  30
000114   210    PRINT 350                                                B  31
000120          GO TO 280                                                B  32
000123   220    PRINT 340                                                B  33
000127          GO TO 280                                                B  34
000132   230    PRINT 330                                                B  35
000136          GO TO 280                                                B  36
000141   240    PRINT 320                                                B  37
000145          GO TO 280                                                B  38
000150   250    PRINT 310                                                B  39
000154          GO TO 280                                                B  40
000157   260    PRINT 300                                                B  41
000163          GO TO 280                                                B  42
000166   270    PRINT 290                                                B  43
000172   280    CONTINUE                                                 B  44
          C     END BRESLAUS PROGRAM                                     B  45
          C     READ IN ANOTHER SET OF DATA                              B  46
000172          RETURN                                                   B  47
          C                                                              B  48
000173   290    FORMAT (1H+,70X,13H SAN SIL CLY ///)                     B  49
000173   300    FORMAT (1H+,70X,13H CLAYEY SAND ///)                     B  50
000173   310    FORMAT (1H+,70X,13H SILTY SAND  ///)                     B  51
000173   320    FORMAT (1H+,70X,13H SANDY SILT  ///)                     B  52
000173   330    FORMAT (1H+,70X,13H CLAYEY SILT ///)                     B  53
000173   340    FORMAT (1H+,70X,13H SILTY CLAY  ///)                     B  54
000173   350    FORMAT (1H+,70X,13H SANDY CLAY  ///)                     B  55
000173   360    FORMAT (1H+,70X,13H       CLAY  ///)                     B  56
000173   370    FORMAT (1H+,70X,13H SILT        ///)                     B  57
000173   380    FORMAT (1H+,70X,13H       SAND  ///)                     B  58
000173          END                                                      B  59-

UNUSED COMPILER SPACE
022300
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                SUBROUTINE MODE(SIZ,WG,TITLE,NO,PHINT)
000010          DIMENSION SIZ(60,10), WG(60,10), TITLE(12,10), AB(20)          A   2
000010          DIMENSION R(100)                                               A   3
000010          NU=NO-1                                                       A  4
000012          DO 10 I=1,NU                                                  A  5
000013          CALL HISPLT (WG(I,1),R)                                        A   6
000016          WRITE (6,90) SIZ(1,1),WG(I,1),(R(J),J=1,100)                   A   7
000052    10    CONTINUE                                                       A   8
000060          WRITE(6,100)SIZ(NO)
000070          AB(1)=0.01                                                     A  10
000072          I=0                                                            A  11
000073    20    CONTINUE                                                       A  12
000073          I=I+1                                                          A  13
000075          L=I+1                                                          A  14
000076          M=I-1                                                          A  15
000077          IF (L.GT.NU) GO TO 70                                          A  16
000105          AB(I)=WG(L,1)-WG(I,1)                                          A  17
000110          IF (M.LE.0) GO TO 20                                           A  18
000111          IF (AB(I)) 30,20,20                                            A  19
000113    30    CONTINUE                                                       A  20
000113          IF (AB(M)*AB(I)) 40,20,20                                      A  21
000117    40    IF (ABS(AB(I)).LT.1.0) GO TO 20                                A  22
000123          IF (I.GT.2) GO TO 50                                           A  23
000126          CMODE=SIZ(I)+(PHINT/2.0)                                      A 23
000130          GO TO 60                                                       A  25
000131    50    CONTINUE                                                       A  26
000131          CMODE=SIZ(I)+(SIZ(I)-SIZ(M))/2.0                               A  27
000137    60    WRITE (6,110) CMODE                                            A  28
000145          GO TO 20                                                       A  29
000151    70    CONTINUE                                                       A  30
000151          RETURN                                                         A  31
        C                                                                      A  32
000152       90 FORMAT(F10.2,/10X,F10.2,10X,100A1)
000152      100 FORMAT(F10.2,/)
000152    110   FORMAT (10X,*MODE = *,F6.2,* PHI*//)                           A  36
000152          END                                                            A  37-

UNUSED COMPILER SPACE
022700


                SUBROUTINE OMIT (L1,L2,L3,L4)                                  I   1
000007          DIMENSION OMI3(4)                                              I   2
000007          COMMON /P140/ OMI3                                             I   3
000007          INTEGER OMI3                                                   I   4
000007          OMI3(1)=L1                                                     I   5
000007          OMI3(2)=L2                                                     I   6
000010          OMI3(3)=L3                                                     I   7
000011          OMI3(4)=L4                                                     I   8
000013          RETURN                                                         I   9
000013          END                                                            I  10-

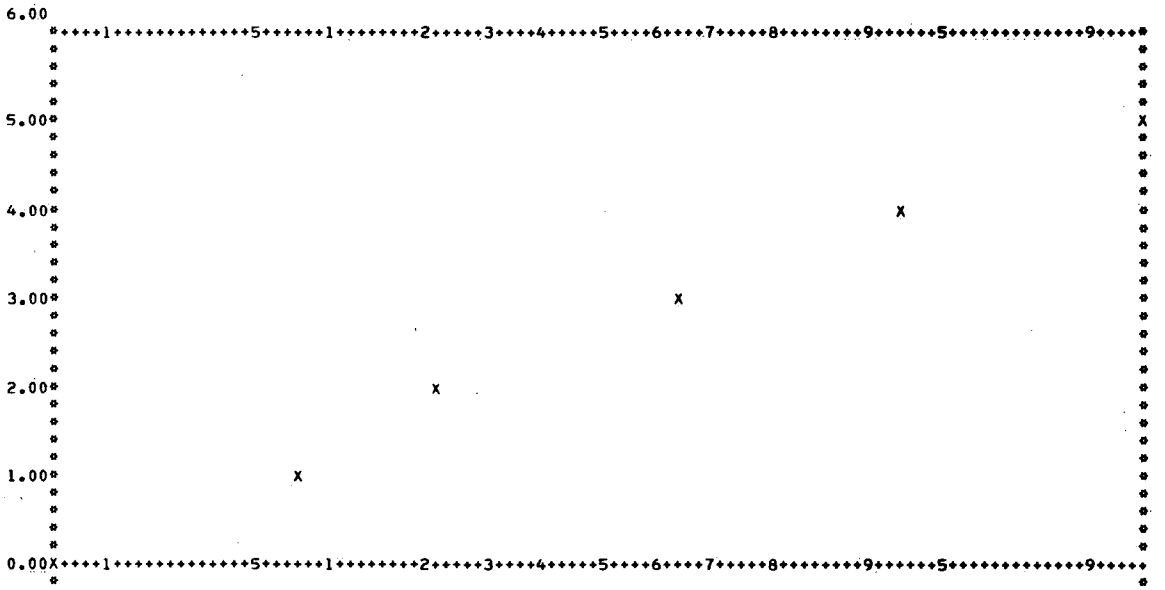
UNUSED COMPILER SPACE
023400


                SUBROUTINE SETLOG (LOG)                                        H   1
000003          COMMON /P135/ ILOG                                             H   2
000003          ILOG=LOG+1                                                     H   3
000005          RETURN                                                         H   4
000005          END                                                            H   5-

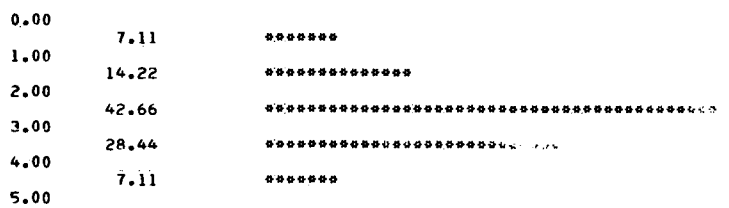
UNUSED COMPILER SPACE
023400
```

Appendix B

CUMULATIVE PLOT VS PHI (PROBABILITY SCALE). GRAPH ENDS = 99.53 AND 0.47 PERCENT



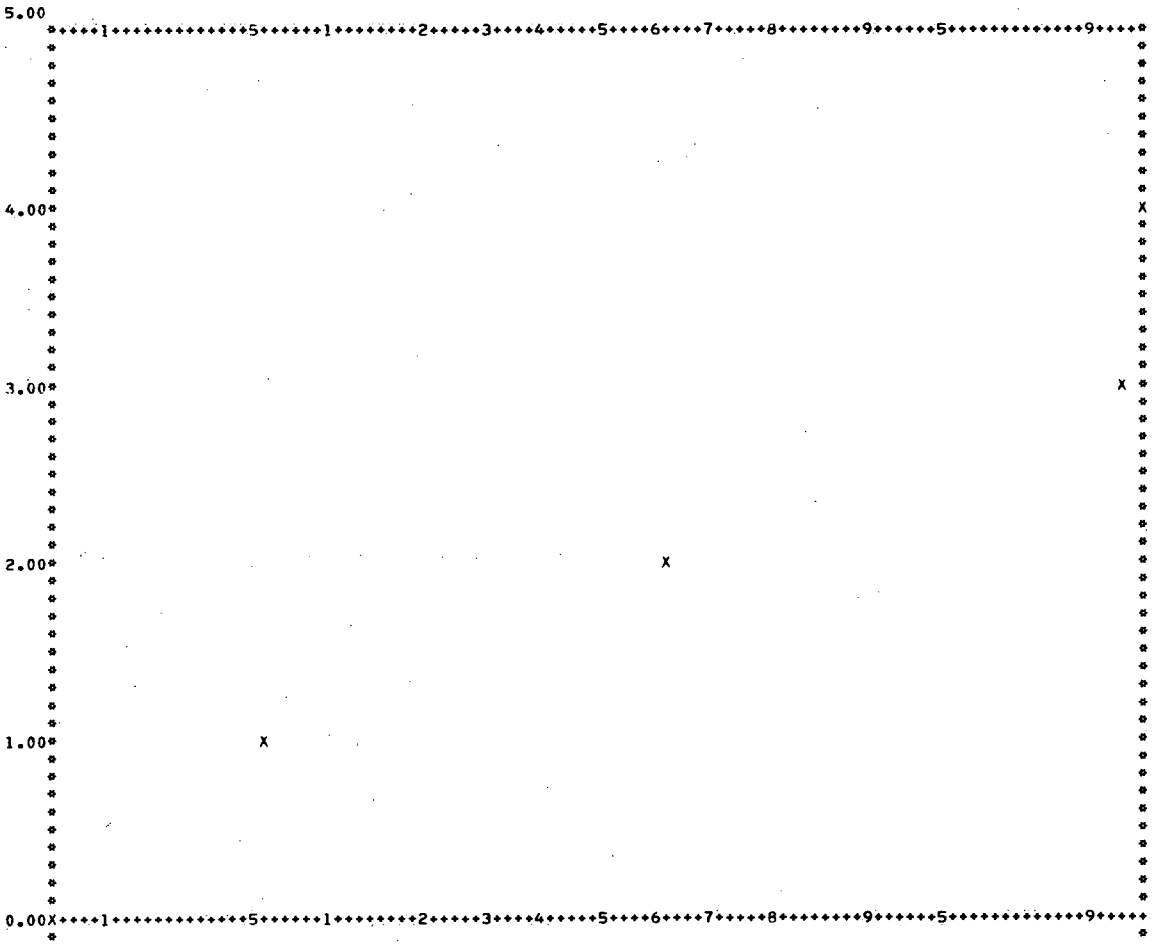
SAMPLE IDENTIFICATION	MEAN	STD DEV	MOMENT MEASURES 1	2	3	4
TEST SAMP 1	2.643	.995	.000	.990	-.145	-.100



MODE = 2.50 PHI

GRAVEL	SAND	SILT	CLAY	
0.00	93.33	5.00	0.00	SAND

CUMULATIVE PLOT VS PHI (PROBABILITY SCALE). GRAPH ENDS = 99.53 AND 0.47 PERCENT



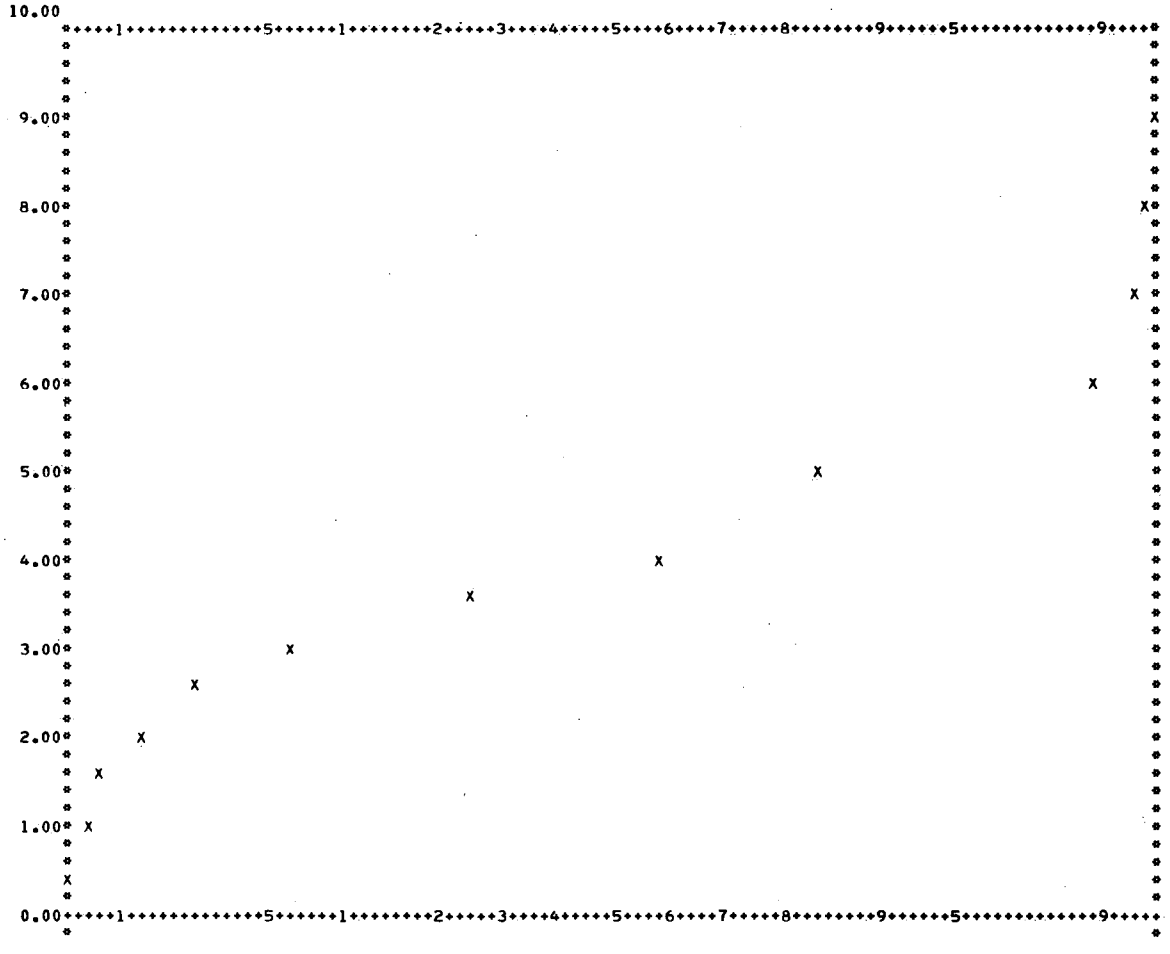
SAMPLE IDENTIFICATION	MEAN	STD DEV	MOMENT MEASURES 1	2	3	4
TEST SAMP 2	1.814	.568	-.000	.323	-.016	-.517

```
0.00
        4.98        *****
1.00
       58.51        ****************************************************
2.00
       35.82        ************************************
3.00
         .20
4.00
```

MODE = 1.50 PHI

GRAVEL	SAND	SILT	CLAY	
0.00	100.00	0.00	0.00	SAND

CUMULATIVE PLOT VS PHI (PROBABILITY SCALE). GRAPH ENDS = 99.53 AND 0.47 PERCENT



SAMPLE IDENTIFICATION	MEAN	STD DEV	MOMENT 1	MOMENT 2	MEASURES 3	MEASURES 4
TEST SAMP 3	4.054	.852	.000	.726	.202	.759

.50		
	.18	
1.00		
	.08	
1.50		
	.45	
2.00		
	1.09	*
2.50		
	4.18	****
3.01		
	17.92	**********
3.51		
	35.93	**********
4.01		
	24.27	**********
5.01		
	14.79	**********
6.01		
	.53	*
7.01		
	.04	
8.01		
	.08	
9.01		

MODE = 3.76 PHI

GRAVEL	SAND	SILT	CLAY	
0.00	60.04	39.77	.19	SILTY SAND

THE RESIDUAL LESS THAN 9 PHI IS .1142 PERCENT

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3 9055 1017 2760 9