UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TERRAIN-ANALYSIS PROCEDURES FOR MODELING RADAR BACKSCATTER

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ABSTRACT

The collection and analysis of detailed information on the surface of natural terrain are important aspects of radar-backscattering modeling. Radar is especially sensitive to surface-relief changes in the millimeter-to-decimeter scale for conventional K-band ($\sim$1-cm wavelength) to L-band ($\sim$25-cm wavelength) radar systems. Surface roughness statistics that characterize these changes in detail have been generated by a comprehensive set of seven programmed calculations for radar-backscatter modeling from sets of field measurements. The seven programs are 1) formatting of data in readable form for subsequent topographic analysis program; 2) relief analysis; 3) power spectral analysis; 4) power spectrum plots; 5) slope angle between slope reversals; 6) slope angle against slope interval plots; and 7) base length slope angle and curvature. This complete Fortran IV software package, "Terrain Analysis", is here presented for the first time. It was originally developed a decade ago for investigations of lunar morphology and surface trafficability for the Apollo Lunar Roving Vehicle.

INTRODUCTION

Radar backscatter has been shown to be especially sensitive to changes in geometry that are responsible for the transition from primarily diffuse backscatter (bright radar image tone) to Rayleigh scattering (dark image tone). For example, McDonald and Waite (1973) showed that at K-band (0.86-cm wavelength) this transition takes place between 0.1- and 0.3-cm mean relief at 10° to 80° incidence angles; it is applicable only to very smooth playa and alluvial fans in desert regions. Schaber, Berlin, and Brown (1976), describing the L-band (25-cm wavelength) radar behavior in Death Valley, California, showed that this same transition between radar-bright (diffuse backscatter) and radar-dark (Rayleigh scattering) image tone takes place at a mean relief between 4 cm and 7 cm for moderate incidence angles 35°-45°. Many unvegetated terrain surfaces have variations in micro-relief that bridge this roughness range; thus such terrains can be easily discriminated from adjacent smoother or rougher surfaces by L-band (and longer wavelength) radar systems. (See Sabins, 1978).

Proper collection and analysis of detailed data on surface geometry are essential to any research on radar backscatter modeling. The procedures for accomplishing these tasks have not been well defined in the open literature, nor have the data requirements for specific radar frequencies and terrain types been identified. In this paper we describe procedures developed to obtain both raw measured and surface-roughness statistics for radar backscatter modeling. We also present for the first time, and in its entirety, a comprehensive and highly flexible software package for terrain analysis. This set of computer programs originally was developed in trafficability studies for the Apollo Lunar Roving Vehicle and investigations of lunar surface geometry (Rozema, 1969; Pike, 1978; U.S. Geological Survey, 1970).

GENERATION OF MICRO RELIEF PROFILES

Surface Profiles from a Templet

Field measurement of terrain micro-relief can be accomplished inexpensively and with satisfactory results using a templet that accurately reflects the topographic variations of a surface over the length of the device (fig. 1). The templet fabricated for evaluation during radar backscatter research in Death Valley (Schaber, Berlin, and Brown, 1976) was made of solid aluminum stock and consisted of 65 moveable rectangular rods capable of measuring maximum relief of approximately one meter over a horizontal distance of one-half meter. The device was moved horizontally to acquire longer profile base-lengths for later statistical analysis. Applicability of such a templet depends on the level of resolution required for calculations of specific roughness statistics; for example, this device cannot record potentially important millimeter-scale relief (high-frequency component) of the topography.

The experimental templet has two distinct advantages: (1) many terrain profiles can be measured cheaply, and (2) fairly high resolution (1.0-cm horizontal by 0.5-cm vertical) can be maintained. Disadvantages include (1) difficulty in transporting the heavy device long distances on foot across adverse terrains, and (2) inability to obtain millimeter-scale relief statistics. Comparison of profiles derived from the templet and from conventional stereophotogrammetric techniques will be made at the end of the next section.

Surface Profiles from Stereo Photographs

High-resolution (± 1-mm horizontal and vertical) surface profiles can be obtained by photogrammetric reduction of high-quality large format (e.g., 70-mm metric camera) photographs taken in overlap and convergent stereo from several meters above the ground surface (Fig. 2). A conventional 60-mm focal-length lens results in profiles approximately one meter long. Calibration of the lens at the measurement distance is required for high precision and ultimate resolution (< 1 mm). Longer profile lengths can be obtained simply by increasing the camera-to-ground distance, but photogrammetric resolution will be reduced.

Photogrammetric reduction of the stereo image data requires an analytical stereoplotter that can accommodate different viewing geometries. A baseline level is established in the model by placing two "leveled" meter sticks orthogonally in the field of view. Horizontal scale is determined from the meter sticks, and vertical scale and exaggeration are computed in the stereoplotter from camera parameters and viewing geometry.

A continuous high-resolution (± 1 mm) topographic profile is recorded in orthogonal directions across the stereo model. A contour map of the entire model could also be produced at a contour interval of 1 to 2 mm; however, a contour map from many stereo models would be prohibitively expensive. If a 1 m^2 area of terrain within a stereo model has homogeneous roughness in all directions, as it true of most micro-terrain surfaces, then orthogonal topographic profiles are sufficient for representative statistics on roughness.

In Figure 3 we directly compare topographic profiles derived from the templet described above and the analytical stereoplotter technique. Note the close similarity between the two profiles but the evident loss of high-frequency (millimeter-scale) relief in the templet results.

TERRAIN ANALYSIS

Parametric description of natural topography, for practical applications (e.g., radar-backscatter modeling) as well as more academic objectives (Pike, 1963; Pike and Rozema, 1975), is a bewilderingly complex subject. Research in this area, which commonly is referred to (not always correctly) as "terrain analysis," embraces aspects as diverse as theoretical topology, numerical taxonomy, and tactical military operations. The resulting literature is vast and it is difficult to keep up with current developments. For a glimpse of the general problem and some recent keys to the literature, see Speight (1974), Pike and Rozema (1975), Speight (1977), and Pike (1978). Many studies in terrain analysis are parochial and often are undertaken to develop a classification scheme for a highly specific set of circumstances. We emphasize that none of these systems have universal applicability in terrain analysis, despite occasional authors' claims to this impossible achievement. Accordingly, the descriptive statistics that we have applied to micro-terrain for modeling radar back-scatter likewise constitute only one way to address the general problem: abstracting the geometry of natural landscapes. The application to radar tends to restrict descriptive variables to those expressing surface roughness rather than other, more exotic, characteristics of the terrain (Pike, 1978; Pike and Rozema, 1975). Moreover, the statistical description of topography at one-millimeter resolution represents application of terrain analysis to one extreme of the scale with which there is little experience on the part of earth scientists. And finally, the statistics are computed from a linear profile, not from an areal sample design (e.g., Grender, 1976; Day, 1979). Some of our subroutines have been converted to accept areal data (elevations at grid intersections), but we have not applied the results to radar work. Thus we were pleasantly surprised to find that our specialized requirements for computation were met so handily by an off-the-shelf package of software nearly a decade old. Although the package described here does not fulfill every need of our radar work, its present usefulness testifies to the flexibility built into the system of description. Undoubtedly this software will meet the requirements of other terrain analysts as well.

COMPUTATION OF ROUGHNESS STATISTICS

The topographic profile shown in figure 2 was digitized at a 3-mm equivalent ground interval and the resulting elevations were used to calculate parameters of surface roughness. Roughness statistics were generated by the Terrain Analysis program developed by the U.S. Geological Survey under NASA funding for trafficability analysis for the Apollo Lunar Roving Vehicle and in incidental studies of lunar morphology (Pike and Rozema, 1975; Pike, 1978; U.S. Geological Survey, 1970). The Terrain Analysis software, written in Fortran IV language, consists of seven integrated data analysis and plotting routines; the entire program is included in Appendix A of this paper. The program furnished nearly 100 individual pieces of graphical and tabular data that describe four major aspects of topographic geometry: (1) relative relief, hypsometry, topographic grain; (2) power (variance) spectral density of relief; (3) slope angle between slope reversals; and (4) base-length slope angle and curvature. A sample output from the Terrain Analysis program, including the plotting subroutine products, is given in Appendix B. Input data were elevation values derived from the profile in figure 1.

The Terrain Analysis program is well documented, and because so many statistical parameters are calculated, only those topographic descriptions that may be unfamiliar to the general reader will be described below. Those seeking more information on the software or its statistical computations should contact the authors.

Program 1 - This initial program of the Terrain Analysis software simply formats the input data in readable form for subsequent analysis. Input consists of topographic elevations, measured at a constant horizontal increment ("delta-L") along a continuous profile.

Program 2 -- Relief Analysis - This part of the Terrain Analysis program provides comprehensive data on the statistical variation of topographic elevations along a profile. The output includes relief, mean elevation, variance, standard deviation, and other standard statistical parameters of elevation such as skewness, kurtosis, elevation-relief ratio (E.R.), hypsometric integral (H) (Pike and Wilson, 1971), and topographic grain (Wood and Snell, 1960). This portion of the program also tabulates the frequency and cumulative percent frequency of elevations within class intervals, so that histograms may be constructed. Ten of these parameters are recalculated from decreasing sample sizes (N), at lengthening sampling intervals (I). This practice reveals the minimum sample size from which stable statistics can be calculated from each data set. In the example given in Appendix B, no fewer than 23 elevations should be used for the calculations.

Hypsometric analysis is valuable in radar backscatter analysis because it gives a quantitative assessment for the proportion of surface area within a unit volume that can readily contribute to radar backscatter and the proportion that would behave quasi-specularly to the radar. Hypsometry is the distribution of ground surface area, or horizontal cross-sectional area of a ground surface, with respect to relief or elevation (Strahler, 1952). Wood and Snell (1960) and Pike (1963) have shown that topographic samples may resemble one another with respect to local relief, average slope, or other geometric aspects, and yet may vary appreciably in appearance as demonstrated by different values of the elevation-relief ratio (E.R.):

$$\text{E.R.} = \frac{\text{mean elevation} - \text{minimum elevation}}{\text{maximum relief}}$$

which was shown by Pike and Wilson (1971) to be equivalent to the hysometric intergral (H), or the proportionate area below the hypsometric function curve. The derivation of the hypsometric function is beyond the scope of this paper but has been well documented by Strahler (1952) and Pike and Wilson (1971). Simply defined, the hypsometric function is the proportion of the total surface area of a unit terrain surface containing elevations greater than a measured elevation. A surface that has exactly equal proportions of its area above and below the mean height value would have a hypsometric integral equal to 0.5.

Topographic grain needs to be determined before computing statistics on roughness or any other aspect of terrain geometry. If the profile obtained by either the templet or photogrammetric technique is of insufficient length to contain most of the relief elements, or is unnecessarily long, then statistical errors will enter the calculations for modeling radar backscatter. Topographic grain of a terrain is essentially the minimum area or linear sample distance on a surface that contains most of the important relief structure (Wood and Snell, 1960). If the size of a progressively larger, nested interval along the horizontal axis of a profile is plotted against the maximum relief within the intervals, relief increases rapidly to a point and then levels off. The sampling interval size corresponding to the point at which relief inflects is the "topographic grain." Most of the topographic characteristics of the sample region will thus be contained within an interval of this size (See Appendix B).

Program 3 -- Power Spectral Analysis - The analysis of relief variance is of significant importance for radar backscatter modeling, as shown by Peake (1959), Valenzuela (1967), and Barrick (1972), who made use of the covariance spectrum of relief in various perturbations of the Bragg-Rice scattering models. W. E. Brown, Jr., and G. G. Schaber (work in progress) have found that covariance spectra obtained by the photogrammetric and statistical analysis technique described above can be used with a Bragg-Rice scattering model to correctly predict radar cross-section values for saltpan and gravels within Death Valley.

This power spectral density (PSD) subprogram computes the various frequency components of the relief (Rozema, 1969). Power spectral or time series analysis examines the frequency content of topographic or surface-roughness profiles. For natural terrain surfaces, most profiles are statistically random functions that can only be represented by the continuous variance spectrum. Elevation amplitudes that contribute to variability of a random isotropic surface above its mean height value thus are associated with a continuum of wavelengths.

Separating a random profile into wavelength bands yields the spectral density of the relief variance, which is given as the square of the amplitude per unit bandwidth of the contributing wavelength bands (Pike and Rozema, 1975). This value is the power spectral density (PSD).

The variance spectral density program used in this study derives the autocovariance function and the Fourier transform of the autocovariance function that is the spectral density function of the variance and vice versa (Pike and Rozema, 1975). Autocorrelation of relief data enhances any periodicities that may be present in the topographic profile.

The "variance" or power spectral density graphs are sloping lines representing continuous functions of topographic (spatial) wavelengths. (See Appendix B). Because the greatest relief within a surface profile (natural terrain) is generally associated with the longer wavelengths, the spectral density decreases rapidly with decreasing terrain wavelengths. The slopes of the PSD curves describe a relation between the relief content of the long and short features (Bryson and Dutton, 1967). An overall slope of -3 is thought to indicate a "uniformity" of topographic slope for all relief features in the sample area, regardless of their size (Bekker, 1969). A slope less steep than -3 indicates that small topographic features (high frequency) are rougher than large (low frequency) features. Likewise, a spectrum slope steeper than -3 suggests more rough, coarse-grained features and less smooth, fine-grained relief forms.

Digital bandpass filtering of the very low frequency data in the surface profiles is performed prior to calculation of the PSD functions. This operation is included because a long-term trend in the profiles affects the PSD function in two ways: (1) it may result in a nonstationary profile, that is, a profile whose statistical properties are affected by a change in origin; and (2) because the amplitude of the profile associated with the low frequency of a long trend would likely be relatively large, enough power would be contributed by the low frequency to obscure that contributed by higher frequencies (Rozema, 1969).

Program 4 -- Power Spectrum Plots - This subroutine plots the elevation variance of relief as frequency (cycles per mm) versus power spectral density (mm^2 per cycle per mm). Conversion of the PSD values to m^2 per cycle per m involves multiplying the PSD values by 10^9; conversion to cycles per m is accomplished by multiplying each frequency value by 10^3. Pike and Rozema (1975) have shown that PSD values are interchangeable with variance [amplitude^2, per wave number (units ^{2})], in the same fashion; frequency (in cycles per unit) is interchangeable with wave number (units^{-1}). Immediately following the PSD plot in Appendix B, a least squares regression line fit equation is given for the PSD data in addition to the total variance of the integrated spectrum.

Program 5 -- Slope Angle Between Slope Reversals - There are innumerable ways to characterize topographic slope. One of them is to identify terrain segments that occur between reversals in slope direction along a profile. Both the length and steepness of the slope are variables.

Radar backscatter power is strongly dependent on the number of reflecting facets on the target area at moderate to high angles of incidence. This program can furnish quantitative data on such facets, which are the areas between two adjacent slope reversals. Every reversal of slope from the input topographic profile is listed, as are the slope angle and slope length between these reversals. Also given are the three steepest and the three longest slopes, and the number of slope reversals per meter. A regression line is computed for slope length and slope angle.

Program 6 -- Slope Angle Against Slope Interval Plots - This subroutine plots each slope length against its slope angle on semi-log scale. The computer-printed graph is an approximation and may differ slightly from the actual values. Where more than nine values occupy the same position, a letter symbol code is printed indicating the number of points at that location. The steepest slope angle printed out is 20 degrees. This value is too low a cut-off for micro-terrain applications, where the slopes are very steep. This graph is only of minor value in its present format.

Program 7 -- Base Length Slope Angle and Curvature - This subprogram is exceptionally comprehensive and flexible, and yields a large amount of information on surface roughness. Two parameters, slope angle and the angle of slope curvature, are computed for different values of the unit cell, or base length (delta-L). Slope angle at the smallest delta-L, the input sampling interval, is simply the slope of the line connecting any two adjacent sample elevations. Curvature is the angle subtended by three adjacent elevations along the traverse (fig. 4). Calculations start with a horizontal sampling interval (delta-L) of X-mm (3.0 mm in the example shown in Appendix B). The subroutine then calculates algebraic and absolute values of statistics for both slope angle and the angle of curvature, including minimum, maximum, mean, variance, standard deviation, skewness, kurtosis and median. Absolute values are unsigned. Algebraic values are positive (slopes facing the end of the profile and convex curvature - Fig. 4), and negative (slopes facing the opposite direction and concave curvatures - Fig. 4). Algebraic frequency distributions are symmetric about the zero values and often approach the Gaussian ideal. Absolute distributions approach the "half-normal" model (Elandt, 1961), and are skewed strongly to the right. Slopes and curvatures calculated by both conventions are necessary, and complement one another.

The dispersion coefficient (algebraic standard deviation divided by absolute mean) is analogous to the usual coefficient of variation (Croxton et al., 1967, p. 198), and is an excellent measure of relative dispersion. The "Elandt coefficient" (informal name by Pike, 1978), defined as absolute mean divided by absolute standard deviation (Elandt, 1961), can be used as a rapid initial test for the "half-normality" of an absolute slope frequency distribution (see Pike, 1978, p. 14-15).

Following a listing of the number of negative and positive values of slope and curvature (and their ratios) are tabulations of algebraic and absolute frequency-distribution statistics. These are intended for histograms and other graphic output. The percent (10 to 90) dispersion of the algebraic values is also listed, in addition to the results of a chi-square test for the normality of the algebraic frequency distribution of both slope and curvature. Regression line-fits are calculated relating cumulative percent frequency and slope angle, and cumulative percent frequency and percent mean slope. Similar regression equations are given for the curvature statistics. These equations enable the histograms to be roughly expressed by only two parameters, slope and coefficient of the fit.

The delta-L value (sampling interval) is then doubled (for example, from 3.0 mm to 6.0 mm) and all calculations are rerun. This stepping of the delta-L value continues until the desired upper limit of sampling interval is reached or until too few cases remain to calculate good statistics. The final calculations in the program are linear regression fits relating delta-L to mean absolute slope and curvature for all iterations. This valuable equation can be used to assess the relation of slope and curvature angles for a specific terrain at various fractions (or multiples) of radar wavelength scales (where delta-L is equated to roughness sampling-interval of the radar).

POSSIBLE PROGRAM IMPROVEMENTS

The Terrain Analysis software has been found to be almost ideal for radar backscatter modeling studies of fine-scale relief, and can be used with topographic information derived from either *in situ* templets or photogrammetric reduction of stereo photographs. Experience with this software, however, has indicated the need for at least four additional computations and plotting subroutines of significance to radar backscatter modeling: (1) height correlation coefficient autocorrelation, or statistical association between various pairs of elevations along a profile; (2) probability density function for surface elevation; (3) probability density function for surface slopes (Pike and Rozema, 1975; Barrick, 1970); and (4) root mean square (rms) slopes and curvatures for all base lengths. These additional programs and subroutines could simply be added to the existing Terrain Analysis software with minimal effort and expense. Autocorrelation of surface heights already is performed as part of the PSD computations (Program 3) and merely needs to be printed out. The information on relief and slope necessary for calculating their probability density functions are available in Programs 2 and 7. Only the rms calculations will require writing an entire new subprogram.

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FIGURE CAPTIONS

Figure 1.--Aluminum templet used to record surface relief, shown in moderately rough saltpan in Death Valley, California. Templet approximately 1.2 m high by 0.5 m wide. A level is built into top crossbar for proper orientation; handles were included for ease in carrying weight, about 65 pounds. Profile shown on templet is left half of those shown in figure 3.

Figure 2.--Example of topographic profile obtained by photogrammetric reduction of metric-camera (70 mm) stereopair photographs. Profile was digitized at 3-mm equivalent ground interval and used as input for Terrain Analysis program (Appendix A; output of program in Appendix B).

Figure 3.--Topographic profiles obtained by *in situ* templet device and by photogrammetric reduction of stereo photomodels. Profiles include that shown in figure 1 and an additional $\sim$ 0.5 m to the right.

Figure 4.--Diagrammetric representation of slope curvature along a profile. Dots show ground surface. Circles are sample elevations measured at a constant horizontal increment (delta-L). Positive curvature shown by α; negative curvature shown by β.

FIGURE 1

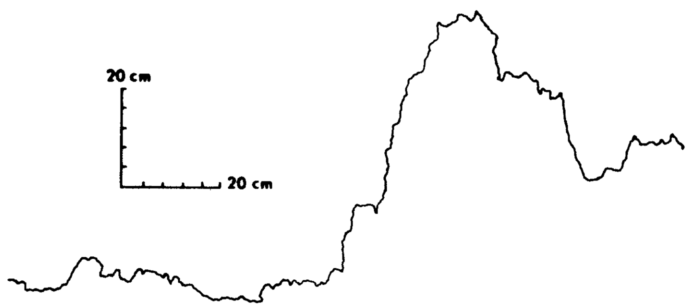

FIGURE 2

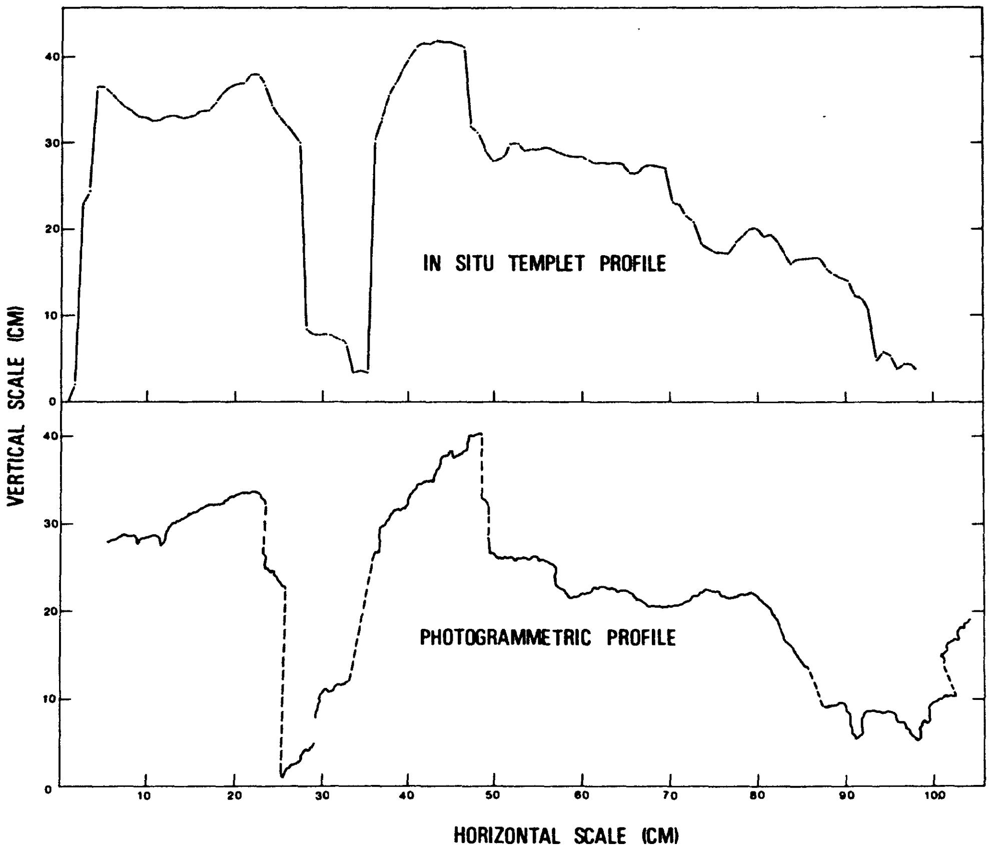
IN SITU TEMPLET PROFILE
PHOTOGRAMMETRIC PROFILE
VERTICAL SCALE (CM)
HORIZONTAL SCALE (CM)
0
10
20
30
40
50
60
70
80
90
100

FIGURE 3

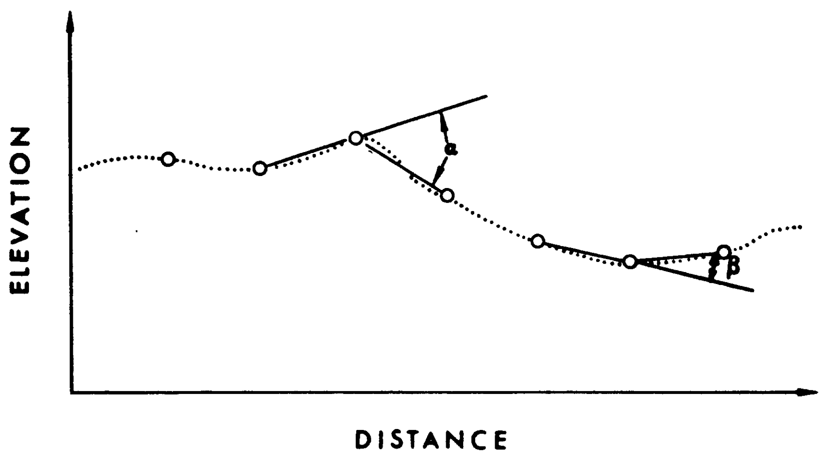

FIGURE 4

APPENDIX A

In this Appendix we list the complete Terrain Analysis software developed under NASA funding to the U.S. Geological Survey for investigation of lunar morphology and trafficability studies for the Apollo Lunar Roving Vehicle. This previously unpublished package was conceived by R. J. Pike, who coordinated the overall effort. The individuals who did the actual programming and were responsible for the seemingly endless refinements demanded by the two senior authors are S. E. Wilson, R. H. Godson, D. K. McMacken, G. I. Selner, J. E. Crawforth, Eric Eliason, J. J. Stapleton, and Loretta Barcus of the U.S. Geological Survey and W. J. Rozema of Northern Arizona University (Flagstaff, Az).

The Terrain Analysis software program is written in Fortran IV language and consists of seven integrated programs and subroutines having the following functions:

(1) formatting of data in readable form for subsequent topographic analysis program

(2) relief analysis

(3) power spectrum analysis

(4) power spectrum plots

(5) slope angle between slope reversals

(6) slope angle against slope interval plots

(7) base length slope angle and curvature

These subprograms and subroutines have been briefly described in the text. Duplicate computer tapes (9 track-800 bpi) are available in either ASCII or EBCDIC at no cost by sending a new blank tape and the sender's return address to the senior author at:

U. S. Geological Survey
Branch of Astrogeologic Studies
2255 North Gemini Drive
Flagstaff, Arizona 86001

PROGRAM 1

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C.... TDA1 ADAPTED FROM 360/65 VERSION OF B157 BYJIM CRAWFORTH, OCT 72
C     PROGRAM TO READ IN DATA FROM CARDS AND STORE ON TEMPORARY DISK
C     FOR SUBSEQUENT TOPOGRAPHIC DATA ANALYSIS PROGRAMS
C
C*********************************************************************
C MODIFICATIONS MADE BY ERIC ELIASON, COMPUTER CENTER DIVISION, MAY 73
C
C ADDITIONAL MODIFICATIONS FOR USE ON MODCOMP II/25 MADE IN AUG 76
C BY JIM STAPLETON AND LORETTA BARCUS
C
C*********************************************************************
C.... SPECIFICATION STATEMENTS
      DIMENSION IFMT(40),HT(30,30)
      REAL ELEVMS,FEET,MILE
C     INTEGER SELECT(9),OP,SCANNO,DISK,PRINT,N2(6),TNPTS
      INTEGER SELECT(9),OP,SCANNO,DISK,PRINT,N2(6),TNPTS,CARD,CRDNUM
C     REAL HEIGHT(1000), SER2(15),STOP(15),SHYP(15),ID(10)
      REAL HEIGHT(1000), SER2(15),STOP(15),SHYP(15),ID(10),APCRDG(5)
      DATA FEET/'FEET'/,MILE/'MILE'/
      DATA ZMTOP/'MTOP'/
      DATA APC /' APC'/, APCM /'APCM'/, APCR /'APCR'/
C.... INITIALIZE FORTRAN I/O UNIT NUMBERS
      DISK=7
      ICARD=8
      IPRINT=5
      CARD = 8
      PRINT = 5
      IM = 3
      REWIND IM
      REWIND DISK
C.... READ FIRST HEADER CARD AND WRITE ON DISK
      READ(ICARD,1000,END=999) ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,
     1 (SELECT(I),I=1,9),OP
 1000 FORMAT(10A4,2I3,1X,I3,1X,A4,1X,A4,9I2,1X,I1)
      IF (TYPE .EQ. ZMTOP) GOTO 500
      WRITE(DISK) ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,(SELECT(I),I=1,9),
     1        OP
      DO 10 I=1,NSCANS
C.... READ SECOND HEADER CARD AND CHECK TO SEE IF STANDARD OR AP/C DATA
C     READ(ICARD,1100,END=999) SCANNO,NPTS,DL,DISTMS,KOPT
      READ(ICARD,1100,END=999) SCANNO,NPTS,DL,DISTMS,FRMT
C1100 FORMAT(I3,I5,F10.0,1X,A4,T80,I1)
 1100 FORMAT(I3,I5,F10.0,1X,A4,A4)
      IF(FRMT.EQ.APCM.OR.FRMT.EQ.APCR) GO TO 3000
      IF(FRMT.NE.APC) GO TO 70
C
C             THE USER WANTS TO READ IN APC DATA.
C
C
C             THE FOLLOWING WAS ADDED TO THIS PROGRAM IN ORDER TO
C             HANDLE APC DATA AND STD DATA IN THE SAME PROGRAM.
C
C.... READ AND AVERAGE 2 TO 5 HEIGHT VALUES FROM THE AP/C
      CRDNUM=0
      DO 55 M = 1,NPTS
   40 READ(CARD,1500)(APCRDG(J),J=1,5),PTS
 1500 FORMAT(20X,5F10.1,F6.0)
      CRDNUM=CRDNUM+1
C.... CHECK THAT THE NUMBER OF POINTS IS 5 OR LESS
      IF(PTS.LT.5.5)GO TO 60
      WRITE(PRINT,1550)PTS,CRDNUM
 1550 FORMAT(' NUMBER OF POINTS LARGER THAN 5, = ',F6.0,' ON CARD ',I4,
     1       //'DATA ON THIS CARD IGNORED.')
      GO TO 40
C.... TAKE THE AVERAGE OF THE AP/C HEIGHT READINGS ON THE CARD
   60 APCSUM=0.0
      DO 50 L=1,5
      APCSUM=APCSUM+APCRDG(L)
   50 CONTINUE
      APCAVG=APCSUM/PTS
      HEIGHT(M) = APCAVG
   55 CONTINUE
      GO TO 75
C
C.... READ DATA CARDS IN THE STANDARD FORMAT OF 10F8.3 AT STATEMENT 70
   70 READ(ICARD,1200,END=999) (HEIGHT(K),K=1,NPTS)
 1200 FORMAT(10F8.3)
C
C.... CHECK THE UNITS FOR THE INPUT DATA
   75 CALL CHECK(ELEVMS,DISTMS,TYPE,HEIGHT,NPTS,DL)
      WRITE(DISK) SCANNO,NPTS,DL,DISTMS,(HEIGHT(K),K=1,NPTS)
   10 CONTINUE
      GO TO 9999
C                INPUT IS ON APC CARDS THAT HAVE NOT BEEN CONSOLIDATED
C
 3000 M = 1
C
      READ(CARD,3001,END = 999) XLB,YLB,ZLB
 3001 FORMAT(10X,3F10.1)
 3005 XLBC = XLB
      YLBC = YLB
      PTS = 1.0
      ZLBS = ZLB
C
C                READ NEXT CARD
 3010 READ(CARD,3001,END = 3998) XLB,YLB,ZLB
      IF(XLB.NE.XLBC.OR.YLB.NE.YLBC) GO TO 3100
      ZLBS = ZLBS + ZLB
      PTS = PTS + 1.0
      GO TO 3010
C
C                AVERAGE HEIGHT AND SAVE IT
 3100 HEIGHT(M) = ZLBS/PTS
      CALL SSWTCH(1,LB)
      IF(LB.NE.1) GO TO 3120
      WRITE(IPRINT,3201) M,XLBC,YLBC,HEIGHT(M),PTS
      GO TO 3130
 3120 IF(ABS(XLB-XLBC).GT.3*DL.OR.ABS(YLB-YLBC).GT.3*DL)
```

```
      1  WRITE(IPRINT,3201) M,XLBC,YLBC,HEIGHT(M),PTS
 3130 CONTINUE
 3201 FORMAT(I10,2F12.2,F12.3,F12.0)
      M = M + 1
      GO TO 3005
 3998 NPTS = M
      HEIGHT(M) = ZLBS/PTS
      WRITE(IPRINT,3201) M, XLBC,YLBC,HEIGHT(M),PTS
      GO TO 75
  999 WRITE(IPRINT,1300)
 1300 FORMAT(' NUMBER OF DATA CARDS IS INCORRECT')
 9999 ENDFILE DISK
      REWIND DISK
      STOP
C***********************************************************************
C BEGINING OF MATRIX OPTION PROCESSING
C***********************************************************************
  500 CONTINUE
      GOTO 9999
      END
      SUBROUTINE CHECK(ELEVMS,DISTMS,TYPE,DATA,NPTS,DL)
      REAL ELEVMS,FEET,MILE
      DIMENSION DATA(1000)
      DATA FEET/'FEET'/,MILE/'MILE'/,PHOT/'PHOT'/
      IF(ELEVMS.EQ.FEET.OR.ELEVMS.EQ.MILE) CALL METERS(ELEVMS,DATA,NPTS)
      IF(DISTMS.EQ.FEET) DL=DL/3.28084
      IF(DISTMS.EQ.MILE) DL=DL*1609.344
      RETURN
      END
      SUBROUTINE METERS(ELEVMS,DATA,NPTS)
      DIMENSION DATA(1000)
      REAL ELEVMS,FEET,MILE
      DATA FEET/'FEET'/,MILE/'MILE'/
      IF (ELEVMS.EQ.FEET) GO TO 10
      GO TO 30
   10 DO 20 I=1,NPTS
      DATA(I)=DATA(I)/3.28084
   20 CONTINUE
      RETURN
   30 DO 40 I=1,NPTS
      DATA(I)=DATA(I)*1609.344
   40 CONTINUE
      RETURN
      END
```

PROGRAM 2

```
C              RELIEF ANALYSIS-TDA2 FOR PDP-11
C              BY GARY SELNER CCD FOR DICK PIKE   APRIL,1969
C     THIS PROGRAM IS DESIGNED TO STUDY THE DISTRIBUTION OF ELEVATIONS
C     AND THE BEHAVIOR OF ELEVATION WITH DISTANCE AS WELL AS THE
C     HYPSOMETRY OF THE SAMPLED AREA.
C
C***********************************************************************
C MODIFICATIONS MADE BY ERIC ELIASON, COMPUTER CENTER DIVISION, MAY 73
C***********************************************************************
      INTEGER SELECT(9),OP,SCANNO,DISK,PRINT,N2(6),TNPTS
      REAL HEIGHT(1000), SER2(15),STOP(15),SHYP(15),ID(10)
      DIMENSION FRED(30),CPC(30)
      DATA CHECK/'LANG'/
      DATA ZMTOP/'MTOP'/
      N2(1) = 1
      N2(2) = 2
      N2(3) = 4
      N2(4) =10
      N2(5) =20
      N2(6) =50
C     SET I/O UNITS
      DISK = 7
      PRINT = 5
      IPRINT = 5
C     START PROGRAM
   10 READ (DISK) ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,(SELECT(I),I=1,9)[illegible]
     1         OP
      IF (ZMTOP .EQ. TYPE) SELECT(1) = 1
      IF (ZMTOP .EQ. TYPE) OP = 3
      IF (TYPE-CHECK) 80,20,80
   20 IF (OP) 40,30,40
   30 SELECT(1) = 2
      SELECT(2) = 6
      SELECT(3) =10
      SELECT(4) =14
      NSEL = 4
      GO TO 150
   40 IF (OP-1) 41,30,41
   41 NSEL = 0
      DO  60   I=1,9
      IF (SELECT(I))  50,70,50
   50 NSEL = NSEL + 1
   60 CONTINUE
   70 GO TO 150
   80 IF (OP) 110,90,110
   90 DO 100 I=1,NSCANS
      SELECT(I) = I
  100 CONTINUE
      NSEL = NSCANS
      GO TO 150
  110 IF (OP-1)  120,90,120
  120 NSEL = 0
      DO  140  I=1,9
      IF (SELECT(I))  130,150,130
```

```
  130 NSEL = NSEL + 1
  140 CONTINUE
  150 CONTINUE
C     START MAIN LOOP FOR EACH SCAN
      DO  250  K1 = 1,NSEL
      K2 = SELECT(K1)
  160 READ(DISK) SCANNO,NPTS,DL,DISTMS,(HEIGHT(I),I=1,NPTS)
      IF (SCANNO-K2) 160,170,160
  170 WRITE (PRINT,1000) ID,K2
 1000 FORMAT('1',1X//' ',40X,'R  E  L  I  E  F   A  N  A  L  Y',
     1 ' S  I  S '/ '0',10A4/' PROFILE NO. ',I3)
      WRITE (PRINT,1002) DL
 1002 FORMAT ('0','DELTA L = ',F8.3,' MMS')
  173 WRITE (PRINT,1003)
 1003 FORMAT ('0','BELOW ARE SOME DESCRIPTIVE PARAMETERS'/' ','FROM N',
     1'ELEVATIONS, EVERY I-TH SAMPLE ELEVATION'//
     4          ' ',' I    N   MINIMUM    MAXIMUM     RELIEF     MEAN',
     5    '          VARIANCE   STD.DEV.   SKEWNESS   KURTOSIS      ',
     6          'E.R.  1     E.R.   2'/)
      DO  200  L = 1,6
      NL = N2(L)
      CALL ALSTAT(HEIGHT,NPTS,NL,XMEAN,XMAX,XMIN,XVAR,XSDEV,XSKEW,
     1          XKURT,N3)
      RELIEF = XMAX - XMIN
      ER1 = (XMEAN - XMIN)/RELIEF
      IF (NL-1) 190,180,190
  180 TMAX = XMAX
      TMIN = XMIN
  190 ER2= (XMEAN - TMIN)/(TMAX-TMIN)
      WRITE (PRINT,1010) NL,N3,XMIN,XMAX,RELIEF,XMEAN,XVAR,XSDEV,
     1    XSKEW,XKURT,ER1,ER2
 1010 FORMAT(' ',I3,I5,4(1X,F9.3 ),1X,F13.2,5(1X,F10.4) )
      IF (NL-1) 199,195,199
  195 SER2(K1) = ER2
  199 CONTINUE
  200 CONTINUE
      WRITE (PRINT,1020)
 1020 FORMAT('0','E.R. 1 IS CALCULATED FROM EACH SAMPLE OF N POINTS ',
     1          'AND IS THE RATIO'/' ','(MEAN - HMIN)/(HMAX - HMIN)'/
     2          ' ','E.R.2 IS THE SAME RATIO, BUT CALCULATED USING ',
     3          'THE TOTAL SAMPLE''S HMAX AND HMIN.'//)
      CALL FREQ(TMAX,TMIN,HEIGHT,NPTS,CLAINT,FRED,CPC)
 1050 FORMAT('0',36X,'CUM. ',1X/' ',34X,'PERCENT',1X/' ','CLASS  CL',
     1          'ASS BOUNDARIES   FREQ.   FREQ.'/)
      WRITE (PRINT,1050)
      DO  210  I=1,30
      C1 = TMIN + (I-1)*CLAINT
      C2 = TMIN + I * CLAINT
      WRITE (PRINT,1040) I,C1,C2,FRED(I),CPC(I)
 1040 FORMAT(' ',I5,2F10.3,F8.0,F8.2)
  210 CONTINUE
      CALL HIPPO(HEIGHT,NPTS,TMIN,TMAX,HBAR)
      IF (TYPE .NE. ZMTOP) CALL TOPGRN(HEIGHT,NPTS,DL,TOPGR)
      IF (TYPE-CHECK) 230,220,230
  220 STOP(K1) = TOPGR
      SHYP(K1) =  HBAR
  230 CONTINUE
  250 CONTINUE
      STOP
       END
      SUBROUTINE ALSTAT(X,N1,N2,XMEAN,XMAX,XMIN,XVAR,XSDEV,XSKEW,XKURT,
     1    N3)
      INTEGER PRINT
      DIMENSION X(1)
      DOUBLE PRECISION XDEV,SUM1,SUM2,SUM3,SUM4,XK4,XK3,XK2
      DATA PRINT/5/
      SUM1 = 0.0D0
      SUM2 = 0.0D0
      SUM3 = 0.0D0
      SUM4 = 0.0D0
      XMAX = 0.1E-30
      XMIN = 0.1E+30
      FN = 0.0
      DO 50 I=1,N1,N2
C     SUMMATION FOR MEAN
      SUM1 = SUM1 + X(I)
C     MAXIMUM COMP
      IF (XMAX-X(I))  10,20,20
   10 XMAX = X(I)
   20 CONTINUE
C     MINIMUM COMP
      IF (XMIN-X(I))  40,40,30
   30 XMIN = X(I)
   40 CONTINUE
      FN = FN + 1.0
   50 CONTINUE
C     COMPUTE MEAN VALUE
      XMEAN = SUM1/FN
C     ACCUMULATE SUMS OF DEVIATIONS FROM MEAN
      DO 60 I=1,N1,N2
      XDEV = X(I) - XMEAN
      SUM2 = SUM2 + XDEV**2
      SUM3 = SUM3 + XDEV**3
      SUM4 = SUM4 + XDEV**4
   60 CONTINUE
C     COMPUTE K - STATISTICS
      N3 = FN
      FN1 = FN  - 1.0
      FN2 = FN1 - 1.0
      FN3 = FN2 - 1.0
      IF (FN3) 500,500,70
   70 XK4 = (FN/(FN1*FN2*FN3))*( (FN+1)*SUM4 - 3.0D0*(FN1/FN)*SUM2**2)
   75 IF (FN2) 510,510,80
   80 XK3= (FN/(FN1*FN2))*SUM3
   85 IF (FN1) 520,520,90
   90 XK2= (1.0/FN1)*SUM2
   95 CONTINUE
C     CONVERT TO MOMENTS
```

```
      XVAR = XK2
      IF (XVAR) 530,530,110
  110 XSDEV = DSQRT(XK2)
      XSKEW = XK3/XK2**1.5
      XKURT = XK4/XK2**2
  115 CONTINUE
      GO TO 9999
C     ERROR CONDITIONS
  500 WRITE (PRINT,1000)
 1000 FORMAT('0','ERROR CONDITION! NUMBER OF POINTS IS LESS THAN 4. '/
     1       ' ','THEREFORE KURTOSIS CAN NOT BE COMPUTED.'/)
      XK4 = 1.0E30
      GO TO 75
  510 WRITE (PRINT,1010)
 1010 FORMAT('0','ERROR CONDITION! NUMBER OF POINTS IS LESS THAN 3. '/
     1       ' ','THEREFORE SKEWNESS CAN NOT BE COMPUTED.'/)
      XK3 = 1.0E30
      GO TO 85
  520 WRITE (PRINT,1020)
 1020 FORMAT('0','ERROR CONDITION! NUMBER OF POINTS IS LESS THAN 2. '/
     1       ' ','THEREFORE STANDARD DEVIATION CAN NOT BE COMPUTED.'/)
      XK2 = 1.0E30
      GO TO 115
  530 WRITE (PRINT,1030)
 1030 FORMAT('0','ERROR CONDITION! NEGATIVE VARIANCE.'/
     1       ' ','THEREFORE STANDARD DEVIATION CAN NOT BE COMPUTED'/)
      XSDEV = 1.0E30
      XSKEW = 1.0E30
      XKURT = 1.0E30
 9999 RETURN
      END
      SUBROUTINE FRED(XMAX,XMIN,X,N,CLAINT,FRED,CPC)
      DIMENSION X(1),FRED(1),CPC(1)
C     COMPUTE CLASS INTERVAL
      CLAINT=(XMAX-XMIN)/30.0
C     CLEAR ARRAYS
      DO  10   I=1,30
      FRED(I) = 0.0
      CPC(I)  = 0.0
   10 CONTINUE
C     CLASSIFY  DATA
      DO  70   K=1,N
      DO  50   I=1,30
      F1 = XMIN + (I-1)*CLAINT
      F2 = XMIN + I * CLAINT
      IF  (X(K)- F1)   40,20,20
   20 IF  (X(K)- F2)   30,40,40
   30 FRED(I) = FRED(I) + 1.0
      GO TO 60
   40 CONTINUE
   50 CONTINUE
   60 CONTINUE
   70 CONTINUE
      FRED(30) = FRED(30) + 1.0
      DO  80   I=1,30
      CPC(I) = (FRED(I)/FLOAT(N))*100.0
   80 CONTINUE
      DO  90   I=2,30
      CPC(I) = CPC(I) + CPC(I-1)
   90 CONTINUE
      RETURN
      END
      SUBROUTINE TOPGRN(A,N,DL,TOPGR)
      DIMENSION RLF(22),RAD(22),A(1000)
      INTEGER     IGH(51,89),IB,IS
      INTEGER PRINT
      DATA IS/'* '/,IB/'  '/,PRINT/5/
 8010 FORMAT(3X,'THE FOLLOWING GRAPH SHOWS THE RELATIONSHIP BETWEEN ',
     1 'INTERVAL'/3X,'AND THE MAXIMUM RELIEF WITHIN A GIVEN INTERVAL'/
     2 5X,'-THE HORIZONTAL AXIS LISTS THE INTERVAL IN MMS'/5X'-THE',
     3 ' VERTICAL AXIS LISTS THE HEIGHT IN MMS ABOVE MINIMUM',
     4 ' ALTITUDE.'/)
 8020 FORMAT(7X,'-',22('1---'),'1-')
 8030 FORMAT(' ',I5,' 1',89A1,1H1)
 8040 FORMAT(' ',6X,'1',89A1,1H1)
 8050 FORMAT(3X,'THE FOLLOWING DATA AND GRAPH GIVE INFORMATION RELATED T
     10 THE TOPOGRAPHIC'/3X,'GRAIN OF A SAMPLE AREA.  IF THE SIZE ',
     2 'OF PROGRESSIVELY LARGER'/3X,'NESTED INTERVALS (HORIZONTAL AXIS)
     3OF A PROFILE IS PLOTTED AGAINST THE')
 8060 FORMAT(3X,'MAXIMUM RELIEF WITHIN THE INTERVAL(VERTICAL AXIS), THE
     1GRAPH INCREASES'/3X,'RAPIDLY TO A POINT AND THEN LEVELS OFF.  THE
     2INTERVAL SIZE OF'/3X,'THE POINT AT WHICH THE GRAPH LEVELS OFF IS T
     3HE TOPOGRAPHIC GRAIN.  MOST')
 8100 FORMAT(3X,'OF THE TOPOGRAPHIC CHARACTERISTICS OF THE SAMPLE REGION
     1 WILL BE CONTAINED'/3X,'WITHIN AN INTERVAL OF THIS SIZE.'//3X,'IN
     2THE FOLLOWING DELTA L IS THE DISTANCE BETWEEN SAMPLE POINTS.  THE'
     3)
 8110 FORMAT(3X,'COMPUTER PRINTED GRAPH IS ONLY AN APPROXIMATION AND MAY
     1 DIFFER SLIGHTLY'/3X,'FROM THE DATA IN THE TABLES.'/)
 8070 FORMAT(22X,'MAXIMUM'/8X,'INTERVAL',7X,'RELIEF'/8X,'(MMS)',6X,
     1 '(MMS)'//
     2         (1X,F14.3,1X,F12.2))
 8080 FORMAT(7X,'0.0',1X,11(F7.0,1X))
 8090 FORMAT(3X,'DELTA L ',11X,'=',F12.3,' MMS'/
     1         3X,'SAMPLE SIZE ',7X,'=',I12,' ELEVATIONS'/
     2         3X,'MINIMUM HEIGHT ',4X,'=',F12.3,' MMS'/
     3         3X,'MAXIMUM RELIEF ',4X,'=',F12.3,' MMS'/
     4         3X,'TOPOGRAPHIC GRAIN  =',F12.3,' MMS'///)
      I=(N+1)/2
      I1=I-1
      AMAX=A(I)
      AMIN=A(I)
      I2=1
      NP2=(N+43)/44
   10 DO 115 J=1,NP2
      IF(N-I) 60,20,20
   20 IF(AMAX-A(I))30,40,40
   30 AMAX=A(I)
```

```
   40 IF(AMIN-A(I))60,60,50
   50 AMIN=A(I)
   60 IF(I1)110,110,70
   70 IF(AMAX-A(I1))80,90,90
   80 AMAX=A(I1)
   90 IF(AMIN-A(I1))110,110,100
  100 AMIN=A(I1)
  110 CONTINUE
      I=I+1
      I1=I1-1
  115 CONTINUE
      RLF(I2)=AMAX-AMIN
      I2=I2+1
      IF (I1.GT.0) GO TO 10
      I2=I2-3
      ANMX=-360.
      DO 140 J=1,I2
      W=RLF(J+1)-RLF(J)
      T=RLF(J+1)-RLF(J+2)
      W=ATAN(W)*57.295
      T=ATAN(T)*57.295
      T=T+W
      IF (ANMX-T) 130,135,135
  130 ANMX=T
      ICOOR=J+1
  135 CONTINUE
  140 CONTINUE
      WRITE (PRINT,8500)
 8500 FORMAT('1',1X)
      NP2=2*NP2
      TOPGR=FLOAT(NP2*ICOOR-1)* DL
      I2=I2+2
      IF(I2.GT.22) GO TO 67
      GO TO 203
   67 WRITE(PRINT,334)
  334 FORMAT(' ','ERROR MESSAGE-I2 IS GREATER THAN 22,THEREFORE,IT WILL
     XBE SET TO 22 ')
      I2=22
  203 DO 200 I=1,22
  200 RAD(I)=FLOAT(NP2*I-1) * DL
      WRITE(PRINT,8050)
      WRITE(PRINT,8060)
      WRITE(PRINT,8100)
      WRITE(PRINT,8110)
      WRITE(PRINT,8090)DL,N,AMIN,RLF(I2),TOPGR
      WRITE(PRINT,8070)(RAD(J1),RLF(J1),J1=1,I2)
      WRITE (PRINT,8500)
      DO 150 I=1,51
      DO 150 J=1,89
  150 IGH(I,J)=IB
      OP=0
  154 OP=OP+1
      DF=OP*25
      IF(DF-RLF(I2))154,155,155
  155 IDF=DF
      DO 160 MG=1,I2
      MG=51-IFIX(50.*RLF(MG)/DF+.5)
  160 IGH(MG,4*NG+1)=IS
      IGH(51,1)=IS
      WRITE(PRINT,8010)
      WRITE(PRINT,8080)(RAD(2*I),I=1,11)
      WRITE(PRINT,8020)
      IPR=3
      DO 190 MG=1,50
      IPR=IPR+1
      IF(4-IPR)170,170,180
  170 DMGR = 102-2*MG
      DMGR = DMGR*IDF
      DMGR = DMGR/100.0
      MGR = DMGR + 0.5
      IPR=0
      WRITE(PRINT,8030)MGR,(IGH(MG,J1),J1=1,89)
      GO TO 185
  180 WRITE(PRINT,8040)(IGH(MG,J1),J1=1,89)
  185 CONTINUE
  190 CONTINUE
      MGR=0
      WRITE(PRINT,8030) MGR,(IGH(51,J2),J2=1,89)
      WRITE(PRINT,8020)
      WRITE(PRINT,8080)(RAD(2*I),I=1,11)
      RETURN
      END
      SUBROUTINE HIPPO (A,N2,AL,A2,HBAR)
      DIMENSION A(1000)
      DIMENSION C(50)
      DIMENSION IC(50), IG(30,50)
      DATA IB/'  '/,IS/'* '/
   10 FORMAT (3X,F5.3,'X',50A1,'X')
   20 FORMAT (//3X,'HYPSOMETRIC INTEGRAL= ',F10.4//)
   30 FORMAT (8X,'X',10('XXXX*'),'X')
   40 FORMAT (12X,'.1',3X,'.2',3X,'.3',3X,'.4',3X,'.5',3X,'.6',3X,'.7',3X
     1,'.8',3X,'.9',3X,'1.0')
   50 FORMAT (3X,'FOLLOWING IS A GRAPH OF THE HYPSOMETRIC FUNCTION,'/3X,
     1'G(R)=PROPORTION OF AREA LYING ABOVE HMIN+R*RELIEF.'/3X,'ON THE HO
     2RIZONTAL AXIS IS R, THE PROPORTION-OF-RELIEF VARIABLE.'/3X,'ON THE
     3 VERTICAL AXIS IS CUMULATIVE PROPORTION OF SAMPLE POINTS,'/3X,'BOT
     4H GRAPHED FROM 0.0 TO 1.0'//)
   60 FORMAT (3X,'AVERAGE HYPSOMETRIC INTEGRAL= ',F8.4)
   70 FORMAT ('1')
      IPRINT=5
      X2=N2
      HBAR=0.0
      DO 160 JKL=1,2
      IF (JKL-2) 71,75,71
   71 CONTINUE
      WRITE (IPRINT,70)
      WRITE (IPRINT,50)
C     ACCUMULATE ALTITUDES INTO RELIEF BRACKETS
```

PROGRAM 3

```
   75 CONTINUE
      R=A2-AL
      DH=R/50.0
      DO 80 I=1,50
   80 IC(I)=0
      DO 110 I=1,N2
      KXY=(A(I)-AL)/DH
      J=KXY+JKL-1
      IF (J) 90,110,90
   90 DO 100 K=1,J
      IF (K .GT. 50) GOTO 100
      IF (K .LT. 01) GOTO 100
      IC(K)=IC(K)+1
  100 CONTINUE
  110 CONTINUE
C     PROPORTION ACCUMULATIONS AND MAKE GRAPH
      DO 125 JM=1,30
      DO 120 JL=1,50
      IG(JM,JL)=IB
  120 CONTINUE
  125 CONTINUE
      DO 130 I=1,50
      L=IC(I)
      C(I)=FLOAT(L)/FLOAT(N2)
      IR=IFIX(29.*C(I))
      IR=30-IR
  130 IG(IR,I)=IS
C     HYPSOMETRIC INTEGRAL AS A DISCRETE SUM
      S=0.0
      DO 140 I=1,50
  140 S=S+C(I)*.02
C     OUTPUT
      DO 150 I=1,30
  150 C(I)=(31-I)*(.03333334)
      IF (JKL-2) 151,155,151
  151 CONTINUE
      WRITE (IPRINT,40)
      WRITE (IPRINT,30)
      WRITE (IPRINT,10) (C(I),(IG(I,J),J=1,50),I=1,30)
      WRITE (IPRINT,30)
      WRITE (IPRINT,40)
      WRITE (IPRINT,45)
   45 FORMAT ('0','          PIKE AND WILSON, 1971, GEOL. SOC. AM. BULL. VOL
     1. 82, 1079-1084.')
  155 CONTINUE
      HBAR=HBAR+S
      WRITE (IPRINT,20) S
  160 CONTINUE
      HBAR=HBAR/2.0
      WRITE (IPRINT,60) HBAR
      RETURN
      END
```

```
C            POWER SPECTRUM ANALYSIS-TDA3 FOR PDP-11
C            BY GARY SELNER CCD FOR DICK PINE MAY,1969
C            REVISED BY WES ROZEMA, JULY 1972
C*********************************************************************
C MODIFICATIONS MADE BY ERIC ELIASON, COMPUTER CENTER DIVISION, MAY 73
C ADDITIONAL MODIFICATIONS MADE FOR USE ON THE MODCOMP II/25, AUG 76
C BY JIM STAPLETON AND LORETTA BARCUS
C*********************************************************************
C
C  CONSIDERING THE PROFILE AS A TIME SERIES, THE CONTRIBUTION OF TOPOGRAPHI
C     FEATURES OF DIFFERENT SIZES TO THE ROUGHNESS OF THE PROFILE IS
C     EXPRESSED AS DENSITY OF THE POWER SPECTRUM OVER VARIOUS FREQUENCY
C     RANGES.
C
C
C
      REAL INSP,LFREQ,LPSD,MNF,MNP,LINT,ID(10),TYPE,ELEVMS
      INTEGER SELECT(9),OP,SCANNO,DISK,PRINT,N2(6),TNPTS
      DIMENSION HPR(2000),F(2000),YOUT(2000),COV(201),WIN(201),FREQ(201)
     1,PSD(201),LFREQ(101),LPSD(101)
      INTEGER PSDDTA
      DATA CHECK/'LANG'/
      DATA ZMTOP/'MTOP'/
      DATA PSDDTA/1/
      IPRINT=5
      IDISK = 7
C
C     READING IDENTIFICATION DATA
C
      REWIND IDISK
      REWIND PSDDTA
  610 READ (IDISK) ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,(SELECT(I),I=1,9),
     1            OP
C*********************************************************************
C DO NOT PERFORM PSD ANA. FOR MATRIX DATA
C*********************************************************************
      IF (TYPE .EQ. ZMTOP) GOTO 7777
      WRITE (IPRINT,1000) (ID(K),K=1,10)
 1000 FORMAT ('1',25X,'P O W E R   S P E C T R U M   A N A L Y S I S'/'0',
     1 25X,'ROZEMA, 1969, U.S. GEOL. SURVEY PROF. PAPER 650-D,D180-D188'
     2,//'0',10A4)
      IF (TYPE-CHECK) 700,620,700
C     LANGLEY DATA
  620 IF (OP) 640,630,640
  630 SELECT(1) = 2
      SELECT(2) = 6
      SELECT(3) =10
      SELECT(4) =14
      NSEL = 4
      GO TO 200
  640 IF (OP-2) 650,660,650
  650 IF (OP-3) 630,660,630
  660 NSEL= 0
      DO 680 I = 1,4
```

```
      IF (SELECT(I)) 670,690,670
  670 NSEL = NSEL + 1
  680 CONTINUE
  690 IF (NSEL.GT.4) NSEL = 4
      GO TO 200
C  NON - LANGLEY DATA
  700 IF(OP) 710,720,710
  710 IF (OP-1) 740,720,740
  720 DO 730 I = 1,4
      SELECT(I) = I
  730 CONTINUE
      NSEL = 4
      GO TO 200
  740 NSEL = 0
      DO 760 I = 1,9
      IF (SELECT(I)) 750,770,750
  750 NSEL = NSEL + 1
  760 CONTINUE
  770 IF (NSEL.GT.4) NSEL = 4
C     ALL SELECTED.  PROCEED WITH READING DATA
  200 N1 = 0
      SUM =0.0
      DO 230  K=1,NSEL
  210 READ (IDISK) SCANNO,NPTS,DL,DISTMS,(HPR(I),I=1,NPTS)
      IF (SCANNO-SELECT(K)) 210,215,210
  215 SUM = SUM + DL
      IF (K.EQ.1) CON = 0.0
      IF (K.NE.1) CON = F(N1)
      I1 = N1 + 1
      I2 = N1 + NPTS
      DO 220 I=I1,I2
      J = I -I1 + 1
      F(I) = HPR(J) + CON
  220 CONTINUE
      N1 = N1 + NPTS
      WRITE (IPRINT,130) SELECT(K),NPTS,DL
  130 FORMAT ('0','PROFILE NUMBER ',I2,' NUMBER OF POINTS IS ',I4,' SAMP
     1LING INTERVAL IS',F8.3,' MMS   ')
  230 CONTINUE
      S      = SUM/FLOAT(NSEL)
      CALL FILT (N1,S,F,N,YOUT)
      IF (N.LT.100) GO TO 500
      MXLAG=N/10
      IF (MOD(MXLAG,2)) 60,70,60
   60 MXLAG=MXLAG+1
   70 T=MXLAG
      MM=MXLAG+1
      DO 20 K=1,MM
      COV(K)=0.0
      KK=N-K+1
      DO 30 I=1,KK
      INDEX=I+K-1
   30 COV(K)=COV(K)+YOUT(I)*YOUT(INDEX)
      COV(K)=COV(K)/N
   20 CONTINUE
      WRITE (IPRINT,108) MXLAG
  108 FORMAT ('0',' MAXIMUM LAG OF ',I4//)
      LL=MXLAG/2+1
      DO 40 K=1,LL
   40 WIN(K)=1.0-(6.0*(K-1)**2/T**2)*(1.0-(K-1)/T)
      LLL=LL+1
      DO 5 K=LLL,MM
    5 WIN(K)=2.0*(1.0-(K-1)/T)**3
      PIM=3.141593/T
      DO 6 J=1,MM
      PSD(J)=0.0
      DO 7 K=2,MM
    7 PSD(J)  =   PSD(J)   +2.0*COV(K)*WIN(K)*COS((K-1)*(J-1)*PIM)
    6 CONTINUE
      DO 8 J=1,MM
      PSD(J)  = 2.0*S*(COV(1)+PSD(J))
    8 FREQ(J)=(J-1)/(2.0*T*S)
      WRITE (IPRINT,109) (FREQ(J),PSD(J),J=1,MM)
  109 FORMAT ('0', 4X,'FOR THE FREQUENCY',8X,'THE PSD VALUE IS'/
     1 (' ',10X,1PE10.3,10X,1PE10.3))
      SUMF=0.0
      SUMP=0.0
      SUMFP=0.0
      SMFSQ=0.0
      NN=2
      DO 55 J=NN,LL
      LFREQ(J)=ALOG10(FREQ(J))
      LPSD(J)=ALOG10(PSD(J))
      SUMF=SUMF+LFREQ(J)
      SUMP=SUMP+LPSD(J)
      SUMFP=SUMFP+LFREQ(J)*LPSD(J)
      SMFSQ=SMFSQ+LFREQ(J)**2
   55 CONTINUE
      DN=LL-NN+1
      MNF=SUMF/DN
      MNP=SUMP/DN
      B=(SUMFP-DN*MNF*MNP)/(SMFSQ-DN*(MNF**2))
      ZLOGA = MNP - B*MNF
      IF (ZLOGA .LT. 0) GOTO 315
      A = 10.0 ** ZLOGA
      GOTO 325
  315 Z = ABS(ZLOGA)
      A = 1.0/(10.0 ** Z)
  325 CONTINUE
      WRITE(IPRINT,1100) ZLOGA,A,B
 1100 FORMAT('OTHE RESULTS OF FITTING A REGRESSION LINE OF THE FORM!',/,
     .'          LOG10(PSD) = LOG10(A) + B * LOG10(FREQ), WHERE A = PSD FOR
     . FREQ = 1, ARE AS FOLLOWS!',/,8X,'LOG10(A) =',F10.4,'     A =',
     .F20.9,'     B =',F20.9)
      INSP=0.0
      DD=1./(2.*T*S)
      DO 13 J=NN,MM
   13 INSP=INSP+.5*DD*(PSD(J)+PSD(J-1))
```

```
      WRITE (IPRINT,115) INSP
  115 FORMAT ('0','TOTAL VARIANCE (INTEGRATED SPECTRUM) IS',1PE10.3)
C.... WRITE PSD DATA ON DISK LOGICAL UNIT 8 FOR USE BY THE PSD PLOT
      WRITE (PSDDTA) MM,(PSD(J),J=1,MM),(FREQ(J),J=1,MM)
  580 ENDFILE PSDDTA
      REWIND PSDDTA
      GO TO 999
  500 WRITE (IPRINT,116)
  116 FORMAT ('0',' THERE ARE NOT ENOUGH POINTS FOR PSD COMPUTATION')
  999 STOP
 7777 CONTINUE
C*************************************************************************
C MM=1 IS A FLAG TO NOT PLOT DATA
C*************************************************************************
      MM = 1
      WRITE(PSDDTA) MM,(PSD(J),J=1,MM),(FREQ(J),J=1,MM)
      GOTO 580
      END
      SUBROUTINE FILT (NY,S,YIN,N,YOUT)
      DIMENSION YIN(2000),YOUT(2000),WEIGT(150)
      IPRINT = 5
      CUT=2./NY
      FCUT=CUT/S
      IF (NY-900) 230,240,240
  240 NW=150
      GO TO 290
  230 IF (NY-650) 250,260,260
  260 NW=100
      GO TO 290
  250 IF (NY-500) 280,270,270
  270 NW=75
      GO TO 290
  280 NW=50
  290 H=.001
      DO 50 L=1,NW
   50 WEIGT(L)=0.0
      WO=0.0
      CALL CHPW (CUT,H,NW,WEIGT,WO)
      WO=-WO
      DO 60 L=1,NW
   60 WEIGT(L)=-WEIGT(L)
      WO=1.0+WO
      I1=NW+1
      I2=NY-NW
      IF (I2.LT.I1) GO TO 150
      N=I2-I1+1
      CALL WTDY (YIN,WO,NW,I1,I2,WEIGT,YOUT)
      WRITE (IPRINT,101) FCUT,H,N
  101 FORMAT ('0','THE PROFILE IS SMOOTHED USING A HIGH-PASS FILTER'/
     1 25X,'(EICHER, USGS COMPUTER DIVISION, PROGRAM NO. W9323)'/
     2' THE CUT-OFF FREQUENCY IS ',F8.6,' PARAMETER H = ',F5.3/
     3' THERE ARE ',I3,' POINTS ON WHICH TO COMPUTE PSD'//)
  150 RETURN
      END
      SUBROUTINE CHPW (CUT,H,NW,WEIGT,WO)
      DIMENSION FILT(151), WEIGT(150)
      KA=NW+1
      SUMHC=H+CUT
      FILT(KA)=SUMHC+SUMHC
      SUM=0.0
      IF (KA.LT.2) GO TO 50
      DEN=0.0
      DNTRM=3.1415927
      RHK=6.2831853*H
      RCPHK=6.2831853*SUMHC
      CPH1=COS(RHK)
      SPH1=SIN(RHK)
      CPCH1=COS(RCPHK)
      SPCH1=SIN(RCPHK)
      FHP1=4.0*H
      FHP=0.0
      CPH=1.0
      SPH=0.0
      CPCH=1.0
      SPCH=0.0
      DO 40 I=1,NW
      C1=CPH*CPH1-SPH*SPH1
      SPH=SPH*CPH1+CPH*SPH1
      CPH=C1
      C2=CPCH*CPCH1-SPCH*SPCH1
      SPCH=SPCH*CPCH1+CPCH*SPCH1
      CPCH=C2
      FHP=FHP+FHP1
      FAC1=1.0-FHP
      IF (ABS(FAC1)-0.0001) 10,20,20
   10 OFAC=0.78539816
      GO TO 30
   20 OFAC=CPH/(FAC1*(1.0+FHP))
   30 DEN=DEN+DNTRM
      FILT(I)=OFAC*(SPCH/DEN)
   40 SUM=SUM+FILT(I)
   50 DELTA=1.0-(FILT(KA)+SUM+SUM)
      TERM=DELTA/FLOAT(NW+NW+1)
      WO=FILT(KA)+TERM+WO
      IF (NW.LT.1) GO TO 70
      DO 60 I=1,NW
   60 WEIGT(I)=WEIGT(I)+FILT(I)+TERM
   70 RETURN
      END
      SUBROUTINE WTDY (YIN,WO,NW,I1,I2,WEIGT,YOUT)
      DIMENSION YIN(2000),YOUT(2000),WEIGT(150)
      K=0
      M=I1
      DO 30 L=M,I2
      SUM=YIN(L)*WO
      IF (NW.LT.1) GO TO 20
      DO 10 J=1,NW
      IPJ=L+J
```

```
      IMJ=L-J
   10 SUM=SUM+(YIN(IMJ)+YIN(IPJ))*WEIGT(J)
   20 N=N+1
   30 YOUT(N) = SUM
      RETURN
      END
```

PROGRAM 4

```
C
C PSD PLOT PROGRAM WRITTEN FOR PINE BY ERIC ELIASON, JUNE 1973
C
C  MODIFIED FOR USE ON THE MODCOMP II/25 IN AUG 76
C  BY JIM STAPLETON AND LORETTA BARCUS
C
      DIMENSION PSD(205),FR(205)
      INTEGER   P(109,109),IBLK,IDASH,IPLUS,IAST,IAX,IAO
      INTEGER PSDDTA
      EQUIVALENCE (IBLK,IB),(IDASH,ID),(IPLUS,IPP),(IAST,IA),
     . (IAX,IX),(IAO,IO)
      DATA IB,ID,IPP,IA,IX,IO/'  ','--','++','**','XX','OO'/
      PSDDTA = 1
      IP = 5
C
      REWIND PSDDTA
C
   60 READ(PSDDTA,END=999) MM,(PSD(J),J=1,MM),(FR(J),J=1,MM)
      IF (MM .EQ. 1) STOP
      PSDMAX = -100.0
      PSDMIN = 10000.0
C*******************************
C FIND MAXIMUM AND MINIMUM POINTS
C*******************************
      DO 10 I = 1,MM
      IF (PSDMAX .LT. PSD(I) .AND. PSD(I) .GT. 0.0) PSDMAX = PSD(I)
      IF (PSDMIN .GT. PSD(I) .AND. PSD(I) .GT. 0.0) PSDMIN = PSD(I)
   10 CONTINUE
      PSDBEG = ALOG10(PSDMIN)
      IF (PSDBEG .LT. 0) PSDBEG = PSDBEG - 1.0
      PSDBEG = AINT(PSDBEG)
C
      PSDEND = ALOG10(PSDMAX)
      IF (PSDEND .LT. 0) PSDEND = AINT(PSDEND)
      IF (PSDEND .GT. 0) PSDEND = AINT(PSDEND+1.0)
      IYBEG = PSDBEG
      IYEND = PSDEND
      YBEG = IYBEG
      YEND = IYEND
      DO 20 I = 1,109
      DO 20 J = 1,109
   20 P(I,J) = IBLK
      IYDEL = IYEND - IYBEG
      YDEL = IYDEL
      DO 25 J = IYBEG,IYEND
      Y = J
      Y = ((Y - YBEG)/YDEL)*108.0
      IY = Y + .5
      IY = IY + 1
      IF (IY .GT. 109) IY = 109
      DO 30 I = 1,109
   30 P(I,IY) = IDASH
   25 CONTINUE
      DO 55 I = 1,109,18
```

```
      DO 55 J = 1,109
   55 P(I,J) = IPLUS
      XBEG = -5.0
      XEND = 1.0
      XDEL = XEND - XBEG
C*****************************
C FILL PLOT MATRIX WITH POINTS
C*****************************
      DO 35 IDATA = 1,MM
      IF (PSD(IDATA) .LE. 0.0) GOTO 40
      IF (FR(IDATA) .LE. 0.0) GOTO 40
      Y = ALOG10(PSD(IDATA))
      X = ALOG10(FR(IDATA))
      Y = ((Y - YBEG)/YDEL)*108.0
      X = ((X - XBEG)/XDEL)*108.0
      IY = Y + .5
      IX = X + .5
      IY = IY + 1
      IX = IX + 1
      IF (IY .GT. 109) GOTO 40
      IF (IX .GT. 109) GOTO 40
      IF (IY .LT. 1) GOTO 40
      IF (IX .LT. 1) GOTO 40
      P(IX,IY) = IAST
      GOTO 35
   40 WRITE(IP,900) PSD(IDATA),FR(IDATA)
  900 FORMAT(' POINTS OFF RANGE OF PLOT, PSD =',1PE10.3,'  FREQUENCY='
     ,1PE10.3)
   35 CONTINUE
C*****************
C WRITE OUT THE PLOT
C**********************
      WRITE(IP,910)
  910 FORMAT('1',35X,'PLOT OF PSD VALUES VERSUS FREQUENCY',/,
     ,'OVERTICAL LOG SCALE - PSD VALUES IN MMS    ',
     ,'SQUARED PER CYCLE PER MM, HORIZONTAL LOG SCALE ',
     ,'- FREQUENCY IN CYCLES PER MM')
      WRITE(IP,915)
  915 FORMAT(' ',10X,'.00001',12X,'.0001',13X,'.001',14X,'.01',15X,
     ,'.1';15X,'1.',15X,'10.')
      DO 50 K = 1,109
      J = 110 - K
      IF ( P(6,J) .EQ. IDASH) GOTO 65
      IF ( P(13,J) .EQ. IDASH) GOTO 65
      IF ( P(25,J) .EQ. IDASH) GOTO 65
      WRITE(IP,920) (P(I,J),I=1,109)
      GOTO 50
   65 POINT = ((J-1.0)/108.0)*YDEL + YBEG
      IF (POINT .LT. 0) POINT = POINT -.5
      IF (POINT .GT. 0) POINT = POINT + .5
      POINT = AINT(POINT)
      IF (POINT .LT. 0) GOTO 70
      POINT = 10.0 ** POINT
      GOTO 75
   70 POINT = ABS(POINT)
      POINT = 1.0/(10.0 ** POINT)
   75 IF (POINT .LT. 0.01) GOTO 80
      WRITE(IP,925) POINT,(P(I,J),I=1,109)
      GOTO 50
   80 WRITE(IP,930) POINT,(P(I,J),I=1,109)
   50 CONTINUE
  920 FORMAT(11X,109A1)
  925 FORMAT(' ',F10.3,109A1)
  930 FORMAT(' ',F10.7,109A1)
      GOTO 60
  999 STOP
      END
```

PROGRAM 5

```
C*************************************************************************
C SLOPE ANGLE BETWEEN SLOPE REVERSALS-TDAS FOR PDP-11
C
C        BY GARY SELNER FOR DICK PIKE APRIL 1969
C        MODIFICATIONS MADE BY ERIC ELIASON 1972,1973
C
C        ADDITIONAL MODIFICATIONS MADE FOR THE MODCOMP II/25
C         IN AUG 76 BY JIM STAPLETON AND LORETTA BARCUS
C
C RATHER THAN ARBATRARILY BOUNDED SLOPE SEGMENTS, THIS SLOPE VALUE
C IS OF THE NATURAL TOPOGRAPHY BETWEEN CHANGES IN SLOPE DIRECTION
C ALONG A PROFILE
C
C
C
C
      INTEGER SELECT(9),OP,SCANNO,DISK,PRINT,N2(6),TNPTS
      REAL MAX1,MAX2,MAX3,MAX01,MAX02,MAX03,ID(10)
      DIMENSION H(1000),SA(999),SL(999)
      DIMENSION LHOLD(60)
      DATA ZMTOP/'MTOP'/
C SET I/O UNITS
      PRINT = 5
      IM = 3
      DISK = 7
      IFILE = 2
C     START PROGRAM
C
C
      REWIND DISK
      REWIND IFILE
      REWIND IM
      IFLAG = 0
   10 READ (DISK) ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,(SELECT(I),I=1,9),
     1    OP
C*************************************************************************
C CHECK FOR MATRIX OPTION
C*************************************************************************
      MOPT = 0
      IF (TYPE .EQ. ZMTOP) MOPT = 1
      IF (MOPT .EQ. 1) NSCANS = 4
      IF (OP) 40,20,40
C     ALL SCANS SELECTED
   20 DO 30 I = 1,NSCANS
      SELECT(I) = I
   30 CONTINUE
      NSEL = NSCANS
      GO TO 100
C      SELECTED SCANS
   40 IF (OP-2) 50,20,50
   50 NSEL = 0
      DO 70 I = 1,9
      IF (SELECT(I)) 80 ,80,60
   60 NSEL = NSEL + 1
   70 CONTINUE
   80 CONTINUE
  100 CONTINUE
C.... WRITE NUMBER OF SELECTED SCANS AND THOSE SCAN NUMBERS ON DISK
C*************************************************************************
C NSEL = 0 IS A FLAG FOR THE SLOPE ANGLE PLOT (TDA6) NOT TO MAKE A PLOT
C FOR THE MATIX DATA INPUT
C*************************************************************************
      IF (NSEL .EQ. 0) NSEL = 1
      IF (MOPT.EQ. 1) NSEL = 0
      WRITE (IFILE) NSEL,SELECT
C     START MAIN LOOP FOR EACH SCAN
      WRITE(PRINT,1200)  ID
 1200 FORMAT('1',28X,'S L O P E   A N G L E   B E T W E E N   S L O P E  R
     1E V E R S A L S','0',43X,10A4)
      IF (MOPT .EQ. 1) NSEL = 4
      DO 500 K1 = 1,NSEL
      K2 = SELECT(K1)
C*************************************************************************
C IF MATRIX OPTION, THEN READ MATRIX DATA FORM UNIT 'IM'
C*************************************************************************
      IF (MOPT .NE. 1) GOTO 7000
      K2 = K1
      IF (IFLAG .EQ. 0)READ(DISK) SCANNO,NPTS,DL,DISTMS,(H(I),I=1,NPTS)
      IFLAG = 1
      READ(IM) NLINES
      IS = 0
      DO 7005 I = 1,NLINES
      READ(IM) NPTS,(H(J+IS),J=1,NPTS)
      IS = IS + NPTS
      LHOLD(I) = IS
 7005 CONTINUE
      IF (K1 .EQ. 3) DL = SQRT(2.0*(DL**2))
      NPTS = IS
      GOTO 7010
 7000 CONTINUE
  110 READ (DISK) SCANNO,NPTS,DL,DISTMS,(H(I),I=1,NPTS)
      IF (SCANNO-K2) 110,120,110
 7010 CONTINUE
  120 WRITE (PRINT,1000)    K2,DL
 1000 FORMAT (////,35X,'PROFILE NO.',I5,8X,'DELTA L =',F9.3,' MMS'//
     1 ' ',4('  REV    SLOPE      SLOPE  ')/
     2 ' ',4('  NO ANGLE(DEG) LENGTH(MM)')/)
      IF (MOPT .EQ. 1 .AND. K2 .EQ. 1) WRITE(PRINT,3050)
      IF (MOPT .EQ. 1 .AND. K2 .EQ. 2) WRITE(PRINT,3055)
      IF (MOPT .EQ. 1 .AND. K2 .EQ. 3) WRITE(PRINT,3060)
      IF (MOPT .EQ. 1 .AND. K2 .EQ. 4) WRITE(PRINT,3065)
 3050 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: WEST TO EAST',/)
 3055 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: NORTH TO SOUTH',
     ./)
 3060 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: SOUTH-WEST TO ',
     .'NORTH-EAST',/)
 3065 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: NORTH-WEST TO ',
     .'SOUTH-EAST',/)
```

```
      NSR = 1
      NANG = 1
      SUMA=ATAN((H(2)-H(1))/DL)
      SUML = DL/COS(SUMA)
      NM1 = NPTS - 1
      IF (MOPT .EQ. 1) MINDEX = 1
      IF (MOPT .EQ. 1) ISTOP = LHOLD(MINDEX)
      DO 410 I = 2,NM1
C***********************************************************************
C IF A MATRIX DATA SET IS BEING WORKED ON (MOPT = 1) AND IF THE
C END OF A DIRECTION VECTOR IS REACHED (I = ISTOP) THEN TERMINATE
C THIS SLOPE/ANGLE TESTING
C***********************************************************************
      IF (MOPT .EQ. 1 .AND. I .EQ. ISTOP) GOTO 5000
      PRSLOP = (H(I)-H(I-1))/DL
      CRSLOP = (H(I+1)-H(I))/DL
      CRANG=ATAN(CRSLOP)
      IF (PRSLOP) 210,220,230
  210 IF (CRSLOP) 280,300,300
  220 IF (CRSLOP) 300,280,300
  230 IF (CRSLOP) 300,300,280
  280 SUMA = SUMA + CRANG
      NANG = NANG + 1
      SUML = SUML + DL/COS(CRANG)
      GO TO 405
 5000 CONTINUE
  300 SA(NSR) = SUMA/FLOAT(NANG)
      SL(NSR) = SUML
C
C     COMPUTES THE THREE LONGEST SLOPES
C
      IF(NSR.EQ.1) GO TO 400
      IF(SL(NSR)-SL(NSR-1)) 710,710,730
  710 IF(NSR-2) 720,720,750
  720 MAXO1= SL(NSR-1)
      MAXO2= SL (NSR)
      MAXO3=0.
      MO1=NSR-1
      MO2=NSR
      GO TO 400
  730 IF(NSR-2) 740,740,750
  740 MAXO1=SL(NSR)
      MAXO2=SL(NSR-1)
      MAXO3=0.
      MO1=NSR
      MO2=NSR-1
      GO TO 400
  750 IF(SL(NSR)-MAXO1) 760,780,780
  760 IF(SL(NSR)- MAXO2) 770,790,790
  770 IF(SL(NSR) -MAXO3) 400,775,775
  775 MAXO3=SL(NSR)
      MO3=NSR
      GO TO 400
  780 MAXO3=MAXO2
      MAXO2=MAXO1
      MAXO1=SL(NSR)
      MO3=MO2
      MO2=MO1
      MO1=NSR
      GO TO 400
  790 MAXO3=MAXO2
      MAXO2=SL(NSR)
      MO3=MO2
      MO2=NSR
  400 CONTINUE
      IF (MOPT .NE. 1) GOTO 5010
      IF (I .NE. ISTOP) GOTO 5010
      MINDEX = MINDEX + 1
      ISTOP = LHOLD(MINDEX)
C***********************************************************************
C THE FOLLOWING IS HIGLY ILLEGAL BUT IT IS THE SOLUTION TO A PROBLEM
C***********************************************************************
      I = I + 1
      CRANG = ATAN(H(I+1)-H(I))/DL
 5010 CONTINUE
      NSR = NSR + 1
      SUMA = CRANG
      SUML = DL/COS(CRANG)
      NANG = 1
  405 CONTINUE
  410 CONTINUE
      NSR = NSR - 1
      IF(NSR.EQ.0) WRITE(PRINT,57)
   57 FORMAT('0',130('*'),/' ',130('*'),/'0','THE NUMBER OF SLOPE REVERS
     XALS IS ZERO.',/' ','NO FURTHER CALCULATIONS CAN BE MADE PROPERLY.'
     X,/' ','THE JOB WILL NOW TERMINATE.')
      IF(NSR.EQ.0) STOP
      TL = DL*FLOAT(NPTS-1)
C
C     COMPUTE THE NUMBER OF SLOPE REVERSALS PER KILOMETER
C
      SRPKM = NSR/(TL/1000.0)
      DO 420 I = 1,NSR
      IF (SA(I)) 510,530,530
  510 SA(I) = -1.0*SA(I)
  530 CONTINUE
      SA(I) = SA(I)*57.29578
C
C     COMPUTES THE THREE STEEPEST SLOPES
C
      IF(  I.EQ.1) GO TO 415
      IF(SA(  I)-SA(  I-1)) 310,310,330
  310 IF(  I-2) 320,320,350
  320 MAX1=SA(  I-1)
      MAX2= SA(  I)
      MAX3=0.
      M1=I-1
      M2=I
```

```
      GO TO 415
  330 IF(  I-2) 340,340,350
  340 MAX1=SA(  I)
      MAX2=SA(  I-1)
      MAX3=0.
      M1=I
      M2=I-1
      GO TO 415
  350 IF(SA(  I)-MAX1) 360,380,380
  360 IF(SA(  I)-MAX2) 370,390,390
  370 IF(SA(  I)-MAX3) 415,375,375
  375 MAX3=SA(I)
      M3=I
      GO TO 415
  380 MAX3=MAX2
      MAX2=MAX1
      MAX1=SA(I)
      M3=M2
      M2=M1
      M1=I
      GO TO 415
  390 MAX3=MAX2
      MAX2=SA(I)
      M3=M2
      M2=I
  415 CONTINUE
  420 CONTINUE
      WRITE (PRINT,1010) (I,SA(I),SL(I),I=1,NSR)
 1010 FORMAT(4(1X,I5,2F10.3))
      IF(NSR.LT.3) GO TO 425
      WRITE(PRINT,1300) SL(M1),MAX1,SL(M2),MAX2,SL(M3),MAX3
 1300 FORMAT(///,' ','THE FIRST STEEPEST SLOPE IS',F9.2,' MMS AT',
     1 F7.2,' DEGREES'//' ','THE SECOND STEEPEST SLOPE IS',F9.2,' MMS
     2 AT',F7.2,' DEGREES'//' ','THE THIRD STEEPEST SLOPE IS',F9.2,
     3 ' MMS AT',F7.2,' DEGREES'////)
      WRITE (PRINT,1400) MAX01,SA(M01),MAX02,SA(M02),MAX03,SA(M03)
 1400 FORMAT (
     1' ','THE FIRST LONGEST SLOPE IS',F9.2,' MMS AT',F7.2,' DEGREES'
     2//' ','THE SECOND LONGEST SLOPE IS',F9.2,' MMS AT',F7.2,
     3' DEGREES'//' ','THE THIRD LONGEST SLOPE IS',F9.2,' MMS AT',
     4 F7.2,' DEGREES'///)
  425 DO 430 I = 1,NSR
      SL(I) = ALOG10(SL(I))
  430 CONTINUE
      WRITE (PRINT,1020) SRPMM
 1020 FORMAT('0','THE NUMBER OF SLOPE REVERSALS PER METER = ',F9.4)
      SUMX=0.
      SUMY=0.
      SUMX2=0.
      SUMXY=0.
      DO 610 I=1,NSR
      SUMX = SUMX + SA(I)
      SUMY = SUMY + SL(I)
  610 CONTINUE
      SUMX = SUMX/FLOAT(NSR)
      SUMY = SUMY/FLOAT(NSR)
      DO 620 I=1,NSR
      DEVX = SA(I) - SUMX
      DEVY = SL(I) - SUMY
      SUMX2 = SUMX2 + DEVX**2
      SUMXY = SUMXY + DEVY*DEVX
  620 CONTINUE
      ZLOGB = SUMXY/SUMX2
      ZLOGA = SUMY - ZLOGB * SUMX
      IF (ZLOGA .LT. 0) GOTO 805
      A = 10.0 ** ZLOGA
      GOTO 815
  805 Z = ABS(ZLOGA)
      A = 1.0/(10.0 ** Z)
  815 IF (ZLOGB .LT. 0) GOTO 825
      B = 10.0 ** ZLOGB
      GOTO 835
  825 Z = ABS(ZLOGB)
      B = 1.0/(10.0 ** Z)
  835 CONTINUE
      WRITE(PRINT,1100) ZLOGA,ZLOGB,A,B
 1100 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:'
     .//,5X,'LOG10(SLOPE LENGTH) = LOG10(A) + (SLOPE ANGLE) * LOG10(B)
     .  ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'   LOG10(B) =',F10.4,
     .,/,14X,'A  =',F10.4,'         B  =',F10.4)
C.... WRITE SLOPE INFORMATION ON DISK
      WRITE (IFILE) NSR,(SA(I),I=1,NSR),(SL(I),I=1,NSR)
  500 CONTINUE
      ENDFILE IFILE
      REWIND IFILE
      STOP
      END
```

PROGRAM 6

```
C      B160B PLOTS SLOPE ANGLE AGAINST SLOPE REVERSALS-TDA6 FOR PDP-11
C*********************************************************************
C MODIFICATIONS MADE BY ERIC ELIASON, COMPUTER CENTER DIVISION, MAY 73
C ADDITIONAL MODIFICATIONS MADE FOR THE MODCOMP II/25 IN AUG 76
C BY JIM STAPLETON AND LORETTA BARCUS
C*********************************************************************
      INTEGER PRINT
      INTEGER     IG(127,101),IBLK,IDASH,IONE,ISY(35)
      DIMENSION SA(800),SL(800),FJK(21),ISEL(9)
      DATA IBLK/'  '/,IDASH/'- '/,IONE/'+ '/,
     1      ISY/'1 ','2 ','3 ','4 ','5 ','6 ','7 ','8 ','9 ','A ','B ',
     2          'C ','D ','E ','F ','G ','H ','I ','J ','K ','L ','M ',
     3          'N ','O ','P ','Q ','R ','S ','T ','U ','V ','W ','X ',
     4          'Y ','Z '/
C     SET CONSTANTS
      PRINT = 5
      IFILE=2
      REWIND IFILE
      READ (IFILE) NSEL,ISEL
      IF (NSEL .EQ. 0) STOP
      WRITE (PRINT,1040)
      WRITE (PRINT,1045)
      WRITE (PRINT,1060)
      WRITE (PRINT,1050)
      WRITE (PRINT,1055)
      WRITE (PRINT,1070)
 1040 FORMAT('1THE FOLLOWING GRAPHS PLOT EACH SLOPE LENGTH AGAINST ',
     1     'ITS SLOPE ANGLE ON SEMI-LOG SCALE.  THE COMPUTER-PRINTED '/
     2     ' ','GRAPH IS AN APPROXIMATION AND MAY DIFFER SLIGHTLY FROM ',
     3     'THE ACTUAL VALUES. WHERE MORE THAN NINE VALUES OCCUPY THE '/
     4     ' ','SAME POSITION, THE SYMBOL PRINTED MAYBE INTERPRETED ',
     5     'AS FOLLOWS '/
     6     ' ','SYMBOL NO. OF VALUES '/)
 1045 FORMAT (' ',' A         10       '/
     8    ' ',' B        11       '/
     9    ' ',' C        12       '/
     A    ' ',' D        13       '/
     B    ' ',' E        14       '/
     C    ' ',' F        15       '/
     D    ' ',' G        16       ')
 1060 FORMAT(' ',' H          17'/
     F    ' ',' I        18       '/
     G    ' ',' J        19       '/
     H    ' ',' K        20       '/
     I    ' ',' L        21       ')
 1050 FORMAT(' ',' M          22       '/
     1       ' ',' N          23       '/
     2       ' ',' O          24       '/
     3       ' ',' P          25       '/
     4       ' ',' Q          26       '/
     5       ' ',' R          27       '/
     6       ' ',' S          28       ')
 1055 FORMAT(' ',' T          29       '/
     8       ' ',' U          30       '/
     9       ' ',' V          31       '/
     A       ' ',' W          32       '/
     B       ' ',' X          33       '/
     C       ' ',' Y          34       '/
     D       ' ',' Z          35 AND OVER'//////////)
 1070 FORMAT(' ','THE SCALE ON THE FOLLOWING GRAPHS IS AS FOLLOWS'/
     1 ' ','THE ABSICCA IS IN DEGREES'/
     2 ' ','THE ORDINATE IS IN MMS   '/)
      DO 3000 K5 = 1,NSEL
      READ (IFILE) NSR,(SA(K6),K6=1,NSR),(SL(K6),K6=1,NSR)
      DO 5 I = 1,21
      FJK(I) = I - 1.0
    5 CONTINUE
C     SET UP GRID
      DO 20 I = 1,127
      DO 10 J=1,101
      IG(I,J)= IBLK
   10 CONTINUE
      DO 15 J = 1,101,5
      IG(I,J) = IONE
   15 CONTINUE
   20 CONTINUE
      DO 40 I = 1,127,18
      DO 30 J=2,100
      IG    (I,J) = IDASH
   30 CONTINUE
   40 CONTINUE
      DO 60   I=1,NSR
      XI = SL(I)
      I1 = XI
      X2 = (XI-I1)*18.0 + 1.5
      IX2 = X2
      IX1 = I1*18 + IX2
      SL(I) = IX1
   60 CONTINUE
      DO 70 I=1,NSR
      XI = SA(I)
      I1 = XI
      X2 = (XI-I1)*5.0 + 1.5
      IX2 = X2
      IX1= I1*5.0 + IX2
      SA(I) = IX1
   70 CONTINUE
      NERR = 0
      DO 140  I=1,NSR
      IY = SL(I)
      IX = SA(I)
      IF ((IY.GT.127).OR.(IY.LE.0).OR.(IX.GT.101).OR.(IX.LE.0))
     1  GO TO 125
      IF (IG(IY,IX)-IBLK)  71,80,71
   71 IF (IG(IY,IX)-IDASH) 72,80,72
   72 IF (IG(IY,IX)-IONE) 90,80,90
   80 IG(IY,IX) = ISY(1)
      GO TO 130
```

```
   90 DO 120 J=1,34
      IF (IG(IY,IX)-ISY(J)) 110,100,110
  100 JP1 = J + 1
      IG(IY,IX) = ISY(JP1)
      GO TO 130
  110 CONTINUE
  120 CONTINUE
      IG(IY,IX) = ISY(35)
      GO TO 130
  125 NERR = NERR + 1
  130 CONTINUE
  140 CONTINUE
      WRITE (PRINT,1000) ISEL(KS)
 1000 FORMAT('1','PROFILE ',I3)
      WRITE (PRINT,1030) (FJK(I),I=1,21)
 1030 FORMAT(' ',7X,21F5.1)
      FMIN = SL(1)
      DO 170 I = 2,NSR
      IF (SL(I).LT.FMIN) FMIN = SL(I)
  170 CONTINUE
      FMAX = SL(1)
      DO 190 I = 2,NSR
      IF (SL(I).GT.FMAX) FMAX = SL(I)
  190 CONTINUE
      I1 = FMIN/18.0
      IBEG = I1*18 + 1
      I1 = FMAX / 18.0
      ILAST = (I1+1)*18 + 1
      DO 150 I = IBEG,ILAST
      IR = ILAST -(I-IBEG)
      I1 = IR-1
      I2 = MOD(I1,18)
      IF (I2) 145,141,145
  141 I2 = I1/18
      F1 = 10.0**I2
      WRITE (PRINT,1020) F1,(IG(IR,J),J=1,101)
 1020 FORMAT(' ',F10.0,101A1)
      GO TO 149
  145 CONTINUE
      WRITE (PRINT,1010) (IG(IR,J),J=1,101)
 1010 FORMAT(' ',10X      ,101A1)
  149 CONTINUE
  150 CONTINUE
      WRITE (PRINT,1030) (FJK(I),I=1,21)
C1030 FORMAT(' ',7X,21F5.1)
      IF (NERR.NE.0) WRITE (PRINT,2000)
 2000 FORMAT('0','THIS   PROFILE CONTAINS SLOPE ANGLES AND/OR SLOPE
     1 'DISTANCES TOO LARGE FOR THE PRINTER PLOT.'/)
 3000 CONTINUE
      REWIND IFILE
 9999 STOP
      END
```

```
C        PROGRAM-BASE LENGTH SLOPE ANGLE AND CURVATURE-TDA7 FOR PDP-
C     SPONSOR-RICHARD PIKE   PROGRAMMER-R.H.GODSON    DATE-MAY,1969
C     THIS PROGRAM READS HEIGHT VALUES FROM DISK AND CALLS SUBROUTINE
C     SLOPES THAT CONVERTS HEIGHTS TO SLOPES AND CURVATURES AND
C     COMPUTES A NUMBER OF STATISTICS.  THIS SUBROUTINE IS CALLED
C     SEVERAL TIMES WITH DIFFERENT MULTIPLES OF THE DISTANCE BETWEEN
C     HEIGHT VALUES
C
C***********************************************************************
C MODIFICATIONS MADE BY ERIC ELIASON, COMPUTER CENTER DIVISION, MAY 73
C ADDITIONAL MODIFICATIONS FOR THE MODCOMP II/25 MADE IN AUG 76
C BY JIM STAPLETON AND LORETTA BARCUS
C***********************************************************************
      INTEGER SELECT(9),OP,SCANUM,SKIP
      REAL ID
      DIMENSION ID(10),ADL(9),BDL(8),CDL(7),DATA(1000),DEL(9),SMEAN(9),
     1 CMEAN(9)
      DIMENSION LHOLD(60)
      REAL MTOP,MSPC
      COMMON LHOLD,MOPT
      DATA MTOP/'MTOP'/,MSPC/'MSPC'/
      MMTEST = 1
      IFLAG = 0
      IM = 3
      ADL(1)=1.
      ADL(2)=2.
      ADL(3)=4.
      ADL(4)=8.
      ADL(5)=20.
      ADL(6)=40.
      ADL(7)=80.
      ADL(8)=100.
      ADL(9)=200.
      BDL(1)=1.
      BDL(2)=2.
      BDL(3)=3.
      BDL(4)=7.
      BDL(5)=17.
      BDL(6)=33.
      BDL(7)=43.
      BDL(6,=67.
      CDL(1)=1.
      CDL(2)=2.
      CDL(3)=4.
      CDL(4)=10.
      CDL(5)=20.
      CDL(6)=26.
      CDL(7)=40.
      IPRINT=5
      IDISK=7
      NN=9
C
      REWIND IM
      REWIND IDISK
```

```
C
      READ(IDISK)       ID,NSCANS,NROWS,NCOLMS,TYPE,ELEVMS,SELECT,OP
C*********************************************************************
C CHECK FOR MATRIX OPTION
C*********************************************************************
      MOPT = 0
      IF (TYPE .EQ. MTOP) MOPT = 1
      IF (MOPT .NE. 1) GOTO 5200
      ADL(1) = 1.0
      ADL(2) = 3.0
      ADL(3) = 5.0
      BDL(1) = 1.0
      BDL(2) = 3.0
      BDL(3) = 5.0
      CDL(1) = 1.0
      CDL(2) = 3.0
      CDL(3) = 5.0
 5200 CONTINUE
      IF (MOPT .NE. 1) GOTO 5000
      SELECT(1) = 1
      SELECT(2) = 2
      SELECT(3) = 3
      SELECT(4) = 4
      GOTO 05
 5000 CONTINUE
      IF(OP.EQ.0.OR.OP.EQ.2) GO TO 3
      GO TO 5
    3 SELECT(1)=2
      SELECT(2)=6
      SELECT(3)=10
      SELECT(4)=14
      SELECT(5)=0
    5 K=1
      J=1
      IF(SELECT(1).EQ.1) GO TO 30
      SKIP=SELECT(1)-1
   10 DO 20 I=1,SKIP
      READ(IDISK,END=160) SCANUM,NPTS,DL,DISTMS,(DATA(KKKK),KKKK=1,NPTS)
   20 CONTINUE
   30 CONTINUE
      IF (MOPT .NE. 1) GOTO 5010
      IF(IFLAG.NE.1)READ(IDISK)SCANUM,NPTS,DL,DISTMS,(DATA(L),L=1,NPTS)
      IFLAG = 1
      READ(IM) NLINES
      IS = 0
      DO 5020 I = 1,NLINES
      READ(IM) NPTS,(DATA(IS+JJJ),JJJ=1,NPTS)
      IS = IS + NPTS
      LHOLD(I) = IS
 5020 CONTINUE
      NPTS = IS
      GOTO 60
 5010 READ(IDISK,END=160) SCANUM,NPTS,DL,DISTMS,(DATA(KKK),KKK=1,NPTS)
      GOTO 60
   40 J=J+1
      IF (MOPT .EQ. 1 .AND. SELECT(J) .EQ. 3) DL = SQRT(2*(DL**2))
      IF(SELECT(J).EQ.0.OR.(J.EQ.10)) GO TO 160
      SKIP=SELECT(J)-(SELECT(J-1)+1)
      IF(SKIP-0)10,30,10
   50 IF(K-NSCANS) 30,30,160
   60 WRITE(IPRINT,1000)
 1000 FORMAT('1',26(/),
     1             16X,'D A T A   F R O M   B A S E   L E N G T H   S L O P E
     2 A N G L E   A N D   C U R V A T U R E   P R O G R A M'///)
      IF (TYPE .EQ. MSPC) GOTO 63
      WRITE(IPRINT,1100) ID,NSCANS,TYPE
 1100 FORMAT(' ',55X,'DATA SET IDENTIFICATION'//,17X,10A4,5X,'NUMBER OF
     1 PROFILES = ',I4,15X,    'TYPE OF DATA = ',A4,//)
      GO TO 65
   63 WRITE(IPRINT,1200) ID,NROWS,NCOLMS,TYPE
 1200 FORMAT(' ',55X,'DATA SET IDENTIFICATION'//,17X,10A4,5X,'ROWS =',I4
     1,1X,'COLUMNS =',I4,5X,'TYPE OF DATA = ',A4,//)
   65 MM=0
      IF (MOPT .EQ. 1 .AND. MMTEST .EQ. 1) WRITE(IPRINT,3050)
      IF (MOPT .EQ. 1 .AND. MMTEST .EQ. 2) WRITE(IPRINT,3055)
      IF (MOPT .EQ. 1 .AND. MMTEST .EQ. 3) WRITE(IPRINT,3060)
      IF (MOPT .EQ. 1 .AND. MMTEST .EQ. 4) WRITE(IPRINT,3065)
      MMTEST = MMTEST + 1
 3050 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: WEST TO EAST',/)
 3055 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: NORTH TO SOUTH',
     ./)
 3060 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: SOUTH-WEST TO ',
     .'NORTH-EAST',/)
 3065 FORMAT(50X,'***** MATRIX OPTION ***** DIRECTION: NORTH-WEST TO ',
     .'SOUTH-EAST',/)
      IF(DL-1.0) 70,100,90
   70 CONTINUE
      IF (MOPT .EQ. 1) NN = 3
      DO 80 I = 1,NN
      IF(ADL(I)-NPTS) 75,150,150
   75 DDL=ADL(I)*DL
      NDL=ADL(I)
      CALL SLOPES(NPTS,DDL,NDL,SCANUM,DATA,YSMEAN,YMEAN)
      MM=MM+1
      DEL(I)=ALOG10(DDL)
      SMEAN(I) =ALOG10(YSMEAN)
      CMEAN(I)=ALOG10(YMEAN)
   80 CONTINUE
      GO TO 150
   90 IF(DL.GE.1.0.AND.DL.LT.2.0)  GO TO 100
      GO TO 120
  100 CONTINUE
      NN = 8
      IF (MOPT .EQ. 1) NN = 3
      DO 110 I = 1,NN
      IF(BDL(I)-NPTS) 105,150,150
  105 DDL=BDL(I)*DL
      NDL=BDL(I)
```

```
      CALL SLOPES(NPTS,DDL,NDL,SCANUM,DATA,YSMEAN,YMEAN)
      MM=MM+1
      DEL(I)=ALOG10(DDL)
      SMEAN(I)=ALOG10(YSMEAN)
      CMEAN(I)=ALOG10(YMEAN)
  110 CONTINUE
      GO TO 150
  120 IF(DL.GE.2.00.AND.DL.LT.3.00) GO TO 130
      NN=7
      GO TO 70
  130 CONTINUE
      NN = 7
      IF (MOPT .EQ. 1) NN = 3
      DO 140 I = 1,NN
      IF(CDL(I)-NPTS) 135,150,150
  135 DDL=CDL(I)*DL
      NDL=CDL(I)
      CALL SLOPES(NPTS,DDL,NDL,SCANUM,DATA,YSMEAN,YMEAN)
      MM=MM+1
      DEL(I)=ALOG10(DDL)
      SMEAN(I)=ALOG10(YSMEAN)
      CMEAN(I)=ALOG10(YMEAN)
  140 CONTINUE
  150 K=K+1
      WRITE(IPRINT,1010)
 1010 FORMAT('1',/////,20X,'RELATION BETWEEN DELTA-L AND MEAN ABSOLUTE S
     .LOPE AND CURVATURE',////)
      CALL LFIT(DEL,SMEAN,MM,5.0,1,MM)
      CALL LFIT(DEL,CMEAN,MM,6.0,1,MM)
      GO TO 40
  160 STOP
      END
      SUBROUTINE SLOPES(NPTS,DDL,NDL,SCANUM,DATA,YSMEAN,YMEAN)
      INTEGER SCANUM
      DIMENSION SLOPE(1000),ASLOPE(1000),CURV(1000),
     1 EXNPTS(30),XNMBER(30),TCUM(30),PCENT(30),CPCENT(30),FREQ(18),
     2 PSLOPE(18),PMEAN(18),GOODFT(10),DATA(1000),XFREQ(18),CFREQ(18),
     3 S(18)
      DIMENSION LHOLD(60)
      COMMON LHOLD,MOPT
      IM = 3
C
      IPRINT=5
 1000 FORMAT(' ',2X,'MINIMUM',5X,'MAXIMUM',7X,'MEAN',6X,'VARIANCE',2X,
     1 'ST DEVIATION',2X,'SKEWNESS',4X,'KURTOSIS',5X,'MEDIAN',/' ',
     2 8(F10.5,2X)///)
 1050 FORMAT(' ',2X,'MINIMUM',5X,'MAXIMUM',7X,'MEAN',6X,'VARIANCE',2X,
     1 'ST DEVIATION',2X,'SKEWNESS',4X,'KURTOSIS',5X,'MEDIAN',2X,'DISP.
     2COEFF.',2X,'ELANDT COEFF.',/' ',10(F10.5,2X)///)
 1100 FORMAT(' ',31X,'ALGEBRAIC STATISTICS'/)
 1200 FORMAT(' ','PROFILE NUMBER =',I3,5X,'DELTA L =',F10.2,' MMS   ',5X,
     1 'NUMBER OF SLOPES OR CURVATURES =',I4,//)
 1300 FORMAT(' ','NUMBER OF NEGATIVE VALUES =',I5,/1X,'NUMBER OF POSITIV
     1E VALUES =',I5,/1X,'RATIO OF NEGATIVE VALUES TO TOTAL =',F5.3,/1X,
     2 'RATIO OF POSITIVE VALUES TO TOTAL =',F5.3,/1X,'NUMBER OF REVERSA
     3LS PER METER OF TRAVERSE =',F9.4)
 1400 FORMAT(' ',31X,'ABSOLUTE STATISTICS'/)
 1500 FORMAT(' ','CHI-SQUARE =',F8.2//)
 1600 FORMAT(' ERROR - NO. SLOPES .LT. 31')
 1700 FORMAT(7X,F5.3,10X,F7.2,6X,F9.4,14X,F6.3)
 1800 FORMAT(///' ',
     1              'PERCENTILE VALUES FOR 7 DEGREES OF FREEDOM FOR THE CH
     2I-SQUARE DISTRIBUTION'/' ','.995',5X,'.99',6X,'.975',5X,'.95',6X,'
     3.90',6X,'.75',6X,'.50',6X,'.25',6X,'.10',6X,'.05'/' ',10(F4.1,5X)
     4/)
 1900 FORMAT(//' ','10 PERCENT TO 90 PERCENT DISPERSION OF THE ALGEBRAIC
     1 VALUES =',F10.5///)
 2000 FORMAT(' ERROR NUMBER CURVES .LT. 31')
 2100 FORMAT('1',25X,'S L O P E   S T A T I S T I C S'////)
 2200 FORMAT(//' ','CUM. PERCENT FREQ.',3X,'CUM. FREQ.',3X,'SLOPE ANGLE'
     1//)
 2300 FORMAT(//' ','CUM. PERCENT FREQ.',3X,'CUM. FREQ.',3X,'SLOPE ANGLE'
     1,3X,'PERCENT OF MEAN SLOPE       '//)
 2400 FORMAT('1',21X,'C U R V A T U R E   S T A T I S T I C S'////)
 2500 FORMAT(///19X,'ALGEBRAIC VALUES'//' ','CLASS',3X,'CLASS BOUNDRIES'
     1,5X,'FREQ.',3X,'CUM. PERCENT FREQ.'/)
 2600 FORMAT (///19X, 'ABSOLUTE VALUES'//)
 2700 FORMAT(' ',2X,I2,2X,F7.3,' TO ',F7.3,F9.1,10X,F6.4)
C
C     GOODNESS OF FIT TABLE FOR 7 DEGREES OF FREEDOM
C
      GOODFT(1)=20.3
      GOODFT(2)=18.5
      GOODFT(3)=16.0
      GOODFT(4)=14.1
      GOODFT(5)=12.0
      GOODFT(6)=9.0
      GOODFT(7)=6.4
      GOODFT(8)=4.3
      GOODFT(9)=2.8
      GOODFT(10)=2.2
C
C     COMPUTING THE ALGEBRAIC AND ABSOLUTE VALUES OF SLOPE AND CURVATURE
C
      J=NDL+1
      K=1
C***********************************************************************
C CHECK FOR MATRIX OPTION
C***********************************************************************
      IF (MOPT .NE. 1) GOTO 5000
      MINDEX = 1
      ISTOP = LHOLD(MINDEX)
      DO 5010 I = 1,NPTS
      IF (J .GT. NPTS) GOTO 45
      IF (I .EQ. ISTOP) GOTO 5040
      IF (J .GT. ISTOP) GOTO 5050
      SLOPE(K) = DATA(J) - DATA(I)
      IF (SLOPE(K) .EQ. 0.0) GOTO 5020
```

```
      SLOPE(K) = ATAN2(SLOPE(K),DDL)*57.296
 5020 ASLOPE(K) = ABS(SLOPE(K))
      IF (K .EQ. 1) GOTO 5030
      CURV(K-1) = SLOPE(K-1) - SLOPE(K)
 5030 J = J + 1
      IF (J .GT. NPTS) GOTO 45
      K = K + 1
      GOTO 5010
 5040 MINDEX = MINDEX + 1
      ISTOP = LHOLD(MINDEX)
 5050 J = J + 1
 5010 CONTINUE
 5000 CONTINUE
      DO 40 I=1,NPTS
      SLOPE(K)= DATA(J)-DATA(I)
      IF(SLOPE(K))10,20,10
   10 SLOPE(K)= ATAN2(SLOPE(K),DDL)*57.296
      GO TO 30
   20 SLOPE(K)=0.
   30 ASLOPE(K)= ABS(SLOPE(K))
      IF(K.EQ.1) GO TO 33
      CURV(K-1)=SLOPE(K-1)-SLOPE(K)
   33 J=J+1
      IF(J-NPTS) 35,35,45
   35 CONTINUE
      K=K+1
   40 CONTINUE
   45 N3=K
      N4=N3-1
      IF(N3.LT.31) GO TO 400
C
C     DETERMING NUMBER OF SLOPE REVERSALS AND SLOPE CURVATURES PER
C     METER OF TRAVERSE. A CHANGE FROM EITHER NEGATIVE OR POSITIVE
C     ANGLES TO ZERO ANGLES AND VISA VERSA IS CONSIDERED A REVERSAL
C
      WRITE(IPRINT,2100)
      DO 370 JJJ=1,2
      K=0
      L=0
      M=0
      DO 90 I=1,N4
      IF(SLOPE(I)) 50,60,70
   50 K=K+1
      IF(SLOPE(I+1)) 80,65,75
   60 IF(SLOPE(I+1)) 77,80,75
   65 L=L+1
      GO TO 80
   70 M=M+1
      IF(SLOPE(I+1)) 77,65,80
   75 L=L+1
      GO TO 80
   77 L=L+1
      GO TO 80
   80 CONTINUE
   90 CONTINUE
      IF(SLOPE(N3)) 92,95,93
   92 K=K+1
      GO TO 95
   93 M=M+1
   95 IF(L)110,100,110
  100 RVRSL=0.
      GO TO 120
  110 RVRSL=1000./(DDL*N3)*L
  120 IF(K) 140,130,140
  130 PERNEG=0.
      GO TO 150
  140 PERNEG=FLOAT(K)/FLOAT(N3)
  150 IF(M) 160,155,160
  155 PERPOS=0.
      GO TO 165
  160 PERPOS=FLOAT(M)/FLOAT(N3)
  165 WRITE(IPRINT,1200) SCANUM,DDL,N3
      KNEG=K
      MPOS=M
C
C     ARRANGING SLOPES IN ASCENDING ORDER
C
      DO 290 I=1,N4
      K=N3-I
      DO 280 J=1,K
      IF(SLOPE(J)-SLOPE(J+1))260,260,250
  250 X=SLOPE(J)
      SLOPE(J)=SLOPE(J+1)
      SLOPE(J+1)=X
  260 CONTINUE
  280 CONTINUE
  290 CONTINUE
C
C     COMPUTING THE MEDIAN
C
      IF(MOD(N3,2).EQ.0) GO TO 420
      INDEX=N3/2+1
      XMDIAN=SLOPE(INDEX)
      GO TO 430
  420 INDEX=N3/2
      JNDEX=N3/2+1
      XMDIAN=(SLOPE(INDEX)+SLOPE(JNDEX))/2.
C
C     ARRANGING SLOPES IN ASCENDING ORDER
C
  430 DO 470 I=1,N4
      K=N3-I
      DO 460 J=1,K
      IF(ASLOPE(J)-ASLOPE(J+1)) 450,450,440
  440 X=ASLOPE(J)
      ASLOPE(J)=ASLOPE(J+1)
      ASLOPE(J+1)=X
  450 CONTINUE
```

```
  460 CONTINUE
  470 CONTINUE
C
C     COMPUTING THE MEDIAN
C
      IF(MOD(N3,2).EQ.0) GO TO 480
      INDEX=N3/2+1
      YMDIAN=ASLOPE(INDEX)
      GO TO 490
  480 INDEX=N3/2
      JNDEX=N3/2+1
      YMDIAN=(ASLOPE(INDEX)+ASLOPE(JNDEX))/2.
  490 CALL    STAT(SLOPE,NPTS,NDL,XMEAN,XMAX,XMIN,XVAR,XSDEV,XSKEW,XKURT,
     1 N3)
      WRITE(IPRINT,1100)
      WRITE(IPRINT,1000) XMIN,XMAX,XMEAN,XVAR,XSDEV,XSKEW,XKURT,XMDIAN
      CALL    STAT(ASLOPE,NPTS,NDL,YMEAN,YMAX,YMIN,YVAR,YSDEV,YSKEW,
     1 YKURT,N3)
      DSPCF=XSDEV/YMEAN
      ELTCF=YMEAN/YSDEV
      WRITE(IPRINT,1400)
      WRITE(IPRINT,1050) YMIN,YMAX,YMEAN,YVAR,YSDEV,YSKEW,YKURT,YMDIAN,
     1 DSPCF,ELTCF
      WRITE(IPRINT,1300) KNEG,MPOS,PERNEG,PERPOS,RVRSL
C
C     PERCENT CUMULATIVE FREQUENCIES FOR ALGEBRAIC TABLE
C
      FREQ(1)=.01
      FREQ(2)=.02
      FREQ(3)=.05
      FREQ(4)=.10
      FREQ(5)=.15
      FREQ(6)=.20
      FREQ(7)=.30
      FREQ(8)=.40
      FREQ(9)=.50
      FREQ(10)=.60
      FREQ(11)=.70
      FREQ(12)=.80
      FREQ(13)=.85
      FREQ(14)=.90
      FREQ(15)=.95
      FREQ(16)=.98
      FREQ(17)=.99
      FREQ(18)=1.00
      NS=1
      NT=18
      C1=.196854
      C2=.115194
      C3=.000344
      C4=.019527
      CHISQR=0.
      WRITE(IPRINT,2500)
C
C     COMPUTING PERCENT FREQUENCIES AND THE EXPECTED NUMBER IN EACH
C     CLASS FOR THE CHI-SQUARE DISTRIBUTION
C
      M = 1
      CINCRM=(XMAX-XMIN)/10.
      BEG=XMIN
      END=XMIN+CINCRM
      DO 230 J=1,10
      K=J
      N=0
      DO 170 I=1,N3
      IF(K.EQ.10) GO TO 169
      IF(SLOPE(I).GE.BEG.AND.SLOPE(I).LT.END) N=N+1
      GO TO 171
  169 IF(SLOPE(I).GE.BEG) N=N+1
  171 CONTINUE
  170 CONTINUE
      XNMBER(J)=N
      IF(J-1)190,180,190
  180 TCUM(1)=XNMBER(1)
      ZB= ABS((BEG-XMEAN)/XSDEV)
      ZE= ABS((END-XMEAN)/XSDEV)
      PB=1.-.5*(1./(1.+C1*ZB+C2*ZB**2+C3*ZB**3+C4*ZB**4)**4)
      PE=1.-.5*(1./(1.+C1*ZE+C2*ZE**2+C3*ZE**3+C4*ZE**4)**4)
      EXNPTS(J)= ABS(PB-PE)*N3
      GO TO 195
  190 TCUM(J)=XNMBER(J)+TCUM(J-1)
      PB=PE
      ZE= ABS((END-XMEAN)/XSDEV)
      PE=1.-.5*(1./(1.+C1*ZE+C2*ZE**2+C3*ZE**3+C4*ZE**4)**4)
      EXNPTS(J)= ABS(PB-PE)*N3
  195 IF(XNMBER(J)) 200,210,200
  200 PCENT(J)=XNMBER(J)/N3
      GO TO 220
  210 PCENT(J)=0.
  220 CPCENT(J)=TCUM(J)/N3
      IF(M.EQ.2) GO TO 227
      WRITE(IPRINT,2700) J,BEG,END,XNMBER(J),CPCENT(J)
C
C     COMPUTING CHI-SQUARE
C
      IF(EXNPTS(J).EQ.0.) GO TO 227
  225 CHISQR= (XNMBER(J)-EXNPTS(J))**2/EXNPTS(J)+CHISQR
  227 BEG=END
      END=END+CINCRM
  230 CONTINUE
C
C     COMPUTING VALUES FOR CUMULATIVE FREQUENCY TABLE
C
      WRITE(IPRINT,2200)
      DO 330 I = NS,NT
      S(I) = N3 * FREQ(I)
      J = S(I)
      IF (J .GT. N3) J = N3
```

```
      IF (J .LT.  1) J = 1
      PSLOPE(I) = SLOPE(J)
      IF (J .EQ. N3) GOTO 328
      T = AMOD( S(I), AINT( S(I)) )
      PSLOPE(I) = (SLOPE(J+1) - SLOPE(J))*T + SLOPE(J)
  328 WRITE(IPRINT,1700) FREQ(I),S(I),PSLOPE(I)
  330 CONTINUE
      DISP=PSLOPE(14)-PSLOPE(5)
      WRITE(IPRINT,1900) DISP
      WRITE(IPRINT,1800) (GOODFT(I),I=1,10)
      WRITE(IPRINT,1500) CHISQR
  335 DO 340 I=1,N3
      SLOPE(I)=ASLOPE(I)
  340 CONTINUE
      XMEAN=YMEAN
      XMAX=YMAX
      XMIN=YMIN
      XSDEV=YSDEV
      FREQ(1) = 1.0
      FREQ(2) = .90
      FREQ(3) = .80
      FREQ(4) = .70
      FREQ(5) = .60
      FREQ(6) = .50
      FREQ(7) = .40
      FREQ(8) = .30
      FREQ(9) = .20
      FREQ(10) = .15
      FREQ(11) = .10
      FREQ(12) = .05
      FREQ(13) = .02
      FREQ(14) = .01
      FREQ(15) = .005
      FREQ(16) = .002
      FREQ(17) = .001
      WRITE(IPRINT,2600)
      WRITE(IPRINT,2300)
      DO 900 I = 1,17
      S(I) = N3 * FREQ(I)
      J = N3 - S(I)
      IF (J .GT. N3) J = N3
      IF (J .LT. 1 ) J = 1
      PSLOPE(I) = SLOPE(J)
      IF (J .EQ. N3) GOTO 905
      TEST = AINT(S(I))
      IF (TEST .EQ. 0.0) GOTO 905
      T = AMOD( S(I), TEST)
      PSLOPE(I) = (SLOPE(J+1) - SLOPE(J))*T + SLOPE(J)
  905 PMEAN(I) = PSLOPE(I)/XMEAN
      WRITE(IPRINT,1700) FREQ(I),S(I),PSLOPE(I),PMEAN(I)
      XFREQ(I) = ALOG10(FREQ(I))
  900 CONTINUE
      NSR = 17
      NS = 1
      NT = 17
      C=1.
      IF(JJJ.EQ.2) C=3.
      CALL LFIT(PSLOPE,XFREQ,NSR,C,NS,NT)
      C=2.
      IF(JJJ.EQ.2) C=4.
      CALL LFIT(PMEAN,XFREQ,NSR,C,NS,NT)
      IF(JJJ-2) 355,9999,355
  355 WRITE(IPRINT,2400)
      N3=N4
      IF(N3.LT.31) GO TO 410
      N4=N4-1
      DO 360 I=1,N3
      SLOPE(I)=CURV(I)
      ASLOPE(I) = ABS(CURV(I))
  360 CONTINUE
      YSMEAN=YMEAN
  370 CONTINUE
      GO TO 9999
  400 WRITE(IPRINT,1600)
      GO TO 9999
  410 WRITE(IPRINT,2000)
 9999 RETURN
      END
      SUBROUTINE   STAT(X,N1,N2,XMEAN,XMAX,XMIN,XVAR,XSDEV,XSKEW,XKURT,
     1      N3)
      DIMENSION X(1000)
      DOUBLE PRECISION XDEV,SUM1,SUM2,SUM3,SUM4,XK4,XK3,XK2
      IPRINT=5
      SUM1 = 0.0D0
      SUM2 = 0.0D0
      SUM3 = 0.0D0
      SUM4 = 0.0D0
      XMAX = 0.1E-30
      XMIN = 0.1E+30
      DO 50 I=1,N3
C     SUMMATION FOR MEAN
      SUM1 = SUM1 + X(I)
C     MAXIMUM COMP
      IF (XMAX-X(I))  10,20,20
   10 XMAX = X(I)
   20 CONTINUE
C     MINIMUM COMP
      IF (XMIN-X(I))  40,40,30
   30 XMIN = X(I)
   40 CONTINUE
   50 CONTINUE
C     COMPUTE MEAN VALUE
      FN=N3
      XMEAN = SUM1/FN
C     ACCUMULATE SUMS OF DEVIATIONS FROM MEAN
      DO 60 I=1,N3
      XDEV = X(I) - XMEAN
      SUM2 = SUM2 + XDEV**2
```

```
      SUM3 = SUM3 + XDEV**3
      SUM4 = SUM4 + XDEV**4
   60 CONTINUE
C     COMPUTE K - STATISTICS
      FN1=FN-1.0
      FN2 = FN1 - 1.0
      FN3 = FN2 - 1.0
      IF (FN3) 500,500,70
   70 XK4 = (FN/(FN1*FN2*FN3))*( (FN+1)*SUM4 - 3.0D0*(FN1/FN)*SUM2
   75 IF (FN2) 510,510,80
   80 XK3= (FN/(FN1*FN2))*SUM3
   85 IF (FN1) 520,520,90
   90 XK2= (1.0/FN1)*SUM2
   95 CONTINUE
C     CONVERT TO MOMENTS
      XVAR = XK2
      IF (XVAR) 530,530,110
  110 XSDEV = DSQRT(XK2)
      XSKEW = XK3/XK2**1.5
      XKURT = XK4/XK2**2
  115 CONTINUE
      GO TO 9999
C     ERROR CONDITIONS
  500 WRITE (IPRINT,1000)
 1000 FORMAT('0ERROR .LT. 4 PTS. KURTOSIS CAN NOT BE COMPUTED')
      XK4 = 1.0E30
      GO TO 75
  510 WRITE (IPRINT,1010)
 1010 FORMAT('0ERROR .LT. 3 PTS. SKEWNESS CAN NOT BE COMPUTED')
      XK3 = 1.0E30
      GO TO 85
  520 WRITE (IPRINT,1020)
 1020 FORMAT('0ERROR .LT. 2 PTS. STAND. DEV. CAN NOT BE COMPUTED')
      XK2 = 1.0E30
      GO TO 115
  530 WRITE (IPRINT,1030)
 1030 FORMAT('0ERROR NEG. VAR.,STAND. DEV. CAN NOT BE COMPUTED')
      XSDEV = 1.0E30
      XSKEW = 1.0E30
      XKURT = 1.0E30
 9999 RETURN
      END
      SUBROUTINE LFIT(SA,SL,NSR,C,NS,NT)
      DIMENSION SA(18),SL(18)
      DOUBLE PRECISION SUMX,SUMY,SUMX2,SUMXY,DEVX,DEVY
      IPRINT = 5
      SUMX = 0.0D0
      SUMY = 0.0D0
      SUMX2 = 0.0D0
      SUMXY = 0.0D0
      NP = NS
      DO 10 I = NP,NT
      SUMX = SUMX + SA(I)
      SUMY = SUMY + SL(I)
   10 CONTINUE
      SUMX = SUMX/FLOAT(NSR)
      SUMY = SUMY/FLOAT(NSR)
      DO 20 I = NP,NT
      DEVX = SA(I) - SUMX
      DEVY = SL(I) - SUMY
      SUMX2 = SUMX2 + DEVX**2
      SUMXY = SUMXY + DEVY*DEVX
   20 CONTINUE
      B = SUMXY/SUMX2
      ZLOGA = SUMY - B*SUMX
      IF (ZLOGA .LT. 0) GOTO 200
      A = 10.0 ** ZLOGA
      GOTO 210
  200 Z = ABS(ZLOGA)
      A = 1.0/(10.0 ** Z)
  210 CONTINUE
      IF(C.EQ.2) GO TO 30
      IF(C.EQ.3.) GO TO 40
      IF(C.EQ.4.) GO TO 50
      IF(C.EQ.5.) GOTO 60
      IF(C.EQ.6.) GOTO 70
      WRITE(IPRINT,1000) ZLOGA,A,B
 1000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
     .'       LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (SLOPE ANGLE)
     .ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'    A =',F10.4,'    B ='
     .,F10.4)
      RETURN
   30 WRITE(IPRINT,2000) ZLOGA,A,B
 2000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
     .'       LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN
     . SLOPE)    ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'    A =',
     .F10.4,'    B =',F10.4)
      RETURN
   40 WRITE(IPRINT,3000) ZLOGA,A,B
 3000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
     .'       LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (CURVATURE ANGLE
     .)    ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'    A =',F10.4,
     .'    B =',F10.4)
      RETURN
   50 WRITE(IPRINT,4000) ZLOGA,A,B
 4000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
     .'       LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN
     . CURVATURE)    ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'    A =',
     .F10.4,'    B =',F10.4)
      RETURN
   60 WRITE(IPRINT,5000) ZLOGA,A,B
 5000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
     1'       LOG10(MEAN ABSOLUTE SLOPE) = LOG10(A) + B * LOG10(DELTA-L)
     .   ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'    A =',F10.4,
     .'    B =',F10.4)
      RETURN
   70 WRITE(IPRINT,6000) ZLOGA,A,B
 6000 FORMAT('0THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:',/,
```

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     .'      LOG10(MEAN ABSOLUTE CURVATURE) = LOG10(A) + B * LOG10(DELTA
     .-L)   ARE AS FOLLOWS:',/,8X,'LOG10(A) =',F10.4,'     A =',F10.4,
     .'     B =',F10.4)
      RETURN
      END
```

APPENDIX B

Included in this Appendix is a sample output from the Terrain Analysis software package listed in Appendix A. The profile shown in Figure 1 was digitized at a 3-mm equivalent ground spacing and these data used as input to the Terrain Analysis program. All linear values are in millimeters and all angles in degrees. Brief descriptions of the tabular and graphical output data are included in the text. *Delta-L is the sampling interval of the profile in millimeters. **Maximum, minimum, and mean values listed under relief analysis (first page of output) are arbitrary elevation values (in millimeters) used in establishing the coordinate system for the stereo model. For brevity, results for only the first two of seven iterations of the base length subroutine are shown.

OUTPUT FROM
PROGRAM 2

R E L I E F   A N A L Y S I S

MODEL 2 OH X-DIR RERUN 02-13-78
PROFILE NO. 1

DELTA L = 3.000 MMS

BELOW ARE SOME DESCRIPTIVE PARAMETERS
FROM NELEVATIONS, EVERY I-TH SAMPLE ELEVATION

I	N	MINIMUM	MAXIMUM	RELIEF	MEAN	VARIANCE	STD.DEV.	SKEWNESS	KURTOSIS	E.R. 1	E.R. 2
1	454	885.200	1451.900	566.700	1085.246	32655.94	180.7095	0.6281	-1.0332	0.3530	0.3530
2	227	885.200	1451.900	566.700	1084.935	32775.73	181.0407	0.6329	-1.0301	0.3525	0.3525
4	114	885.300	1451.900	566.600	1085.100	32899.87	181.3832	0.6416	-1.0164	0.3526	0.3527
10	46	885.200	1451.900	566.700	1084.250	33677.67	183.5148	0.6648	-0.9674	0.3512	0.3512
20	23	887.000	1451.900	564.900	1082.874	34228.09	185.0084	0.7004	-0.8960	0.3467	0.3488
50	10	892.500	1426.100	533.600	1080.160	32793.67	181.0902	0.9588	-0.1745	0.3517	0.3440

E.R. 1 IS CALCULATED FROM EACH SAMPLE OF N POINTS AND IS THE RATIO
(MEAN - HMIN)/(HMAX - HMIN)
E.R.2 IS THE SAME RATIO, BUT CALCULATED USING THE TOTAL SAMPLE'S HMAX AND HMIN.

CLASS	CLASS BOUNDARIES		FREQ.	CUM. PERCENT FREQ.
1	885.200	904.090	40.	8.81
2	904.090	922.980	46.	18.94
3	922.980	941.870	69.	34.14
4	941.870	960.760	52.	45.59
5	960.760	979.650	9.	47.58
6	979.650	998.540	11.	50.00
7	998.540	1017.430	4.	50.88
8	1017.430	1036.320	4.	51.76
9	1036.320	1055.209	0.	51.76
10	1055.209	1074.100	17.	55.51
11	1074.100	1092.990	5.	56.61
12	1092.990	1111.879	10.	58.81
13	1111.879	1130.770	20.	63.22
14	1130.770	1149.660	4.	64.10
15	1149.660	1168.550	4.	64.98
16	1168.550	1187.439	36.	72.91
17	1187.439	1206.330	7.	74.45
18	1206.330	1225.220	2.	74.89
19	1225.220	1244.109	4.	75.77
20	1244.109	1263.000	2.	76.21
21	1263.000	1281.890	11.	78.63
22	1281.890	1300.779	9.	80.62
23	1300.779	1319.669	14.	83.70
24	1319.669	1338.560	24.	88.99
25	1338.560	1357.450	3.	89.65
26	1357.450	1376.339	3.	90.31
27	1376.339	1395.229	3.	90.97
28	1395.229	1414.120	8.	92.73
29	1414.120	1433.009	14.	95.81
30	1433.009	1451.899	19.	100.00

FOLLOWING IS A GRAPH OF THE HYPSOMETRIC FUNCTION,
G(R)=PROPORTION OF AREA LYING ABOVE HMIN+R*RELIEF.
ON THE HORIZONTAL AXIS IS R, THE PROPORTION-OF-RELIEF VARIABLE.
ON THE VERTICAL AXIS IS CUMULATIVE PROPORTION OF SAMPLE POINTS,
BOTH GRAPHED FROM 0.0 TO 1.0

```
         .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
     XXXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*X
1.000X                                                  X
0.967X                                                  X
0.933X                                                  X
0.900X**                                                X
0.867X                                                  X
0.833X  *                                               X
0.800X                                                  X
0.767X                                                  X
0.733X                                                  X
0.700X   *                                              X
0.667X    *                                             X
0.633X                                                  X
0.600X                                                  X
0.567X     *                                            X
0.533X      **                                          X
0.500X        ****                                      X
0.467X            ****                                  X
0.433X                ***                               X
0.400X                   *                              X
0.367X                    *****                         X
0.333X                                                  X
0.300X                         *                        X
0.267X                          ******                  X
0.233X                                ***               X
0.200X                                   **             X
0.167X                                     *            X
0.133X                                      ***         X
0.100X                                         ******   X
0.067X                                               *  X
0.033X                                                **X
     XXXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*XXXX*X
         .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
```

PIKE AND WILSON, 1971, GEOL. SOC. AM. BULL. VOL. 82, 1079-1084.

HYPSOMETRIC INTEGRAL=   0.3430

HYPSOMETRIC INTEGRAL=   0.3629

AVERAGE HYPSOMETRIC INTEGRAL=   0.3530

THE FOLLOWING DATA AND GRAPH GIVE INFORMATION RELATED TO THE TOPOGRAPHIC GRAIN OF A SAMPLE AREA. IF THE SIZE OF PROGRESSIVELY LARGER NESTED INTERVALS (HORIZONTAL AXIS) OF A PROFILE IS PLOTTED AGAINST THE MAXIMUM RELIEF WITHIN THE INTERVAL(VERTICAL AXIS), THE GRAPH INCREASES RAPIDLY TO A POINT AND THEN LEVELS OFF. THE INTERVAL SIZE OF

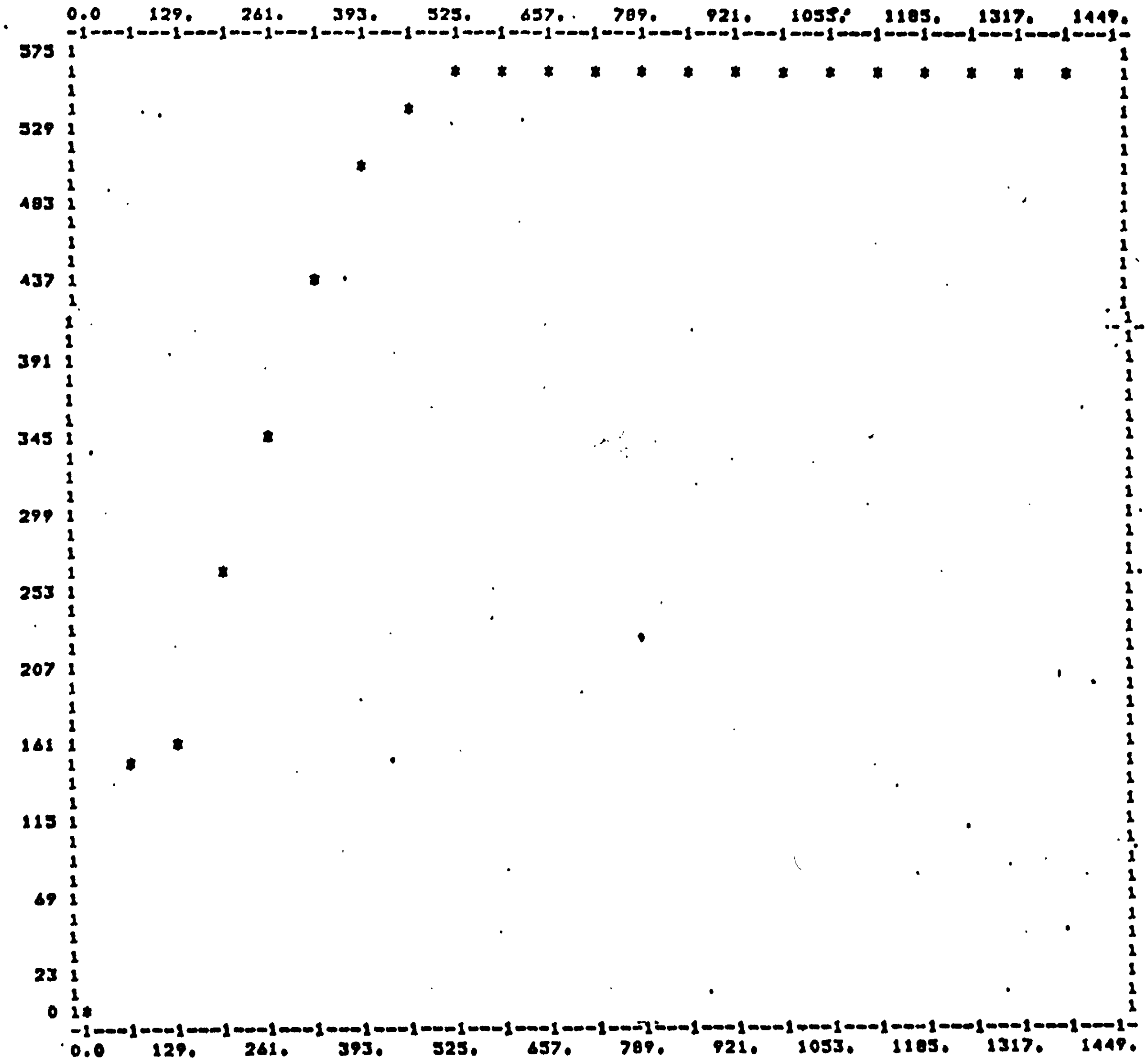
THE POINT AT WHICH THE GRAPH LEVELS OFF IS THE TOPOGRAPHIC GRAIN. MOST OF THE TOPOGRAPHIC CHARACTERISTICS OF THE SAMPLE REGION WILL BE CONTAINED WITHIN AN INTERVAL OF THIS SIZE.

IN THE FOLLOWING DELTA L IS THE DISTANCE BETWEEN SAMPLE POINTS. THE COMPUTER PRINTED GRAPH IS ONLY AN APPROXIMATION AND MAY DIFFER SLIGHTLY FROM THE DATA IN THE TABLES.

DELTA L	=	3.000 MMS
SAMPLE SIZE	=	454 ELEVATIONS
MINIMUM HEIGHT	=	885.200 MMS
MAXIMUM RELIEF	=	566.700 MMS
TOPOGRAPHIC GRAIN	=	591.000 MMS

INTERVAL (MMS)	MAXIMUM RELIEF (MMS)
63.000	146.20
129.000	159.30
195.000	259.90
261.000	348.30
327.000	442.30
393.000	508.00
459.000	544.70
525.000	561.30
591.000	566.70
657.000	566.70
723.000	566.70
789.000	566.70
855.000	566.70
921.000	566.70
987.000	566.70
1053.000	566.70
1119.000	566.70
1185.000	566.70
1251.000	566.70
1317.000	566.70
1383.000	566.70

THE FOLLOWING GRAPH SHOWS THE RELATIONSHIP BETWEEN INTERVAL
AND THE MAXIMUM RELIEF WITHIN A GIVEN INTERVAL
-THE HORIZONTAL AXIS LISTS THE INTERVAL IN MMS
-THE VERTICAL AXIS LISTS THE HEIGHT IN MMS ABOVE MINIMUM ALTITUDE.



OUTPUT FROM
PROGRAM 3

P O W E R   S P E C T R U M   A N A L Y S I S

ROZEMA, 1969, U.S. GEOL. SURVEY PROF. PAPER 650-D,D180-D188

MODEL 2 ON X-DIR RERUN 02-13-78

PROFILE NUMBER 1 NUMBER OF POINTS IS 454 SAMPLING INTERVAL IS 3.000 MMS

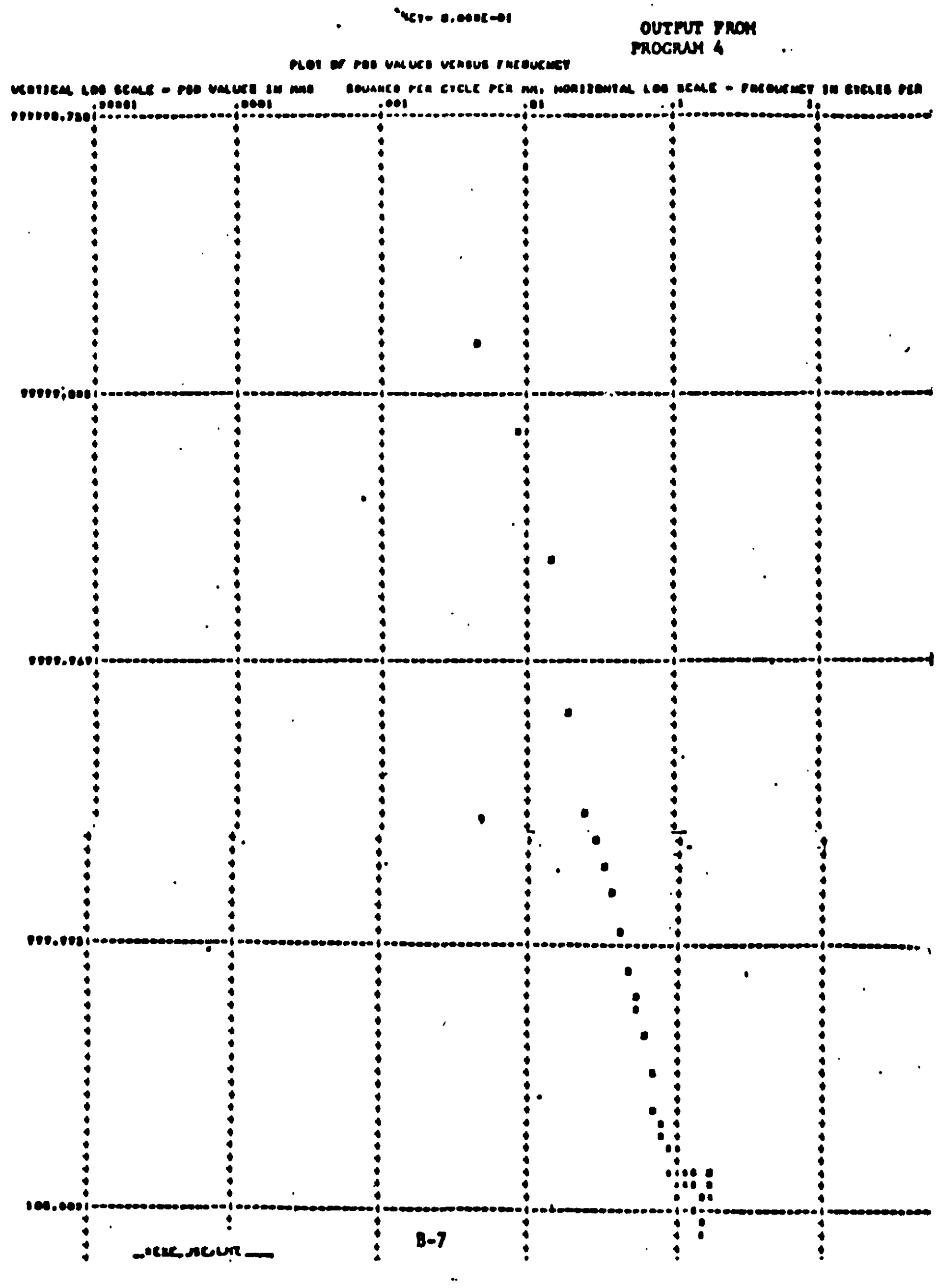
THE PROFILE IS SMOOTHED USING A HIGH-PASS FILTER
(EICHER, USGS COMPUTER DIVISION, PROGRAM NO. W9323)
THE CUT-OFF FREQUENCY IS 0.001468 PARAMETER H = 0.001
THERE ARE 354 POINTS ON WHICH TO COMPUTE PSD

MAXIMUM LAG OF 36

FOR THE FREQUENCY	THE PSD VALUE IS
0.000E-01	1.852E+05
4.630E-03	1.440E+05
9.259E-03	6.945E+04
1.389E-02	2.318E+04
1.852E-02	6.749E+03
2.315E-02	2.861E+03
2.778E-02	2.212E+03
3.241E-02	1.838E+03
3.704E-02	1.427E+03
4.167E-02	1.048E+03
4.630E-02	7.915E+02
5.093E-02	6.464E+02
5.556E-02	5.882E+02
6.019E-02	4.816E+02
6.481E-02	3.380E+02
6.944E-02	2.514E+02
7.407E-02	2.207E+02
7.870E-02	1.975E+02
8.333E-02	1.872E+02
8.796E-02	1.716E+02
9.259E-02	1.420E+02
9.722E-02	1.248E+02
1.019E-01	1.150E+02
1.065E-01	1.145E+02
1.111E-01	1.295E+02
1.157E-01	1.439E+02
1.204E-01	1.496E+02
1.250E-01	1.426E+02
1.296E-01	1.237E+02
1.343E-01	9.961E+01
1.389E-01	8.062E+01
1.435E-01	8.053E+01
1.481E-01	9.724E+01
1.528E-01	1.187E+02
1.574E-01	1.370E+02
1.620E-01	1.312E+02
1.667E-01	1.188E+02

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(PSD) = LOG10(A) + B * LOG10(FREQ), WHERE A = PSD FOR FREQ = 1, ARE AS FOLLOWS:
LOG10(A) = -0.3840 A = 0.413009048 B = -2.454790115
TOTAL VARIANCE (INTEGRATED SPECTRUM) IS 1.626E+03

OUTPUT FROM
PROGRAM 4



B-7

OUTPUT FROM
PROGRAM 5

SLOPE ANGLE BETWEEN SLOPE REVERSALS

MODEL 2 OH X-DIR RERUN 02-13-78

PROFILE NO. 1 DELTA L = 3.000 MMS

REV NO	SLOPE ANGLE(DEG)	SLOPE LENGTH(MM)	REV NO	SLOPE ANGLE(DEG)	SLOPE LENGTH(MM)	REV NO	SLOPE ANGLE(DEG)	SLOPE LENGTH(MM)	REV NO	SLOPE ANGLE(DEG)	SLOPE LENGTH(MM)
1	8.734	9.160	2	9.462	3.041	3	0.000	3.000	4	40.102	25.631
5	0.000	3.000	6	16.698	6.264	7	6.609	6.061	8	13.082	6.174
9	9.462	3.041	10	23.426	3.269	11	10.883	18.436	12	19.840	9.655
13	24.232	25.130	14	7.520	6.082	15	51.953	63.693	16	20.202	9.900
17	34.179	12.012	18	44.096	52.871	19	22.446	9.990	20	9.373	6.112
21	33.607	15.279	22	29.560	37.061	23	40.733	37.471	24	46.713	8.782
25	14.148	9.351	26	18.887	12.834	27	11.312	3.059	28	25.738	17.253
29	37.616	8.438	30	48.803	21.612	31	30.186	14.650	32	35.547	26.821
33	11.263	6.131	34	29.854	64.035	35	23.429	3.270	36	20.213	6.540
37	29.517	6.899	38	12.071	6.177	39	13.120	6.164	40	20.939	13.005
41	9.462	3.041	42	9.462	3.041	43	20.904	6.592	44	28.424	10.633
45	14.932	3.105	46	10.365	6.107	47	10.365	6.107	48	15.521	9.342
49	1.906	3.002	50	3.813	3.007	51	41.103	44.436	52	42.026	9.141
53	26.766	28.723	54	26.822	14.774	55	34.795	7.458	56	29.009	10.427
57	18.873	19.295	58	33.731	15.221	59	3.813	3.007	60	16.702	3.132
61	7.597	3.027	62	13.949	6.204	63	30.984	51.066	64	21.658	10.064
65	55.429	86.051	66	5.711	3.015	67	61.807	55.336	68	39.806	3.905
69	37.400	3.700	70	32.329	7.104	71	30.904	10.892	72	36.237	19.911
73	61.015	181.770	74	32.346	3.551	75	60.701	109.585	76	9.462	3.041
77	52.891	118.047	78	23.892	9.862	79	22.901	7.043	80	16.633	6.276
81	46.176	26.796	82	19.181	6.374	83	3.818	3.007	84	32.187	18.853
85	51.683	20.903	86	56.102	155.964	87	33.405	24.853	88	32.639	25.910
89	44.689	23.350	90	40.842	58.480	91	49.012	15.526	92	49.797	9.296
93	30.968	3.499	94	53.560	19.188	95	32.346	3.551	96	20.032	6.727
97	43.609	8.484	98	64.149	178.206	99	0.000	3.000	100	45.000	4.243
101	33.690	7.211	102	33.018	7.157	103	16.698	3.132	104	16.698	3.132
105	41.021	29.299	106	27.525	23.883	107	59.082	82.264	108	37.554	24.980
109	15.120	18.720	110	21.348	19.508	111	61.424	12.629	112	52.706	11.765
113	37.764	22.769									

THE FIRST STEEPEST SLOPE IS 178.21 MMS AT 64.15 DEGREES

THE SECOND STEEPEST SLOPE IS 55.34 MMS AT 61.81 DEGREES

THE THIRD STEEPEST SLOPE IS 12.63 MMS AT 61.42 DEGREES

THE FIRST LONGEST SLOPE IS 181.77 MMS AT 61.02 DEGREES

THE SECOND LONGEST SLOPE IS 178.21 MMS AT 64.15 DEGREES

THE THIRD LONGEST SLOPE IS 155.96 MMS AT 56.18 DEGREES

THE NUMBER OF SLOPE REVERSALS PER METER = 83.1494

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THE FOLLOWING GRAPHS PLOT EACH SLOPE LENGTH AGAINST ITS SLOPE ANGLE ON SEMI-LOG SCALE.  THE COMPUTER-PRINTED
GRAPH IS AN APPROXIMATION AND MAY DIFFER SLIGHTLY FROM THE ACTUAL VALUES. WHERE MORE THAN NINE VALUES OCCUPY THE
SAME POSITION, THE SYMBOL PRINTED MAYBE INTERPRETED AS FOLLOWS
SYMBOL NO. OF VALUES

  A         10
  B         11
  C         12
  D         13
  E         14
  F         15
  G         16
  H         17
  I         18
  J         19
  K         20
  L         21
  M         22
  N         23
  O         24
  P         25
  Q         26
  R         27
  S         28
  T         29
  U         30
  V         31
  W         32
  X         33
  Y         34
  Z         35 AND OVER


  THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:

     LOG10(SLOPE LENGTH) = LOG10(A) + (SLOPE ANGLE) * LOG10(B)    ARE AS FOLLOWS:
        LOG10(A) =    0.4810    LOG10(B) =    0.0202
               A =    3.0269           B =    1.0477



  $EXE JSF,LMI
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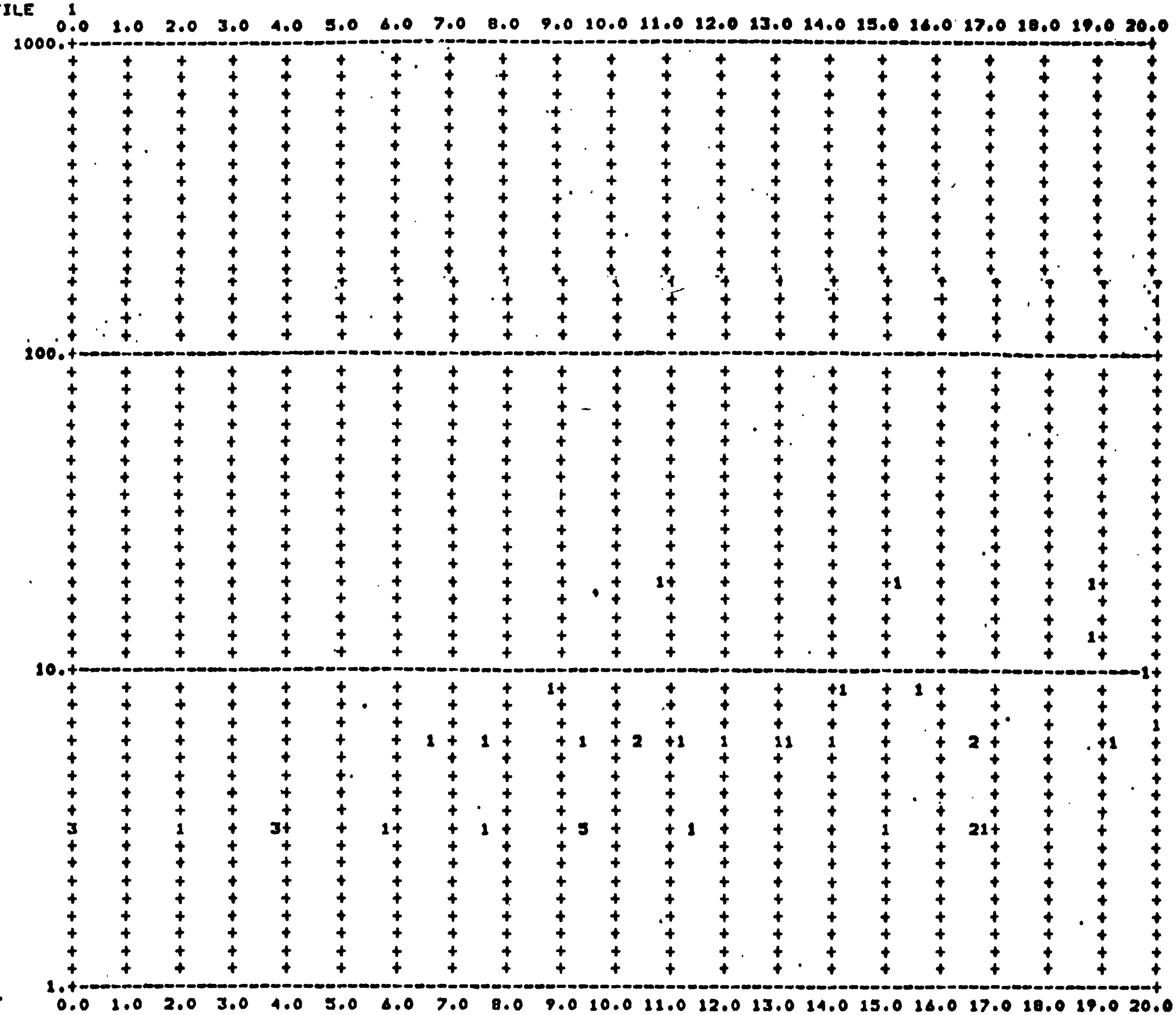
THE SCALE ON THE FOLLOWING GRAPHS IS AS FOLLOWS
THE ABSCISSA IS IN DEGREES
THE ORDINATE IS IN MMS

OUTPUT FROM
PROGRAM 6

PROFILE 1



THIS PROFILE CONTAINS SLOPE ANGLES AND/OR SLOPE DISTANCES TOO LARGE FOR THE PRINTER PLOT.

OUTPUT FROM
PROGRAM 7

D A T A F R O M B A S E L E N G T H S L O P E A N G L E A N D C U R V A T U R E P R O G R A M

DATA SET IDENTIFICATION

MODEL 2 ON X-DIR RERUN 02-13-78 NUMBER OF PROFILES = 1 TYPE OF DATA = URV

S L O P E S T A T I S T I C S

PROFILE NUMBER = 1 DELTA L = 3.00 MMS NUMBER OF SLOPES OR CURVATURES = 453

ALGEBRAIC STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN
-87.29547	87.84738	3.03776	1796.36279	42.38351	0.01421	-0.98158	1.91101

ABSOLUTE STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN	DISP. COEFF.	ELANDT COEFF.
0.00000	87.84738	36.41495	476.62927	21.83184	0.37277	-0.84876	33.69020	1.16390	1.66797

NUMBER OF NEGATIVE VALUES = 221
NUMBER OF POSITIVE VALUES = 229
RATIO OF NEGATIVE VALUES TO TOTAL =0.488

RATIO OF POSITIVE VALUES TO TOTAL =0.506
NUMBER OF REVERSALS PER METER OF TRAVERSE = 83.1494

ALGEBRAIC VALUES .

CLASS	CLASS BOUNDRIES	FREQ.	CUM. PERCENT FREQ.
1	-87.295 TO -69.781	13.0	0.0287
2	-69.781 TO -52.267	36.0	0.1082
3	-52.267 TO -34.753	41.0	0.1987
4	-34.753 TO -17.238	73.0	0.3598
5	-17.238 TO 0.276	61.0	0.4945
6	0.276 TO 17.790	54.0	0.6137
7	17.790 TO 35.305	51.0	0.7263
8	35.305 TO 52.819	52.0	0.8411
9	52.819 TO 70.333	53.0	0.9581
10	70.333 TO 87.847	19.0	1.0000

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE
0.010	4.53	-82.5361
0.020	9.06	-78.7016
0.050	22.65	-66.3025
0.100	45.30	-53.1303
0.150	67.95	-40.9156
0.200	90.60	-34.2103
0.300	135.90	-23.5917
0.400	181.20	-14.9324
0.500	226.50	1.9087
0.600	271.80	14.9323
0.700	317.10	30.9649
0.800	362.40	46.3030
0.850	385.05	53.1640
0.900	407.70	59.3855
0.950	430.35	69.2900
0.980	443.94	77.8397
0.990	448.47	82.3736
1.000	453.00	87.8474

10 PERCENT TO 90 PERCENT DISPERSION OF THE ALGEBRAIC VALUES = 100.30112

PERCENTILE VALUES FOR 7 DEGREES OF FREEDOM FOR THE CHI-SQUARE DISTRIBUTION

.995	.99	.975	.95	.90	.75	.50	.25	.10	.05
20.3	18.5	16.0	14.1	12.0	9.0	6.4	4.3	2.8	2.2

CHI-SQUARE = 34.96

ABSOLUTE VALUES

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE	PERCENT OF MEAN SLOPE
1.000	453.00	0.0000	0.000
0.900	407.70	9.4623	0.260
0.800	362.40	14.9324	0.410
0.700	317.10	20.1343	0.553
0.600	271.80	28.0704	0.771
0.500	226.50	33.6902	0.925
0.400	181.20	40.9135	1.124
0.300	135.90	50.1954	1.378
0.200	90.60	56.8894	1.562
0.150	67.95	61.8221	1.698
0.100	45.30	67.1806	1.845
0.050	22.65	75.6096	2.076
0.020	9.06	81.5155	2.239
0.010	4.53	84.2736	2.314
0.005	2.27	86.0974	2.364
0.002	0.91	87.2955	2.397
0.001	0.45	87.2955	2.397

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (SLOPE ANGLE) ARE AS FOLLOWS:
LOG10(A) = 0.5154 A = 3.2768 B = -0.0294

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN SLOPE) ARE AS FOLLOWS:
LOG10(A) = 0.5154 A = 3.2768 B = -1.0705

C U R V A T U R E S T A T I S T I C S

PROFILE NUMBER = 1 DELTA L = 3.00 MMS NUMBER OF SLOPES OR CURVATURES = 452

ALGEBRAIC STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN
-149.44556	131.74463	0.12164	1165.64453	34.14154	-0.10424	2.43628	0.16063

ABSOLUTE STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN	DISP. COEFF.	ELANDT COEFF.
0.00000	149.44556	24.24335	576.61646	24.01284	1.88206	4.35075	17.99183	1.40828	1.00960

NUMBER OF NEGATIVE VALUES = 215
NUMBER OF POSITIVE VALUES = 230
RATIO OF NEGATIVE VALUES TO TOTAL =0.476
RATIO OF POSITIVE VALUES TO TOTAL =0.509
NUMBER OF REVERSALS PER METER OF TRAVERSE = 176.2536

ALGEBRAIC VALUES

CLASS	CLASS BOUNDRIES	FREQ.	CUM. PERCENT FREQ.
1	*49.446 TO *21.327	1.0	0.0022

2	#21.327 TO -93.208	4.0	0.0111
3	-93.208 TO -65.089	11.0	0.0354
4	-65.089 TO -36.969	33.0	0.1084
5	-36.969 TO -8.850	102.0	0.3341
6	-8.850 TO 19.269	196.0	0.7677
7	19.269 TO 47.388	75.0	0.9336
8	47.388 TO 75.507	19.0	0.9757
9	75.507 TO 103.626	6.0	0.9889
10	103.626 TO 131.745	5.0	1.0000

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE
0.010	4.52	-102.4371
0.020	9.04	-81.1298
0.050	22.60	-56.7936
0.100	45.20	-40.8179
0.150	67.80	-29.7705
0.200	90.40	-22.9107
0.300	135.60	-10.8095
0.400	180.80	-4.7661
0.500	226.00	0.0044
0.600	271.20	7.0525
0.700	316.40	13.6935
0.800	361.60	22.1815
0.850	384.20	28.2733
0.900	406.80	34.8890
0.950	429.40	51.3592
0.980	442.96	77.5254
0.990	447.48	98.6255
1.000	452.00	131.7446

10 PERCENT TO 90 PERCENT DISPERSION OF THE ALGEBRAIC VALUES = 64.65945

PERCENTILE VALUES FOR 7 DEGREES OF FREEDOM FOR THE CHI-SQUARE DISTRIBUTION

.995	.99	.975	.95	.90	.75	.50	.25	.10	.05
20.3	18.5	16.0	14.1	12.0	9.0	6.4	4.3	2.8	2.2

CHI-SQUARE = 495.89

ABSOLUTE VALUES

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE	PERCENT OF MEAN SLOPE
1.000	452.00	0.0000	0.000
0.900	406.80	2.0949	0.086
0.800	361.60	5.5358	0.228
0.700	316.40	8.9213	0.368
0.600	271.20	12.6900	0.523
0.500	226.00	17.9875	0.742
0.400	180.80	22.6006	0.932

0.300	135.60	29.2624	1.207
0.200	90.40	36.2448	1.495
0.150	67.80	45.0001	1.856
0.100	45.20	53.1033	2.194
0.050	22.60	77.3971	3.193
0.020	9.04	92.7667	3.826
0.010	4.52	111.9515	4.618
0.005	2.26	117.7562	4.857
0.002	0.90	131.7446	5.434
0.001	0.45	131.7446	5.434

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM!
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (CURVATURE ANGLE) ARE AS FOLLOWS!
LOG10(A) = 0.0581 A = 1.1431 B = -0.0204

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM!
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN CURVATURE) ARE AS FOLLOWS!
LOG10(A) = 0.0581 A = 1.1431 B = -0.4934

S L O P E S T A T I S T I C S

PROFILE NUMBER = 1 DELTA L = 6.00 MMS NUMBER OF SLOPES OR CURVATURES = 452

ALGEBRAIC STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN
-84.97992	85.97678	3.32249	1784.43213	42.24254	0.00979	-0.91329	0.00000

ABSOLUTE STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN	DISP. COEFF.	ELANDT COEFF.
0.00000	85.97678	35.56265	527.98877	22.97800	0.33493	-0.97413	32.68645	1.18783	1.54768

NUMBER OF NEGATIVE VALUES = 225
NUMBER OF POSITIVE VALUES = 219
RATIO OF NEGATIVE VALUES TO TOTAL =0.498
RATIO OF POSITIVE VALUES TO TOTAL =0.485
NUMBER OF REVERSALS PER METER OF TRAVERSE = 35.0295

ALGEBRAIC VALUES

CLASS	CLASS BOUNDRIES	FREQ.	CUM. PERCENT FREQ.
1	-84.980 TO -67.884	22.0	0.0487
2	-67.884 TO -50.789	31.0	0.1173
3	-50.789 TO -33.693	33.0	0.1903
4	-33.693 TO -16.597	74.0	0.3540
5	-16.597 TO 0.498	73.0	0.5155
6	0.498 TO 17.594	50.0	0.6261
7	17.594 TO 34.690	41.0	0.7168
8	34.690 TO 51.785	52.0	0.8319
9	51.785 TO 68.881	50.0	0.9425
10	68.881 TO 85.977	26.0	1.0000

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE
0.010	4.52	-80.9640
0.020	9.04	-76.9919
0.050	22.60	-67.5164
0.100	45.20	-53.1303
0.150	67.80	-43.1268
0.200	90.40	-33.6902
0.300	135.60	-22.6199
0.400	180.80	-12.2234
0.500	226.00	0.0000
0.600	271.20	13.3173
0.700	316.40	29.8254
0.800	361.60	45.9392
0.850	384.20	54.5263
0.900	406.80	60.0998
0.950	429.40	71.0253
0.980	442.96	76.9938
0.990	447.48	81.3136
1.000	452.00	85.9768

10 PERCENT TO 90 PERCENT DISPERSION OF THE ALGEBRAIC VALUES = 104.02658

PERCENTILE VALUES FOR 7 DEGREES OF FREEDOM FOR THE CHI-SQUARE DISTRIBUTION

.995	.99	.975	.95	.90	.75	.50	.25	.10	.05
20.3	18.5	16.0	14.1	12.0	9.0	6.4	4.3	2.8	2.2

CHI-SQUARE = 43.69

ABSOLUTE VALUES

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE	PERCENT OF MEAN SLOPE
1.000	452.00	0.0000	0.000
0.900	406.80	7.5928	0.214
0.800	361.60	12.7710	0.359
0.700	316.40	18.7756	0.528
0.600	271.20	25.0193	0.704
0.500	226.00	32.3496	0.910
0.400	180.80	39.8057	1.119
0.300	135.60	49.3989	1.389
0.200	90.40	58.5231	1.646
0.150	67.80	62.4475	1.756
0.100	45.20	69.5137	1.955
0.050	22.60	75.8629	2.133
0.020	9.04	80.0079	2.250
0.010	4.52	84.6156	2.379
0.005	2.26	84.8569	2.386
0.002	0.90	85.9484	2.417
0.001	0.45	85.9484	2.417

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (SLOPE ANGLE) ARE AS FOLLOWS:
LOG10(A) = 0.4565 A = 2.8610 B = -0.0287

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN SLOPE) ARE AS FOLLOWS:
LOG10(A) = 0.4565 A = 2.8610 B = -1.0189

C U R V A T U R E S T A T I S T I C S

PROFILE NUMBER = 1 DELTA L = 6.00 MMS NUMBER OF SLOPES OR CURVATURES = 451

ALGEBRAIC STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN
-133.00092	106.82596	0.10724	695.24365	26.36747	-0.28968	4.93699	0.00000

ABSOLUTE STATISTICS

MINIMUM	MAXIMUM	MEAN	VARIANCE	ST DEVIATION	SKEWNESS	KURTOSIS	MEDIAN	DISP. COEFF.	ELANDT COEFF.
0.00000	133.00092	17.95416	372.18701	19.29214	2.54821	9.13031	12.54291	1.46860	0.93065

NUMBER OF NEGATIVE VALUES = 219
NUMBER OF POSITIVE VALUES = 221
RATIO OF NEGATIVE VALUES TO TOTAL =0.486
RATIO OF POSITIVE VALUES TO TOTAL =0.490
NUMBER OF REVERSALS PER METER OF TRAVERSE = 65.0406

ALGEBRAIC VALUES

CLASS	CLASS BOUNDRIES	FREQ.	CUM. PERCENT FREQ.
1	*33.001 TO *09.018	2.0	0.0044
2	*09.018 TO -85.036	2.0	0.0089
3	-85.036 TO -61.053	4.0	0.0177
4	-61.053 TO -37.070	18.0	0.0576
5	-37.070 TO -13.088	77.0	0.2284
6	-13.088 TO 10.895	221.0	0.7184
7	10.895 TO 34.878	98.0	0.9357
8	34.878 TO 58.861	19.0	0.9778
9	58.861 TO 82.843	6.0	0.9911
10	82.843 TO 106.826	4.0	1.0000

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE
0.010	4.51	-90.5528
0.020	9.02	-57.8386
0.050	22.55	-38.3138
0.100	45.10	-28.9903
0.150	67.65	-21.0873
0.200	90.20	-15.4255

0.300	135.30	-8.9620
0.400	180.40	-3.5557
0.500	225.50	0.0000
0.600	270.60	4.1214
0.700	315.70	9.5978
0.800	360.80	16.5660
0.850	383.35	21.4095
0.900	405.90	26.5432
0.950	428.45	37.4033
0.980	441.98	61.7758
0.990	446.49	73.8843
1.000	451.00	106.8260

10 PERCENT TO 90 PERCENT DISPERSION OF THE ALGEBRAIC VALUES = 47.63046

PERCENTILE VALUES FOR 7 DEGREES OF FREEDOM FOR THE CHI-SQUARE DISTRIBUTION

.995	.99	.975	.95	.90	.75	.50	.25	.10	.05
20.3	18.5	16.0	14.1	12.0	9.0	6.4	4.3	2.8	2.2

CHI-SQUARE = 3083.47

ABSOLUTE VALUES

CUM. PERCENT FREQ.	CUM. FREQ.	SLOPE ANGLE	PERCENT OF MEAN SLOPE
1.000	451.00	0.0000	0.000
0.900	405.90	1.6008	0.089
0.800	360.80	3.8164	0.213
0.700	315.70	6.6283	0.369
0.600	270.60	9.4770	0.528
0.500	225.50	12.5345	0.698
0.400	180.40	16.1049	0.897
0.300	135.30	21.0870	1.174
0.200	90.20	27.1099	1.510
0.150	67.65	33.1657	1.847
0.100	45.10	37.7287	2.101
0.050	22.55	52.6835	2.934
0.020	9.02	73.8330	4.112
0.010	4.51	102.9824	5.736
0.005	2.26	106.5894	5.937
0.002	0.90	132.4699	7.378
0.001	0.45	132.4699	7.378

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (CURVATURE ANGLE) ARE AS FOLLOWS:
LOG10(A) = -0.0655 A = 0.8600 B = -0.0210

THE RESULTS OF FITTING A REGRESSION LINE OF THE FORM:
LOG10(CUM. PERCENT FREQ.) = LOG10(A) + B * (PERCENT OF MEAN CURVATURE) ARE AS FOLLOWS:
LOG10(A) = -0.0655 A = 0.8600 B = -0.3764