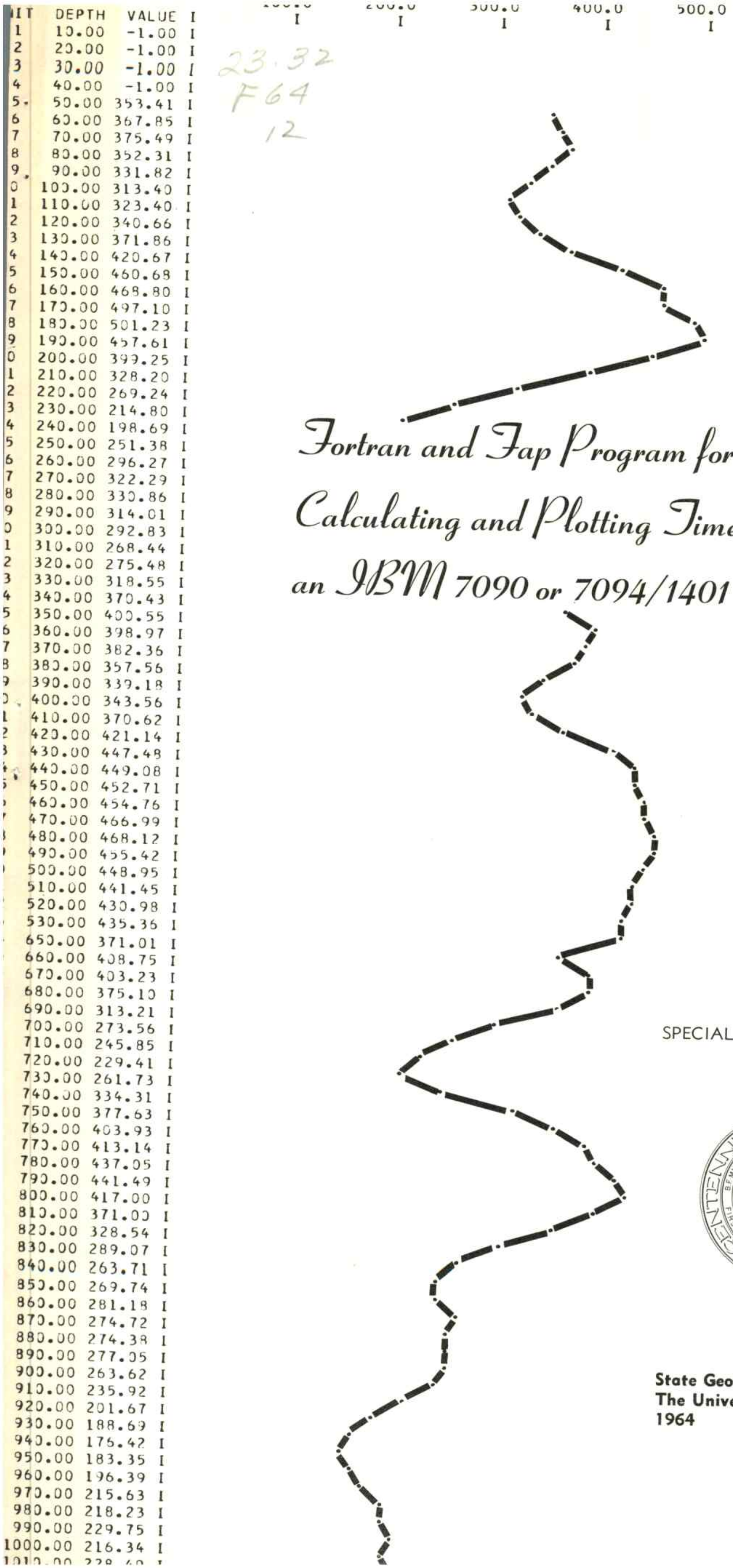

```
        100.0     200.0     300.0     400.0     500.0
          I         I         I         I         I
IIT   DEPTH   VALUE I
1    10.00   -1.00 I
2    20.00   -1.00 I
3    30.00   -1.00 I
4    40.00   -1.00 I
5    50.00  353.41 I
6    60.00  367.85 I
7    70.00  375.49 I
8    80.00  352.31 I
9    90.00  331.82 I
0   100.00  313.40 I
1   110.00  323.40 I
2   120.00  340.66 I
3   130.00  371.86 I
4   140.00  420.67 I
5   150.00  460.68 I
6   160.00  468.80 I
7   170.00  497.10 I
8   180.00  501.23 I
9   190.00  457.61 I
0   200.00  399.25 I
1   210.00  328.20 I
2   220.00  269.24 I
3   230.00  214.80 I
4   240.00  198.69 I
5   250.00  251.38 I
6   260.00  296.27 I
7   270.00  322.29 I
8   280.00  330.86 I
9   290.00  314.01 I
0   300.00  292.83 I
1   310.00  268.44 I
2   320.00  275.48 I
3   330.00  318.55 I
4   340.00  370.43 I
5   350.00  400.55 I
6   360.00  398.97 I
7   370.00  382.36 I
8   380.00  357.56 I
9   390.00  339.18 I
0   400.00  343.56 I
1   410.00  370.62 I
2   420.00  421.14 I
3   430.00  447.48 I
4   440.00  449.08 I
5   450.00  452.71 I
    460.00  454.76 I
    470.00  466.99 I
    480.00  468.12 I
    490.00  455.42 I
    500.00  448.95 I
    510.00  441.45 I
    520.00  430.98 I
    530.00  435.36 I
    650.00  371.01 I
    660.00  408.75 I
    670.00  403.23 I
    680.00  375.10 I
    690.00  313.21 I
    700.00  273.56 I
    710.00  245.85 I
    720.00  229.41 I
    730.00  261.73 I
    740.00  334.31 I
    750.00  377.63 I
    760.00  403.93 I
    770.00  413.14 I
    780.00  437.05 I
    790.00  441.49 I
    800.00  417.00 I
    810.00  371.00 I
    820.00  328.54 I
    830.00  289.07 I
    840.00  263.71 I
    850.00  269.74 I
    860.00  281.18 I
    870.00  274.72 I
    880.00  274.38 I
    890.00  277.05 I
    900.00  263.62 I
    910.00  235.92 I
    920.00  201.67 I
    930.00  188.69 I
    940.00  176.42 I
    950.00  183.35 I
    960.00  196.39 I
    970.00  215.63 I
    980.00  218.23 I
    990.00  229.75 I
   1000.00  216.34 I
```

Fortran and Fap Program for Calculating and Plotting Time-Trend Curves Using an IBM 7090 or 7094/1401 Computer System

By
William T. Fox
Williams College

SPECIAL DISTRIBUTION PUBLICATION 12

1864 - 1964
1889-1964

State Geological Survey
The University of Kansas, Lawrence, Kansas
1964

COMPUTER CONTRIBUTIONS

With the vast amount of data being made available at an increased rate through the many publication outlets, and through other means of distribution, it is often difficult for a geologist to evaluate this flood of information or any part of it in the time available. To help alleviate this dilemma, the modern, high-speed electronic computer has been called on to aid the geologist in retrieving important information more quickly and to synthesize masses of data in hope of finding systematic and regular patterns. If an underlying trend enabling one to understand order can be recognized, then the basic problem being studied is essentially solved, or at least a large part of it is.

The geologist today is relying on many trend-seeking devices to predict more accurately events or occurrences in the earth's system. This program reported by W. T. Fox on time-trend curves is one such trend-searching aid, just as the trend-surface program reported by J. W. Harbaugh (Special Distribution Publication 3) is designed to help the geologist find the basic patterns. Once information is quickly and easily reduced to a simple pattern, then that pattern can be compared either quantitatively or qualitatively to other simple patterns to establish the degree of similarity or dissimilarity. In this manner another correlation tool is made available, and it is now possible to compare variables (in this instance, limestone percentage), from locality to locality in a fashion similar to correlating electric and radioactivity logs. Geologists should find many uses for these time-trend curve techniques.

The Kansas Geological survey will make the source deck of punched cards available for a limited time for the nominal sum of $5.00. On the inside back cover of this report is a list of publications on computer contributions in geology made available by or through the Kansas Survey. Because the Survey is making every effort to make the computer programs and results as useful as possible, any comments or suggestions are welcomed and should be addressed to the editor.

The Editor

FORTRAN and FAP Program for
Calculating and Plotting Time-Trend Curves Using
an IBM 7090 or 7094/1401 Computer System

by

William T. Fox

INTRODUCTION

The program is designed to compute and plot a series of smoothed curves based on a sequence of geologic observations taken from a traverse or a stratigraphic section. Nine smoothed curves are computed with varying degrees of smoothing for each of ten variables with up to 500 observations per variable. The curves are then used to study underlying trends, which in turn can be used for correlation or environmental interpretation.

The formulae which are used to smooth or graduate the data are obtained by fitting a polynomial to the data. The derivation and application of the smoothing formulae are explained by Whittaker and Robinson (1929, p. 291-299). The ungraduated values, U_x, are plotted against the corresponding distance values, X, to compute the smoothed values, U_x'. A parabolic curve is fitted to n points on each side of the value being smoothed (U_{-n}, U_{-n-1}, ..., U_o, ...U_n), with the constants of the curve determined by the method of least squares. The ordinate of the parabola at X = 0 is taken as the graduated value U_o'. A parabolic curve is then computed for each value in the sequence and the graduated values are plotted as the smoothed curve.

The nine smoothing formulae used in the program contain from five to 21 terms. The number of terms in the smoothing formula is equal to the number of observations on both sides of the central value plus the central value or 2n + 1. When the number of terms is small (n = 2 to n = 4) the parabola used for computing the smoothed value is based on a small number of observations on each side of the value being smoothed. Therefore, the smoothed curve based on a smoothing formula with a small number of terms closely resembles a curve plotted on the observed data. When the number of terms in the smoothing formula is large (n = 8 to n = 10), the small scale fluctuations are subdued and the underlying trend of sedimentation is emphasized.

By comparing the total sum of squares of deviations from the smoothed curves with the total sum of squares of deviations from the mean, it is possible to compute the amount of the total variability accounted for by each of the smoothed curves. The total sum of squares of deviations from the smoothed curve is obtained by summing the square of the difference between each observed value and its corresponding graduated value. The curves which account for the greatest percent of the total variability are used to delineate the major underlying trends of sedimentation.

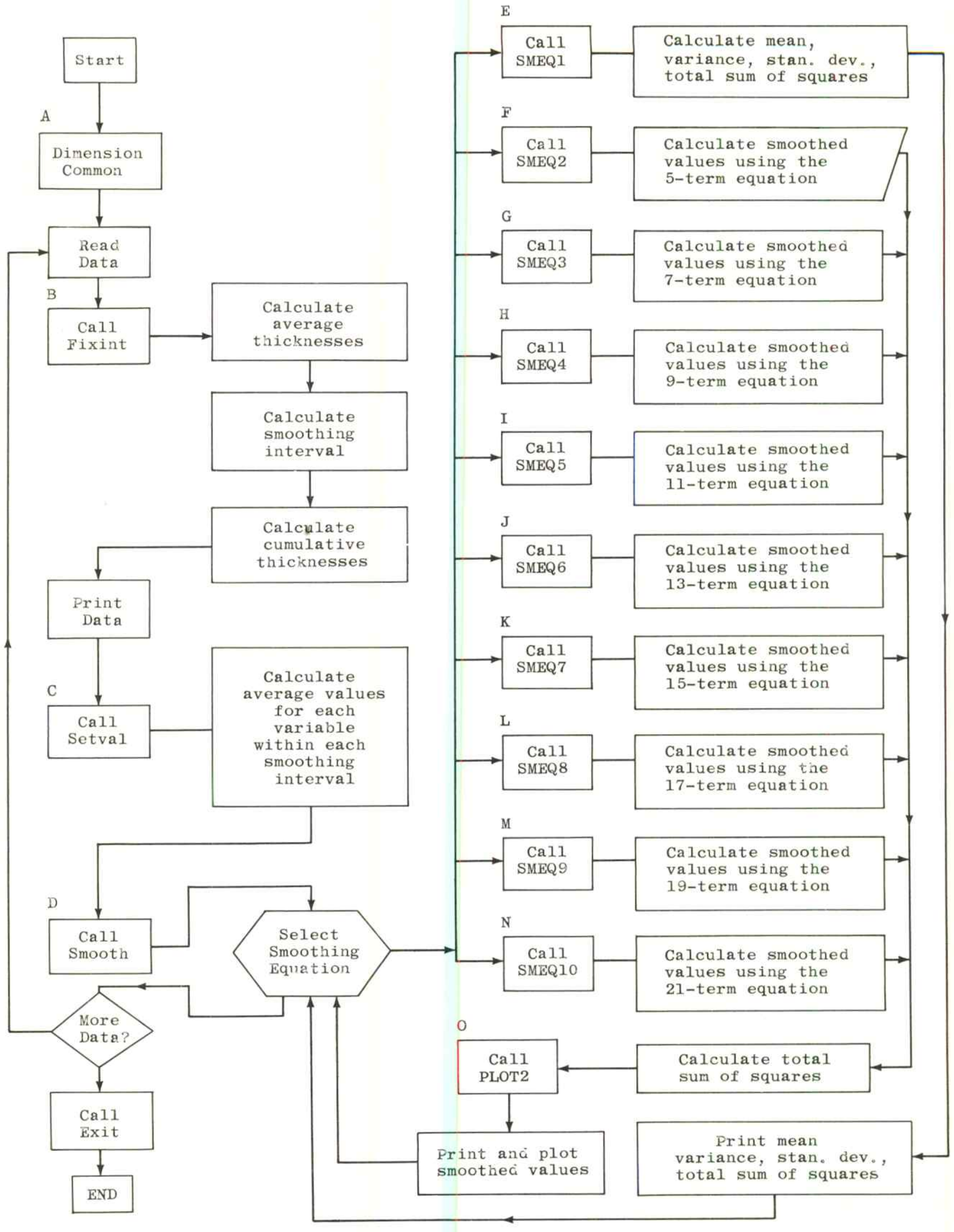

Figure 1.--A simplified flow diagram showing major steps in time-trend analysis program.

The program for computing and plotting smoothed curves is written in FORTRAN and may be used on any IBM 7090-7094/1401 computer system. The program was developed at the Williams College Geology Department with the cooperation of C. Wallace Jordan and John Pfaltz of the Mathematics Department. John Pfaltz wrote the FORTRAN and FAP subroutines which are used to plot the smoothed curves. The IBM 7094 computer at the Massachusetts Institute of Technology was used to debug and test the program. The project was financed by the National Science Foundation research grant G-23333.

STEPS IN PROGRAM FOR SMOOTHING DATA

The program consists of a main program for reading in the data and 14 subroutines for establishing the smoothing interval, calculating smoothed values, and plotting smoothed curves. A simplified flow chart showing the major steps in the program is given in Figure 1. The main program and subsequent subroutines, given in Table 1, are assigned letters from A through O. Within the individual subroutines each line or card is given a number so that each statement in the program is designated by a letter and a number which denotes the subroutine and position within the subroutine. The main program and various subroutines are described in the following section.

A. Main Program--The main program is used to read the program control cards and data cards which are used in the various subroutines to compute and plot the smoothed curves. The steps in this part of the program are tabulated below:

(1) Comment, dimension, common, and format statements: lines A-1 through A-14.

(2) Read and print the program control cards and read the data: lines A-15 through A-25.

(3) Call the three major subroutines FIXINT, SETVAL, and SMOOTH and print a listing of the data: lines A-26 through A-35.

(4) Check for another set of data cards: line A-36.

(5) If there is no more data, call EXIT and END: line A-37.

B. Subroutine FIXINT--The subroutine FIXINT (Fix Interval) is used to determine the spacing between data points which is used by the following subroutines. The thickness values for the individual sedimentary units vary considerably and must be converted to equal intervals to be used by the smoothing equations. Two options are available in the program for determining the smoothing interval. First, the smoothing interval (SMINT) can be read in with the data as a constant (SMCON), or second, it can be calculated as a multiple (AVMULT) of the average thickness. The cumulative thickness at the top of each interval (CUMINT) is calculated for printing out with the data. The steps in this subroutine are tabulated below:

(1) Comment, dimension, and common statements: lines B-1 through B-9.

(2) Assign values to constants: lines B-10 through B-14.

(3) Calculate the average thickness for each sedimentary unit: lines B-15 through B-22.

(4) Calculate the smoothing interval (SMINT): lines B-23 through B-27.

(5) Calculate the index (K) and cumulative thickness (CUMINT) for each smoothing interval: lines B-28 through B-32.

(6) Return to the main program: line B-33.

C. Subroutine SETVAL--The subroutine SETVAL (Set Value) is used to calculate the average for each variable within each consecutive smoothing interval (SMINT). The observed value (VAL) for each sedimentary unit is converted to an average value (U) which is used in the following subroutines. Where there is a covered interval or lack of data, a -1 is read in place of the observed value. The steps in the subroutine are tabulated below:

(1) Comment, dimension, and common statements: lines C-1 through C-10.

(2) Assign value to constant: lines C-11 through C-16.

(3) Check for covered interval: line C-17.

(4) Calculate the average value (U) for each interval (SMINT): lines C-18 through C-27.

(5) Assign -1 to interval when there is no data: lines C-28 through C-33.

(6) Assign a new value to the thickness (TH) for the next calculation of U: line C-34.

(7) Return to the main program: line C-36.

D. Subroutine SMOOTH--The subroutine is designed to select the smoothing equation indicated by the "read SW" statement in the main program. Ten SMEQ (Smoothing Equation) subroutines are called to calculate the graduated values (W) from the average values (U) for each interval (SMINT). The subroutine is also used to calculate the mean, variance, standard deviation, and total sum of squares of deviations from the mean. For each smoothed curve, the total sum of squares of deviations from the smoothed curve is calculated to determine the percent of the total variability accounted for by curve. Subroutine PLOT is called to print the graduated values (W) and plot the observed data and smoothed curves. The steps in the subroutine are tabulated below:

(1) Comment, dimension, and common statements: lines D-1 through D-9.

(2) Loop to call smoothing equations for each variable (I): lines D-15 through D-81.

(3) Loop to select smoothing equation (J): lines D-16 and D-17.

(4) Assigning values to constants: lines D-10 through D-14 and D-18 through D-24.

(5) Computed GO TO statement to select subroutines to be used in the program: line D-25.

(6) Call SMEQ1 (Smoothing equation 1) to compute the mean, variance, standard deviation, and total sum of squares for the averaged values (U) of the observed data within each smoothing interval: lines D-26 through D-42.

(7) Call subroutines SMEQ2 through SMEQ10 to calculate the graduated values (W) using the various smoothing equations: lines D-43 through D-59.

(8) Calculate and print the total sum of squares of the deviations from the smoothed curves to estimate the percent of the total variability accounted for by each of the smoothed curves: lines D-60 through D-68.

(9) Call subroutine PLOT1 to print the graduated values (W) and plot the smoothed curves: lines D-70 through D-79.

(10) Return to the main program: line D-82.

E. Subroutine SMEQ1--The subroutine is used to calculate the sum (SUM), sum of squares (SUMSQ), and number of observations (FLN) of the averaged values (U) within each interval (K) for each variable (I). The following steps are used in the subroutine:

(1) Comment, dimension, and common statements: lines E-1 through E-9.

(2) Calculation of the sum, sum of squares, and number of units: lines E-10 through E-16.

(3) Return to subroutine SMOOTH: line E-17.

F-N. Subroutines SMEQ2 through SMEQ10--These subroutines are used to calculate the nine smoothing curves for each variable using a family of smoothing equations with the number of terms increasing from 5 to 21. The smoothing equations are used to calculate the graduated values (W) based on the averaged values (U) for each interval (K) and each variable (I). The subroutines are also used to calculate the sum, sum of squares of deviations from the smoothed curve, and the number of graduated values. The steps in the subroutines are tabulated below:

(1) Comment, dimension, and common statements: lines F-N-1 through F-N-8.

(2) Loop for each value (U) in the K sequence with n values lost on each end of the series (KMINJ, KMAXJ): lines F-N-9 through F-24, N-27.

(3) Assign values to constants and test for no data (-1): lines F-N-10 through F-N-16.

(4) Calculate the graduated values (W) for each variable (I) within each interval (K): lines F-N-17 through F-18, N-21.

(5) Calculate sum (SUM) total sum of squares of deviations from the smoothed curve (SUMSQ), and number of graduated values (FLN): lines F-19, N-22 through F-22, N-25.

(6) Assign values (-1) to no data points: lines F-23, N-26.

(7) Return to subroutine SMOOTH: lines F-25, N-28.

O. Subroutine PLOT1--This FORTRAN and FAP subroutine is used to print the graduated values and plot the smoothed curves. The subroutine is called for each smoothed value and prints (K) the number in the sequence, (CUMINT) the cumulative thickness below the top of the section or the end of the traverse, and (W) the graduated value. The subroutine uses the next 60 spaces to plot a period for the graduated value (W). The W values are multiplied by a scale factor (SCALE) to keep the plot within the allotted space.

Table 1.--Main program and subroutines used in time-trend program.

```
      SMOOTHING PROGRAM FOR GEOLOGIC DATA

C      WILLIAM T FOX, GEOLOGY DEPARTMENT
C      WILLIAMS COLLEGE, WILLIAMSTOWN, MASS.
C                                                                       A-1
C     THE MAIN PROGRAM IS USED TO READ IN THE DATA WHICH IS PROCESSED   A-2
C     BY THE VARIOUS SUBROUTINES                                        A-3
C                                                                       A-4
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),    A-5
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)                    A-6
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ, A-7
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC,TH,THMIN,SW A-8
    1 FORMAT(10F2.0)                                                    A-9
    5 FORMAT(3I5,4F7.2)                                                 A-10
    7 FORMAT(12A6)                                                      A-11
    9 FORMAT (1H0,8HLOCATION,I5)                                        A-12
   15 FORMAT(1H1,12HDATA FOLLOWS)                                       A-13
   20 FORMAT(1H0,1X,5H  NUM,9H  TH(NUM) ,9H  CUMTOT ,8H  VALUES)        A-14
    2 READ 1,(SW(J),J=1,10)                                             A-15
      IF (SW(1)-99.) 3,35,3                                             A-16
    3 READ 5 ,LOC,IMAX,NMAX,THMIN,SMCON,AVMULT,SCALE                    A-17
      PRINT 5,LOC,IMAX,NMAX,THMIN,SMCON,AVMULT,SCALE                    A-18
      READ 7,(FMT(M),M=1,12)                                            A-19
      READ 7,(FMPT(M),M=1,12)                                           A-20
      KMIN=2                                                            A-21
      NMIN=2                                                            A-22
      NMAX=NMAX+1                                                       A-23
      DO 10 NUM=NMIN,NMAX                                               A-24
   10 READ FMT,TH(NUM),(VAL(I,NUM),I=1,IMAX)                            A-25
      CALL FIXINT                                                       A-26
      PRINT 9, LOC                                                      A-27
      PRINT 15                                                          A-28
      PRINT 20                                                          A-29
      DO 25 NUM = NMIN,NMAX                                             A-30
      NDA=NUM-1                                                         A-31
   25 PRINT FMPT,NDA,TH(NUM),CUMTOT(NUM),(VAL(I,NUM),I=1,IMAX)          A-32
      CALL SETVAL                                                       A-33
      SCALE = 100./(2.*SCALE)                                           A-34
      CALL SMOOTH                                                       A-35
      GO TO 2                                                           A-36
   35 CALL EXIT                                                         A-37
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE FIXINT                                                 B-1
C                                                                       B-2
C     SUBROUTINE FIXINT IS USED TO FIX THE VERTICAL SMOOTHING INTERVWL  B-3
C     (SMINT) WHICH IS THEN USED IN SUBROUTINE SETVAL                   B-4
C                                                                       B-5
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),    B-6
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)                    B-7
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ, B-8
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC,TH,THMIN,SW B-9
      ROCTH=0.0                                                         B-10
      ROCN=0.0                                                          B-11
      TOTH=0.0                                                          B-12
      CUMTOT(NMIN-1)=THMIN                                              B-13
      CUMINT(KMIN-1)=THMIN                                              B-14
      DO 5 NUM=NMIN,NMAX                                                B-15
      IF (VAL(1,NUM)) 4,3,3                                             B-16
    3 ROCTH=ROCTH + TH(NUM)                                             B-17
      ROCN=ROCN+1.                                                      B-18
    4 TOTH = TOTH + TH(NUM)                                             B-19
      CUMTOT(NUM)=CUMTOT(NUM-1)+TH(NUM)                                 B-20
    5 CONTINUE                                                          B-21
      AVROC=ROCTH/ROCN                                                  B-22
      IF (SMCON) 6,6,7                                                  B-23
    6 SMINT = AVMULT*AVROC                                              B-24
```

```
      GO TO 8
    7 SMINT = SMCON
    8 FLKTOT = TOTH/SMINT
      KTOT=FLKTOT
      KMAX=KMIN+KTOT-1
      DO 9 K = KMIN,KMAX
      CUMINT(K)=CUMINT(K-1)+SMINT
    9 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SETVAL
C
C    SUBROUTINE SETVAL IS USED TO SET THE AVERAGE VALUE, U(I,K), WITHIN
C    EACH VERTICAL SEGMENT (K) FOR EACH VARIABLE (I). THE AVERAGE VALUE
C    U(I,K) IS THEN USED IN SUBROUTINE SMOOTH.
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC,TH,THMIN,SW
      NUM=NMIN
      DO 26 K=KMIN,KMAX
      DEF=SMINT
      SUMTH=0.0
      DO 2 I=1,IMAX
    2 SUMVAL(I)=0.0
    4 IF (VAL(1,NUM)) 16,6,6
    6 SUMTH=SUMTH+TH(NUM)
      IF(SUMTH-SMINT) 8,12,12
    8 DO 10 I=1,IMAX
   10 SUMVAL(I) =SUMVAL(I) + TH(NUM) * VAL(I,NUM)
      NUM=NUM+1
      DEF = SMINT-SUMTH
      GO TO 4
   12 DO 14 I=1,IMAX
   14 U(I,K) = (SUMVAL(I) + DEF * VAL(I,NUM)) / SMINT
      GO TO 24
   16 SUMTH = SUMTH + TH(NUM)
      IF (SUMTH-SMINT) 18,20,20
   18 NUM=NUM+1
      GO TO 16
   20 DO 22 I=1,IMAX
   22 U(I,K)=-1.0
   24 TH(NUM)=SUMTH-SMINT
   26 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMOOTH
C
C    SUBROUTINE SMOOTH IS USED TO SELECT THE SMOOTHING EQUATION WHICH
C    IS USED TO GRADUATE THE AVERAGE VALUES, U(I,K).
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC,TH,THMIN,SW
      SC2=10./SCALE
      SC4=20./SCALE
      SC6=30./SCALE
      SC8=40./SCALE
      SC10=50./SCALE
      DO 45 I=1,IMAX
      DO 40 J = 1,10
      IF(SW(J)) 40,40,1
    1 SUM=0.0
```

```
      SUMSQ=0.0
      FLN=0.0
      KMINJ=KMIN+J
      KMAXJ=KMAX-J
      DO 4 K=KMIN,KMINJ
    4 W(K)=-1.0
      GO TO (11,12,13,14,15,16,17,18,19,20),J
   11 CALL SMEQ1
      AVG=SUM/FLN
      TOTSS=SUMSQ-SUM**2./FLN
      VAR=TOTSS/(FLN-1.)
      STDEV=SQRTF(VAR)
      PRINT 5, LOC,I
    5 FORMAT(1H1,2X,11HAT LOCATION,I5,2X,12HFOR VARIABLE,I5)
      PRINT 7,AVG,VAR,STDEV
    7 FORMAT(1H0,2X,6HMEAN =,F7.2,2X,10HVARIANCE =,F10.2,2X,
     120HSTANDARD DEVIATION =,F10.2)
      PRINT 8 ,TOTSS,FLN
    8 FORMAT(1H0,2X,22HTOTAL SUM OF SQUARES =,F12.2,2X,
     117HNUMBER OF UNITS =,F5.0)
      FLN1=FLN
      DO 9 K=KMIN,KMAX
    9 W(K)=U(I,K)
      GO TO 31
   12 CALL SMEQ2
      GO TO 25
   13 CALL SMEQ3
      GO TO 25
   14 CALL SMEQ4
      GO TO 25
   15 CALL SMEQ5
      GO TO 25
   16 CALL SMEQ6
      GO TO 25
   17 CALL SMEQ7
      GO TO 25
   18 CALL SMEQ8
      GO TO 25
   19 CALL SMEQ9
      GO TO 25
   20 CALL SMEQ10
   25 PCTSS=100.*(SUMSQ/TOTSS)*(FLN1/FLN)
      PRINT 26,LOC,I,J
   26 FORMAT(1H1,2X,11HAT LOCATION,I5,2X,12HFOR VARIABLE,I5,2X,
     122HAND SMOOTHING EQUATION,I5)
      PRINT 28,SUMSQ.FLN
   28 FORMAT(1H0,2X,22HTOTAL SUM OF SQUARES =,F12.2,2X,
     117HNUMBER OF UNITS =,F5.0)
      PRINT 29, PCTSS
   29 FORMAT(1H0,2X,33HPERCENT OF TOTAL SUM OF SQUARES =,F6.2)
      KMAX1=KMAXJ+1
      DO 30 K=KMAX1,KMAX
   30 W(K)=-1.
   31 PRINT 32, SC2,SC4,SC6,SC8,SC10
   32 FORMAT(1H0,26X,F5.1,5X,F5.1,5X,F5.1,5X,F5.1,4X,F6.1)
      PRINT 34
   34 FORMAT(21H UNIT  DEPTH  VALUE I,9X,1HI,9X,1HI,9X,1HI,9X,
     11HI,9X,1HI)
      DO 38 K=KMIN,KMAX
      KPLOT=K-1
   38 CALL PLOT1(KPLOT,CUMINT(K),W(K),SCALE)
   40 CONTINUE
   45 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ1
C
C     SUBROUTINE SMEQ1 IS USED IN THE COMPUTATION OF THE MEAN, VARIANCE,
C     STANDARD DEVIATION OF THE AVERAGED VALUES, U(I,K).
C
```

```
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMIN,KMAX
      IF (U(I,K)) 15,3,3
    3 W(K)=U(I,K)
      SUM=SUM+W(K)
      SUMSQ=SUMSQ+W(K)**2.
      FLN=FLN+1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ2
C
C     5 TERM SMOOTHING EQUATION USING 2 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(17.*U(I,K)+12.*(U(I,K+1)+U(I,K-1))-3.*(U(I,K+2)+U(I,K-2)))
     1/35.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ3
C
C     7 TERM SMOOTHING EQUATION USING 3 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(7.*U(I,K)+6.*(U(I,K+1)+U(I,K-1))+3.*(U(I,K+2)+U(I,K-2))
     1-2.*(U(I,K+3)+U(I,K-3)))/21.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ4
C
C     9 TERM SMOOTHING EQUATION USING 4 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(59.*U(I,K)+54.*(U(I,K+1)+U(I,K-1))+39.*(U(I,K+2)+U(I,K-2))
     1+14.*(U(I,K+3)+U(I,K-3))-21.*(U(I,K+4)+U(I,K-4)))/231.

      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ5
C
C     11 TERM SMOOTHING EQUATION USING 5 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(89.*U(I,K)+84.*(U(I,K+1)+U(I,K-1))+69.*(U(I,K+2)
     1 +U(I,K-2))+44.*(U(I,K+3)+U(I,K-3))+9.*(U(I,K+4)+U(I,K-4))
     2-36.*(U(I,K+5)+U(I,K-5)))/429.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ6
C
C     13 TERM SMOOTHING EQUATION USING 6 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
```

```
  5 DO 7 K=KM,KP
    IF (U(I,K)) 13,7,7
  7 CONTINUE
 11 W(K)=(25.*U(I,K)+24.*(U(I,K+1)+U(I,K-1))+21.*(U(I,K+2)
   1+U(I,K-2))+16.*(U(I,K+3)+U(I,K-3))+9.*(U(I,K+4)+U(I,K-4))
   2-11.*(U(I,K+6)+U(I,K-6)))/143.
    SUM=SUM+W(K)
    SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
    FLN=FLN+1.
    GO TO 15
 13 W(K)=-1.
 15 CONTINUE
    RETURN
    END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ7
C
C     15 TERM SMOOTHING EQUATION USING 7 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(176.*U(I,K)+162.*(U(I,K+1)+U(I,K-1))+147.*(U(I,K+2)
     1+U(I,K-2))+122.*(U(I,K+3)+U(I,K-3))+87.*(U(I,K+4)
     2+U(I,K-4))+42.*(U(I,K+5)+U(I,K-5))-13.*(U(I,K+6)+U(I,K-6))-78.
     3*(U(I,K+7)+U(I,K-7)))/1105.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ8
C
C     17 TERM SMOOTHING EQUATION USING 8 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(43.*U(I,K)+42.*(U(I,K+1)+U(I,K-1))+39.*(U(I,K+2)
     1+U(I,K-2))+34.*(U(I,K+3)+U(I,K-3))+27.*(U(I,K+4)
     2+U(I,K-4))+18.*(U(I,K+5)+U(I,K-5))+7.*(U(I,K+6)+U(I,K-6))
     3-6.*(U(I,K+7)+U(I,K-7))-21.*(U(I,K+8)+U(I,K-8)))/323.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ9
C
C    19 TERM SMOOTHING EQUATION USING 9 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(269.*U(I,K)+264.*(U(I,K+1)+U(I,K-1))+249.*(U(I,K+2)
     1+U(I,K-2))+224.*(U(I,K+3)+U(I,K-3))+189.*(U(I,K+4)+U(I,K-4))
     2+144.*(U(I,K+5)+U(I,K-5))+89.*(U(I,K+6)+U(I,K-6))+24.*(U(I,K+7)
     3+U(I,K-7))-51.*(U(I,K+8)+U(I,K-8))-136.*(U(I,K+9)+U(I,K-9)))/
     42261.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE SMEQ10
C
C    21 TERM SMOOTHING EQUATION USING 10 TERMS ON EACH SIDE OF U(I,K)
C
      DIMENSION CUMINT(500),CUMTOT(500),FMT(12),FMPT(12),SUMVAL(10),
     1SW(10),TH(500),U(10,500),VAL(10,500),W(10,500)
      COMMON AVMULT,CUMINT,CUMTOT,FLN,I,IMAX,J,K,KMAX,KMAXJ,KMIN,KMINJ,
     1NUM,NMIN,NMAX,SCALE,SMCON,SMINT,I,SUM,SUMSQ,U,VAL,W,LOC
      DO 15 K=KMINJ,KMAXJ
      KM=K-J
      KP=K+J
      IF(W(K-1)) 5,3,3
    3 IF(U(I,KP)) 13,11,11
    5 DO 7 K=KM,KP
      IF (U(I,K)) 13,7,7
    7 CONTINUE
   11 W(K)=(329.*U(I,K)+324.*(U(I,K+1)+U(I,K-1))  +309.*(U(I,K+2)
     1+U(I,K-2))+284.*(U(I,K+3)+U(I,K-3))+249.*(U(I,K+4)+U(I,K-4))
     2+204.*(U(I,K+5)+U(I,K-5))+149.*(U(I,K+6)+U(I,K-6))+84.*(U(I,K+7)
     3+U(I,K-7))+9.(U(I,K+8)+ U(I,K-8))   -76.*(U(I,K+9)+U(I,K-9))
     4-171.*(U(I,K+10)+U(I,K-10)))/3059.
      SUM=SUM+W(K)
      SUMSQ = SUMSQ + (U(I,K)-W(K))**2.0
      FLN=FLN+1.
      GO TO 15
   13 W(K)=-1.
   15 CONTINUE
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
      SUBROUTINE PLOT1(N,Y,X1,SCALE)
      DIMENSION ALPHA (10)
    1 FORMAT (1H ,I3,F8.2,F7.2,2H I,10A6)
      DO 10 IX=1,10
B  10 ALPHA(IX)=606060606060
      IV=X1*SCALE
      CALL SHIFTV(IV,ALPHA(1))
      PRINT 1,N,Y,X1.(ALPHA(JX).JX=1,10)
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
*      FAP


       ENTRY   SHIFTV                                                    0-19
       ENTRY   SHIFTW                                                    0-20
       ENTRY   SHIFTZ                                                    0-21



SHIFTV SXA     MOVE+2,1                                                  0-22
       CLA     V                       PICK UP SYMBOL FOR V              0-23
       STO     SYMBOL                                                    0-24
       TRA     SHIFT                                                     0-25
SHIFTW SXA     MOVE+2,1                                                  0-26
       CLA     W                       PICK UP SYMBOL FOR W              0-27
       STO     SYMBOL                                                    0-28
       TRA     SHIFT                                                     0-29
SHIFTZ SXA     MOVE+2,1                                                  0-30
       CLA     Z                       PICK UP SYMBOL FOR Z              0-31
       STO     SYMBOL                                                    0-32
SHIFT  CLA*    1,4                                                       0-33
       TZE     MOVE+2                                                    0-34
       TMI     MOVE+2                                                    0-35
       SUB     =1                      ARG-1/6                           0-36
       LDQ     =0                                                        0-37
       XCA                                                               0-38
       LRS     18                                                        0-39
       DVH     =6                                                        0-40
       STA     REMAIN                  STORE REMAINDER IN SHIFT INST.    0-41
       CLA     =0                                                        0-42
       XCA                                                               0-44
       ADD     ONE                     WORD INDEX = QUOTIENT+1           0-45
       PAX     ,1                                                        0-46
       CLA     =0                                                        0-47
       LDQ     REMAIN                                                    0-48
       MPY     =6                                                        0-49
       XCA                                                               0-50
       STA     MOVE                                                      0-51
       CLA     2,4                                                       0-52
       ADD     =1                                                        0-53
       STA     MOVE+1                                                    0-54
       CLA     BLANK                                                     0-55
       LDQ     SYMBOL                                                    0-56
MOVE   LGR     **                                                        0-57
       STQ     **,1                    SHIFT SYMBOL NUMBER OF SPACES     0-58
       AXT     **,1                    DETERMINED BY REMAINDER           0-59
       TRA     3,4                                                       0-60
V      BCI     1,.                                                       0-61
W      BCI     1,*                                                       L-62
Z      BCI     1,0                                                       0-63
BLANK  BCI     1,                                                        0-64
REMAIN PZE                                                               0-65
SYMBOL PZE                                                               0-67
ONE    OCT     000000000001                                              0-68
       END                                                               0-69
```

INPUT TO TIME-TREND PROGRAM

Smoothing-equation control card--The first card of the data is used to select the smoothing-equation subroutines which will be used in the program. The first 20 columns are used with two columns assigned to each smoothing subroutine. To call all ten subroutines, fill out columns 1-20 as follows: 01020304050607080910. To omit a subroutine, punch a zero in place of the number of the subroutine to be omitted. At the end of the data cards, include a card with 99 punched in columns 1 and 2 of the first 20 columns. As many sets of data cards as desired may be inserted before the 99 card which terminates the run. A listing of the input cards is given in Table 2.

Variable definition card--The second card in each data set is used to define seven variables used to control the operation of the program. The first three variables are in fixed-point mode and the last four in floating-point mode. The variables are read in according to format (3I5, 4F7.2). The card is punched as follows:

(1) Location number (LOC) in columns 1 through 5.

(2) Number of variables (IMAX) in columns 6 through 10.

(3) Number of sedimentary units (NMAX) in columns 11 through 15.

(4) Minimum value for cumulative thickness (THMIN) in columns 16 through 22.

(5) Pre-set constant for the smoothing interval (SMCON) in columns 23 through 29.

(6) A constant (AVMULT) which is multiplied by the average thickness to determine the smoothing interval in columns 30 through 36.

(7) Scale factor (SCALE) which is used in the plotting subroutine in columns 37 through 43. If values read between 0 and 1, use scale factor of 1, if between 0 and 10, use scale factor of 10, if between 0 and 100, use scale factor of 100.

Variable format cards--The third and fourth cards of each data set are used to define the format for reading and printing the data. The format for the data input must include space for one thickness reading and one value reading for each variable in each sedimentary unit. The format statement for the data output includes one fixed-point variable (NUM) for the unit number, the thickness of each unit, TH(NUM), the cumulative thickness, CUMTOT(NUM) and a value reading VAL (I,NUM) for each variable.

Data cards--Data cards follow the format cards. Each data card contains a thickness reading, TH(NUM), and a value reading, VAL(I,NUM), for each variable. The number of data cards is specified by NMAX and the number of variables is defined by IMAX. The format is given in the first variable format card. The last card of the last data set must have 99 in the first two columns.

OUTPUT FROM TIME-TREND PROGRAM

Input variables--The first line of the output gives the variables which were read in from the variable definition card. A complete listing of the output from a sample run is given in Table 3.

Data--A tabular listing of the data is printed according to the format specified by the second variable format card. The data output includes the unit number (NUM), cumulative thickness (CUMTOT) and value for each variable (VAL).

Statistical measures of the data--The following statistical measures based on the average values (U) computed in subroutine SETVAL for each variable (I) are calculated and printed by subroutine SMOOTH:

(1) Location number and variable number.

(2) Mean, variance, and standard deviation.

(3) Total sum of squares of deviations from the mean and the number of units not including covered interval.

Statistical measures of time-trend curves--The following statistical measures based on the time-trend curves calculated by the SMEQ subroutines are printed by subroutine SMOOTH:

(1) Location, variable, and smoothing equation number.

(2) Total sum of squares of deviations from the time-trend curve and number of graduated values (W).

(3) Percent of the total sum of squares of deviations from the mean accounted for by the time-trend curve.

Table 2.--An example of input to time-trend program used to smooth a sequence of alternating limestone and shale. A value of 10 on a variable scale is assigned to limestone units, 0 to shale, and intermediate values to variations in between. Thickness is measured in centimeters, and smoothing interval (SMINT) is 10.

```
(card 1)           01020304000600080000
(card 2)             51    1   80    0.00    10.00    0.00    10.00
(card 3)           (2F7.2)
(card 4)           (I5,3F10.2)
(card 5)             11.30   10.00
(card 6)             11.20    1.00
  ...                 2.80   10.00
  ...                15.40    0.00
  ...                10.10   10.00
  ...                 7.50    0.00
  ...                 5.40   10.00
  ...                 6.30    0.00
  ...                 3.10   10.00
  ...                17.80    1.00
  ...                 5.80   10.00
  ...                 3.40    0.00
  ...                 9.80   10.00
  ...                14.00    1.00
  ...                 2.10   10.00
  ...                 8.80    1.00
  ...                 1.40   10.00
  ...                 4.60    0.00
  ...                 1.80   10.00
  ...                16.90    0.00
  ...                 ....    ....
  ...                 ....    ....
  ...                 5.70   10.00
  ...                24.70    2.00
(last card)        99000000000000000000
```

Table 3.--A listing of output from a sample run of time-trend program used to smooth a sequence of alternating limestone and shale layers. Smoothing equations 1, 2, 3, 4, 6, and 8 are used in this example. Output represents a small portion of a much thicker sequence in the Richmond Group, Upper Ordovician, in southeastern Indiana.

```
     DATA FOLLOWS

        NUM    TH(NUM)    CUMTOT    VALUES
        1       11.30      11.30     10.00
        2       11.20      22.50      1.00
        3        2.80      25.30     10.00
        4       15.40      40.70     0.
        5       10.10      50.80     10.00
        6        7.50      58.30     0.
        7        5.40      63.70     10.00
        8        6.30      70.00     0.
        9        3.10      73.10     10.00
       10       17.80      90.90      1.00
       11        5.80      96.70     10.00
       12        3.40     100.10     0.
       13        9.80     109.90     10.00
       14       14.00     123.90      1.00
       15        2.10     126.00     10.00
       16        8.80     134.80      1.00
       17        1.40     136.20     10.00
       18        4.60     140.80     0.
       19        1.80     142.60     10.00
       20       16.90     159.50     0.
       21        2.40     161.90     10.00
       22        6.20     168.10     0.
       23        1.80     169.90     10.00
       24       21.90     191.80     0.
       25        2.20     194.00     10.00
       26        4.70     198.70     0.
       27        4.80     203.50     10.00
       28       12.10     215.60     0.
       29        3.80     219.40     10.00
       30        9.20     228.60      1.00
       31        2.80     231.40     10.00
       32        1.30     232.70     0.
       33        1.60     234.30     10.00
       34        2.70     237.00     0.
       35        9.00     246.00     10.00
       36        3.50     249.50     0.
       37        4.80     254.30     10.00
       38        1.30     255.60     0.
       39        4.10     259.70     10.00
       40       16.20     275.90      6.00
       41        8.30     284.20     10.00
       42        2.00     286.20     0.
       43        3.80     290.00     10.00
       44        7.40     297.40      2.00
       45       11.90     309.30     10.00
       46        4.10     313.40     0.
       47        4.20     317.60     10.00
       48        6.40     324.00      1.00
       49        4.60     328.60     10.00
       50       23.40     352.00      1.00
       51        3.30     355.30     10.00
       52        7.70     363.00      2.00
       53        2.70     365.70     10.00
       54        2.90     368.60     0.
       55       12.10     380.70     10.00
       56        3.90     384.60     0.
       57         .80     385.40     10.00
       58        6.40     391.80     0.
       59        2.60     394.40     10.00
       60        1.50     395.90     0.
       61        1.60     397.50     10.00
       62        4.80     402.30     0.
       63        4.00     406.30     10.00
       64         .90     407.20     0.
       65        1.60     408.80     10.00

       66       10.40     419.20     0.
       67        1.30     420.50     10.00
       68        6.10     426.60     0.
       69        1.20     427.80     10.00
       70        8.90     436.70     0.
       71        5.80     442.50     10.00
       72        4.50     447.00     0.
       73        8.80     455.80     10.00
       74        8.00     463.80     0.
       75        3.70     467.50     10.00
       76       29.10     496.60      1.00
       77        9.20     505.80     10.00
       78        9.80     515.60     0.
       79        5.70     521.30     10.00
       80       24.70     546.00      2.00
```

```
  AT LOCATION   51   FOR VARIABLE    1

  MEAN =   4.01  VARIANCE =      7.66  STANDARD DEVIATION =      2.77

  TOTAL SUM OF SQUARES =      405.94  NUMBER OF UNITS =   54

                            2.0       4.0       6.0       8.0      10.0
UNIT  DEPTH  VALUE I         I         I         I         I         I
  1   10.00  10.00 I                                                 .
  2   20.00   2.17 I         .
  3   30.00   3.05 I              .
  4   40.00   0.   I
  5   50.00   9.30 I                                             .
  6   60.00   2.50 I           .
  7   70.00   3.70 I                 .
  8   80.00   3.79 I                 .
  9   90.00   1.00 I    .
 10  100.00   5.89 I                            .
 11  110.00   9.81 I                                                .
 12  120.00   1.00 I    .
 13  130.00   2.89 I             .
 14  140.00   1.88 I        .
 15  150.00   1.80 I       .
 16  160.00    .50 I .
 17  170.00   3.70 I                 .
 18  180.00   0.   I
 19  190.00   0.   I
 20  200.00   3.50 I                .
 21  210.00   3.50 I                .
 22  220.00   3.86 I                  .
 23  230.00   2.26 I          .
 24  240.00   6.00 I                             .
 25  250.00   6.50 I                               .
 26  260.00   8.58 I                                         .
 27  270.00   6.00 I                             .
 28  280.00   7.64 I                                     .
 29  290.00   8.00 I                                      .
 30  300.00   4.08 I                   .
 31  310.00   9.30 I                                             .
 32  320.00   4.44 I                     .
 33  330.00   5.14 I                        .
 34  340.00   1.00 I    .
 35  350.00   1.00 I    .
 36  360.00   4.44 I                     .
 37  370.00   4.70 I                      .
 38  380.00  10.00 I                                                 .
 39  390.00   1.50 I      .
 40  400.00   4.20 I                   .
 41  410.00   5.60 I                          .
 42  420.00    .80 I   .
 43  430.00   1.70 I       .
 44  440.00   3.30 I               .
 45  450.00   5.50 I                          .
 46  460.00   5.80 I                           .
 47  470.00   3.95 I                  .
 48  480.00   1.00 I    .
 49  490.00   1.00 I    .
 50  500.00   4.06 I                   .
 51  510.00   5.80 I                           .
 52  520.00   4.40 I                     .
 53  530.00   3.04 I              .
```

```
AT LOCATION    51   FOR VARIABLE     1   AND SMOOTHING EQUATION     2

TOTAL SUM OF SQUARES =       156.06   NUMBER OF UNITS =    50

PERCENT OF TOTAL SUM OF SQUARES = 41.52

                              2.0       4.0       6.0       8.0      10.0
UNIT  DEPTH    VALUE I         I         I         I         I         I
  1    10.00   -1.00 I
  2    20.00   -1.00 I
  3    30.00     .57 I  .
  4    40.00    3.83 I                  .
  5    50.00    4.80 I                       .
  6    60.00    5.35 I                          .
  7    70.00    3.07 I              .
  8    80.00    2.73 I             .
  9    90.00    2.65 I            .
 10   100.00    6.16 I                              .
 11   110.00    6.79 I                                 .
 12   120.00    4.17 I                    .
 13   130.00    1.40 I      .
 14   140.00    2.39 I           .
 15   150.00    1.13 I     .
 16   160.00    1.97 I         .
 17   170.00    1.81 I        .
 18   180.00     .93 I    .
 19   190.00     .58 I  .
 20   200.00    2.57 I            .
 21   210.00    4.03 I                   .
 22   220.00    3.04 I              .
 23   230.00    3.62 I                 .
 24   240.00    4.85 I                       .
 25   250.00    7.45 I                                    .
 26   260.00    7.28 I                                   .
 27   270.00    7.23 I                                   .
 28   280.00    7.43 I                                    .
 29   290.00    6.59 I                                .
 30   300.00    6.88 I                                 .
 31   310.00    6.31 I                               .
 32   320.00    6.67 I                                .
 33   330.00    3.48 I                .
 34   340.00    1.83 I        .
 35   350.00    1.51 I       .
 36   360.00    3.17 I               .
 37   370.00    7.02 I                                  .
 38   380.00    6.24 I                              .
 39   390.00    4.71 I                       .
 40   400.00    3.55 I                 .
 41   410.00    4.16 I                    .
 42   420.00    2.25 I          .
 43   430.00    1.28 I     .
 44   440.00    3.51 I                 .
 45   450.00    5.31 I                          .
 46   460.00    5.69 I                           .
 47   470.00    3.69 I                 .
 48   480.00    1.34 I      .
 49   490.00    1.38 I      .
 50   500.00    3.84 I                  .
 51   510.00    5.37 I                          .
 52   520.00    4.65 I                      .
 53   530.00   -1.00 I
```

```
  AT LOCATION   51  FOR VARIABLE    1  AND SMOOTHING EQUATION    3

  TOTAL SUM OF SQUARES =      191.28  NUMBER OF UNITS =   48

  PERCENT OF TOTAL SUM OF SQUARES = 53.01

                            2.0       4.0       6.0       8.0      10.0
UNIT  DEPTH  VALUE I         I         I         I         I         I
  1   10.00  -1.00 I
  2   20.00  -1.00 I
  3   30.00  -1.00 I
  4   40.00   2.89 I             .
  5   50.00   4.21 I                    .
  6   60.00   4.70 I                      .
  7   70.00   3.94 I                  .
  8   80.00   1.98 I        .
  9   90.00   4.70 I                      .
 10  100.00   5.11 I                        .
 11  110.00   5.25 I                         .
 12  120.00   4.81 I                       .
 13  130.00   2.84 I             .
 14  140.00    .89 I   .
 15  150.00   2.13 I         .
 16  160.00   1.73 I       .
 17  170.00   1.12 I    .
 18  180.00   1.12 I    .
 19  190.00   1.61 I       .
 20  200.00   2.15 I         .
 21  210.00   3.02 I              .
 22  220.00   3.67 I                 .
 23  230.00   3.85 I                  .
 24  240.00   5.38 I                         .
 25  250.00   6.42 I                               .
 26  260.00   7.40 I                                    .
 27  270.00   7.75 I                                     .
 28  280.00   6.85 I                                 .
 29  290.00   6.96 I                                 .
 30  300.00   6.97 I                                 .
 31  310.00   6.59 I                               .
 32  320.00   5.47 I                          .
 33  330.00   3.93 I                  .
 34  340.00   2.02 I         .
 35  350.00   1.92 I        .
 36  360.00   4.05 I                   .
 37  370.00   5.55 I                          .
 38  380.00   5.71 I                           .
 39  390.00   5.53 I                          .
 40  400.00   4.36 I                    .
 41  410.00   2.49 I           .
 42  420.00   2.76 I            .
 43  430.00   2.37 I          .
 44  440.00   3.19 I              .
 45  450.00   5.07 I                        .
 46  460.00   4.99 I                       .
 47  470.00   3.49 I                .
 48  480.00   2.08 I         .
 49  490.00   2.20 I          .
 50  500.00   3.40 I                .
 51  510.00   4.64 I                      .
 52  520.00  -1.00 I
 53  530.00  -1.00 I
```

```
  AT LOCATION    51   FOR VARIABLE     1   AND SMOOTHING EQUATION     4

  TOTAL SUM OF SQUARES =       198.31  NUMBER OF UNITS =   46

  PERCENT OF TOTAL SUM OF SQUARES = 57.35

                                2.0       4.0       6.0       8.0      10.0
UNIT   DEPTH     VALUE I         I         I         I         I         I
  1    10.00     -1.00 I
  2    20.00     -1.00 I
  3    30.00     -1.00 I
  4    40.00     -1.00 I
  5    50.00      3.46 I                .
  6    60.00      3.83 I                  .
  7    70.00      3.34 I               .
  8    80.00      4.55 I                     .
  9    90.00      3.90 I                  .
 10   100.00      4.84 I                       .
 11   110.00      4.62 I                      .
 12   120.00      4.32 I                    .
 13   130.00      3.33 I               .
 14   140.00      2.11 I         .
 15   150.00      1.30 I     .
 16   160.00      1.50 I      .
 17   170.00      1.11 I    .
 18   180.00      1.34 I     .
 19   190.00      1.93 I        .
 20   200.00      2.13 I         .
 21   210.00      2.43 I           .
 22   220.00      3.55 I                .
 23   230.00      4.76 I                      .
 24   240.00      5.24 I                         .
 25   250.00      6.11 I                             .
 26   260.00      7.32 I                                   .
 27   270.00      7.33 I                                   .
 28   280.00      7.37 I                                   .
 29   290.00      7.10 I                                  .
 30   300.00      6.93 I                                 .
 31   310.00      6.47 I                               .
 32   320.00      4.81 I                       .
 33   330.00      3.69 I                 .
 34   340.00      2.76 I            .
 35   350.00      3.08 I              .
 36   360.00      3.94 I                  .
 37   370.00      4.34 I                    .
 38   380.00      5.70 I                           .
 39   390.00      5.51 I                          .
 40   400.00      4.24 I                    .
 41   410.00      3.02 I              .
 42   420.00      2.16 I         .
 43   430.00      3.38 I               .
 44   440.00      3.75 I                 .
 45   450.00      4.00 I                  .
 46   460.00      4.14 I                   .
 47   470.00      3.46 I                .
 48   480.00      3.06 I              .
 49   490.00      2.93 I             .
 50   500.00      3.25 I               .
 51   510.00     -1.00 I
 52   520.00     -1.00 I
 53   530.00     -1.00 I
```

```
AT LOCATION    51  FOR VARIABLE     1  AND SMOOTHING EQUATION     6

TOTAL SUM OF SQUARES =       202.85  NUMBER OF UNITS =    42

PERCENT OF TOTAL SUM OF SQUARES = 64.25

UNIT  DEPTH   VALUE I
  1   10.00   -1.00 I
  2   20.00   -1.00 I
  3   30.00   -1.00 I
  4   40.00   -1.00 I
  5   50.00   -1.00 I
  6   60.00   -1.00 I
  7   70.00    3.69 I
  8   80.00    4.57 I
  9   90.00    4.57 I
 10  100.00    4.52 I
 11  110.00    3.42 I
 12  120.00    3.84 I
 13  130.00    3.42 I
 14  140.00    2.66 I
 15  150.00    2.07 I
 16  160.00    1.14 I
 17  170.00    1.07 I
 18  180.00    1.62 I
 19  190.00    1.67 I
 20  200.00    2.04 I
 21  210.00    2.89 I
 22  220.00    3.68 I
 23  230.00    4.35 I
 24  240.00    5.80 I
 25  250.00    6.09 I
 26  260.00    6.64 I
 27  270.00    7.09 I
 28  280.00    7.60 I
 29  290.00    7.55 I
 30  300.00    6.44 I
 31  310.00    5.53 I
 32  320.00    4.28 I
 33  330.00    4.50 I
 34  340.00    4.05 I
 35  350.00    3.78 I
 36  360.00    4.26 I
 37  370.00    4.02 I
 38  380.00    4.31 I
 39  390.00    4.10 I
 40  400.00    4.12 I
 41  410.00    4.04 I
 42  420.00    3.83 I
 43  430.00    3.64 I
 44  440.00    3.07 I
 45  450.00    3.37 I
 46  460.00    3.18 I
 47  470.00    3.42 I
 48  480.00    3.99 I
 49  490.00   -1.00 I
 50  500.00   -1.00 I
 51  510.00   -1.00 I
 52  520.00   -1.00 I
 53  530.00   -1.00 I
```

```
AT LOCATION   51  FOR VARIABLE    1  AND SMOOTHING EQUATION    8

TOTAL SUM OF SQUARES =      191.52  NUMBER OF UNITS =   38

PERCENT OF TOTAL SUM OF SQUARES = 67.04

                              2.0       4.0       6.0       8.0       10.0
UNIT   DEPTH   VALUE I         I         I         I         I         I
  1    10.00   -1.00 I
  2    20.00   -1.00 I
  3    30.00   -1.00 I
  4    40.00   -1.00 I
  5    50.00   -1.00 I
  6    60.00   -1.00 I
  7    70.00   -1.00 I
  8    80.00   -1.00 I
  9    90.00    3.68 I                 .
 10   100.00    4.19 I                   .
 11   110.00    3.98 I                  .
 12   120.00    3.44 I                .
 13   130.00    2.57 I           .
 14   140.00    2.62 I            .
 15   150.00    2.36 I          .
 16   160.00    1.95 I        .
 17   170.00    1.70 I       .
 18   180.00    1.20 I    .
 19   190.00    1.56 I      .
 20   200.00    2.52 I           .
 21   210.00    2.97 I             .
 22   220.00    3.96 I                  .
 23   230.00    4.44 I                     .
 24   240.00    5.34 I                         .
 25   250.00    5.90 I                            .
 26   260.00    6.88 I                                 .
 27   270.00    7.19 I                                  .
 28   280.00    6.82 I                                 .
 29   290.00    6.55 I                               .
 30   300.00    5.84 I                            .
 31   310.00    5.85 I                            .
 32   320.00    5.23 I                         .
 33   330.00    4.72 I                      .
 34   340.00    4.62 I                      .
 35   350.00    4.55 I                     .
 36   360.00    4.13 I                   .
 37   370.00    3.77 I                 .
 38   380.00    3.66 I                 .
 39   390.00    3.49 I                .
 40   400.00    4.09 I                   .
 41   410.00    4.28 I                    .
 42   420.00    4.25 I                    .
 43   430.00    3.74 I                 .
 44   440.00    3.29 I               .
 45   450.00    3.19 I              .
 46   460.00    3.17 I              .
 47   470.00   -1.00 I
 48   480.00   -1.00 I
 49   490.00   -1.00 I
 50   500.00   -1.00 I
 51   510.00   -1.00 I
 52   520.00   -1.00 I
 53   530.00   -1.00 I
```

Graduated values and plot of time-trend curve--The graduated values (W) calculated by the SMEQ subroutines are printed and plotted by the PLOT1 subroutine which is called in subroutine SMOOTH. Each line includes the unit number (K), the cumulative thickness for the smoothing interval (CUMINT), and the graduated value (W). The graduated value (W) is plotted as a period. The plot is 60 spaces wide, but this can be varied by modifying the format statements in subroutine PLOT1.

APPLICATIONS OF TIME-TREND PROGRAM

Time-trend analysis has been used extensively by Vistelius (1961) for correlation of sedimentary deposits in Russia. Vistelius uses a single parameter such as grain size or porosity for correlation between adjacent measured sections. The time-trend curves are based on observations taken at equally spaced intervals throughout the section.

An earlier version of this program has been used by Fox and Brown (in press) for plotting smoothed curves used in the environmental interpretation of limestones. Trends in the lithology of the limestones are compared with trends in fossil distribution and thin-section data are used to interpret energy levels in the depositional environment.

The program should have wide application in many stratigraphic studies. The time-trend curves can be used for correlation and environmental interpretation in any sequence of sedimentary rocks. By using the percent of the total sum of squares as a measure of the amount of the total variability accounted for by each of the curves, it is possible to study the size and distribution of sedimentary cycles within the sequence.

REFERENCES

Fox, W. T., and Brown, J. A., in press, The use of time-trend analysis for environmental interpretation of limestones: Jour. Geology.

Vistelius, A. B., 1961, Sedimentation time-trend functions and their application for correlation of sedimentary deposits: Jour. Geology, v. 69, p. 703-728.

Whittaker, E. T., and Robinson, G., 1929, The calculus of observations, in, A treatise of numerical mathematics, 2nd. ed.: Blackie and Son, Ltd., London, p. 395.

KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN and FAP Program for Calculating and Plotting Time-Trend Curves

Computer: IBM 7090-7094

Date: August, 1964

Programming language: FORTRAN and FAP

Author, organization: William T. Fox, Department of Geology
Williams College, Williamstown, Massachusetts

Direct inquiries to: Author or Daniel F. Merriam, State Geological Survey, Lawrence, Kansas

Name: William T. Fox

Address: Department of Geology
Williams College, Williamstown, Mass.

Purpose/description: The program is used to compute and plot a series of smoothed or graduated curves based on a sequence of geologic observations taken from a traverse or stratigraphic section. Nine smoothing formulae are used which correspond to cycles of increasing magnitude within the data. The total sum of squares of deviations from the smoothed curve is used to compute the percent of total variability accounted for by each curve.

Mathematical method: Least-squares analysis is used to fit a series of third-order polynomials to the data.

Restrictions, range: The program is limited to 500 observations on each of 10 variables, but can be modified to handle 500 observations on 30 variables or 1,500 observations on 10 variables.

Storage requirements: Program uses 24,757 storage locations. Dummy F2PM must be used with result runs.

Equipment specifications: (7090-7094 with 32,000+ locations of high-speed memory)

Memory 20K ____ 40K ____ 60K ____ K ____

Automatic divide: Yes ____ No ____

Indirect addressing: Yes ____ No ____

Other special features required ____

Additional remarks (include at author's discretion: fixed/float, relocatability; optional: running time, approximate number of times run successfully, programming hours) Compiles from FORTRAN and FAP source decks in 4.80 minutes. The running time is about 2 minutes to compute all nine curves for 100 observations on a single variable. The program has been successfully run several times on the 7094 computer at M. I. T.

KANSAS GEOLOGICAL SURVEY COMPUTER CONTRIBUTIONS

Special Distribution Publication

3. BALGOL program for trend-surface mapping using an IBM 7090 computer, by J.W. Harbaugh, 1963 . . . .$0.50
4. FORTRAN II program for coefficient of association (Match-Coeff) using an IBM 1620 computer, by R.L. Kaesler, F.W. Preston, and D.I. Good, 1963 . . . .$0.25
9. BALGOL programs for calculation of distance coefficients and correlation coefficients using an IBM 7090 computer, by J.W. Harbaugh, 1964 . . . .$0.50
11. Trend-surface analysis of regional and residual components of geologic structure in Kansas, by D.F. Merriam and J.W. Harbaugh, 1964 . . . .$0.50
12. FORTRAN and FAP program for calculating and plotting time-trend curves using an IBM 7090 or 7094/1401 computer system, by W.T. Fox, 1964 . . . .$0.50

Report of Studies

170-3 Mathematical conversion of section, township, and range notation to Cartesian Coordinates, by D.I. Good, 1964 . . . .$0.25

Bulletin

171 A computer method for four-variable trend analysis illustrated by a study of oil-gravity variations in southeastern Kansas, by J.W. Harbaugh, 1964 . . . . in press

Reprints (available for limited time)

Computer helps map oil structures, by D.F. Merriam and J.W. Harbaugh (reprinted from The Oil and Gas Journal, v. 61, no. 47, 1963) . . . . no charge

Use of trend-surface residuals in interpreting geologic structures, by D.F. Merriam (reprinted from Stanford University Publications, Geological Sciences, v. 9, no. 2, 1964) . . . . no charge