DANIEL F. MERRIAM, Editor

FORTRAN II TIME-TREND PACKAGE FOR THE IBM 1620 COMPUTER

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Editor's Remarks

In addition to making computer programs available, the Geological Survey provides information in machinable form. At present two sets of data have been made available (1) a list of all wells drilled into Precambrian rocks in the State, and (2) compendium of helium data.

The Precambrian well data have been available for several years and consist of well location, name, elevation, Precambrian datum, rock type, overlying formation, total depth, and year drilled. Information on more than 2,650 wells has been compiled, and the list is updated yearly.

Now helium data have been released. They consist of well location, geologic formation and lithology, depth of sample zone, wellhead pressure, date of well completion, date sampled and composition.

Copies of the data will be sent post paid, by certified mail according to the following price schedule:

(1) 32-page printout $5.00
(2) returnable magnetic tape copy $20.00
(3) duplicate card deck $25.00

The data are areally concentrated in the southern half of the State, and vertically concentrated in gas-producing zones. There are a few helium only analyses, but the data include all analyses for which helium was specifically analyzed. Thus, data are included from noncommercial gas wells, oil wells, water wells and composite samples.

The Geological Survey's file record and master card decks will be updated whenever information is available.

In making this information available, the Geological Survey is fulfilling yet another service to the State and profession. It is anticipated that in the future other data will be released. The Geological Survey is the only geological organization now known to be distributing data decks as well as computer program decks. An up-to-date list of publications is available on request.

Comments and suggestions concerning the COMPUTER CONTRIBUTION series are welcome and should be addressed to the Editor.

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INTRODUCTION

Many types of geologic data are distributed serially, either through time or along a geographic coordinate. Although such data are ordered, it is seldom equally spaced, especially in the time sense. Geologic information that may be uniformly ordered through time (time series) includes that from varved sequences or annual growth of organisms, such as tree rings or bands on certain corals. Most other types of data, such as measurements of a stratigraphic succession, represent a nonuniform time series in which the length of the units are not known. In these instances, distance is used as an approximator of time, and the data sequence is considered as a geographic series. Other types of geographic series have no time connotation; examples include data collected along a traverse or information produced by a linear recorder attached to equipment such as an x-ray diffraction unit or infrared spectrometer.

Serial methods have been applied primarily in three types of investigation. They have been used for the extraction of components, in the examination for periodicity, and to obtain numerical approximations of sequences. Component extraction consists of curve fitting by various methods so that the data are separated into (1) an underlying "trend" and (2) superposed "noise" or error, which is a random component. Filtering of seismographic records to remove random fluctuations is an example of this application. More recently, data from stratigraphic sequences have been smoothed by curve fitting to aid in the detection of long-term trends.

Techniques borrowed from market analysis have been applied widely in the search for periodicity in oscillatory data. Autocorrelation has been used to examine oscillatory sedimentary sequences such as cyclothems in an attempt to objectively test the hypothesis of rhythmic sedimentation. Statistical tests are available for determining the validity of suspected trends in data and are useful in such diverse areas as stratigraphic analysis and prediction of crude-oil reserves.

One of the most recent innovations is the application of time-series statistics to problems of stratigraphic correlation. Although the data usually do not meet the criteria necessary for valid time series, stratigraphic correlations on the basis of such parameters as coded lithologies or drilling times have been successful. Most of these applications have utilized cross-correlation, cross-association, or related statistics. It is also possible to compare certain types of serial data by reducing the sequences to equations and clustering them on the basis of the similarity of their coefficients.

PROGRAM DESCRIPTIONS

The accompanying series of programs are written in FORTRAN II for use on an IBM 1620 computer having 20K bits core storage. Restrictions in programs for this computer are typical of those inherent in older machines and also in a new generation of instruments such as the PDP-8, IBM 1130 and 1800, SDS Sigma 2, and other small computers. These machines are most generally available to geologists at smaller universities and in oil and mining company field offices. Even on campuses having large data-processing centers, many departments and agencies maintain small computers for their own instructional or routine use. They are usually the only type of computer available in many installations outside the United States. Persons having computers similar in characteristics to the IBM 1620 should find this collection of programs easily adaptable to their use.

Because of computer size restrictions, the different operations cannot be combined into a single large program with options. They are separated, therefore, into a series of independent programs capable of being used separately or in conjunction with one another. A "single" program with options in FORTRAN IV written for the GE 625 also is available. The following five programs constitute the package:

PROGRAM 1 - Equal Spacing and Data Smoothing.
This program will accept unevenly spaced sequential data and convert it to equal spacing.

It also will smooth equally spaced data by Sheppard's equation, Spencer's equation, an n-term sliding trapezoidal approximation, or an n-term sliding average.

PROGRAM 2 - Autocorrelation and Cross-Correlation. The program will accept one sequence of equally spaced data and perform an autocorrelation, or will accept two data chains and perform cross-correlation. Either foreward or backward matching is possible, with chains moving in steps of n.

PROGRAM 3 - Burnaby's Cross-Difference Product. The cross-difference product (CDP) was proposed by Burnaby (1953) as an alternative to cross-correlation. This program will accept two chains of equally spaced data and compute the CDP for matches moving forward or backward in steps of n.

PROGRAM 4 - Cross Association. This program is an adaptation of a procedure developed by Sackin and Sneath (1965) for the comparison of non-numeric sequences. Unlike other programs in this package, it requires integer data (usually of an arbitrary nature, such as sandstone = 1, shale = 2, limestone = 3, etc.).

All programs require PDQ FORTRAN Processor C2 without reread version 1 modification 0, and PDQ FORTRAN fixed format subroutines without reread version 1 modification 0 (IBM User's Group Program 2.0.031) for operation on the IBM 1620. Minimal machine requirements consist of an IBM 1620 Model I central processing unit with 20K bits storage, automatic divide, and indirect addressing. A 1622 card read punch and a 407 accounting machine or similar line printer also are required. Examples of output are included in Appendix.

OPERATING INSTRUCTIONS

Program 1 - Equal Spacing and Smoothing Program.

This program was designed for analysis of stratigraphic sequences, but is not limited to such problems. Data consist of the distances between successive data points (x values) and the value of the variable at the points (y values). For example, x may be the thickness in feet of stratigraphic units, and y a code for a lithology or some sedimentary parameter (Fox, 1964). In the example here, drilling-time logs are used, x is the interval between successive recording points, and y is the time in minutes required to drill the interval.

This program requires two passes. Data are processed on the first pass to produce a new set of data cards containing estimated values of y' at specified equally spaced values of x. Values of y' are computed by a rectangular integration method described by Fox (1964). This intermediate output is entered into the computer and smoothed by one of the specified smoothing equations:

(1) Sheppard's 5-term equation (Whittaker and Robinson, 1926, Vistelius, 1961).

$$\hat{y}_0 = \frac{1}{35}\,[\,17y'_0 + 12\,(y'_{+1} + y'_{-1}) - 3\,(y'_{+2} + y'_{-2})\,] \qquad (1)$$

(2) Spencer's 21-term equation (Whittaker and Robinson, 1926, Vistelius, 1961).

$$\begin{aligned}\hat{y}_0 = \frac{1}{350}\,[\,&60y'_0 + 57\,(y'_{+1} + y'_{-1}) + 47\,(y'_{+2} + y'_{-2}) \\ &+ 33\,(y'_{+3} + y'_{-3}) + 18\,(y'_{+4} + y'_{-4}) \\ &+ 6\,(y'_{+5} + y'_{-5}) - 2\,(y'_{+6} + y'_{-6}) - 5\,(y'_{+7} + y'_{-6}) \\ &- 5\,(y'_{+8} + y'_{-8}) - 3\,(y'_{+9} + y'_{-9}) - (y'_{+10} + y'_{-10})\,]\end{aligned} \qquad (2)$$

(3) Sliding average with specified span.

$$\hat{y}_0 = \frac{y'_{-m} + \dots\dots y'_{-1} + y'_0 + y'_{+1} + \dots\dots y'_{+m}}{2m + 1} \qquad (3)$$

Span (2m + 1) may be any odd value from 3 to 101. A sliding average weights all points within the span equally in the calculation of $\hat{y}_i$.

(4) Trapezoidal rule approximation with specified span.

$$\hat{y}_0 = \frac{y'_{-m} + 2y'_{-(m-1)} + \dots 2y'_{-1} + 2y'_0 + 2y'_{+1} + \dots 2y_{+(m-1)} + y'_{+m}}{4m} \qquad (4)$$

Output from the second pass consists of a cumulative total of x, smoothed value of $\hat{y}$, observed value of y', and the deviation at each point. After processing all points, total thickness of raw data, total thickness of equally spaced data, and total thickness of smoothed data are punched. A measure of goodness of fit of smoothed to equally spaced data then is computed by the equation:

$$R^2 = \frac{[\,n\Sigma y' - (\Sigma y')^2\,] - \Sigma(y' - \hat{y})^2}{n\Sigma y'^2 - (\Sigma y')^2}\ . \qquad (5)$$

Expected and observed numbers of runs in the smoothed data sequence are next computed (Miller and Kahn, 1962, p. 331). The expected number of runs in a random sequence of numbers is

$$E_{(r)} = (2n-1)/3\ , \qquad (6)$$

and the expected number of nonruns is

$$E_{(nr)} = (2n-2) - E_{(r)}\ . \qquad (7)$$

Nonrandomness can be tested in a 2 x 2 contingency table of the form

$$\chi^2 = \frac{(O_{(r)} - E_{(r)})^2}{E_{(r)}} + \frac{(O_{(nr)} - E_{(nr)})^2}{E_{(nr)}} \qquad (8)$$

with one degree of freedom. $O_{(r)}$ and $O_{(nr)}$ are the number of observed runs and nonruns, respectively. The program prints $E_{(r)}$, $O_{(r)}$, and χ^2. The standard deviation of smoothed values also is printed.

A series of statistics pertaining to the equally spaced data is next produced. These include $E_{(r)}$, $O_{(r)}$, χ^2, and the standard deviation of the equal spaced values. The slope (β) of the linear regression of y' on x is computed, accompanied by a t-value and degrees of freedom for testing the hypothesis that the slope is zero. This feature is useful for the detection of linear bias or trend in the data.

After loading the Program 1 object deck and subroutines, the message LOAD DATA will be typed on the console typewriter. The following sequence of cards should then be entered.

CARD 1 - Control card containing the following options code:

- Col. 1- 2 Blank.
- Col. 3 Selection of smoothing equation.
  - 1 = Sheppard's 5-term smoothing equation.
  - 2 = Spencer's 21-term smoothing equation.
  - 3 = Sliding average.
  - 4 = Trapezoidal approximation.
- Col. 4- 6 Integer specifying the number of terms in smoothing equation. This must be 005 for Sheppard's equation, 021 for Spencer's equation, and an odd number between 003 and 101 if a sliding average or trapezoidal approximation is used.
- Col. 7-16 Length of interval between equally spaced data. This number must contain a decimal point.

CARD 2 - This is a title card containing any desired alphanumeric information in col. 1-80.

CARD 3 - This is the first of any number of data cards, each containing one set of x and y values.

- Col. 1-10 Values of x. This number must contain a decimal point.
- Col. 11-20 Values of y. This number must contain a decimal point.

END CARD - This card is placed at the end of the data deck and contains the number 9.0E 48 punched in col. 1-7.

After completion of punching of intermediate output, the message ENTER EQUAL SPACED DATA will be typed on the console typewriter. The set of intermediate output should be loaded and final output will then be produced. At the completion of calculations, the message STOP 100 will be typed and the machine will pause. A new data set may be entered at this time. If more than one smoothing operation is necessary on a set of data, turn SENSE SWITCH 1 to ON. A new control card should be prepared and inserted in the original data deck and the procedure outlined above repeated. No new intermediate output will be produced, however, because the smoothed data produced on the initial run is used for Pass 2.

```
C     TIME TREND ANALYSIS -- PROGRAM 1
C     EQUAL SPACING AND SMOOTHING PROGRAM
C     ROBERT SAMPSON -- PROGRAMMER
C     ISU COMPUTER CENTER PROJECT NO. 75
      BEGIN TRACE
      DIMENSION SLITH(101)
    1 DO 100 I=1,101
  100 SLITH(I)=0.0
      SX=0.0
      SY=0.0
      SXY=0.0
      SXX=0.0
      SYY=0.0
      READ 1000,IEQ,NT,AINT
      READ 1001
      TTH=0.0
      IF (SENSE SWITCH 1) 60,61
   61 PUNCH 1001
      PUNCH 1023
      PUNCH 1013,AINT
   60 READ 1002,DATT,DATL
      NTT=0
      DATTL=DATT
```

```
      DATLL=DATL
      TSTH=AINT
      SL=0.0
      GO TO 3
    2 READ 1002,DATTL,DATLL
      IF (DATTL-9.0E 48) 3,4,3
    3 TTHL=TTH+DATTL
    7 IF (TTHL-TSTH) 5,6,6
    5 DIF=TTH-TSTH+AINT
      IF (DIF) 80,81,81
   80 SL=SL+(DATTL+DIF)*DATLL
      GO TO 84
   81 SL=SL+DATTL*DATLL
   84 TTH=TTHL
      DATL=DATLL
      GO TO 2
    6 DIF=TTH-TSTH+AINT
      IF (DIF) 82,83,83
   83 DIF=0.0
   82 SL=SL+(DATTL-(TTHL-TSTH)+DIF)*DATLL
      SL=SL/AINT
      NTT=NTT+1
      IF (SENSE SWITCH 1) 8,9
    9 PUNCH 1003,NTT,TSTH,SL
    8 SX=SX+TSTH
      SY=SY+SL
      SXY=SXY+TSTH*SL
      SXX=SXX+TSTH*TSTH
      SYY=SYY+SL*SL
      TSTH=TSTH+AINT
      SL=0.0
      GO TO 7
    4 NTM=2
      IF (SENSE SWITCH 1) 90,91
   91 PUNCH 1014
   90 PRINT 1024
      READ 1015
      PUNCH 1001
      EXECUTE PROCEDURE 5000
      PUNCH 1022,AINT
      PUNCH 1021
      RCN=0.0
      RCN1=0.0
      AN=NTT
      READ 1004,SLITH(1)
      READ 1004,SLITH(2)
      RCL=SGN(SLITH(2)-SLITH(1))
      MID=NT/2+1
      NTT=0
      SSD=0.0
      SSY=0.0
      SSYY=0.0
      TS=NT/2
      TST=TS*AINT
   15 NTM=NTM+1
      READ 1004,SLITH(NTM)
      IF (SLITH(NTM)-9.0E 48) 10,11,10
   10 RC=SGN(SLITH(NTM)-SLITH(NTM-1))
      IF (RC) 12,13,12
   12 IF (RC-RCL) 14,13,14
   14 RCN=RCN+1.0
      RCL=RC
```

```
 13 IF (NT-NTM) 99,16,15
 16 GO TO (41,42,43,44),IEQ
 41 SLC=17.0*SLITH(3)+12.0*(SLITH(2)+SLITH(4))-3.0*(SLITH(1)+SLITH(5))
    SLC=SLC/35.0
    GO TO 45
 42 SLC=60.0*SLITH(11)+57.0*(SLITH(10)+SLITH(12))
    SLC=SLC+47.0*(SLITH(9)+SLITH(13))+33.0*(SLITH(8)+SLITH(14))
    SLC=SLC+18.0*(SLITH(7)+SLITH(15))+6.0*(SLITH(6)+SLITH(16))
    SLC=SLC-2.0*(SLITH(5)+SLITH(17))-5.0*(SLITH(4)+SLITH(18))
    SLC=SLC-5.0*(SLITH(3)+SLITH(19))-3.0*(SLITH(2)+SLITH(20))
    SLC=(SLC-(SLITH(1)+SLITH(21)))/360.0
    GO TO 45
 43 ANT=NT
    SUM=0.0
    DO 102 I=1,NT
102 SUM=SUM+SLITH(I)
    SLC=SUM/ANT
    GO TO 45
 44 SLC=SLITH(1)+SLITH(NT)
    N=NT-1
    DO 103 I=2,N
103 SLC=SLC+2.0*SLITH(I)
    ANT=N
    SLC=SLC/(2.0*ANT)
 45 NTT=NTT+1
    IF (NTT-1) 99,200,201
200 SLCL=SLC
    GO TO 202
201 IF (NTT-2) 99,203,204
203 RCL1=SGN(SLC-SLCL)
    GO TO 200
204 RC1=SGN(SLC-SLCL)
    SLCL=SLC
    IF (RC1) 205,202,205
205 IF (RC1-RCL1) 206,202,206
206 RCN1=RCN1+1.0
    RCL1=RC1
202 TST=TST+AINT
    DIF=SLITH(MID)-SLC
    SSD=SSD+DIF*DIF
    SSY=SSY+SLC
    SSYY=SSYY+SLC*SLC
    PUNCH 1005,NTT,TST,SLC,SLITH(MID),DIF
    DO 101 I=2,NT
101 SLITH(I-1)=SLITH(I)
    NTM=NTM-1
    GO TO 15
 11 PUNCH 1014
    AN2=NTT
    SSSXY=SXY-SX*SY/AN
    SSSX=SXX-SX*SX/AN
    SSSY=SYY-SY*SY/AN
    B=SSSXY/SSSX
    T=SSSXY/SQRT((SSSY*SSSX-SSSXY*SSSXY)/(AN-2.0))
    ND=AN-2.0
    TSTH=TSTH-AINT
    TST=TST-TS*AINT-AINT
    GF=(SSSY-SSD)/SSSY
    ER=(2.0*AN-1.0)/3.0
    ENR=AN-2.0-ER
    ONR=AN-2.0-RCN
    CHI=((ER-RCN)**2)/ER+((ONR-ENR)**2)/ENR
```

```
      ER1=(2.0*AN2-1.0)/3.0
      ENR1=AN2-2.0-ER1
      ONR1=AN2-2.0-RCN1
      CHI1=((ER1-RCN1)**2)/ER1+((ONR1-ENR1)**2)/ENR1
      SDL=SQRT(SYY/AN-(SY/AN)**2)
      SDSL=SQRT(SSYY/AN2-(SSY/AN2)**2)
      PUNCH 1001
      PUNCH 1012,TTHL
      PUNCH 1006,TSTH
      PUNCH 1007,TST
      PUNCH 1009,GF
      EXECUTE PROCEDURE 5000
      PUNCH 1008,ER1,RCN1,CHI1
      PUNCH 1016,SDSL
      PUNCH 1023
      PUNCH 1008,ER,RCN,CHI
      PUNCH 1010,SDL
      PUNCH 1011,B,T,ND
   99 STOP 100
      GO TO 1
      BEGIN PROCEDURE 5000
      GO TO (71,72,73,74),IEQ
   71 PUNCH 1017
      GO TO 70
   72 PUNCH 1018
      GO TO 70
   73 PUNCH 1019,NT
      GO TO 70
   74 PUNCH 1020,NT
   70 END PROCEDURE 5000
 1000 FORMAT (2I3,F10.2)
 1001 FORMAT (40H
     140H
 1002 FORMAT (2F10.2)
 1003 FORMAT (I6,2F15.5)
 1004 FORMAT (21X,F15.5)
 1005 FORMAT (I6,4F15.5)
 1006 FORMAT (/,1X,25HTOTAL EQUAL SPACED DATA =,F12.4)
 1007 FORMAT (/,26HTOTAL SMOOTHED THICKNESS =,F12.4)
 1008 FORMAT (19HEXPECTED NO. RUNS =,F10.1,21H  OBSERVED NO. RUNS =,
     1,F10.1,8H  CHI2 =,F10.4)
 1009 FORMAT (/,17HGOODNESS OF FIT =,F12.4,/)
 1010 FORMAT (/,20HSTANDARD DEVIATION =,F12.4)
 1011 FORMAT (/,10HSLOPE(B) =,F12.4,5X,3HT =,F12.4,5H WITH,I5,
     119H DEGREES OF FREEDOM)
 1012 FORMAT (/,9X,17HTOTAL THICKNESS =,F12.3)
 1013 FORMAT (/,10HINTERVAL =,F12.4,//,
     134H  UNIT  CUMULATIVE TOTAL     VALUE)
 1014 FORMAT (23X,7H9.0E 48)
 1015 FORMAT (1X,//////)
 1016 FORMAT (/,20HSTANDARD DEVIATION =,F12.4,//)
 1017 FORMAT (/,25H5 TERM SMOOTHING EQUATION)
 1018 FORMAT (/,26H21 TERM SMOOTHING EQUATION)
 1019 FORMAT (/,I4,21H TERM SLIDING AVERAGE)
 1020 FORMAT (/,I4,24H TERM TRAPEZOID EQUATION)
 1021 FORMAT (/,38H  UNIT      CUM. TOTAL  SMOOTHED VALUE,
     16X,5HVALUE,8X,9HDEVIATION)
 1022 FORMAT (/,10HINTERVAL =,F12.4)
 1023 FORMAT (/,17HEQUAL SPACED DATA)
 1024 FORMAT (23HENTER EQUAL SPACED DATA)
      END TRACE
      END
```

Program 2 - Autocorrelation and Cross-Correlation.

This program uses as input either equally spaced data (y') or smoothed data ($\hat{y}$) produced by Program 1. The program accepts two sets of sequential data, called Chain A and Chain B. Chain B is compared to Chain A by computing the correlation coefficient at successive positions of match. Chain B is in effect "moved" past A in steps of specified size and the degree of coincidence of the overlapping parts of the chains computed at each step. The equation for the correlation coefficient is

$$R = \frac{\Sigma AB - \frac{\Sigma A \Sigma B}{n}}{\sqrt{(\Sigma A^2 - \frac{(\Sigma A)^2}{n})(\Sigma B^2 - \frac{(\Sigma B)^2}{n})}}, \qquad (9)$$

where n = number of overlapping positions. An indeterminate value of R may be produced if all values of A or B (or both) are the same, then

$$(\Sigma A^2 - \frac{(\Sigma A)^2}{n}) = 0 \text{ or } (\Sigma B^2 - \frac{(\Sigma B)^2}{n}) = 0 .$$

This situation can arise only near the ends of the chains, where a short sequence of identical numbers can produce indeterminancy. In these situations, an R of .0000, followed by an asterisk (*), will be printed.

Chain B. may be moved either forward or backward past Chain A. Output consists of the sequential number of the match position, the number of terms being compared at that match, the upper and lower limits of the A terms and B terms and the cross-correlation coefficient. A t-value and degrees of freedom are printed for testing the hypothesis that the correlation is equal to zero, using the equation

$$t_{n-2} = R\sqrt{(n-2) / (1-R^2)} \qquad . \qquad (10)$$

This program also will compute autocorrelations of specified steps along a single chain. Under this option, a data sequence is placed in both A and B chain positions automatically. Analysis and output are the same as in cross-correlation with the exception of column headings.

After loading the Program 2 object deck and subroutines, the message LOAD DATA will be typed out. The following sequence of data cards should be entered.

CARD 1 - Control card

- Col. 1-3 Integer specifying length of sliding step.
- Col. 4-5 Blank.
- Col. 6 Selection of match direction.
  - 1 = Both forward and reverse matches.
  - 0 = Forward matches only.
- Col. 9 Selection of correlation type.
  - 1 = Autocorrelation.
  - 0 = Cross-correlation.

CARD 2 - This is a title card containing any desired alphanumeric information in col. 1-80.

CARDS 3 THROUGH 9 - The seven header cards produced by Program 1. If data other than output from Program 1 are used, seven blank cards should be inserted here.

CARD 10 - This is the first data card of Chain A. Up to 350 cards may be included in this set, which must be equal to or longer than Chain B. Data card format is (21X, F15.5), which reads intermediate or final output from Program 1.

END CARD - This card is placed at the end of Chain A data cards and contains the number 9.0E 48 punched in col. 24-31. This card is included automatically in output from Program 1.

CARDS 11 THROUGH 16 - The seven header cards produced by Program 1. If data other than output from Program 1 are used, seven blank cards should be inserted here.

CARD 17 - This is the first data card of Chain B. Up to 350 cards may be included in this set, which must not be longer than Chain A. Card format is (21X, F15.5).

END CARD - A card containing the number 9.0E 48 punched in col. 24-31 should terminate Chain B. This card is produced by Program 1.

Note: Equally spaced or smoothed data produced by Program 1 are in the proper format for input to Program 2. Output from the smoothing pass has extra cards containing statistical measures that must be removed from the end of the data deck before processing on this program. No other changes are necessary.

```
C      TIME TREND ANALYSIS -- PROGRAM 2
C      CROSS CORRELATION AND AUTO CORRELATION
C      ROBERT SAMPSON -- PROGRAMMER
C      ISU COMPUTER CENTER PROJECT NO. 75
       BEGIN TRACE
       DIMENSION A(351),B(351)
     1 READ 1000,INC,IR,IOP
       READ 1001
       READ 1002
       N1=0
```

```
      N2=0
      IRD=0
    2 N1=N1+1
      READ 1003,A(N1)
      IF (A(N1)-9.0E 48) 2,3,2
    3 IF (IOP) 34,34,30
   30 N2=N1
      DO 130 I=1,N2
  130 B(I)=A(I)
      GO TO 19
   34 READ 1003
    4 N2=N2+1
      READ 1003,B(N2)
      IF (B(N2)-9.0E 48) 4,19,4
   19 N1=N1-1
      N2=N2-1
    5 PUNCH 1001
      IF (IRD) 6,6,7
    6 PUNCH 1004
      GO TO 8
    7 PUNCH 1005
    8 PUNCH 1008,INC
      IF (IOP) 31,31,32
   31 PUNCH 1009
      GO TO 33
   32 PUNCH 1010
   33 PUNCH 1006
      NS=0
      NS1=1
      NS2=N2
      N=INC-1
      IF (INC-2) 9,9,10
    9 N=INC+1
   10 NE1=NS1+N
      NE2=NS2-N
   11 AN=NE1-NS1+1
      NS=NS+1
      SA=0.0
      SB=0.0
      SAB=0.0
      SBB=0.0
      SAA=0.0
      N=NE2-1
      DO 100 I=NS1,NE1
      SA=SA+A(I)
      SAA=SAA+A(I)*A(I)
      N=N+1
      SB=SB+B(N)
      SBB=SBB+B(N)*B(N)
  100 SAB=SAB+A(I)*B(N)
      STAR=.14
      R=0.0
      RB=SQRT((SAA-SA*SA/AN)*(SBB-SB*SB/AN))
      IF (RB) 40,41,40
   40 STAR=0.0
      R=(SAB-SA*SB/AN)/RB
   41 T=9999.9999
      IF (R*R-1.0) 12,13,99
   12 T=R*SQRT((AN-2.0)/(1.0-R*R))
   13. NDF=AN-2.0
      N=AN
```

```
      NE=NE2
      NB=NS2
      IF (IRD) 16,16,15
   15 NE=N2-NS2+1
      NB=N2-NE2+1
   16 PUNCH 1007,NS,N,NS1,NE1,NE,NB,R,STAR,T,NDF
      NE1=NE1+INC
      NE2=NE2-INC
      IF (N1-NE1) 20,21,21
   20 NE1=NE1-INC
      NE2=NE2+INC
      NS1=NS1+INC
      NS2=NS2-INC
      IF (NE1-NS1-1) 98,98,11
   21 IF (NE1-NS1+1-N2) 11,11,22
   22 NS1=NS1+INC
      NE2=NE2+INC
      GO TO 11
   98 IF (IR) 99,99,17
   17 IRD=1
      IR=0
      K=N2/2
      N=N2+1
      DO 101 I=1,K
      C=B(I)
      N=N-1
      B(I)=B(N)
  101 B(N)=C
      GO TO 5
   99 STOP 100
      GO TO 1
 1000 FORMAT (3I3)
 1001 FORMAT (40H                                                                   ,
     140H                                                                       )
 1002 FORMAT (1X,//////)
 1003 FORMAT (21X,F15.5)
 1004 FORMAT (/,32X,15HFORWARD MATCHES,/)
 1005 FORMAT (/,32X,15HREVERSE MATCHES,/)
 1006 FORMAT (19H  POSITION OF TERMS,4X,5HTERMS,7X,5HTERMS,6X,
     111HCOEFFICIENT,8X,1HT,8X,4HD.F.,/)
 1007 FORMAT (3I8,I4,I8,I4,F15.4,A1,F14.4,I6)
 1008 FORMAT (14HSLIDING STEP =,I4)
 1009 FORMAT (/,19H    MATCH     NUMBER,6X,1HA,11X,1HB,5X,
     117HCROSS-CORRELATION)
 1010 FORMAT (/,19H    MATCH     NUMBER,6X,1HA,11X,1HB,5X,
     116HAUTO-CORRELATION)
      END TRACE
      END
```

Program 3 - Burnaby's Cross-Difference Product

Burnaby (1953) proposed the cross-difference product (E) as an alternative to the correlation coefficient for testing the agreement between pairs of time series. The method has the advantage of negating the effect of first-order autocorrelations within the data sequences.

Within two Chains A and B, an overlap of m positions will result in two series $A_1, A_2, \ldots A_m$ and $B_1, B_2, \ldots B_m$, where subscripts indicate correspondence at that match position. The cross-difference product is defined as

$$E_{m,m+1} = (A_m - B_{m+1})(B_m - A_{m+1}). \qquad (11)$$

In the overlapped set of m values in each chain, there are $\frac{m}{2}$ independent values of E. The mean value of E is given by

$$E_\mu = \frac{1}{n}(E_{1,2} + E_{3,4} + E_{5,6} + \ldots + E_{m-1,m}). \qquad (12)$$

The significance of E_m may be calculated by testing the hypothesis that $E_\mu = 0$, using the following equation

$$t_{m-1} = \frac{E_\mu \sqrt{m}}{S} , \qquad (13)$$

where

$$S = \frac{\Sigma E_{ij}^2 - (\Sigma E_{ij})^2}{n\,(n-1)} . \qquad (14)$$

The cross-difference product has been used by Burnaby to test the significance of observed agreements between Pleistocene varved sequences in New York. In these sequences, autocorrelation effects are strong; this method of cross-comparison is especially effective.

Operation instructions for this program are identical to those given for Program 2 with the following exception:

CARD 1 - This is a control card
- Col. 1-3 Integer giving length of sliding step.
- Col. 4-5 Blank.
- Col. 6 Selection of match direction.
  - 1 = forward and reverse matches.
  - 0 = no reverse matches.

All other cards are identical to those described in Program 2. Note that there is no provision for autocorrelation using the cross-difference product.

```
C     TIME TREND ANALYSIS -- PROGRAM 3
C     CROSS DIFFERENCE PRODUCT
C     ROBERT SAMPSON -- PROGRAMMER
C     ISU COMPUTER CENTER PROJECT NO. 75
      BEGIN TRACE
      DIMENSION A(351),B(351)
    1 READ 1000,INC,IR
      READ 1001
      READ 1002
      N1=0
      N2=0
      IRD=0
    2 N1=N1+1
      READ 1003,A(N1)
      IF (A(N1) - 9.0E 48) 2,3,2
    3 READ 1002
    4 N2=N2+1
      READ 1003,B(N2)
      IF (B(N2) - 9.0E 48) 4,5,4
    5 N1 = N1 - 1
      N2 = N2 - 1
    6 PUNCH 1001
      IF (IRD) 7,7,8
    7 PUNCH 1004
      GO TO 9
    8 PUNCH 1005
    9 PUNCH 1008,INC
      PUNCH 1006
      NS = 0
      NS1 = 1
      NS2 = N2
      N = INC - 1
      IF (INC - 2) 10,10,11
   10 N = INC + 1
   11 NE1 = NS1 + N
      NE2 = NS2 - N
   12 AN = NE1 - NS1 + 1
      NS = NS + 1
      SE = 0.0
      SEE = 0.0
      N = NE2 - 1
      NE = NE1 - 1
```

```
      DO 100 I = NS1 , NE
      N = N + 1
      E = (A(I)-B(N+1))*(B(N)-A(I+1))
      SE = SE + E
  100 SEE = SEE + E * E
      AN = AN - 1.0
      EU = SE / AN
      T = 9999.9999
      IF (EU) 13,14,13
   13 T = EU*SQRT(AN)*(AN-1.0)/(AN*SEE-SE*SE)
   14 N = AN + 1.0
      NDF = N - 2
      NE = NE2
      NB = NS2
      IF (IRD) 15,15,16
   16 NE = N2 - NS2 + 1
      NB = N2 - NE2 + 1
   15 PUNCH 1007,NS,N,NS1,NE1,NE,NB,EU,T,NDF
      NE1 = NE1 + INC
      NE2 = NE2 - INC
      IF (N1 - NE1) 20,21,21
   20 NE1 = NE1 - INC
      NE2 = NE2 + INC
      NS1 = NS1 + INC
      NS2 = NS2 - INC
      IF (NE1 - NS1 - 1) 98,98,12
   21 IF (NE1 - NS1 + 1 - N2) 12,12,22
   22 NS1 = NS1 + INC
      NE2 = NE2 + INC
      GO TO 12
   98 IF (IR) 99,99,17
   17 IRD = 1
      IR = 0
      K = N2 / 2
      N = N2 + 1
      DO 101  I = 1 , K
      C = B(I)
      N = N - 1
      B(I) = B(N)
  101 B(N) = C
      GO TO 6
   99 STOP 100
      GO TO 1
 1000 FORMAT (2I3)
 1001 FORMAT (40H                                        ,
     140H                                        )
 1002 FORMAT (1X,//////)
 1003 FORMAT (21X,F15.5)
 1004 FORMAT (/,32X,15HFORWARD MATCHES,/)
 1005 FORMAT (/,32X,15HREVERSE MATCHES,/)
 1006 FORMAT (/,19H    MATCH    NUMBER,6X,1HA,11X,1HB,6X,
     116HCROSS DIFFERENCE,
     2/,19H  POSITION OF TERMS,4X,5HTERMS,7X,5HTERMS,8X,7HPRODUCT,
     310X,1HT,8X,4HD.F.,/)
 1007 FORMAT (3I8,I4,I8,I4,2F15.4,I6)
 1008 FORMAT (14HSLIDING STEP =,I4)
      END TRACE
      END
```

Program 4 - Cross Association

Cross association is a procedure for matching two sequences on the basis of number of identical elements at each match position. The procedure was devised originally by Sackin and Sneath (1965) for the comparison of amino acid chains. ALGOL and FORTRAN IV programs to compute cross associations have been published by Sackin, Sneath, and Merriam (1965). Development of the method and geologic applications are described more fully in that publication.

Unlike other programs in this package, the cross-association program requires integer data. This data usually represents arbitrarily coded states, such as 1 = limestone, 2 = shale, 3 = sandstone, etc. Two data chains are moved past each other in specified steps and the number of matches in the overlap computed. The binomial probability of a match at any position is given by

$$P_r = \frac{s \sum_{j=1}^{s} \sum_{t=1}^{r} A_{tj} B_{tj}}{mn}, \qquad (15)$$

where

A_{tj} = no. of occurrences of t elements (t = 1, 2, 3, ...r) in the jth class (j = 1, 2, 3, ...s) of Chain A,
B_{tj} = no. of occurrences of t elements (t = 1, 2, 3, ...r) in the jth class (j = 1, 2, 3, ...s) of Chain B,
s = length of sliding step,
m = length of Chain A, and
n = length of Chain B.

This is equivalent to

$$P_r = \frac{\textbf{total number of matches summed over all match positions}}{\textbf{total number of comparisons summed over all match positions}}$$

At each match position, the program computes and prints the sequential number of the match position, number of terms being compared, the limits of the A terms and B terms, percent of matches, standard deviation, and corrected and uncorrected chi-square values for testing the significance of the matches.

The deviation of the number of matches from the expected number of matches at each position (based on the binomial probability, P_r) is given in terms of standard deviations by

$$\sigma = \sqrt{\lambda + \varphi}\left(2 \arcsin\sqrt{\frac{\lambda}{\lambda+\varphi}} - 2 \arcsin\sqrt{P_r}\right), \qquad (16)$$

where

λ = no. of matches, and
φ = no. of mismatches.

The arcsin transformation produces variates which are distributed approximately as a standard normal distribution. The derivation and significance of this transformation is given in Sackin, Sneath, and Merriam (1965).

The significance of a match may be tested by a contingency table against the hypothesis that the number of matches is equal to the number expected from a random distribution. The statistic from the contingency table is distributed as χ^2 with one degree of freedom

$$\chi^2 = \frac{(O_\lambda - E_\lambda)^2}{E_\lambda} + \frac{(O_\varphi - E_\varphi)^2}{E_\varphi}, \qquad (17)$$

where

O_λ = observed number of matches,
O_φ = observed number of mismatches,
E_λ = expected number of matches = $P_r(\lambda+\varphi)$,

and

E_φ = expected number of mismatches = $(\lambda+\varphi) - P_r(\lambda+\varphi)$.

If E_λ is small, as in match positions near ends of chains, the contingency table test produces a closer approximation of χ^2 if Yate's correction is applied. The test has the form

$$\chi^2 = \frac{(|O_\lambda - E_\lambda| - 1/2)^2}{E_\lambda} + \frac{(|O_\varphi - E_\varphi| - 1/2)^2}{E_\varphi} \qquad (18)$$

with one degree of freedom.

After loading the Program 4 object deck and subroutines, the message LOAD DATA will be typed. The following sequence of cards should be entered into the computer:

CARD 1 - Control card

Col.	1- 3	Integer specifying the length of sliding step.
Col.	4- 5	Blank.
Col.	6	Selection of match direction. 1 = forward and reverse matches. 0 = forward matches only.
Col.	7-16	Lower limit of O. If O ≤ limit, a marker line is printed on output at the position of occurrence. Number must contain a decimal.
Col.	17-26	Upper limit of O. If O ≥ limit, a marker line is printed on output at the position of occurrence. Number must contain a decimal.

CARD 2 - Title card. This card contains any desired alphanumeric information in col. 1-80.

CARD 3 - This is the first data card of Chain A. Up to 350 cards may be included in this set, which must be equal to or longer than Chain B.

Col.	1-10	Values of y. These numbers must contain a decimal point.

END CARD - This card is placed at the end of Chain A and contains the number 9.0E 48 punched in col. 1-10.

CARD 4 - This is the first data card of Chain B. Up to 350 data cards may be included in this set, which must not be longer than Chain A.

Col. 1-10 Values of y. These numbers must contain a decimal point.

END CARD - A card containing the number 9.0E 48 in col. 1-10 should be placed at the end of Chain B.

Operation of this program requires two special functions, DRH and DLH, which respectively drop the fractional and integer parts of a number. These are included in the library of PDQ FORTRAN II, but it may be necessary to add them as subprograms to other compiler systems.

```
C     TIME TREND ANALYSIS -- PROGRAM 4
C     CROSS ASSOCIATION
C     ISU COMPUTER CENTER PROJECT NUMBER 75
C     ROBERT SAMPSON -- PROGRAMMER
      DIMENSION A(351)
      BEGIN TRACE
    1 READ 1000,INC,IR,SDL,SDH
      READ 1001
      N1=0
      N2=0
      SUM=0.0
      SUM1=0.0
      IRD=0
    2 READ 1003,B
      IF (B-9.0E 48) 4,7,4
    4 N1=N1+1
      A(N1)=B
      GO TO 2
    7 READ 1003,B
      IF (B-9.0E 48) 5,6,5
    5 N2=N2+1
      A(N2)=A(N2)+B/10000.0
      GO TO 7
    6 PUNCH 1001
      IF (IRD) 8,8,9
    8 PUNCH 1007
      GO TO 10
    9 PUNCH 1005
   10 PUNCH 1008,INC
      DO 101 NM=1,2
      GO TO (18,13),NM
   18 IF (IRD) 13,13,25
   13 NS1=1
      NS2=N2
      NE1=NS1+INC-1
      NE2=NS2-INC+1
      NS=0
      SCHI=0.0
   14 NS=NS+1
      AMAT=0.0
      N=NE2-1
      TMP=NE1-NS1+1
      DO 102 J=NS1,NE1
      N=N+1
      IF (DRH(A(J))-DLH(A(N))*10000.0) 102,15,102
   15 AMAT=AMAT+1.0
  102 CONTINUE
      GO TO (16,17),NM
   16 SUM=SUM+AMAT
      SUM1=SUM1+TMP
      GO TO 19
```

```
  17 R=AMAT/TMP
     E=TMP*PR
     EP=TMP-E
     OP=TMP-AMAT
     CHI=((AMAT-E)**2)/E+((OP-EP)**2)/EP
     CHIY=((ABS(AMAT-E)-.5)**2)/E+((ABS(OP-EP)-.5)**2)/EP
     SCHI=SCHI+CHI
     X=SQRT(R)
     EXECUTE PROCEDURE 5000
     SD=SQRT(TMP)*2.0*(ASX-ASPR)
     IF (SD-SDL) 61,61,60
  60 IF (SD-SDH) 19,61,61
  61 N=TMP
     R=R*100.0
     NE=NE2
     NB=NS2
     IF (IRD) 30,30,31
  31 NE=N2-NS2+1
     NB=N2-NE2+1
  30 PUNCH 1004,NS,N,NS1,NE1,NE,NB,R,SD,CHI,CHIY
  19 NE1=NE1+INC
     NE2=NE2-INC
     IF (N1-NE1) 20,21,21
  20 NE1=NE1-INC
     NE2=NE2+INC
     NS1=NS1+INC
     NS2=NS2-INC
     IF (NE1-NS1) 98,14,14
  21 IF (NE1-NS1+1-N2) 14,14,22
  22 NS1=NS1+INC
     NE2=NE2+INC
     GO TO 14
  98 GO TO (24,23),NM
  23 PUNCH 1010,SCHI
     GO TO 101
  24 PR=SUM/SUM1
     X=SQRT(PR)
     EXECUTE PROCEDURE 5000
     ASPR=ASX
  25 PUNCH 1009,PR
     PUNCH 1006
 101 CONTINUE
     IF (IR) 99,99,32
  32 IRD=1
     IR=0
     K=N2/2
     N=N2+1
     DO 103 I=1,K
     C=DLH(A(I))
     N=N-1
     A(I)=DRH(A(I))+DLH(A(N))
 103 A(N)=DRH(A(N))+C
     GO TO 6
  99 STOP 100
     GO TO 1
     BEGIN PROCEDURE 5000
     ASX=1.5707963
     IF (X-1.0) 70,71,71
  70 ASX=ATAN(X/SQRT(1.0-X*X))
  71 END PROCEDURE 5000
1000 FORMAT (2I3,2F10.2)
```

```
1001 FORMAT (40H                                                          ,
    140H                                                                  )
1003 FORMAT (F10.2)
1004 FORMAT (3I8,I4I8,I4,4F10.4)
1005 FORMAT (/,32X,15HREVERSE MATCHES,/)
1006 FORMAT (/,50H  MATCH   NUMBER          A           B     PER CENT,
    129H STANDARD   CHI-SQ     CHI-SQ,/,
    259HPOSITION OF TERMS      TERMS          TERMS   MATCHS   DEVIATION,
    31X,19HUNCORRECTED (YATES),/)
1007 FORMAT (/,32X,15HFORWARD MATCHES,/)
1008 FORMAT (14HSLIDING STEP = ,I4,/)
1009 FORMAT (14HPROB(MATCH) =   ,F12.8)
1010 FORMAT (/,26HSUM CHI-SQ(UNCORRECTED) = ,F15.6)
     END TRACE
     END
```

Discussion

These programs were written for a particular study and reflect the objectives of that work. Reviewers have suggested several simple modifications to the programs that may increase their versatility and make them more useful for other types of problems. The suggested changes include:

(1) Modification of Program 1 to give an alternative method of obtaining equally spaced data, by true point sampling. That is, at specified intervals the actual lithology encountered is taken as datum for the point. Provision must be made for the situation if the point falls on a boundary.

(2) Modification of Program 1 to give smoothed data formed by the averaging of nonoverlapping intervals. This would be useful for time-series analysis.

(3) Modification of Program 2 to produce autocovariances as well as autocorrelation. Autocovariances may then be used directly for power-spectrum calculations.

REFERENCES

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APPENDIX

Program Application from Pennsylvanian of Kansas

Drilling-time logs, records of the time necessary to drill 1-, 5-, or 10-foot intervals of rock section, are available for thousands of wells in the Midcontinent region. They are extremely valuable in correlating stratigraphic units from well to well and can be used for this purpose with almost the same reliability as electric and radioactivity logs.

Drilling time is plotted on log strips so depth is the vertical scale (usually plotted at 50 or 100 feet to the inch to correspond to the vertical scale of other logs), and time is the horizontal scale, time increasing to the right. Soft beds drill rapidly, hard beds drill slowly, and intermediate beds drill at in between rates. If drilling time is plotted against depth, and the points connected, a curve results that resembles other types of mechanical logs. This curve, of course, represents bed hardness which to a degree reflects lithology.

Because the original data is in digitized form, it is easily adapted for time-trend analysis. Additional information, beyond that of simple bed to bed correlation, may be gained by subjecting this raw data to various time-trend analyses. Data illustrating this program package were taken from an unpublished manuscript by D. F. Merriam (personal communication, 1967).

In Merriam's work, portions of the drilling-time logs for five wells in central Kansas were subjected to time-trend analysis. Partial output is listed here. For each well, 100 values at 5-foot intervals were used in the stratigraphic interval which includes the Lansing-Kansas City Groups (Missourian, Upper Pennsylvanian). Correlation of the original data from well to well was obscure because of large variance in drilling time; part of this "noise" can be attributed to recording error.

It was anticipated that the time-trend analysis would (1) aid in eliminating some "noise" and help in the visual correlation of the different beds from well to well, (2) give data on the overall trend of increasing or decreasing carbonate content with stratigraphic position, and (3) emphasize differences (changes in lithology as revealed by drilling time) of certain beds to allow a meaningful and more complete analysis of the changes in the stratigraphic sequence.

The following listings are included to illustrate the form of output from the time-trend package.

Sample input data with control, title, and END card.

```
001005 5.0
PRODUCERS CORP. OF NEVADA, NO. 1 MANEVAL  SEC 12, T 13 S, R 2 W     WELL NUM. 1 -
  5.00       6.00       5.00       8.00       5.00       4.00       5.00       8.00
  5.00       5.00       5.00       8.00       5.00       7.00       5.00       7.00
  5.00       4.00       5.00       6.00       5.00       5.00       5.00       8.00
  5.00       4.00       5.00       7.00       5.00       5.00       5.00       9.00
  5.00       5.00       5.00       6.00       5.00       5.00       5.00       8.00
  5.00       5.00       5.00       7.00       5.00       5.00       5.00       9.00
  5.00       6.00       5.00       5.00       5.00       5.00       5.00      11.00
  5.00       5.00       5.00       2.00       5.00       5.00       5.00       7.00
  5.00       4.00       5.00       3.00       5.00       3.00       5.00       6.00
  5.00       5.00       5.00       8.00       5.00       1.00       5.00       5.00
  5.00       4.00       5.00       7.00       5.00       1.00       5.00       7.00
  5.00       3.00       5.00       6.00       5.00       5.00       5.00       4.00
  5.00       5.00       5.00       7.00       5.00       6.00       5.00       5.00
  5.00       6.00       5.00       7.00       5.00       7.00       5.00       5.00
  5.00       5.00       5.00       6.00       5.00       6.00       5.00       7.00
  5.00       4.00       5.00       4.00       5.00       5.00       5.00       5.00
  5.00       8.00       5.00       6.00       5.00       6.00       5.00       5.00
  5.00       4.00       5.00       6.00       5.00       5.00       5.00       3.00
  5.00       5.00       5.00       4.00       5.00       7.00       5.00       6.00
  5.00       6.00       5.00       5.00       5.00       3.00       5.00       4.00
  5.00       7.00       5.00       6.00       5.00       6.00       5.00       6.00
  5.00       5.00       5.00       5.00       5.00       7.00       5.00       6.00
  5.00       9.00       5.00       6.00       5.00       7.00       5.00       6.00
  5.00       8.00       5.00       7.00       5.00       6.00       5.00       5.00
  5.00      10.00       5.00       6.00       5.00       8.00       5.00       6.00
                                                                   9.0E 48
```

Pass 1 output giving equally spaced data. Note that data are integral because equal-spacing interval corresponds to distance between original data points.

PRODUCERS CORP. OF NEVADA, NO. 1 MANEVAL SEC 12, T 13 S, R 2 W WELL NUM. 1 -

EQUAL SPACED DATA

INTERVAL = 5.0000

UNIT	CUMULATIVE TOTAL	VALUE			
1	5.00000	6.00000	51	255.00000	4.00000
2	10.00000	5.00000	52	260.00000	7.00000
3	15.00000	4.00000	53	265.00000	5.00000
4	20.00000	4.00000	54	270.00000	5.00000
5	25.00000	5.00000	55	275.00000	5.00000
6	30.00000	5.00000	56	280.00000	5.00000
7	35.00000	6.00000	57	285.00000	5.00000
8	40.00000	5.00000	58	290.00000	5.00000
9	45.00000	4.00000	59	295.00000	3.00000
10	50.00000	5.00000	60	300.00000	1.00000
11	55.00000	4.00000	61	305.00000	1.00000
12	60.00000	3.00000	62	310.00000	5.00000
13	65.00000	5.00000	63	315.00000	6.00000
14	70.00000	6.00000	64	320.00000	7.00000
15	75.00000	5.00000	65	325.00000	6.00000
16	80.00000	4.00000	66	330.00000	5.00000
17	85.00000	8.00000	67	335.00000	6.00000
18	90.00000	4.00000	68	340.00000	5.00000
19	95.00000	5.00000	69	345.00000	7.00000
20	100.00000	6.00000	70	350.00000	3.00000
21	105.00000	7.00000	71	355.00000	6.00000
22	110.00000	5.00000	72	360.00000	7.00000
23	115.00000	9.00000	73	365.00000	7.00000
24	120.00000	8.00000	74	370.00000	6.00000
25	125.00000	10.00000	75	375.00000	8.00000
26	130.00000	8.00000	76	380.00000	8.00000
27	135.00000	8.00000	77	385.00000	7.00000
28	140.00000	6.00000	78	390.00000	8.00000
29	145.00000	7.00000	79	395.00000	9.00000
30	150.00000	6.00000	80	400.00000	8.00000
31	155.00000	7.00000	81	405.00000	9.00000
32	160.00000	5.00000	82	410.00000	11.00000
33	165.00000	2.00000	83	415.00000	7.00000
34	170.00000	3.00000	84	420.00000	6.00000
35	175.00000	8.00000	85	425.00000	5.00000
36	180.00000	7.00000	86	430.00000	7.00000
37	185.00000	6.00000	87	435.00000	4.00000
38	190.00000	7.00000	88	440.00000	5.00000
39	195.00000	7.00000	89	445.00000	5.00000
40	200.00000	6.00000	90	450.00000	7.00000
41	205.00000	4.00000	91	455.00000	5.00000
42	210.00000	6.00000	92	460.00000	5.00000
43	215.00000	6.00000	93	465.00000	3.00000
44	220.00000	4.00000	94	470.00000	6.00000
45	225.00000	5.00000	95	475.00000	4.00000
46	230.00000	6.00000	96	480.00000	6.00000
47	235.00000	5.00000	97	485.00000	6.00000
48	240.00000	6.00000	98	490.00000	6.00000
49	245.00000	7.00000	99	495.00000	5.00000
50	250.00000	6.00000	100	500.00000	6.00000

9.OF 48

Pass 2 output giving data smoothed by Sheppard's equation, and associated statistics.

PRODUCERS CORP. OF NEVADA, NO. 1 MANEVAL SEC 12, T 13 S, R 2 W WELL NUM. 1 -

5 TERM SMOOTHING EQUATION

INTERVAL = 5.0000

UNIT	CUM. TOTAL	SMOOTHED VALUE	VALUE	DEVIATION
1	15.00000	5.51428	5.00000	-.51428
2	20.00000	4.08571	4.00000	-.08571
3	25.00000	4.17142	4.00000	-.17142
4	30.00000	4.65714	5.00000	.34285
5	35.00000	5.42857	5.00000	-.42857
6	40.00000	5.57142	6.00000	.42857
7	45.00000	5.00000	5.00000	.00000
8	50.00000	4.51428	4.00000	-.51428
9	55.00000	4.48571	5.00000	.51428
10	60.00000	3.91428	4.00000	.08571
11	65.00000	3.60000	3.00000	-.60000
12	70.00000	4.74285	5.00000	.25714
13	75.00000	5.74285	6.00000	.25714
14	80.00000	4.74285	5.00000	.25714
15	85.00000	5.54285	4.00000	-1.54285
16	90.00000	5.77142	8.00000	2.22857
17	95.00000	5.54285	4.00000	-1.54285
18	100.00000	4.57142	5.00000	.42857
19	105.00000	6.25714	6.00000	-.25714
20	110.00000	5.97142	7.00000	1.02857
21	115.00000	6.71428	5.00000	-1.71428
22	120.00000	7.37142	9.00000	1.62857
23	125.00000	9.28571	8.00000	-1.28571
24	130.00000	8.88571	10.00000	1.11428
25	135.00000	8.85714	8.00000	-.85714
26	140.00000	7.22857	8.00000	.77142
27	145.00000	6.85714	6.00000	-.85714
28	150.00000	6.22857	7.00000	.77142
29	155.00000	6.77142	6.00000	-.77142
30	160.00000	6.40000	7.00000	.60000
31	165.00000	4.74285	5.00000	.25714
32	170.00000	2.42857	2.00000	-.42857
33	175.00000	3.85714	3.00000	-.85714
34	180.00000	6.62857	8.00000	1.37142
35	185.00000	7.34285	7.00000	-.34285
36	190.00000	6.42857	6.00000	-.42857
37	195.00000	6.74285	7.00000	.25714
38	200.00000	7.00000	7.00000	.00000
39	205.00000	5.57142	6.00000	.42857
40	210.00000	4.94285	4.00000	-.94285
41	215.00000	5.48571	6.00000	.51428
42	220.00000	5.57142	6.00000	.42857
43	225.00000	4.68571	4.00000	-.68571
44	230.00000	4.91428	5.00000	.08571
45	235.00000	5.48571	6.00000	.51428
46	240.00000	5.51428	5.00000	-.51428
47	245.00000	6.00000	6.00000	.00000
48	250.00000	6.74285	7.00000	.25714
49	255.00000	5.57142	6.00000	.42857
50	260.00000	5.37142	4.00000	-1.37142

51	265.00000	5.54285	7.00000	1.45714
52	270.00000	5.77142	5.00000	-.77142
53	275.00000	4.82857	5.00000	.17142
54	280.00000	5.00000	5.00000	.00000
55	285.00000	5.00000	5.00000	.00000
56	290.00000	5.17142	5.00000	-.17142
57	295.00000	4.65714	5.00000	.34285
58	300.00000	3.00000	3.00000	.00000
59	305.00000	1.00000	1.00000	.00000
60	310.00000	1.77142	1.00000	-.77142
61	315.00000	4.14285	5.00000	.85714
62	320.00000	6.42857	6.00000	-.42857
63	325.00000	6.65714	7.00000	.34285
64	330.00000	6.00000	6.00000	.00000
65	335.00000	5.51428	5.00000	-.51428
66	340.00000	5.22857	6.00000	.77142
67	345.00000	6.20000	5.00000	-1.20000
68	350.00000	5.11428	7.00000	1.88571
69	355.00000	4.88571	3.00000	-1.88571
70	360.00000	5.14285	6.00000	.85714
71	365.00000	7.08571	7.00000	-.08571
72	370.00000	6.65714	7.00000	.34285
73	375.00000	6.77142	6.00000	-.77142
74	380.00000	7.48571	8.00000	.51428
75	385.00000	7.82857	8.00000	.17142
76	390.00000	7.42857	7.00000	-.42857
77	395.00000	8.00000	8.00000	.00000
78	400.00000	8.48571	9.00000	.51428
79	405.00000	8.42857	8.00000	-.42857
80	410.00000	9.51428	9.00000	-.51428
81	415.00000	9.62857	11.00000	1.37142
82	420.00000	8.02857	7.00000	-1.02857
83	425.00000	5.48571	6.00000	.51428
84	430.00000	5.94285	5.00000	-.94285
85	435.00000	5.54285	7.00000	1.45714
86	440.00000	5.20000	4.00000	-1.20000
87	445.00000	4.31428	5.00000	.68571
88	450.00000	5.77142	5.00000	-.77142
89	455.00000	5.97142	7.00000	1.02857
90	460.00000	5.85714	5.00000	-.85714
91	465.00000	4.05714	5.00000	.94285
92	470.00000	4.45714	3.00000	-1.45714
93	475.00000	4.37142	6.00000	1.62857
94	480.00000	5.28571	4.00000	-1.28571
95	485.00000	5.31428	6.00000	.68571
96	490.00000	6.25714	6.00000	-.25714
97	495.00000	5.65714	6.00000	.34285

PRODUCERS CORP. OF NEVADA, NO. 1 MANEVAL SEC 12, T 13 S, R 2 W WELL NUM. 1 -
TOTAL THICKNESS = 500.000
TOTAL EQUAL SPACED DATA = 500.0000
TOTAL SMOOTHED THICKNESS = 480.0000
GOODNESS OF FIT = .7697
5 TERM SMOOTHING EQUATION
EXPECTED NO. RUNS = 64.3 OBSERVED NO. RUNS = 44.0 CHI2 = 19.9084
STANDARD DEVIATION = 1.5121
EQUAL SPACED DATA
EXPECTED NO. RUNS = 66.3 OBSERVED NO. RUNS = 54.0 CHI2 = 7.0966
STANDARD DEVIATION = 1.7182
SLOPE(B) = .0013 T = 1.1269 WITH 98 DEGREES OF FREEDOM

Program 2 cross-correlation between well 1 and well 4, both smoothed by Sheppard's equation. Incomplete listings of both forward and reverse matches are given.

5 TERM SMOOTHING EQUATION FOR WELL 1 VS. 5 TERM SMOOTHING EQUATION FOR WELL 4 -

FORWARD MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		CROSS-CORRELATION COEFFICIENT	T	D.F.
1	3	1	3	100	102	.8381	1.5366	1
2	4	1	4	99	102	-.9811	-7.1793	2
3	5	1	5	98	102	-.5435	-1.1216	3
4	6	1	6	97	102	-.0265	-.0530	4
5	7	1	7	96	102	.8437	3.5155	5
6	8	1	8	95	102	.6445	2.0649	6
7	9	1	9	94	102	-.3247	-.9086	7
8	10	1	10	93	102	-.7290	-3.0123	8
9	11	1	11	92	102	-.3777	-1.2239	9
10	12	1	12	91	102	.0355	.1126	10
11	13	1	13	90	102	.0878	.2923	11
12	14	1	14	89	102	-.1400	-.4900	12
13	15	1	15	88	102	.0600	.2168	13
14	16	1	16	87	102	.2745	1.0683	14
15	17	1	17	86	102	.1937	.7646	15
16	18	1	18	85	102	-.0011	-.0046	16
17	19	1	19	84	102	.2572	1.0978	17
18	20	1	20	83	102	.4310	2.0268	18
19	21	1	21	82	102	.4786	2.3764	19
20	22	1	22	81	102	.4702	2.3827	20
21	23	1	23	80	102	.4819	2.5207	21
22	24	1	24	79	102	.4806	2.5706	22
23	25	1	25	78	102	.5447	3.1153	23
24	26	1	26	77	102	.6014	3.6885	24
25	27	1	27	76	102	.6458	4.2293	25
26	28	1	28	75	102	.5748	3.5823	26
27	29	1	29	74	102	.5253	3.2083	27
28	30	1	30	73	102	.4733	2.8434	28
29	31	1	31	72	102	.4027	2.3696	29
30	32	1	32	71	102	.2135	1.1973	30
31	33	1	33	70	102	.1529	.8619	31
32	34	1	34	69	102	.2244	1.3030	32
33	35	1	35	68	102	.3127	1.8914	33
34	36	1	36	67	102	.3488	2.1704	34
35	37	1	37	66	102	.3293	2.0638	35
36	38	1	38	65	102	.1870	1.1425	36
37	39	1	39	64	102	.0271	.1650	37
38	40	1	40	63	102	-.0179	-.1104	38
39	41	1	41	62	102	-.0053	-.0332	39
40	42	1	42	61	102	-.0745	-.4728	40
41	43	1	43	60	102	-.1046	-.6734	41
42	44	1	44	59	102	-.0269	-.1746	42
43	45	1	45	58	102	.0592	.3892	43
44	46	1	46	57	102	-.0437	-.2905	44
45	47	1	47	56	102	-.2306	-1.5902	45
46	48	1	48	55	102	-.3659	-2.6669	46
47	49	1	49	54	102	-.4647	-3.5980	47
48	50	1	50	53	102	-.5588	-4.6693	48

5 TERM SMOOTHING EQUATION FOR WELL 1 VS. 5 TERM SMOOTHING EQUATION FOR WELL 4 -

REVERSE MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		CROSS-CORRELATION COEFFICIENT	T	D.F.
1	3	1	3	1	3	.0000*	.0000	1
2	4	1	4	1	4	.0000*	.0000	2
3	5	1	5	1	5	.0000*	.0000	3
4	6	1	6	1	6	.0000*	.0000	4
5	7	1	7	1	7	.4182	1.0297	5
6	8	1	8	1	8	-.0699	-.1717	6
7	9	1	9	1	9	-.2952	-.8176	7
8	10	1	10	1	10	-.2017	-.5826	8
9	11	1	11	1	11	.1129	.3411	9
10	12	1	12	1	12	.4409	1.5535	10
11	13	1	13	1	13	.4352	1.6033	11
12	14	1	14	1	14	.3324	1.2209	12
13	15	1	15	1	15	.0611	.2210	13
14	16	1	16	1	16	-.2836	-1.1069	14
15	17	1	17	1	17	-.6086	-2.9707	15
16	18	1	18	1	18	-.5836	-2.8748	16
17	19	1	19	1	19	-.4777	-2.2425	17
18	20	1	20	1	20	-.5118	-2.5275	18
19	21	1	21	1	21	-.4351	-2.1066	19
20	22	1	22	1	22	-.4526	-2.2702	20
21	23	1	23	1	23	-.5605	-3.1015	21
22	24	1	24	1	24	-.6637	-4.1626	22
23	25	1	25	1	25	-.7059	-4.7807	23
24	26	1	26	1	26	-.7857	-6.2235	24
25	27	1	27	1	27	-.7601	-5.8503	25
26	28	1	28	1	28	-.6153	-3.9802	26
27	29	1	29	1	29	-.4491	-2.6119	27
28	30	1	30	1	30	-.3422	-1.9273	28
29	31	1	31	1	31	-.2142	-1.1809	29
30	32	1	32	1	32	-.1170	-.6455	30
31	33	1	33	1	33	-.1083	-.6070	31
32	34	1	34	1	34	-.1639	-.9404	32
33	35	1	35	1	35	-.1738	-1.0142	33
34	36	1	36	1	36	-.1633	-.9652	34
35	37	1	37	1	37	-.2442	-1.4902	35
36	38	1	38	1	38	-.3985	-2.6071	36
37	39	1	39	1	39	-.4553	-3.1110	37
38	40	1	40	1	40	-.3877	-2.5930	38
39	41	1	41	1	41	-.3075	-2.0188	39
40	42	1	42	1	42	-.1892	-1.2189	40
41	43	1	43	1	43	-.0609	-.3908	41
42	44	1	44	1	44	.0164	.1067	42
43	45	1	45	1	45	.0223	.1467	43
44	46	1	46	1	46	.0744	.4952	44
45	47	1	47	1	47	.0651	.4379	45
46	48	1	48	1	48	-.0139	-.0946	46
47	49	1	49	1	49	-.0916	-.6313	47
48	50	1	50	1	50	-.1310	-.9157	48
49	51	1	51	1	51	-.1775	-1.2632	49
50	52	1	52	1	52	-.1741	-1.2507	50
51	53	1	53	1	53	-.0764	-.5472	51
52	54	1	54	1	54	.0107	.0772	52

Program 2 auto-correlation of data from well 1 smoothed by Sheppard's equation. Incomplete examples of both forward and reverse matches are listed.

5 TERM SMOOTHING EQUATION FOR WELL 1 -

FORWARD MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		AUTO-CORRELATION COEFFICIENT	T	D.F.
1	3	1	3	95	97	-.8102	-1.3823	1
2	4	1	4	94	97	-.4726	-.7585	2
3	5	1	5	93	97	-.3042	-.5531	3
4	6	1	6	92	97	.4023	.8789	4
5	7	1	7	91	97	.4430	1.1050	5
6	8	1	8	90	97	.6436	2.0602	6
7	9	1	9	89	97	.0049	.0130	7
8	10	1	10	88	97	-.5235	-1.7379	8
9	11	1	11	87	97	-.8781	-5.5064	9
10	12	1	12	86	97	-.3090	-1.0274	10
11	13	1	13	85	97	.3635	1.2945	11
12	14	1	14	84	97	.6106	2.6711	12
13	15	1	15	83	97	.2673	1.0005	13
14	16	1	16	82	97	.3399	1.3527	14
15	17	1	17	81	97	.0825	.3208	15
16	18	1	18	80	97	-.1721	-.6991	16
17	19	1	19	79	97	-.3515	-1.5483	17
18	20	1	20	78	97	-.1448	-.6211	18
19	21	1	21	77	97	-.0933	-.4087	19
20	22	1	22	76	97	-.0945	-.4247	20
21	23	1	23	75	97	-.2006	-.9385	21
22	24	1	24	74	97	-.2535	-1.2296	22
23	25	1	25	73	97	-.4270	-2.2647	23
24	26	1	26	72	97	-.5563	-3.2798	24
25	27	1	27	71	97	-.6853	-4.7055	25
26	28	1	28	70	97	-.6516	-4.3802	26
27	29	1	29	69	97	-.6421	-4.3532	27
28	30	1	30	68	97	-.5306	-3.3132	28
29	31	1	31	67	97	-.4296	-2.5620	29
30	32	1	32	66	97	-.3050	-1.7544	30
31	33	1	33	65	97	-.3582	-2.1363	31
32	34	1	34	64	97	-.3017	-1.7906	32
33	35	1	35	63	97	-.1885	-1.1026	33
34	36	1	36	62	97	-.0440	-.2572	34
35	37	1	37	61	97	.0647	.3838	35
36	38	1	38	60	97	.2607	1.6205	36
37	39	1	39	59	97	.3706	2.4273	37
38	40	1	40	58	97	.4454	3.0669	38
39	41	1	41	57	97	.5148	3.7505	39
40	42	1	42	56	97	.5511	4.1774	40
41	43	1	43	55	97	.4819	3.5221	41
42	44	1	44	54	97	.4160	2.9654	42
43	45	1	45	53	97	.4697	3.4896	43
44	46	1	46	52	97	.4883	3.7122	44
45	47	1	47	51	97	.3903	2.8438	45
46	48	1	48	50	97	.2531	1.7743	46
47	49	1	49	49	97	.2223	1.5631	47
48	50	1	50	48	97	.1712	1.2045	48

5 TERM SMOOTHING EQUATION FOR WELL 1

REVERSE MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS	B TERMS	AUTO-CORRELATION COEFFICIENT	T	D.F.
1	3	1 3	1 3	-.4046	-.4424	1
2	4	1 4	1 4	.4235	.6611	2
3	5	1 5	1 5	.8172	2.4562	3
4	6	1 6	1 6	.1346	.2717	4
5	7	1 7	1 7	-.7112	-2.2623	5
6	8	1 8	1 8	-.7487	-2.7670	6
7	9	1 9	1 9	-.0467	-.1237	7
8	10	1 10	1 10	.1217	.3468	8
9	11	1 11	1 11	.1230	.3719	9
10	12	1 12	1 12	.5427	2.0437	10
11	13	1 13	1 13	.4079	1.4820	11
12	14	1 14	1 14	-.4923	-1.9596	12
13	15	1 15	1 15	-.4674	-1.9063	13
14	16	1 16	1 16	-.2762	-1.0756	14
15	17	1 17	1 17	-.0184	-.0715	15
16	18	1 18	1 18	-.0383	-.1535	16
17	19	1 19	1 19	.3763	1.6747	17
18	20	1 20	1 20	.2729	1.2038	18
19	21	1 21	1 21	.1066	.4676	19
20	22	1 22	1 22	-.2577	-1.1928	20
21	23	1 23	1 23	-.2463	-1.1650	21
22	24	1 24	1 24	-.3204	-1.5866	22
23	25	1 25	1 25	-.3853	-2.0026	23
24	26	1 26	1 26	-.4619	-2.5518	24
25	27	1 27	1 27	-.3608	-1.9344	25
26	28	1 28	1 28	-.3259	-1.7578	26
27	29	1 29	1 29	-.3906	-2.2049	27
28	30	1 30	1 30	-.5178	-3.2030	28
29	31	1 31	1 31	-.5749	-3.7842	29
30	32	1 32	1 32	-.5426	-3.5389	30
31	33	1 33	1 33	-.4046	-2.4640	31
32	34	1 34	1 34	-.2955	-1.7501	32
33	35	1 35	1 35	-.2850	-1.7080	33
34	36	1 36	1 36	-.3928	-2.4910	34
35	37	1 37	1 37	-.3350	-2.1037	35
36	38	1 38	1 38	-.2573	-1.5977	36
37	39	1 39	1 39	-.1487	-.9151	37
38	40	1 40	1 40	-.0681	-.4210	38
39	41	1 41	1 41	.1214	.7642	39
40	42	1 42	1 42	.1934	1.2471	40
41	43	1 43	1 43	.1855	1.2093	41
42	44	1 44	1 44	.1504	.9859	42
43	45	1 45	1 45	.3045	2.0969	43
44	46	1 46	1 46	.3808	2.7322	44
45	47	1 47	1 47	.3921	2.8597	45
46	48	1 48	1 48	.3705	2.7060	46
47	49	1 49	1 49	.4179	3.1541	47
48	50	1 50	1 50	.3218	2.3553	48
49	51	1 51	1 51	.2096	1.5007	49
50	52	1 52	1 52	.1495	1.0697	50
51	53	1 53	1 53	.0399	.2853	51
52	54	1 54	1 54	-.1969	-1.4487	52

Program 3 output listing of cross difference product between wells 1 and 4, smoothed by Sheppard's equation. Incomplete listings of both forward and reverse matches are given.

5 TERM SMOOTHING EQUATION FOR WELL 1 VS. 5 TERM SMOOTHING EQUATION FOR WELL 4 -

FORWARD MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		CROSS DIFFERENCE PRODUCT	T	D.F.
1	3	1	3	94	96	-2.1575	-.5421	1
2	4	1	4	93	96	-2.3172	-.7244	2
3	5	1	5	92	96	-1.6853	-.4264	3
4	6	1	6	91	96	-.9598	-.4517	4
5	7	1	7	90	96	-.2439	-.1711	5
6	8	1	8	89	96	-.4537	-.5778	6
7	9	1	9	88	96	-.9813	-.2556	7
8	10	1	10	87	96	-1.2537	-.2783	8
9	11	1	11	86	96	-1.2103	-.1324	9
10	12	1	12	85	96	-.9353	-.0771	10
11	13	1	13	84	96	-.7753	-.0852	11
12	14	1	14	83	96	-.7529	-.2380	12
13	15	1	15	82	96	-.5913	-.4257	13
14	16	1	16	81	96	-.3945	-.1348	14
15	17	1	17	80	96	-.4669	-.0786	15
16	18	1	18	79	96	-.6192	-.1238	16
17	19	1	19	78	96	-.4268	-.1302	17
18	20	1	20	77	96	-.2897	-.1174	18
19	21	1	21	76	96	-.3002	-.1167	19
20	22	1	22	75	96	-.4129	-.0980	20
21	23	1	23	74	96	-.6506	-.0662	21
22	24	1	24	73	96	-1.1163	-.0450	22
23	25	1	25	72	96	-1.4935	-.0459	23
24	26	1	26	71	96	-1.7443	-.0386	24
25	27	1	27	70	96	-1.9776	-.0293	25
26	28	1	28	69	96	-2.5494	-.0287	26
27	29	1	29	68	96	-2.9994	-.0354	27
28	30	1	30	67	96	-3.3114	-.0438	28
29	31	1	31	66	96	-3.4267	-.0429	29
30	32	1	32	65	96	-3.8128	-.0345	30
31	33	1	33	64	96	-4.0341	-.0301	31
32	34	1	34	63	96	-3.7803	-.0274	32
33	35	1	35	62	96	-3.6487	-.0282	33
34	36	1	36	61	96	-3.6504	-.0205	34
35	37	1	37	60	96	-3.7932	-.0153	35
36	38	1	38	59	96	-4.3875	-.0164	36
37	39	1	39	58	96	-4.8313	-.0177	37
38	40	1	40	57	96	-4.7524	-.0151	38
39	41	1	41	56	96	-4.6776	-.0137	39
40	42	1	42	55	96	-4.9261	-.0154	40
41	43	1	43	54	96	-4.9003	-.0206	41
42	44	1	44	53	96	-4.4578	-.0262	42
43	45	1	45	52	96	-4.0288	-.0227	43
44	46	1	46	51	96	-4.3421	-.0143	44
45	47	1	47	50	96	-4.9594	-.0095	45
46	48	1	48	49	96	-5.4298	-.0072	46
47	49	1	49	48	96	-5.6660	-.0064	47
48	50	1	50	47	96	-5.9091	-.0067	48

5 TERM SMOOTHING EQUATION FOR WELL 1 VS. 5 TERM SMOOTHING EQUATION FOR WELL 4 -

REVERSE MATCHES

SLIDING STEP = 1

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		CROSS DIFFERENCE PRODUCT	T	D.F.
1	3	1	3	1	3	-1.8930	-1.7342	1
2	4	1	4	1	4	-2.0576	-1.3372	2
3	5	1	5	1	5	-3.3175	-.3526	3
4	6	1	6	1	6	-4.7175	-.2995	4
5	7	1	7	1	7	-5.2386	-1.5245	5
6	8	1	8	1	8	-5.5814	-.9847	6
7	9	1	9	1	9	-6.0718	-.2293	7
8	10	1	10	1	10	-6.1953	-.1332	8
9	11	1	11	1	11	-5.9451	-.1138	9
10	12	1	12	1	12	-5.7525	-.1126	10
11	13	1	13	1	13	-5.8833	-.1229	11
12	14	1	14	1	14	-5.7888	-.1436	12
13	15	1	15	1	15	-5.5922	-.2075	13
14	16	1	16	1	16	-5.7676	-.2618	14
15	17	1	17	1	17	-6.0066	-.1873	15
16	18	1	18	1	18	-5.6988	-.1347	16
17	19	1	19	1	19	-5.6660	-.1165	17
18	20	1	20	1	20	-6.0468	-.0851	18
19	21	1	21	1	21	-6.3652	-.0765	19
20	22	1	22	1	22	-6.7100	-.0674	20
21	23	1	23	1	23	-7.7672	-.0379	21
22	24	1	24	1	24	-9.1880	-.0223	22
23	25	1	25	1	25	-10.4346	-.0183	23
24	26	1	26	1	26	-11.3314	-.0165	24
25	27	1	27	1	27	-11.8907	-.0138	25
26	28	1	28	1	28	-11.9998	-.0116	26
27	29	1	29	1	29	-11.8382	-.0103	27
28	30	1	30	1	30	-11.6677	-.0098	28
29	31	1	31	1	31	-11.5042	-.0096	29
30	32	1	32	1	32	-11.2369	-.0095	30
31	33	1	33	1	33	-11.0518	-.0097	31
32	34	1	34	1	34	-10.9885	-.0106	32
33	35	1	35	1	35	-11.2541	-.0122	33
34	36	1	36	1	36	-11.0304	-.0128	34
35	37	1	37	1	37	-10.7467	-.0136	35
36	38	1	38	1	38	-10.6723	-.0152	36
37	39	1	39	1	39	-10.4653	-.0166	37
38	40	1	40	1	40	-9.8084	-.0176	38
39	41	1	41	1	41	-9.4570	-.0184	39
40	42	1	42	1	42	-9.4090	-.0166	40
41	43	1	43	1	43	-9.4069	-.0134	41
42	44	1	44	1	44	-9.3346	-.0122	42
43	45	1	45	1	45	-9.3532	-.0127	43
44	46	1	46	1	46	-9.0682	-.0150	44
45	47	1	47	1	47	-8.5771	-.0194	45
46	48	1	48	1	48	-8.2760	-.0251	46
47	49	1	49	1	49	-8.3784	-.0289	47
48	50	1	50	1	50	-8.4515	-.0308	48
49	51	1	51	1	51	-8.2936	-.0300	49
50	52	1	52	1	52	-8.1060	-.0228	50
51	53	1	53	1	53	-8.0853	-.0150	51
52	54	1	54	1	54	-8.2402	-.0107	52

Control cards and sample input data for Program 4, from Sackin, Sneath, and Merriam (1965), giving coded lithologies found in two Pennsylvanian wells in Kansas and Oklahoma. Refer to the original article for key to the coded states.

```
001001 -100.0      -100.0
NORTHERN OKLAHOMA    --   SOUTHERN KANSAS
 7.    9.    1.    1.    1.    9.    8.    6.    6.            9.    7.    7.
 6.    6.    7.    2.    2.    2.    6.    9.    7.            6.    6.    6.
 5.    8.    6.    9.    6.    1.    9.    2.    6.            8.    7.    8.
 6.    6.    9.    8.    9.    2.    6.    1.    3.            6.    6.    6.
 9.    7.    8.    6.    6.    1.    8.    2.    1.            9.    7.    7.
 6.    1.    2.    8.    9.    2.    7.    9.    2.            6.    6.    6.
 7.    9.    8.    6.    3.    9.    6.    6.    9.0E 48       8.    7.    9.
 6.    7.    6.    9.    2.    6.    9.    9.    7.            6.    6.    .0
 8.    6.    5.    6.    4.    8.    6.    6.    6.            1.    7.    7.0
 3.    2.    2.    3.    6.    7.    8.    8.    1.            6.    6.    6.0
                                                                          5.0
                                                                          4.0
                                                                          6.0
                                                                           9.0E48
```

Partial output listing for cross-association between two wells. Both forward and reverse matches are given.

NORTHERN OKLAHOMA -- SOUTHERN KANSAS

FORWARD MATCHES

SLIDING STEP = 1

PROB(MATCH) = .18378553

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		PER CENT MATCHS	STANDARD DEVIATION	CHI-SQ UNCORRECTED	CHI-SQ (YATES)
1	1	1	1	36	36	.0000	-.8861	.2251	.6665
2	2	1	2	35	36	50.0000	.9682	1.3331	.0584
3	3	1	3	34	36	.0000	-1.5347	.6755	.0058
4	4	1	4	33	36	25.0000	.3221	.1169	.0921
5	5	1	5	32	36	60.0000	1.9812	5.7741	3.3328
6	6	1	6	31	36	16.6666	-.1103	.0117	.1753
7	7	1	7	30	36	14.2857	-.2934	.0781	.0434
8	8	1	8	29	36	12.5000	-.4621	.1842	.0007
9	9	1	9	28	36	33.3333	1.0345	1.3417	.5300
10	10	1	10	27	36	.0000	-2.8021	2.2516	1.1931
11	11	1	11	26	36	45.4545	1.9689	5.3758	3.7223
12	12	1	12	25	36	8.3333	-1.0407	.8072	.2764
13	13	1	13	24	36	30.7692	1.0452	1.3305	.6327
14	14	1	14	23	36	7.1428	-1.2909	1.1781	.5482
15	15	1	15	22	36	46.6666	2.3933	8.0017	6.2270
16	16	1	16	21	36	.0000	-3.5444	3.6026	2.4816
17	17	1	17	20	36	41.1764	2.0915	5.8901	4.4683
18	18	1	18	19	36	.0000	-3.7594	4.0530	2.9204
19	19	1	19	18	36	52.6315	3.2139	14.8605	12.6648
20	20	1	20	17	36	.0000	-3.9628	4.5033	3.3615
21	21	1	21	16	36	38.0952	2.0359	5.4421	4.2071
22	22	1	22	15	36	9.0909	-1.2830	1.2650	.7216

23	23	1	23	14	36	52.1739	3.4922	17.5116	15.3311
24	24	1	24	13	36	.0000	-4.3410	5.4040	4.2483
25	25	1	25	12	36	28.0000	1.1454	1.5427	.9680
26	26	1	26	11	36	15.3846	-.4079	.1553	.0198
27	27	1	27	10	36	29.6296	1.3773	2.2784	1.5901
28	28	1	28	9	36	7.1428	-1.8256	2.3563	1.6668
29	29	1	29	8	36	27.5862	1.1839	1.6390	1.0826
30	30	1	30	7	36	16.6666	-.2467	.0586	.0000
31	31	1	31	6	36	29.0322	1.4028	2.3455	1.6891
32	32	1	32	5	36	9.3750	-1.4919	1.7292	1.1811
33	33	1	33	4	36	24.2424	.8243	.7564	.4160
34	34	1	34	3	36	11.7647	-1.0839	.9914	.5995
35	35	1	35	2	36	28.5714	1.4303	2.4240	1.7922

NORTHERN OKLAHOMA -- SOUTHERN KANSAS

REVERSE MATCHES

SLIDING STEP = 1

PROB(MATCH) = .18378553

MATCH POSITION	NUMBER OF TERMS	A TERMS		B TERMS		PER CENT MATCHS	STANDARD DEVIATION	CHI-SQ UNCORRECTED	CHI-SQ (YATES)
1	1	1	1	1	1	100.0000	2.2554	4.4411	.6665
2	2	1	2	1	2	.0000	-1.2531	.4503	.0584
3	3	1	3	1	3	33.3333	.5972	.4472	.0058
4	4	1	4	1	4	.0000	-1.7722	.9006	.0921
5	5	1	5	1	5	20.0000	.0920	.0087	.2339
6	6	1	6	1	6	16.6666	-.1103	.0117	.1753
7	7	1	7	1	7	28.5714	.6396	.4848	.0434
8	8	1	8	1	8	37.5000	1.2218	1.9499	.8835
9	9	1	9	1	9	11.1111	-.6193	.3168	.0175
10	10	1	10	1	10	30.0000	.8638	.9003	.2922
11	11	1	11	1	11	.0000	-2.9388	2.4768	1.4031
12	12	1	12	1	12	41.6666	1.7917	4.3384	2.9248
13	13	1	13	1	13	7.6923	-1.1683	.9896	.4054
14	14	1	14	1	14	50.0000	2.5618	9.3320	7.3430
15	15	1	15	1	15	13.3333	-.5365	.2545	.0293
16	16	1	16	1	16	37.5000	1.7280	3.8998	2.7293
17	17	1	17	1	17	.0000	-3.6535	3.8278	2.7007
18	18	1	18	1	18	66.6666	4.3466	27.9793	24.8528
19	19	1	19	1	19	.0000	-3.8624	4.2781	3.1407
20	20	1	20	1	20	50.0000	3.0620	13.3314	11.3068
21	21	1	21	1	21	.0000	-4.0606	4.7285	3.5827
22	22	1	22	1	22	45.4545	2.7844	10.7516	9.0224
23	23	1	23	1	23	8.6956	-1.3785	1.4375	.8645
24	24	1	24	1	24	41.6666	2.5339	8.6768	7.1938
25	25	1	25	1	25	4.0000	-2.4169	3.4455	2.5536
26	26	1	26	1	26	26.9230	1.0450	1.2654	.7599
27	27	1	27	1	27	14.8148	-.4983	.2285	.0527
28	28	1	28	1	28	32.1428	1.6905	3.5363	2.6782
29	29	1	29	1	29	10.3448	-1.2450	1.2477	.7696
30	30	1	30	1	30	30.0000	1.4962	2.7010	1.9818
31	31	1	31	1	31	12.9032	-.8422	.6195	.3082
32	32	1	32	1	32	31.2500	1.6986	3.5341	2.7282
33	33	1	33	1	33	12.1212	-1.0047	.8613	.4947
34	34	1	34	1	34	32.3529	1.8890	4.4261	3.5436
35	35	1	35	1	35	11.4285	-1.1619	1.1269	.7112

KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN II Time-Trend Package for the IBM 1620 Computer

Computer: IBM 1620 Date: 20 November 1967

Programming language: PDQ FORTRAN II

Author, organization: John C. Davis, Kansas Geological Survey and Robert J. Sampson, Idaho State University, Pocatello

Direct inquiries to: Authors, or

Name: Daniel F. Merriam Address: Kansas Geological Survey
University of Kansas, Lawrence, Kansas 66044

Purpose/description: Computes cross- and autocorrelations, cross-difference products, or cross associations between chains of numeric data.

Mathematical method:

Restrictions, range: Chains containing up to 350 points may be used.

Storage requirements:

Equipment specifications: Memory 20K X 40K 60K K

Automatic divide: Yes X No Indirect addressing Yes X No

Other special features required Requires PDQ FORTRAN II compiler and subroutine set.

Additional remarks (include at author's discretion: fixed/float, relocatability; optional: running time, approximate number of times run successfully, programming hours) Also written in FORTRAN IV for the GE 625 as a single program.

COMPUTER CONTRIBUTIONS

Kansas Geological Survey
University of Kansas
Lawrence, Kansas

Computer Contribution

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

Recent reprint (available for a limited time)

Re-interpretation of the *Cyrtina septosa* Band data, Lower Carboniferous of Derbyshire, England, by computer analysis, by H.E. Sadler and D.F. Merriam (reprinted from *Sedimentology*, v. 8, no. 1, p. 55-61). . . . . no charge