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FORTRAN II Trend-Surface Program With Unrestricted Input

For the IBM 1620 Computer

by

Robert J. Sampson and John C. Davis

INTRODUCTION

Three-dimensional geologic data are often conveniently summarized and interpreted by reduction to a simple geometric shape. A surface can be fitted to the data by an extension of the least-squares, curve-fitting procedure used in curvilinear correlation and regression analysis. The fitted surface is an approximation or "trend" of the data, whereas deviations from the surface indicate local irregularities. There are many geological applications for this technique (see Merriam and Harbaugh, 1964).

The program described here will produce trend-surface and residual values of the general first-, second-, third-, and fourth-degree equations. The equations used to generate the surfaces, correlation coefficients, and related values for each order are also printed.

For a limited time, a punched card deck of this program may be obtained from the Kansas Geological Survey, University of Kansas, Lawrence, Kansas, for \$7.50.

PROGRAM DESCRIPTION

This program differs from previously published trend-surface programs (Good, 1964; Harbaugh, 1963; McIntyre, 1963; Whitten, 1963) in one major aspect. Data are not stored in a DIMENSION array within the computer, but are processed and accumulated as read in. The program, therefore, is theoretically capable of incorporating an infinite number of data points. Data storage positions used in other programs are used instead to store a larger matrix, allowing surfaces of a higher degree to be calculated in a smaller computer. This program utilizes a 15×16 matrix to generate the fourth-degree (quartic) equation. A modification of the program can be made in which the matrix is punched out, then used as input in a separate machine pass to solve the necessary equations. The additional storage space thus freed can be used in an IBM 1620 for an expanded 28×29 matrix that will produce fifth- and sixth-degree surfaces. Experiments have shown, however, that output accuracy beyond four decimal places becomes uncertain in this modification.

This program is designed for an IBM 1620 computer having 20K bits storage, the smallest computer in common use for research in the United States. Two machine passes are necessary, requiring about 12 minutes

per 100 data points on each pass. Approximately 18K bits of computer space are required for storage of the program and subroutines on each pass. Machine requirements are minimal, consisting of the basic IBM 1620 unit with automatic divide and indirect addressing, a 1622 Card Read Punch or equivalent, and a modified PDQ FORTRAN compiler. A 407 accounting machine or similar line printer is used for printing the output.

No relocateable subroutines are required on the first pass. On the second pass, three relocateable subroutines are used. Two of these, SQRT and ABS, are incorporated in the PDQ compiler. The third relocateable subroutine, called SGN, was added to PDQ from the UTO FORTRAN compiler written by E. S. Lee and J. A. Field (IBM User's Group, No. 2.0.024). SGN is used to determine the sign of correlation coefficients so that they may be reapplied to the coefficients after extracting the roots. If desired, this subroutine may be written into the program rather than being incorporated in the compiler. The subroutine performs the operation

$$X < 0 = -1 \qquad X = 0 = 0 \qquad X > 0 = +1$$

Although two machine passes are required for the execution of this program, there is no intermediate output. The matrix generated on the first pass is used to solve the simultaneous equations of the surfaces by a modification of the Gauss-Jordan method (Golden, 1965, p. 93). If desired the matrix can be punched out after completion of the first pass. Coefficients to the equations are carried over to the second pass and the trend and residual values computed. In order to keep the program as compact and flexible as possible, contour maps are not printed. Output is in the form of listings of x , y , and z coordinates of the trend-surface and residual values. Statements are also produced giving the coefficients of each trend-surface equation, the standard deviations of each surface, the variance explained and not explained by the surface, coefficients of determination and coefficients of correlation (see appendix).

Data input and operation procedures have been kept as simple as possible. Input cards are written in fixed-form format. This program specifies three ten-character fields with three decimal places, but this can be modified if desired. Coordinates are read x , y , and z , from left to right on the cards. After loading the PDQ compiler and Part 1 of the program, data cards and commands are delivered to the machine in the following order:

Card 1 - This card is a 72-character title card containing alphanumeric information in columns 1 through 72. The last 8 columns on the card are reserved for unassignable page numbers. This information will be reproduced at the head of the output.

Card 2 - This is the first of any number of cards containing the xyz coordinates; x is punched in columns 1 - 10, y in columns 11 - 20, and z in columns 21 - 30. The field specifications may be changed by

altering FORMAT Statement 1000. Cards will be accepted and operated upon until the last card in the reader stacker has been read.

If the coefficient matrices are not desired, SENSE SWITCH 1 should be on. Otherwise, the matrices will be punched at the completion of computations.

Following completion of Part 1, the computer will type the statement, LOAD NEXT PASS BY PUSHING RESET AND LOAD, and return to manual mode. Part 2 of the program is then loaded, followed by the xyz data cards. The header card is not re-run. Pushing RESET and LOAD will restore the machine to automatic mode and the remainder of the program will be processed. The program was tested using Good's sample input data giving tops of the Arbuckle Group in Kansas (Good, 1964, p. 35). The program processes 200 data points in 45 minutes machine time and produces results comparable to those of Good.

Each printer output sheet begins with the statement from the header card, and a page number. A minus in the 80th column of the header card directs the printer to skip to a new page. All related output is printed sequentially on numbered pages. The coefficient matrix (optional) constitutes the first set of data. The second set contains the xyz coordinates, and the final set contains the equation coefficients and error measures.

If more storage space is available, Part III of Good's (1964) program may be added, thus combining the advantages of faster computation and unrestricted input with map printing. The program, or a modification of it, is advantageous even when large computers are available, because of no input restrictions.

This program was written by Robert J. Sampson at the Idaho State University Computer Center as a part of the ISU Geology Department Research Project 12. Machine time was donated by the ISU Computer Center, with the support of NSF Grant GP-2275.

REFERENCES

- Golden, J. T., 1965, FORTRAN IV programming and computing: Prentice-Hall, Inc., 270 p.
- Good, D. I., 1964, FORTRAN II trend-surface program for the IBM 1620: Kansas Geol. Survey Sp. Dist. Publ. 14, 54 p.
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- McIntyre, D. B., 1963, Program for computation of trend-surfaces and residuals of degree 1 through 8: Pomona College, Seaver Lab., Dept. Geol., Claremont, California, 24 p.
- Merriam, D. F., and Harbaugh, J. W., 1964, Trend-surface analysis of regional and residual components of geologic structure in Kansas: Kansas Geol. Survey Sp. Dist. Publ. 11, 27 p.
- Whitten, E. H. T., 1963, A surface-fitting program suitable for testing geological models which involve areally-distributed data: ONR Task No. 389-135, Tech. Rept. No. 2, 56 p.

APPENDIX

```

C      TREND SURFACE PROGRAM      PART 1
C      COMPILE WITH PDQ FORTRAN COMPILER AND FIXED FORMAT SUBROUTINES.
COMMON D(4,15),T(18),IPAGE,ZBAR,AN
DIMENSION A(9,9),B(9,9),C(15,16)
BEGIN TRACE
DO 100 I=1,9
DO 100 J=1,9
A(I,J)=0.0
100 B(I,J)=0.0
READ 1006,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18)
IF (SENSE SWITCH 9) 1,1
1 READ 1000,X,Y,Z
DO 101 I=1,9
K=10-I
DO 102 J=1,K
SUM=(X**(I-1))*(Y**(J-1))
A(I,J)=A(I,J)+SUM
102 B(I,J)=B(I,J)+SUM*Z
101 CONTINUE
IF (SENSE SWITCH 9) 20,1
20 N5=0
IC=0
DO 103 I=1,5
IX=I+1
DO 104 J=1,I
IC=IC+1
IX=IX-1
JC=0
IE=IX+4
DO 105 I1=IX,IE
IX1=I1+1
JE=J+I1-IX
DO 106 J1=J,JE
JC=JC+1
IX1=IX1-1
JX1=J1+0
106 C(IC,JC)=A(IX1,JX1)
105 CONTINUE
104 CONTINUE
103 CONTINUE
JC=0
DO 116 I=1,5
IX=I+1
DO 107 J=1,I
IX=IX-1
JC=JC+1
107 C(JC,16)=B(IX,J)
116 CONTINUE
IPAGE=0
IF (SENSE SWITCH 1 ) 22,21
21 DO 23 I=1,15
IF (I-1) 122,121,122
122 IF (I-12) 123,121,123
121 IPAGE=IPAGE+1
PUNCH 1003,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18),IPAGE
PUNCH 1004
123 DO 24 J=1,15,5

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24 PUNCH 1001,C(I,J),C(I,J+1),C(I,J+2),C(I,J+3),C(I,J+4)
23 PUNCH 1002,C(I,16)
22 DO 108 M=1,15
    DO 118 M1=1,15
        IF (M-M1) 2,118,2
        2 F=-C(M1,M)/C(M,M)
        DO 109 M2=M,16
109 C(M1,M2)=C(M1,M2)+(F*C(M,M2))
118 CONTINUE
    IF (M-3) 4,3,4
    4 IF (M-6) 5,3,5
    5 IF (M-10) 108,3,108
    3 N5=N5+1
    DO 111 M3=1,M
111 D(N5,M3)=C(M3,16)/C(M3,M3)
108 CONTINUE
    DO 112 M3=1,15
112 D(4,M3)=C(M3,16)/C(M3,M3)
    ZBAR=B(1,1)/A(1,1)
    AN=A(1,1)
    PRINT 1005
    PAUSE
1000 FORMAT (3F10.3)
1001 FORMAT (5E16.8)
1002 FORMAT (E16.8/)
1003 FORMAT (18A4,5H PAGE,12,1H-)
1004 FORMAT (/,18HCOEFFICIENT MATRIX,/)
1005 FORMAT (40HLOAD NEXT PASS BY PUSHING RESET AND LOAD)
1006 FORMAT (18A4)
    END TRACE
    END

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C TREND SURFACE PROGRAM--PART 2
C COMPILE WITH PDQ FORTRAN COMPILER AND FIXED FORMAT SUBROUTINES.
C AFTER COMPILING PART 2,REMOVE THE FIRST 2 CARDS FROM THE OBJECT
C DECK.
C WHEN RUNNING PROGRAM REMOVE HEADER CARD FROM DATA CARDS.
COMMON D(4,15),T(18),IPAGE,ZBAR,AN
DIMENSION C(5,5)
BEGIN TRACE
V=0.0
S1=0.0
S2=0.0
S3=0.0
S4=0.0
ILINE=17
IF (SENSE SWITCH 9) 1,1
1 READ 1000,X,Y,Z
DO 100 I=1,5
K=6-I
DO 101 J=1,K
101 C(I,J)=(X**(I-1))*(Y**(J-1))
100 CONTINUE
Z1=D(1,1)+C(2,1)*D(1,2)+C(1,2)*D(1,3)
Z21=D(2,1)+C(2,1)*D(2,2)+C(1,2)*D(2,3)+C(3,1)*D(2,4)
Z22=          +C(2,2)*D(2,5)+C(1,3)*D(2,6)
Z2=Z21+Z22
Z31=D(3,1)+C(2,1)*D(3,2)+C(1,2)*D(3,3)+C(3,1)*D(3,4)
Z32=          +C(2,2)*D(3,5)+C(1,3)*D(3,6)+C(4,1)*D(3,7)

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```

Z33=      +C(3,2)*D(3,8)+C(2,3)*D(3,9)+C(1,4)*D(3,10)
Z3=Z31+Z32+Z33
Z41=D(4,1)+C(2,1)*D(4,2)+C(1,2)*D(4,3)+C(3,1)*D(4,4)
Z42=      +C(2,2)*D(4,5)+C(1,3)*D(4,6)+C(4,1)*D(4,7)
Z43=      +C(3,2)*D(4,8)+C(2,3)*D(4,9)+C(1,4)*D(4,10)
Z44=      +C(5,1)*D(4,11)+C(4,2)*D(4,12)+C(3,3)*D(4,13)
Z45=      +C(2,4)*D(4,14)+C(1,5)*D(4,15)
Z4=Z41+Z42+Z43+Z44+Z45
R1=Z-Z1
R2=Z-Z2
R3=Z-Z3
R4=Z-Z4
V=V+(Z-ZBAR)**2
S1=S1+(Z-Z1)**2
S2=S2+(Z-Z2)**2
S3=S3+(Z-Z3)**2
S4=S4+(Z-Z4)**2
ILINE=ILINE+1
IF (ILINE-18) 3,2,3
2 ILINE=0
  IPAGE=IPAGE+1
  PUNCH 1001,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18),IPAGE
  PUNCH 1031
3 PUNCH 1002,X,Y,Z,Z1,Z2,Z3,Z4,R1,R2,R3,R4
  IF (SENSE SWITCH 9) 4,1
4 E1=V-S1
  E2=V-S2
  E3=V-S3
  E4=V-S4
  TD1=E1/V
  TD2=E2/V
  TD3=E3/V
  TD4=E4/V
  SD1=SQRT(S1/AN)
  SD2=SQRT(S2/AN)
  SD3=SQRT(S3/AN)
  SD4=SQRT(S4/AN)
  CC1=SGN(TD1)*SQRT(ABS(TD1))
  CC2=SGN(TD2)*SQRT(ABS(TD2))
  CC3=SGN(TD3)*SQRT(ABS(TD3))
  CC4=SGN(TD4)*SQRT(ABS(TD4))
  IPAGE=IPAGE+1
  PUNCH 1001,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18),IPAGE
  PUNCH 1003,D(1,1),D(1,2),D(1,3)
  PUNCH 1004,D(2,1),D(2,2),D(2,3),D(2,4),D(2,5),D(2,6)
  PUNCH 1005,D(3,1),D(3,2),D(3,3),D(3,4),D(3,5),D(3,6),D(3,7),
1D(3,8),D(3,9),D(3,10)
  PUNCH 1006,D(4,1),D(4,2),D(4,3),D(4,4),D(4,5),D(4,6),D(4,7),
1D(4,8),D(4,9)
  PUNCH 1026,D(4,10),D(4,11),D(4,12),D(4,13),D(4,14),D(4,15)
  PUNCH 1007
  PUNCH 1008,SD1,SD2,SD3,SD4
  PUNCH 1009,E1,E2,E3,E4
  PUNCH 1010,S1,S2,S3,S4
  PUNCH 1011,V
  PUNCH 1012,TD1,TD2,TD3,TD4
  PUNCH 1013,CC1,CC2,CC3,CC4
1000 FORMAT (3F10.3)

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1001 FORMAT (18A4,4HPAGE,I3,1H-)
1002 FORMAT (3F10.3,/,23X,7HSURFACE,2X,4F12.3,/,23X,8HRESIDUAL,1X,
14F12.3)
1003 FORMAT (/,31HCOEFFICIENTS OF LINEAR EQUATION ,/,3HZ =,F15.7,
17H + ,F15.7,7H X + ,F15.7,2H Y)
1004 FORMAT (/,34HCOEFFICIENT OF QUADRATIC EQUATION ,/,3HZ =,
1F15.7,7H + ,F15.7,7H X + ,F15.7,7H Y + ,/,3X,F15.7,
27H X2 + ,F15.7,7H XY + ,F15.7,7H Y2 + )
1005 FORMAT (/,29HCOEFFICIENT OF CUBIC EQUATION,/,3HZ =,
1F15.7,7H + ,F15.7,7H X + ,F15.7,7H Y + ,/,3X,F15.7,
27H X2 + ,F15.7,7H XY + ,F15.7,7H Y2 + ,/,3X,F15.7,7H X3 + ,
3F15.7,7H X2Y + ,F15.7,7H XY2 + ,/,3X,F15.7,7H Y3 )
1006 FORMAT (/,33HCOEFFICIENT OF 4TH ORDER EQUATION ,/,3HZ =,
1F15.7,7H + ,F15.7,7H X + ,F15.7,7H Y + ,/,3X,F15.7,
27H X2 + ,F15.7,7H XY + ,F15.7,7H Y2 + ,/,3X,F15.7,7H X3 + ,
3F15.7,7H X2Y + ,F15.7,7H XY2 + )
1007 FORMAT (/,25X,14HERROR MEASURES,/,7HSURFACE,24X,6HLINEAR,5X,
19HQUADRATIC,7X,5HCUBIC,8X,3H4TH,/)
1008 FORMAT (18HSTANDARD DEVIATION ,6X,4F14.6/)
1009 FORMAT (19HVARIATION EXPLAINED,/,10HBY SURFACE,14X,4E14.6,/)
1010 FORMAT (23HVARIATION NOT EXPLAINED,/,10HBY SURFACE,14X,4E14.6,/)
1011 FORMAT (15HTOTAL VARIATION,9X,E14.6,/)
1012 FORMAT (14HCOEFFICIENT OF,/,13HDETERMINATION,11X,4F14.6,/)
1013 FORMAT (14HCOEFFICIENT OF,/,11HCORRELATION ,13X,4F14.6)
1026 FORMAT (3X,F15.7,7H Y3 + ,F15.7,7H X4 + ,F15.7,7H X3Y + ,/,
13X,F15.7,7H X2Y2 + ,F15.7,7H XY3 + ,F15.7,7H Y4 )
1031 FORMAT (/,3X,7HX-COORD,3X,7HY-COORD,3X,7HZ-COORD,8X,6HLINEAR,3X,
19HQUADRATIC,7X,5HCUBIC,6X,3H4TH,/)
END TRACE
END

```

Sample input - not complete (from Good, 1964).

TOP OF ARBUCKLE IN KANSAS			ISU GEOLOGY DEPT. PROJECT 12		
16.75	-8.66	-1709.	41.30	-16.38	-1077.
12.13	-18.02	-2934.	22.75	-21.67	-2780.
23.36	-22.10	-2961.	35.93	-14.53	-707.
29.80	-10.58	-2240.	21.59	-21.16	-2677.
13.18	-3.92	-1478.	28.20	-6.40	-2801.
22.18	-16.24	-1872.	30.50	-19.83	-2678.
12.34	-4.81	-1826.	41.20	-3.50	-2586.
22.01	-3.36	-2584.	31.38	-17.74	-2190.
14.18	-17.13	-2810.	.30	-.40	-2029.
10.85	-1.32	-1477.	3.90	-15.65	-2208.
39.33	-21.14	-1119.	2.40	-24.00	-3167.
49.30	-14.85	-125.	24.30	-23.90	-3367.
46.00	-2.15	-1891.	43.10	-15.34	-399.
15.10	-18.50	-3062.	8.90	-21.00	-3603.
28.96	-10.30	-2540.	47.30	-4.92	-1400.
4.31	-8.15	-1800.	24.80	-21.10	-2959.
18.90	-16.69	-2300.	12.60	-14.83	-2545.
5.90	-8.96	-2017.	22.72	-11.15	-1431.
7.80	-1.78	-1578.	20.40	-21.82	-3022.
5.96	-1.50	-1693.	1.15	-25.85	-1923.
2.10	-2.65	-1800.	26.49	-6.43	-2431.
21.11	-12.26	-1505.	45.90	-13.25	-638.
29.92	-4.00	-1921.	.85	-4.20	-1803.
41.99	-5.31	-2056.	10.50	-5.50	-1907.
21.86	-4.01	-2466.	51.20	-25.01	134.

COEFFICIENT MATRIX

.50000000E 02	.11149800E 04	-.61395000E 03	.35157925E 05	-.14332120E 05
.10452256E 05	.12891535E 07	-.45346551E 06	.24147720E 06	-.20149287E 06
.51654693E 08	-.16613002E 08	.76773919E 07	-.45697853E 07	.41296646E 07
-.10195800E 06				
.11149800E 04	.35157925E 05	-.14332120E 05	.12891535E 07	-.45346551E 06
.24147720E 06	.51654693E 08	-.16613002E 08	.76773919E 07	-.45697853E 07
.21888232E 10	-.66882541E 09	.28363782E 09	-.14652153E 09	.91907949E 08
-.20233390E 07				
-.61395000E 03	-.14332120E 05	.10452256E 05	-.45346551E 06	.24147720E 06
-.20149287E 06	-.16613002E 08	.76773919E 07	-.45697853E 07	.41296646E 07
-.66882541E 09	.28363782E 09	-.14652153E 09	.91907949E 08	-.87950566E 08
.13159583E 07				
.35157925E 05	.12891535E 07	-.45346551E 06	.51654693E 08	-.16613002E 08
.76773919E 07	.21888232E 10	-.66882541E 09	.28363782E 09	-.14652153E 09
.96197949E 11	-.28661433E 11	.11566082E 11	-.54812682E 10	.29835784E 10
-.55143482E 08				
-.14332120E 05	-.45346551E 06	.24147720E 06	-.16613002E 08	.76773919E 07
-.45697853E 07	-.66882541E 09	.28363782E 09	-.14652153E 09	.91907949E 08
-.28661433E 11	.11566082E 11	-.54812682E 10	.29835784E 10	-.19233251E 10
.25416475E 08				
.10452256E 05	.24147720E 06	-.20149287E 06	.76773919E 07	-.45697853E 07
.41296646E 07	.28363782E 09	-.14652153E 09	.91907949E 08	-.87950566E 08
.11566082E 11	-.54812682E 10	.29835784E 10	-.19233251E 10	.19257257E 10
-.23178065E 08				
.12891535E 07	.51654693E 08	-.16613002E 08	.21888232E 10	-.66882541E 09
.28363782E 09	.96197949E 11	-.28661433E 11	.11566082E 11	-.54812682E 10
.43336025E 13	-.12801636E 13	.50362108E 12	-.22693437E 12	.11338040E 12
-.17456881E 10				
-.45346551E 06	-.16613002E 08	.76773919E 07	-.66882541E 09	.28363782E 09
-.14652153E 09	-.28661433E 11	.11566082E 11	-.54812682E 10	.29835784E 10
-.12801636E 13	.50362108E 12	-.22693437E 12	.11338040E 12	-.63447138E 11
.63939312E 09				
.24147720E 06	.76773919E 07	-.45697853E 07	.28363782E 09	-.14652153E 09
.91907949E 08	.11566082E 11	-.54812682E 10	.29835784E 10	-.19233251E 10
.50362108E 12	-.22693437E 12	.11338040E 12	-.63447138E 11	.41442099E 11
-.42972737E 09				
-.20149287E 06	-.45697853E 07	.41296646E 07	-.14652153E 09	.91907949E 08
-.87950566E 08	-.54812682E 10	.29835784E 10	-.19233251E 10	.19257257E 10
-.22693437E 12	.11338040E 12	-.63447138E 11	.41442099E 11	-.43080168E 11
.45599045E 09				
.51654693E 08	.21888232E 10	-.66882541E 09	.96197949E 11	-.28661433E 11
.11566082E 11	.43336025E 13	-.12801636E 13	.50362108E 12	-.22693437E 12
.19866301E 15	-.58798550E 14	.22891094E 14	-.10044573E 14	.47729880E 13
-.61155375E 11				
-.16613002E 08	-.66882541E 09	.28363782E 09	-.28661433E 11	.11566082E 11
-.54812682E 10	-.12801636E 13	.50362108E 12	-.22693437E 12	.11338040E 12
-.58798550E 14	.22891094E 14	-.10044573E 14	.47729880E 13	-.24554443E 13
.18279822E 11				
.76773919E 07	.28363782E 09	-.14652153E 09	.11566082E 11	-.54812682E 10
.29835784E 10	.50362108E 12	-.22693437E 12	.11338040E 12	-.63447138E 11
.22891094E 14	-.10044573E 14	.47729880E 13	-.24554443E 13	.13931634E 13
-.10370456E 11				
-.45697853E 07	-.14652153E 09	.91907949E 08	-.54812682E 10	.29835784E 10
-.19233251E 10	-.22693437E 12	.11338040E 12	-.63447138E 11	.41442099E 11
-.10044573E 14	.47729880E 13	-.24554443E 13	.13931634E 13	-.91344968E 12
.81715481E 10				
.41296646E 07	.91907949E 08	-.87950566E 08	.29835784E 10	-.19233251E 10
.19257257E 10	.11338040E 12	-.63447138E 11	.41442099E 11	-.43080168E 11
.47729880E 13	-.24554443E 13	.13931634E 13	-.91344968E 12	.98054978E 12
-.94297047E 10				

TOP OF ARBUCKLE IN KANSAS

ISU GEOLOGY DEPT. PROJECT 12

X-COORD	Y-COORD	Z-COORD	LINEAR	QUADRATIC	CUBIC	4TH
16.750	-8.660	-1709.000				
		SURFACE	-2083.406	-2220.336	-2026.676	-1823.527
		RESIDUAL	374.406	511.336	317.676	114.527
12.130	-18.020	-2934.000				
		SURFACE	-2463.003	-2548.387	-2669.781	-2884.068
		RESIDUAL	-470.996	-385.612	-264.218	-49.931
23.360	-22.100	-2961.000				
		SURFACE	-2283.618	-2714.492	-2957.909	-3052.510
		RESIDUAL	-677.381	-246.507	-3.090	91.510
29.800	-10.580	-2240.000				
		SURFACE	-1796.793	-2044.254	-1880.947	-1886.744
		RESIDUAL	-443.206	-195.745	-359.052	-353.255
13.180	-3.920	-1478.000				
		SURFACE	-2045.053	-2201.935	-1924.538	-1826.644
		RESIDUAL	567.053	723.935	446.538	348.644
22.180	-16.240	-1872.000				
		SURFACE	-2152.005	-2354.530	-2419.415	-2227.574
		RESIDUAL	280.005	482.530	547.415	355.574
12.340	-4.810	-1826.000				
		SURFACE	-2091.580	-2137.280	-1902.881	-1793.851
		RESIDUAL	265.580	311.280	76.881	-32.148
22.010	-3.360	-2584.000				
		SURFACE	-1799.619	-2475.560	-2179.161	-2296.249
		RESIDUAL	-784.380	-108.439	-404.838	-287.750
14.180	-17.130	-2810.000				
		SURFACE	-2384.969	-2490.994	-2598.150	-2655.644
		RESIDUAL	-425.031	-319.006	-211.849	-154.355
10.850	-1.320	-1477.000				
		SURFACE	-2033.695	-2189.252	-1914.830	-1595.006
		RESIDUAL	556.695	712.252	437.830	118.006
39.330	-21.140	-1119.000				
		SURFACE	-1841.188	-1423.721	-1615.948	-1285.423
		RESIDUAL	722.188	304.721	496.948	166.423
49.300	-14.850	-125.000				
		SURFACE	-1407.333	-241.144	238.948	50.766
		RESIDUAL	1282.333	116.144	-363.948	-175.766
46.000	-2.150	-1891.000				
		SURFACE	-1141.434	-1743.343	-2460.614	-1699.927
		RESIDUAL	-749.565	-147.656	569.614	-191.073
15.100	-18.500	-3062.000				
		SURFACE	-2398.966	-2600.505	-2717.381	-2906.871
		RESIDUAL	-663.033	-461.494	-344.618	-155.128
28.960	-10.300	-2540.000				
		SURFACE	-1810.909	-2083.045	-1910.647	-1919.996
		RESIDUAL	-729.091	-456.954	-629.352	-620.003
4.310	-8.150	-1800.000				
		SURFACE	-2393.197	-1678.142	-1925.166	-1757.479
		RESIDUAL	593.197	-121.857	125.166	-42.521
18.900	-16.690	-2300.000				
		SURFACE	-2249.877	-2440.958	-2524.090	-2427.154
		RESIDUAL	-50.122	140.958	224.090	127.154
5.900	-8.960	-2017.000				
		SURFACE	-2374.235	-1802.496	-1977.747	-1736.931
		RESIDUAL	357.235	-214.503	-39.253	-280.068
7.800	-1.780	-1578.000				
		SURFACE	-2125.856	-1964.940	-1805.045	-1618.382
		RESIDUAL	547.856	386.940	227.045	40.382
5.960	-1.500	-1693.000				
		SURFACE	-2166.010	-1834.651	-1758.339	-1618.511
		RESIDUAL	473.010	141.651	65.339	-74.489
2.100	-2.650	-1800.000				
		SURFACE	-2298.377	-1470.860	-1695.364	-1884.708
		RESIDUAL	498.377	-329.140	-104.635	84.708
21.110	-12.260	-1505.000				
		SURFACE	-2069.609	-2254.690	-2159.812	-1886.226
		RESIDUAL	564.609	749.690	654.812	381.226
29.920	-4.000	-1921.000				
		SURFACE	-1611.384	-2382.816	-2253.752	-2659.544
		RESIDUAL	-309.615	461.816	332.752	738.544
41.990	-5.310	-2056.000				
		SURFACE	-1333.389	-1675.117	-1793.667	-2256.407
		RESIDUAL	-722.610	-380.882	-262.332	200.407
21.860	-4.010	-2466.000				
		SURFACE	-1821.531	-2434.420	-2132.107	-2276.760
		RESIDUAL	-644.468	-31.580	-333.892	-189.240

X-COORD	Y-COORD	Z-COORD	LINEAR	QUADRATIC	CUBIC	4TH
41.300	-16.380	-1077.000				
		SURFACE	-1658.026	-1136.515	-1029.181	-854.393
		RESIDUAL	581.026	59.515	-47.818	-222.606
22.750	-21.670	-2780.000				
		SURFACE	-2287.589	-2702.395	-2929.225	-3050.148
		RESIDUAL	-492.410	-77.604	149.225	270.148
35.930	-14.530	-707.000				
		SURFACE	-1746.603	-1627.349	-1559.909	-1373.184
		RESIDUAL	1039.603	920.349	852.909	666.184
21.590	-21.160	-2677.000				
		SURFACE	-2303.665	-2702.547	-2903.979	-3064.393
		RESIDUAL	-373.334	25.547	226.979	387.393
28.200	-6.400	-2801.000				
		SURFACE	-1722.657	-2259.259	-2038.558	-2374.021
		RESIDUAL	-1078.342	-541.740	-762.441	-426.978
30.500	-19.830	-2678.000				
		SURFACE	-2034.817	-2140.796	-2367.818	-2146.236
		RESIDUAL	-643.182	-537.203	-310.182	-531.763
41.200	-3.500	-2586.000				
		SURFACE	-1303.818	-1928.026	-2230.815	-2444.871
		RESIDUAL	-1282.181	-657.974	-355.184	-141.128
31.380	-17.740	-2190.000				
		SURFACE	-1954.005	-1991.876	-2113.186	-1837.214
		RESIDUAL	-235.995	-198.123	-76.813	-352.785
.300	-.400	-2029.000				
		SURFACE	-2282.915	-1341.745	-1647.684	-1878.429
		RESIDUAL	253.915	-687.255	-381.315	-150.570
3.900	-15.650	-2208.000				
		SURFACE	-2611.644	-2089.229	-2419.196	-2501.102
		RESIDUAL	403.644	-118.770	211.196	293.102
2.400	-24.000	-3167.000				
		SURFACE	-2882.021	-3097.165	-2735.800	-2969.409
		RESIDUAL	-284.978	-69.834	-431.199	-197.591
24.300	-23.900	-3367.000				
		SURFACE	-2309.007	-2843.999	-3124.190	-3077.051
		RESIDUAL	-1057.992	-523.000	-242.809	-289.949
43.100	-15.340	-399.000				
		SURFACE	-1582.346	-961.673	-763.781	-690.876
		RESIDUAL	1183.346	562.673	364.781	291.876
8.900	-21.000	-3603.000				
		SURFACE	-2629.662	-2821.003	-2854.775	-3435.451
		RESIDUAL	-973.337	-781.996	-748.224	-167.549
47.300	-4.920	-1400.000				
		SURFACE	-1184.321	-1267.528	-1537.044	-1607.347
		RESIDUAL	-215.679	-132.471	137.044	207.347
24.800	-21.100	-2959.000				
		SURFACE	-2218.420	-2560.246	-2804.064	-2818.088
		RESIDUAL	-740.579	-398.753	-154.935	-140.912
12.600	-14.830	-2545.000				
		SURFACE	-2362.393	-2319.224	-2406.727	-2255.649
		RESIDUAL	-182.606	-225.775	-138.272	-289.350
22.720	-11.150	-1431.000				
		SURFACE	-1996.936	-2227.644	-2081.351	-1872.206
		RESIDUAL	565.936	796.644	650.351	441.206
20.400	-21.820	-3022.000				
		SURFACE	-2352.935	-2805.622	-2992.263	-3227.348
		RESIDUAL	-669.064	-216.377	-29.736	205.348
1.150	-25.850	-1923.000				
		SURFACE	-2965.819	-3380.429	-2643.125	-2073.015
		RESIDUAL	1042.819	1457.429	720.125	150.015
26.490	-6.430	-2431.000				
		SURFACE	-1768.014	-2290.113	-2045.561	-2316.438
		RESIDUAL	-662.985	-140.886	-385.438	-114.561
45.900	-13.250	-638.000				
		SURFACE	-1451.539	-723.074	-405.635	-548.977
		RESIDUAL	813.539	85.074	-232.364	-89.023
.850	-4.200	-1803.000				
		SURFACE	-2373.864	-1343.678	-1730.870	-1986.040
		RESIDUAL	570.864	-459.321	-72.129	183.040
10.500	-5.500	-1907.000				
		SURFACE	-2158.606	-2034.577	-1878.058	-1739.321
		RESIDUAL	251.606	127.577	-28.941	-167.678
51.200	-25.010	134.000				
		SURFACE	-1639.321	45.590	249.819	108.708
		RESIDUAL	1773.321	88.409	-115.819	25.292

COEFFICIENTS OF LINEAR EQUATION

$$Z = -2279.6456000 + 26.0385320 X + 27.7028460 Y$$

COEFFICIENT OF QUADRATIC EQUATION

$$Z = -1321.7799000 + 2.0097406 X^2 - 108.5919600 X - 2.7505044 XY - 31.9564550 Y - 4.2564670 Y^2$$

COEFFICIENT OF CUBIC EQUATION

$$Z = -1642.9889000 + 1.9221719 X^2 + .0315090 X^3 - 13.5383300 X - 4.1182501 XY - .1042092 X^2Y - .1845793 Y - 5.5286453 Y^2 - .2423811 XY^2 - .1607853 Y^3$$

COEFFICIENT OF 4TH ORDER EQUATION

$$Z = -1854.9382000 + 9.3042420 X^2 + .1497681 X^3 + 3.2379154 Y^3 + .0078628 X^2Y^2 + 129.6346700 X + 11.1533530 XY - .4846042 X^2Y + .0269931 XY^3 + 166.2485500 Y + 40.2986040 Y^2 + .6243866 XY^2 + .0085549 X^3Y + .0745968 Y^4$$

ERROR MEASURES

SURFACE	LINEAR	QUADRATIC	CUBIC	4TH
STANDARD DEVIATION	705.266490	462.898670	380.659250	284.937930
VARIATION EXPLAINED BY SURFACE	.829044E 07	.224467E 08	.259154E 08	.291010E 08
VARIATION NOT EXPLAINED BY SURFACE	.248700E 08	.107137E 08	.724507E 07	.405948E 07
TOTAL VARIATION	.331604E 08			
COEFFICIENT OF DETERMINATION	.250009	.676911	.781514	.877580
COEFFICIENT OF CORRELATION	.500009	.822746	.884033	.936792

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN II trend-surface program with unrestricted input for the IBM 1620 computer

Computer: IBM 1620

Date: January 27, 1966

Programming language: FORTRAN II

Author, organization: Robert J. Sampson, Computer Center, Idaho State University, Pocatello, Idaho and

John C. Davis, Department of Geology, Idaho State University, Pocatello, Idaho

Direct inquiries to: Authors or

Name: D. F. Merriam

Address: Kansas Geological Survey

Univ. of Kansas, Lawrence, Kansas

Purpose/description: Program computes first-, second-, third-, and fourth- degree trend-surface and residual values for any number of data points.

Mathematical method: Surfaces are fitted by the least-squares criterion. Equations are solved by the Gauss-Jordan method of approximations.

Restrictions, range: Program is limited to surfaces of the fourth degree or smaller. There are no restrictions on the number of data points used.

Storage requirements: Program and data occupy approximately 18K bits of the memory space of a 20K IBM 1620.

Equipment specifications:

Memory 20K 40K 60K K

Automatic divide: Yes No Indirect addressing: Yes No

Other special features required Modified PDQ FORTRAN Compiler

Additional remarks (include at author's discretion: fixed/float, relocatability; optional: running time, approximate number of times run successfully, programming hours) 100 data points require approximately 24 minutes.

COMPUTER CONTRIBUTIONS
 Kansas Geological Survey
 University of Kansas
 Lawrence, Kansas

Special Distribution Publication

3.	BALGOL program for trend-surface mapping using an IBM 7090 computer, by J. W. Harbaugh, 1963	\$0.50
4.	FORTTRAN 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.	FORTTRAN 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
13.	FORTTRAN program for factor and vector analysis of geologic data using an IBM 7090 or 7094/1401 computer system, by Vincent Manson and John Imbrie, 1964	\$0.50
14.	FORTTRAN II trend-surface program for the IBM 1620, by D. I. Good, 1964	\$0.50
15.	Application of factor analysis to petrologic variations of Americus Limestone (Lower Permian), Kansas and Oklahoma, by J. W. Harbaugh and Ferruh Demirmen, 1964	\$0.50
23.	ALGOL program for cross-association of nonnumeric sequences using a medium-size computer, by M. J. Sackin, P. H. A. Sneath, and D. F. Merriam, 1965	\$0.50
24.	BALGOL program and geologic application for single and double Fourier series using IBM 7090/7094 computers, by F. W. Preston and J. W. Harbaugh, 1965	\$0.75
26.	FORTTRAN II trend-surface program with unrestricted input for the IBM 1620 computer, by R. J. Sampson and J. C. Davis, 1966	\$0.25

Report of Studies

170-3	Mathematical conversion of section, township, and range notation to Cartesian Coordinates, by D. I. Good, 1964	\$0.25
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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	\$0.75
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Reprints (available for limited time)

Use of asymmetric frequency distribution curves of core analysis data in calculating oil reserves, by F. W. Preston and J. S. Van Scoyoc (reprinted from <u>Stanford University Publications, Geological Sciences</u> , v. 9, no. 2, 1964)	no charge
Pattern recognition studies of geologic structure using trend-surface analysis, by D. F. Merriam and R. H. Lippert (reprinted from <u>Colorado School Mines Quarterly</u> , v. 59, no. 4, 1964)	no charge
Trend-surface mapping of hydrodynamic oil traps with the IBM 7090/7094 computer, by J. W. Harbaugh (reprinted from <u>Colorado School Mines Quarterly</u> , v. 59, no. 4, 1964)	no charge
Fourier series analysis in geology, by J. W. Harbaugh and F. W. Preston (reprinted from <u>College of Mines, Arizona University</u> , v. 1, 1965)	no charge
Geology and the computer, by D. F. Merriam (reprinted from <u>New Scientist</u> , v. 26, no. 444, 1965)	no charge
Application of factor analysis to the Upper Cambrian Reagan Sandstone of central and northwest Kansas, by M. N. McElroy and R. L. Kaesler (reprinted from <u>The Compass</u> , v. 42, no. 3, p. 188-201, 1965)	no charge

