



By
Donald I. Good

SPECIAL DISTRIBUTION PUBLICATION 14

STRUCTURE TOP OGALLALA FORMATION (PLIOCENE) IN KANSAS - CI = 500 FEET

CONTOURED CUBIC SURFACE

PLOTTING LIMITS

```

MAXIMUM X =      24.000000    MINIMUM X =      0.000000
MAXIMUM Y =      0.000000    MINIMUM Y =     -21.000000

```

X-SCALE IS HORIZONTAL

$$X\text{-VALUE} = 0.00 + .3157 \times (\text{SCALE VALUE})$$

Y-SCALE IS VERTICAL

CONTOUR INTERVAL = 500.00
REFERENCE CONTOUR (.....) = 2500.00

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

```

0.00 000000
-0.52 000000
-1.05 00000000
-1.57 00000000
-2.10 00000000
-2.63 00000000
-3.15 000000000
-3.68 000000000
-4.21 000000000
-4.73 000000000
-5.26 000000000
-5.78 0000000000
-6.31 0000000000
-6.84 0000000000
-7.36 0000000000
-7.89 0000000000
-8.42 0000000000
-8.94 0000000000
-9.47 0000000000
-9.99 0000000000
-10.52 00000000
-11.05 000000000
-11.57 000000000
-12.10 000000000
-12.63 000000000
-13.15 00000000
-13.68 0000000
-14.21 00000000
-14.73 0000000
-15.26 0000000
-15.78 000000
-16.31 000000
-16.84 000000
-17.36 00000
-17.89 00000
-18.42 000
-18.94 00
-19.47 00
-19.99 0
-20.52 0
-21.05

```

[illegible]

123456789 123456789 123456789 123456789

State Geological Survey
The University of Kansas, Lawrence
1964



KANSAS GEOLOGICAL SURVEY COMPUTER CONTRIBUTIONS

Special Distribution Publication

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

Report of Studies

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

Bulletin

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

Reprints (available for limited time)

- Computer helps map oil structures, by D.F. Merriam and J. W. Harbaugh (reprinted from The Oil and Gas Journal, v. 61, no. 47, 1963) no charge
- Use of trend-surface residuals in interpreting geologic structures, by D.F. Merriam (reprinted from Stanford University Publications, Geological Sciences, v. 9, no. 2, 1964) no charge
- 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 Stanford University Publications, Geological Sciences, v. 9, no. 2, 1964) no charge

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FORTRAN II TREND-SURFACE PROGRAM
FOR THE IBM 1620

by

Donald I. Good

INTRODUCTION

The main objective of this FORTRAN II program is the fitting of first-, second-, and third-degree polynomial surfaces (trend surfaces) to a set of xyz-coordinate values. These polynomials are of the form $z = f(x,y)$. No operations are performed on the xyz-coordinates before the surfaces are fitted. The output of the program gives (1) the equations of the polynomials, (2) measures of the goodness of fit of the surfaces, (3) a table of the values of the surfaces evaluated at each xy-coordinate and the corresponding residuals, (4) contour maps of the trend surfaces, and (5) plots on the xy-plane of the z-coordinates and each order of residual.

The program originally was intended to be a translation into FORTRAN II of a trend-surface program written in BALGOL by Harbaugh (1963). Because the BALGOL program was written for an IBM 7090 computer and the FORTRAN II program was to be used on an IBM 1620 computer, it became obvious after some attempts at translation that almost a completely new program would have to be written in FORTRAN II for the IBM 1620. However, the FORTRAN II program was modeled after Harbaugh's BALGOL program and hence, there are several similarities between the output of the two programs.

Because this paper is mainly a program documentation, no discussion is included on the use of trend surfaces by geologists. For the reader who is not familiar with trend-surface analysis, several references can be recommended, (Forgotson, 1963; Harbaugh, 1963; Krumbein, 1956, 1959; Merriam, 1964; Merriam and Harbaugh, 1963, 1964; Miller, 1956; Whitten, 1959, 1961). From this point it is assumed that the reader is completely familiar with the mathematical methods of determining trend surfaces and their subsequent interpretation and use.

Card decks of the FORTRAN II source programs may be obtained, for a limited time from the Kansas Geological Survey for \$25.00.

Thanks are expressed to Dean A. Lebestky and Dr. Floyd W. Preston for assistance in the development of this program and to John R. Dempsey for use of his FORTRAN II subroutine, EMSLVR.

MATHEMATICAL DESCRIPTION

The program comprises a generalized first-, second-, and third-degree polynomial surface-fitting procedure. From an initial set of three-dimensional data (xyz-coordinates), any of the first-, second-, or third-degree polynomials can be determined that best fit the data according to the least-squares criterion of best fit. In calculation of the coefficients of these polynomials, x and y are independent variables and z is the dependent variable.

Linear equation

$$z = A_{1,1} + A_{1,2}x + A_{1,3}y$$

Quadric equation

$$z = A_{2,1} + A_{2,2}x + A_{2,3}y + A_{2,4}x^2 + A_{2,5}xy + A_{2,6}y^2$$

Cubic equation

$$z = A_{3,1} + A_{3,2}x + A_{3,3}y + A_{3,4}x^2 + A_{3,5}xy + A_{3,6}y^2 + A_{3,7}x^3 + A_{3,8}x^2y + A_{3,9}xy^2 + A_{3,10}y^3$$

The surfaces represented by these polynomials hereafter are referred to as linear, quadric, and cubic trend surfaces, respectively. The coefficients of the polynomials are calculated using the least-squares criterion of best fit. This method requires the solution of a system of not more than ten linear equations in ten unknowns. The system can be represented by a 10x11 matrix if the 11th column of the matrix is the constant column. This matrix can be generated numerically in a rather simple manner. First, the two matrices B and C, are multiplied algebraically:

Matrix B

1

x

y

x²

xy 1 x y x² xy y² x³ x²y xy² y³ z

y²

x³

x²y

xy²

y³

Matrix C

For instance, the first five diagonal elements of the resulting 10x11 matrix are

$$\begin{matrix} 1 & & & & \\ & x^2 & & & \\ & & y^2 & & \\ & & & x^4 & \\ & & & & x^2y^2 \end{matrix}$$

Second, each variable in each element of the 10x11 matrix is given a subscript, i, and the element placed within a summation operator that sums the numerical values of the algebraic quantities from 1 to N where N is the total number of data points. For example, if Σ is used as the operator that sums its subscripted operands from 1 to N, the element of the first row and first column of the 10x11 matrix is

$$\Sigma 1 = N,$$

the element of the first row and the second column is

$$\sum x_i,$$

and the element of the second row and the eleventh column is

$$\sum x_i z_i.$$

After the operator $\sum$ has operated on each element of the algebraic matrix, the resulting 10x11 matrix correctly represents the system of equations that must be solved to determine the coefficients of the equations of the polynomials. If coefficients of the equation of the linear surface are calculated, then twelve terms of the 10x11 matrix are used--the first three terms of the first row, first three terms of the second row, and first three terms of the third row. (This will be called the 3x3 form of the matrix.) Also the first three terms of the eleventh column are used as the constant column. If coefficients of the equation of the quadric surface are calculated, then the matrix is solved in its 6x6 form and the first six elements of column eleven are used as the constant column. If coefficients of the equation of the cubic surface are calculated, then the matrix is solved in its complete (10x10) form.

The necessary systems of equations are solved by the subroutine EMSLVR. This subroutine utilizes the Gauss elimination method with the additional feature that the coefficient matrix is diagonalized after the elimination of each variable. This feature is necessary to minimize round-off error. This is the extent of the mathematical determinations made by the program. The remainder of the program involves various forms of output.

DESCRIPTIONS OF FORTRAN II PROGRAMS

Because this trend-surface program is used on an IBM 1620, the problem of core space immediately becomes significant. To solve this problem the program actually is broken into three mainline programs. These three programs are related in such a way that only a minimum of intermediate output is required. Considerable communication among the programs is accomplished by use of related DIMENSION and COMMON statements and of identical precision (floating point, 8; fixed point, 4) in the three mainlines. For instance, the X, Y, and Z data arrays that are read into the first mainline (Part I) are used in the other mainlines (Parts II and III). In each of the three parts, X, Y, and Z are each dimensioned at 300 elements and then are listed in a COMMON statement, COMMON X,Y,Z. Using this procedure, the FORTRAN II compiler assigns the same core locations to the elements of the X, Y, and Z arrays in each of the three mainlines. This procedure minimizes the need for intermediate output since each consecutive mainline "knows" where these variables are stored in each preceding mainline. (In the case of the X, Y, and Z arrays, however, it is also necessary to write these arrays on magnetic tape as intermediate output. These arrays are cited here merely to exemplify the method of communication among the three mainlines.)

Part I

Part I consists of four major components: (1) the xyz-coordinate data for the program are read into the computer; (2) the necessary coefficient matrices are calculated; (3) the coefficient matrices are solved in their specified forms; and (4) the largest coefficient matrix necessary is punched if punching is specified.

Part II

Part II consists of four main components: (1) each trend-surface value and residual value is calculated and punched for each xy-coordinate contained in the data set. The residual value is determined by subtracting the value of z calculated at the xy-coordinate from the observed z value; (2) the equations of the surfaces are punched (the equations of the surfaces are not punched until this time as a paper saving maneuver); (3) the error measures of the trend surfaces are calculated and punched; and (4) the trend surfaces are contoured with respect to distance above the xy-plane.

Part III

In Part III the original data (z -coordinates) and the first-, second-, and third-order residuals are plotted on the xy-plane.

Necessary FORTRAN II Subprograms

Each of the three mainline programs requires several FORTRAN II subprograms. These subprograms which are listed below are not described but are included in the program listings.

Part I

RANGE, EMSLVR.

Part II

ZL, ZQ, ZC, IREF, RANGE, ORDR3A, CONTUR.

Part III

ICALC, RANGE, PLOT3, ORDER3.

Listings of Mainline Programs and Subprograms

The following are the FORTRAN II source programs and all subprograms that are necessary for the complete trend-surface program. On none of these programs is the precision of the machine specified. The Alberta FORTRAN II compiler used at The University of Kansas requires a different method of specification of precision than does the IBM FORTRAN II compiler. For this reason the cards that control the precision are omitted from the source decks printed here. Before compilation of the source decks, however, this control must be present such that a mantissa of eight digits is used in all floating point calculations and four digits are used in all fixed point calculations. If it is desired to alter the precision from eight floating point figures and four fixed point figures, the floating point precision may be varied by changing the precision parameter. The varying of the fixed point precision not only requires variation of the fixed point precision parameter, but also requires alteration of most of the source statements listed in the section "Modifications for Machines other than the 1620." If the precision is changed, it must be the same for all three programs.

The card identification columns (73-80) of the FORTRAN statement cards are coded as follows:

Column 73 contains the part number 1, 2, or 3. For instance, Part I and all its necessary subroutines contain a 1 in column 73.

Column 74 contains the segment number of each mainline or subprogram within a given part.
The mainline contains a 1 in column 74 and all other necessary subprograms are numbered sequentially in the order in which they are called by the mainline.

Columns 78, 79, and 80 contain the card number of each mainline or subprogram. The cards for each mainline or subprogram are numbered sequentially beginning with one.

Object decks of these programs as compiled by the University of Alberta FORTRAN II compiler are available on the systems tape of the Kansas Geological Survey. This tape is labeled "Kansas Geological Survey Tape II"; it is available to all users of the Kansas University Computation Center through the closed shop system. The procedure for calling these programs from this tape is described later under Input Data Preparation.

C	PROGRAM - TREND SURFACE PART I	
C	LANGUAGE - FORTRAN II	11000001
C	COMPUTER - IBM 1620 60K CORE	11000002
C	PRECISION - DECIMAL 08, INTEGER 04	11000003
C	PROGRAMMER - DONALD I GOOD	11000004
C	DATE COMPLETED - APRIL 1964	11000005
C	FOR DOCUMENTATION SEE KANSAS GEOLOGICAL SURVEY SPECIAL	11000006
C	DISTRIBUTION PUBLICATION 14	11000007
C		11000008
C		11000009
	DIMENSION X(300), Y(300), Z(300), ID(40), A(10,3), MTD(4), U(10),	11000010
	1 T(10,11), TW(10,11)	11000011
	COMMON X, Y, Z, I, ID, N, A, MTD, SUMZ, FN, T, TW	11000012
	EQUIVALENCE (MTD(1), M5), (MTD(2), M6), (MTD(3), M7)	11000013
	EQUIVALENCE (MTD(4), M4)	11000014
C		11000015
	3 DO 4 I=1,3,1	11000016
	DO 4 J=1,10,1	11000017
	4 A(J,I)=0.0	11000018
	DO 5 I = 1,40,1	11000019
	5 ID(I) = 0	11000020
C	-----	11000021
C	READ IN DATA PARAMETERS	11000022
C	-----	11000023
	READ 20, (ID(I), I = 1,40,1)	11000024
	20 FORMAT (1X, 39A2, A1)	11000025
	READ 95, N, (MTD(I), I = 1,4,1)	11000026
	95 FORMAT (1X, I3, 1X, 4I1)	11000027
C	-----	11000028
C	CHECK DATA PARAMETERS	11000029
C	-----	11000030
	NERR = 0	11000031
	CALL RANGE(1,300,N,NKR)	11000032
	KAW=1	11000033
	IF(NKR) 600, 600, 700	11000034
C		11000035
	600 CALL RANGE(0,1,M5,NKR)	11000036
	KAW=2	11000037
	IF(NKR) 605, 605, 700	11000038
C		11000039
	605 CALL RANGE(0,1,M6,NKR)	11000040
	KAW=3	11000041
	IF(NKR) 610, 610, 700	11000042
		11000043

C	610 CALL RANGE(0,1,M7,NKR)	11000044
	KAW=4	11000045
	IF(NKR) 615, 615, 700	11000046
C	615 CALL RANGE(0,1,M4,NKR)	11000047
	KAW=5	11000048
	IF(NKR) 620, 620, 700	11000049
C	620 IA = MTD(1) + MTD(2) + MTD(3)	11000050
	KAW=6	11000051
	IF (IA) 700, 700, 710	11000052
C	700 PUNCH 705, KAW	11000053
	705 FORMAT (1X, 13HPROGRAM ERROR I3)	11000054
	NERR = 1	11000055
	GO TO (600,605,610,615,620,706),KAW	11000056
C	710 IF(NERR) 100, 100, 706	11000057
	706 TYPE 707	11000058
	707 FORMAT(12HINVALID DATA)	11000059
	PAUSE	11000060
	GO TO 3	11000061
C	-----	11000062
C	READ IN XYZ-COORDINATES	11000063
C	-----	11000064
	100 READ 105, (X(I), Y(I), Z(I), I = 1,N,1)	11000065
	105 FORMAT (11X, 3F15.6)	11000066
C	-----	11000067
C	CALCULATE COEFFICIENT MATRIX AND COLUMN VECTOR	11000068
C	-----	11000069
	I = 4	11000070
	107 I = I - 1	11000071
	IF(MTD(I) - 1) 107, 108, 108	11000072
	108 L = I	11000073
C	-----	11000074
C	SELECT ORDER OF LARGEST COEFFICIENT MATRIX TO BE GENERATED	11000075
C	-----	11000076
	GO TO (121, 122, 123), L	11000077
	121 MM = 3	11000078
	GO TO 124	11000079
	122 MM = 6	11000080
	GO TO 124	11000081
	123 MM = 10	11000082
	124 MM1 = MM + 1	11000083
C	-----	11000084
C	ZERO COEFFICIENT MATRIX AND COLUMN VECTOR	11000085
C	-----	11000086
	DO 10 I = 1,MM,1	11000087
	DO 10 J = 1,MM1,1	11000088
	10 T(I,J) = 0.0	11000089
C	-----	11000090
C	CALCULATE COLUMN VECTOR AND UNIQUE TERMS OF COEFFICIENT MATRIX	11000091
C	BELOW MAIN DIAGONAL	11000092
C	-----	11000093
	DO 185 I = 1,N,1	11000094
	U(1) = 1.	11000095
	U(2) = X(I)	11000096
	U(3) = Y(I)	11000097
C	-----	11000098
	IF (L - 2) 117, 115, 115	11000099
	115 U(4) = X(I) * X(I)	11000100
	U(5) = X(I) * Y(I)	11000101
	U(6) = Y(I) * Y(I)	11000102
C	-----	11000103
	IF (L - 3) 117, 116, 116	11000104
	116 U(7) = U(4) * X(I)	11000105
	U(8) = U(4) * Y(I)	11000106
	U(9) = X(I) * U(6)	11000107
	U(10) = U(6) * Y(I)	11000108
C	-----	11000109
	DO 185 J = 1,MM,1	11000110
	T(J,MM1) = T(J,MM1) + U(J) * Z(I)	11000111
C	-----	11000112
	GO TO (720, 730, 750), L	11000113
		11000114
		11000115
		11000116
		11000117
		11000118

720	IA = J	11000119
	GO TO 180	11000120
C		11000121
730	GO TO (110, 735, 740, 735, 735, 740), J	11000122
C		11000123
750	GO TO (110, 120, 130, 120, 130, 130, 120, 130, 130, 130), J	11000124
110	IA = 1	11000125
	GO TO 180	11000126
735	IA = 4	11000127
	GO TO 180	11000128
740	IA = 6	11000129
	GO TO 180	11000130
120	IA = 7	11000131
	GO TO 180	11000132
130	IA = 10	11000133
C		11000134
180	DO 185 K = IA,MM,1	11000135
185	T(K,J) = T(K,J) + U(J) * U(K)	11000136
C		11000137
C	GENERATE REMAINDER OF TERMS OF COEFFICIENT MATRIX BFLOW	11000138
C	MAIN DIAGONAL	11000139
C		11000140
	GO TO (209, 186, 187),L	11000141
C		11000142
186	T(3,3) = T(6,1)	11000143
	T(4,3) = T(5,2)	11000144
	T(5,3) = T(6,2)	11000145
	T(5,5) = T(6,4)	11000146
	GO TO 188	11000147
C		11000148
187	T(4,2) = T(7,1)	11000149
	T(5,2) = T(8,1)	11000150
	T(6,2) = T(9,1)	11000151
	T(3,3) = T(6,1)	11000152
	T(4,3) = T(8,1)	11000153
	T(5,3) = T(9,1)	11000154
	T(6,3) = T(10,1)	11000155
	T(7,3) = T(8,2)	11000156
	T(8,3) = T(9,2)	11000157
	T(9,3) = T(10,2)	11000158
	T(4,4) = T(7,2)	11000159
	T(5,4) = T(8,2)	11000160
	T(6,4) = T(9,2)	11000161
	T(5,5) = T(9,2)	11000162
	T(6,5) = T(10,2)	11000163
	T(7,5) = T(8,4)	11000164
	T(8,5) = T(9,4)	11000165
	T(9,5) = T(10,4)	11000166
	T(6,6) = T(10,3)	11000167
	T(7,6) = T(9,4)	11000168
	T(8,6) = T(10,4)	11000169
	T(8,8) = T(9,7)	11000170
	T(9,6) = T(10,5)	11000171
	T(9,8) = T(10,7)	11000172
	T(9,9) = T(10,8)	11000173
C		11000174
188	T(2,2) = T(4,1)	11000175
	T(3,2) = T(5,1)	11000176
C		11000177
C	GENERATE TERMS OF COEFFICIENT MATRIX ABOVE MAIN DIAGONAL	11000178
C		11000179
209	DO 216 J = 1,MM,1	11000180
	DO 216 K = 1,MM,1	11000181
	IF (J - K) 210, 216, 216	11000182
210	T(J,K) = T(K,J)	11000183
216	CONTINUE	11000184
C		11000185
C	SET UP TERMS NECESSARY FOR TREND SURFACE PART II	11000186
C		11000187
	SUMZ=T(1,MM,1)	11000188
	FN=T(1,1)	11000189
C	-----	11000190
C	SOLVE MATRICES	11000191
C	-----	11000192
	IP = 0	11000193
217	IP = IP + 1	11000194

IF (IP - L) 261, 261, 584	11000195
C	11000196
C IF MTD(IP) = 1, THE MATRIX FOR THE COEFFICIENTS OF THE IPTH DEGREE	11000197
C POLYNOMIAL IS SOLVED	11000198
C	11000199
261 IF (MTD(IP)) 217, 217, 218	11000200
C	11000201
218 GO TO (219,220,221),IP	11000202
219 M=3	11000203
GO TO 234	11000204
220 M=6	11000205
GO TO 234	11000206
221 M=10	11000207
234 M1=M+1	11000208
DO 250 J = 1,M,1	11000209
TW(J,M1) = T(J,MM1)	11000210
DO 250 K = 1,M,1	11000211
250 TW(J,K) = T(J,K)	11000212
C	11000213
CALL EMSLVR(TW,U,1,M,0,MAT)	11000214
C	11000215
MTD(IP) = MTD(IP) + MAT	11000216
IF (MAT) 217, 217, 259	11000217
259 DO 260 J = 1,M,1	11000218
260 A(J,IP) = U(J)	11000219
GO TO 217	11000220
C	11000221
C PUNCH COEFFICIENT MATRIX AND COLUMN VECTOR	11000222
C	11000223
584 IF (M4) 580,580,534	11000224
534 PUNCH 317, (ID(I), I = 1,40,1)	11000225
317 FORMAT (1H1 39A2, A1)	11000226
PUNCH 541	11000227
541 FORMAT (1H0 18HCOEFFICIENT MATRIX)	11000228
DO 550 I = 1,MM,1	11000229
550 PUNCH 555, (T(I,J), J = 1,MM,1)	11000230
555 FORMAT (1H0 E11.4, 5(1X, E11.4) / 1H9 23X, 4(1X, E11.4))	11000231
PUNCH 566	11000232
566 FORMAT (1H0 13HCOLUMN VECTOR)	11000233
PUNCH 555, (T(I,MM1), I = 1,MM,1)	11000234
580 CONTINUE	11000235
END	11000236
SUBROUTINE RANGE(LL,LU,N,NER)	12000001
C	12000002
C RANGE DETERMINES WHETHER OR NOT N FALLS IN THE CLOSED	12000003
C INTERVAL (LL,LU)	12000004
C	12000005
NER = 0	12000006
IF (LL - N) 5, 15, 10	12000007
5 IF (LU - N) 10, 15, 15	12000008
10 NER = 1	12000009
15 RETURN	12000010
END	12000011
SUBROUTINE EMSLVR(A,COE,MORDER,N,MTPQ,NPQ)	13000001
C	13000002
C EMSLVR WRITTEN ORIGINALLY BY JOHN DEMPSEY TO SOLVE UP TO A 20X21	13000003
C MATRIX. CONSTANT COLUMN IS ASSUMED TO BE THE LAST COLUMN OF THE	13000004
C MATRIX	13000005
C N = ORDER OF MATRIX	13000006
C COE = VARIABLES TO BE SOLVED FOR	13000007
C MATRIX IS ORDERED AFTER THE ELIMINATION OF EACH VARIABLE IF	13000008
C MORDER = 1	13000009
C	13000010
C SUBROUTINE MODIFIED BY DON GOOD FOR CHECKING OF ARGUMENTS AND	13000011
C REDUCING MAXIMUM MATRIX SIZE TO 10X11	13000012
C	13000013
C	13000014
C DIMENSION A(10,11),IC(10),COE(10),ACOE(10)	13000015
C	13000016
C CHECK ARGUMENTS FOR VALIDITY	13000017
C	13000018

NPQ=1	13000019
CALL RANGE(0,1,MORDER,KER)	13000020
KAR=1	13000021
IF(KER)23,23,25	13000022
23 CALL RANGE(0,1,MTPO,KER)	13000023
KAR=2	13000024
IF(KER)24,24,25	13000025
24 CALL RANGE(1,10,N,KER)	13000026
KAR=3	13000027
IF(KER)27,27,25	13000028
25 PUNCH 26,KAR	13000029
26 FORMAT(1X, 23HSUBROUTINE EMSLVR ERROR 12)	13000030
NPQ=-1	13000031
GO TO (23,24,1601),KAR	13000032
C	13000033
27 IF(NPQ) 1601, 12, 12	13000034
C	13000035
12 NM=N	13000036
NN=0	13000037
KK=0	13000038
MM=0	13000039
NP1=N+1	13000040
NM1=N-1	13000041
DO 3 J=1,N	13000042
3 A(J,NP1)=-A(J,NP1)	13000043
IF(MORDER)799,75,799	13000044
C	13000045
MATRIX ORDERING ROUTINE	13000046
C	13000047
799 DO 800 J = 1,10	13000048
800 IC(J)=J	13000049
KKK=0	13000050
999 KKK=KKK+1	13000051
AB=ABSF(A(KKK,KKK))	13000052
IBIG=KKK	13000053
JBIG=KKK	13000054
DO 901 I=KKK,N	13000055
DO 901 J=KKK,N	13000056
IF(AB-ABSF(A(I,J)))900,901,901	13000057
900 AB=ABSF(A(I,J))	13000058
IBIG=I	13000059
JBIG=J	13000060
901 CONTINUE	13000061
910 DO 920 I=1, NP1	13000062
AX=A(KKK,I)	13000063
A(KKK,I)=A(IBIG,I)	13000064
920 A(IBIG,I)=AX	13000065
DO 930 J=1,N	13000066
AY=A(J,KKK)	13000067
A(J,KKK)=A(J,JBIG)	13000068
930 A(J,JBIG)=AY	13000069
IF(KKK-1)940,940,950	13000070
940 K1=JBIG	13000071
DUM=IC(KKK)	13000072
IC(KKK)=IC(JBIG)	13000073
IC(JBIG)=DUM	13000074
IF(NM1-1)71,71,999	13000075
950 IF(KKK-2)951,951,960	13000076
951 K2=JBIG	13000077
DUM=IC(KKK)	13000078
IC(KKK)=IC(JBIG)	13000079
IC(JBIG)=DUM	13000080
IF(NM1-2)71,71,999	13000081
960 IF(KKK-3)961,961,970	13000082
961 K3=JBIG	13000083
DUM=IC(KKK)	13000084
IC(KKK)=IC(JBIG)	13000085
IC(JBIG)=DUM	13000086
IF(NM1-3)71,71,999	13000087
970 IF(KKK-4)971,971,980	13000088
971 K4=JBIG	13000089
DUM=IC(KKK)	13000090
IC(KKK)=IC(JBIG)	13000091
IC(JBIG)=DUM	13000092
IF(NM1-4)71,71,999	13000093
980 IF(KKK-5)981,981,990	13000094

981	K5=JBIG	13000095
	DUM=IC(KKK)	13000096
	IC(KKK)=IC(JBIG)	13000097
	IC(JBIG)=DUM	13000098
	IF(NM1-5)71,71,999	13000099
990	IF(KKK-6)991,991,1000	13000100
991	K6=JBIG	13000101
	DUM=IC(KKK)	13000102
	IC(KKK)=IC(JBIG)	13000103
	IC(JBIG)=DUM	13000104
	IF(NM1-6)71,71,999	13000105
1000	IF(KKK-7)1001,1001,1003	13000106
1001	K7=JBIG	13000107
	DUM=IC(KKK)	13000108
	IC(KKK)=IC(JBIG)	13000109
	IC(JBIG)=DUM	13000110
	IF(NM1-7)71,71,999	13000111
1003	IF(KKK-8)1004,1004,602	13000112
1004	K8=JBIG	13000113
	DUM=IC(KKK)	13000114
	IC(KKK)=IC(JBIG)	13000115
	IC(JBIG)=DUM	13000116
	IF(NM1-8)71,71,999	13000117
602	IF(KKK-9)603, 603, 612	13000118
603	K9=JBIG	13000119
	DUM=IC(KKK)	13000120
	IC(KKK)=IC(JBIG)	13000121
	IC(JBIG)=DUM	13000122
	IF(NM1-9)71,71,999	13000123
612	K10=JBIG	13000124
	DUM=IC(KKK)	13000125
	IC(KKK)=IC(JBIG)	13000126
	IC(JBIG)=DUM	13000127
71	CONTINUE	13000128
C	-----	13000129
C	MATRIX SOLUTION ROUTINE	13000130
C	-----	13000131
75	NN=NN+1	13000132
	NNN=NN+1	13000133
	MM=MM+1	13000134
	DO 80 I=NN,N	13000135
	DO 80 J=NNN,NP1	13000136
	A(I,J)=A(I,J)/A(I,NN)	13000137
80	CONTINUE	13000138
	KK=KK+1	13000139
	IF(KK-NM1)85,85,100	13000140
85	DO 90 I=NNN,N	13000141
	DO 90 J=NNN,NP1	13000142
	A(I,J)=A(I,J)-A(NN,J)	13000143
90	CONTINUE	13000144
	IF(MORDER)91,75,91	13000145
91	IF(KK-NM1+1)92,92,75	13000146
92	KKK=MM	13000147
	GO TO 999	13000148
100	COE(NP1)=1.0	13000149
	DO 110 K=1,NM	13000150
	SUM=0.0	13000151
	J=NP1-K	13000152
	L=J+1	13000153
	DO 109 I=L,NP1	13000154
109	SUM=SUM-A(J,I)*COE(I)	13000155
110	COE(J)=SUM	13000156
	IF(MORDER)1500,1500,500	13000157
500	CONTINUE	13000158
	K1=IC(1)	13000159
	K2=IC(2)	13000160
	K3=IC(3)	13000161
	K4=IC(4)	13000162
	K5=IC(5)	13000163
	K6=IC(6)	13000164
	K7=IC(7)	13000165
	K8=IC(8)	13000166
	K9=IC(9)	13000167
	K10=IC(10)	13000168
	DO 1005 J=1,10	13000169
1005	ACOE(J)=COE(J)	13000170

COE(K1)=ACOE(1)	13000171
COE(K2)=ACOE(2)	13000172
COE(K3)=ACOE(3)	13000173
COE(K4)=ACOE(4)	13000174
COE(K5)=ACOE(5)	13000175
COE(K6)=ACOE(6)	13000176
COE(K7)=ACOE(7)	13000177
COE(K8)=ACOE(8)	13000178
COE(K9)=ACOE(9)	13000179
COE(K10)=ACOE(10)	13000180
1500 CONTINUE	13000181
IF(MTPO)1500,1600,1400	13000182
1400 CONTINUE	13000183
PUNCH 2	13000184
DO 1600 J=1,NM	13000185
PUNCH 1,COE(J),J,IC(J)	13000186
1600 CONTINUE	13000187
1601 RETURN	13000188
1 FORMAT(1H E15.6,2I8)	13000189
2 FORMAT(1H141H VARIABLE	13000190
END	13000191
C PROGRAM - TREND SURFACE PART II	21000001
C LANGUAGE - FORTRAN II	21000002
C COMPUTER - IBM 1620 60K CORE	21000003
C PRECISION - DECIMAL 08, INTEGER 04	21000004
C PROGRAMMER - DONALD I GOOD	21000005
C DATE COMPLETED - APRIL 1964	21000006
C FOR DOCUMENTATION SEE KANSAS GEOLOGICAL SURVEY SPECIAL	21000007
C DISTRIBUTION PUBLICATION 14	21000008
C	21000009
C	21000010
DIMENSION X(300), Y(300), Z(300), ID(40), A(10,3),MTD(4),	21000011
1 IREFU(11), IREFL(26), RL(300), RQ(300), RC(300), VAR(3),	21000012
2SQ(3),TVAR(3), SD(3), DET(3), COR(3), IND(300)	21000013
COMMON X, Y, Z, IDI, ID, N, A, MTD, SUMZ, FN, XMAX, XMIN, YMAX,	21000014
1 YMIN, IPLOT	21000015
EQUIVALENCE (X,RL), (Y,RQ), (Z,RC), (IDI, IND)	21000016
C -----	21000017
C DETERMINE MAXIMUM AND MINIMUM VALUES OF X AND Y ARRAYS	21000018
C -----	21000019
XMAX = X(1)	21000020
XMIN = X(1)	21000021
YMAX = Y(1)	21000022
YMIN = Y(1)	21000023
C	21000024
DO 870 I=2,N,1	21000025
IF(XMAX-X(I))835,840,840	21000026
835 XMAX = X(I)	21000027
840 IF (XMIN - X(I))850,850,845	21000028
845 XMIN = X(I)	21000029
850 IF (YMAX - Y(I))855,860,860	21000030
855 YMAX = Y(I)	21000031
860 IF (YMIN - Y(I))870,870,865	21000032
865 YMIN = Y(I)	21000033
870 CONTINUE	21000034
C -----	21000035
C WRITE DATA ARRAYS ON INTERMEDIATE TAPES 1 AND 2	21000036
C -----	21000037
REWIND 1	21000038
WRITE TAPE 1, X, Y	21000039
REWIND 2	21000040
WRITE TAPE 2, Z	21000041
C -----	21000042
C CALCULATE AND PUNCH TREND SURFACE Z-VALUES, RESIDUALS, AND	21000043
C ERROR TERMS	21000044
C -----	21000045
DO 321 I=1,3,1	21000046
321 SQ(I)=0.0	21000047
ZSQ=0.0	21000048

C	316 PUNCH 317, (ID(I), I=1,40,1)	21000049
	317 FORMAT (1H1 39A2, A1)	21000050
	PUNCH 319	21000051
	319 FORMAT (1H0 11H X-COORD 12H Y-COORD 12H Z-COORD	21000052
	112H LN-SURF 12H LN-RESD 12H QD-SURF / 1H9 23X,	21000053
	212H QD-RESD 12H CB-SURF 12H CB-RESD)	21000054
C		21000055
	DO 465 I = 1,N,1	21000056
C		21000057
	XT = X(I)	21000058
	YT = Y(I)	21000059
	ZT = Z(I)	21000060
C		21000061
	Z1=ZL(A,X(I),Y(I),MTD(1))	21000062
	Z2=ZQ(A,X(I),Y(I),MTD(2))	21000063
	Z3=ZC(A,X(I),Y(I),MTD(3))	21000064
C		21000065
	IF (MTD(1)) 334, 334, 330	21000066
330	RL(I)=Z(I)-Z1	21000067
	GO TO 335	21000068
334	RL(I) = 0.0	21000069
335	IF (MTD(2)) 349, 349, 345	21000070
345	RQ(I)=Z(I)-Z2	21000071
	GO TO 350	21000072
349	RQ(I) = 0.0	21000073
350	IF (MTD(3)) 364, 364, 360	21000074
360	RC(I)=Z(I)-Z3	21000075
	GO TO 365	21000076
364	RC(I) = 0.0	21000077
C		21000078
	365 SQ(1)=SQ(1)+RL(I)*RL(I)	21000079
	SQ(2)=SQ(2)+RQ(I)*RQ(I)	21000080
	SQ(3)=SQ(3)+RC(I)*RC(I)	21000081
	ZSQ = ZSQ + ZT * ZT	21000082
C		21000083
	465 PUNCH 470, XT, YT, ZT, Z1, RL(I), Z2, RQ(I), Z3, RC(I)	21000084
	470 FORMAT (1X, F11.3, 5F12.3 / 1H9 23X, 3F12.3)	21000085
C		21000086
	WRITE RESIDUAL ARRAYS ON INTERMEDIATE TAPE 2	21000087
C		21000088
	WRITE TAPE 2, RL, RQ, RC	21000089
C		21000090
	-----	21000091
C		21000092
	CALCULATE ERROR MEASURES	21000093
C		21000094
	TVARI=ZSQ-(SUMZ*SUMZ)/FN	21000095
	SN=N-1	21000096
	RSN=1./SN	21000097
C		21000098
	DO 520 I=1,3,1	21000099
	IF(MTD(I))500,500,480	21000100
C		21000101
	480 SD(I)=SQRTF(RSN*SQ(I))	21000102
	VAR(I)=TVARI-SQ(I)	21000103
	TVAR(I)=TVARI	21000104
	DET(I)=VAR(I)/TVARI	21000105
	IF(DET(I))485,490,490	21000106
C		21000107
	485 COR(I)=-SQRTF(-DET(I))	21000108
	GO TO 520	21000109
	490 COR(I)=SQRTF(DET(I))	21000110
	GO TO 520	21000111
C		21000112
	500 SD(I)=0.0	21000113
	VAR(I)=0.0	21000114
	TVAR(I)=0.0	21000115
	DET(I)=0.0	21000116
	COR(I)=0.0	21000117
C		21000118
	520 CONTINUE	21000119
C		21000120
	-----	21000121
C		21000122
	PUNCH 317, (ID(I), I = 1,40,1)	21000123
C		21000124
	IF(MTD(1))40,40,35	

35 PUNCH 585	21000125
585 FORMAT (1H0 31HCOEFFICIENTS OF LINEAR EQUATION)	21000126
PUNCH 595, (A(I,1),I = 1,3,1)	21000127
595 FORMAT (4H0Z = F15.5, 2H + F14.5, 4H X + F13.5, 2H Y)	21000128
C	21000129
40 IF(MTD(2))50,50,45	21000130
45 PUNCH 605	21000131
605 FORMAT (1H0 32HCOEFFICIENTS OF QUADRIC EQUATION)	21000132
PUNCH 615, (A(I,2),I = 1,6,1)	21000133
615 FORMAT (4H0Z = F15.5, 2H + F14.5, 4H X + F13.5, 4H Y + F13.5,	21000134
1 5H X2 + / F13.5, 5H XY + F13.5, 3H Y2)	21000135
C	21000136
50 IF(MTD(3))640,640,55	21000137
55 PUNCH 625	21000138
625 FORMAT (1H0 30HCOEFFICIENTS OF CUBIC EQUATION)	21000139
PUNCH 635, (A(I,3),I = 1,10,1)	21000140
635 FORMAT (4H0Z = F15.5, 2H + F14.5, 4H X + F13.5, 4H Y + F13.5,	21000141
1 5H X2 + / F13.5, 5H XY + F13.5, 5H Y2 + F13.5, 5H X3 + F13.5,	21000142
2 6H X2Y + / F13.5, 6H XY2 + F13.5, 3H Y3)	21000143
C	21000144
C PUNCH ERROR MEASURES	21000145
C	21000146
640 PUNCH 645, (SD(I),I=1,3,1),(VAR(I),I=1,3,1), (SQ(I),I=1,3)	21000147
645 FORMAT (1H5 29X, 14HERROR MEASURES / 1H0 7HSURFACE 31X, 6HLINEAR	21000148
18X, 7HQUADRIC 10X, 5HCUBIC / 1H0 18HSTANDARD DEVIATION 11X, 3F15.2	21000149
2/ 1H0 19HVARIATION EXPLAINED / 1X, 10HBY SURFACE 19X, 3E15.8 / 1H02	21000150
323HVARIATION NOT EXPLAINED / 1X,10HBY SURFACE 19X, 3E15.8)	21000151
C	21000152
PUNCH 655,(TVAR(I),I=1,3),(DET(I),I=1,3),(COR(I),I=1,3)	21000153
655 FORMAT (1H0 15HTOTAL VARIATION 14X, 3E15.8 / 1H0 14HCOEFFICIENT OF	21000154
1/ 1X, 13HDETERMINATION 16X, 3F15.8 / 1H0 14HCOEFFICIENT OF / 1X,	21000155
211HCCORRELATION 18X, 3F15.8)	21000156
C	21000157
C GENERATE CHARACTERS FOR SUBROUTINE CONTUR	21000158
C	21000159
CALL IREF (IREFU, IREFL)	21000160
C	21000161
C READ IN NUMBER OF CONTOUR MAPS AND RESIDUAL INDICATOR	21000162
C	21000163
IK=0	21000164
116 READ 117, NUMB, IPLOT	21000165
117 FORMAT (I5, 1X, I1)	21000166
CALL RANGE(0, 1, IPLOT, I)	21000167
IF(I) 734, 734, 741	21000168
741 KAW = 11	21000169
PUNCH 710, KAW	21000170
GO TO 720	21000171
C	21000172
C ORDER X AND Y ARRAYS AND PUT ON TAPES 1 AND 3	21000173
C	21000174
734 IF (IPLOT) 735, 118, 735	21000175
735 DO 740 I = 1,N,1	21000176
740 IND(I) = I	21000177
REWIND 1	21000178
READ TAPE 1, X, Y	21000179
CALL ORDR3A (X,Y,IND,1,N,0,I)	21000180
REWIND 3	21000181
WRITE TAPE 3, X, Y, IND	21000182
CALL ORDR3A (Y,X,IND,1,N,1,I)	21000183
REWIND 1	21000184
WRITE TAPE 1, X, Y, IND	21000185
C	21000186
C READ CONTOUR PARAMETERS	21000187
C	21000188
118 IK=IK+1	21000189
IF(NUMB-IK)300,119,119	21000190
119 READ 125, MP, IOR, M3, MT, NCOL, CON, REF	21000191
125 FORMAT (1X, 4I1, I4, 2F10.2)	21000192
C	21000193
C CHECK PLOTTING PARAMETERS FOR VALIDITY	21000194
C	21000195
NERR=0	21000196
CALL RANGE(1,3,MP,NKR)	21000197
KAW=7	21000198
IF(NKR)700,700,705	21000199
700 CALL RANGE(0,1,M3,NKR)	21000200

KAW=8	21000201
IF(NKR)715,715,705	21000202
705 PUNCH 710,KAW	21000203
710 FORMAT(1X, 13HPROGRAM ERROR I3)	21000204
NERR=1	21000205
IF(KAW-8)700,720,720	21000206
C	21000207
715 IF(NERR)730,730,720	21000208
720 TYPE 725	21000209
725 FORMAT (12HINVALID DATA)	21000210
PAUSE	21000211
GO TO 118	21000212
C	21000213
730 IF(M3)30,126,30	21000214
126 READ 127, XPMAX, XPMIN, YPMAX, YPMIN	21000215
127 FORMAT (1X, 4F15.6)	21000216
GO TO 107	21000217
C	21000218
30 XPMAX = XMAX	21000219
XPMIN = XMIN	21000220
YPMAX = YMAX	21000221
YPMIN = YMIN	21000222
C	21000223
107 IF(MTD(MP)) 118, 118, 108	21000224
C	21000225
C PUNCH MAP TITLES AND CALL SUBROUTINE CONTUR	21000226
C	21000227
108 PUNCH 317, (ID(I), I = 1,40,1)	21000228
C	21000229
GO TO (245, 255, 266), MP	21000230
C	21000231
245 PUNCH 251	21000232
251 FORMAT (1H0 24HCONTOURED LINEAR SURFACE)	21000233
GO TO 275	21000234
255 PUNCH 261	21000235
261 FORMAT (1H0 25HCONTOURED QUADRIC SURFACE)	21000236
GO TO 275	21000237
266 PUNCH 271	21000238
271 FORMAT (1H0 23HCONTOURED CUBIC SURFACE)	21000239
C	21000240
275 CALL CONTUR (MP, IOR, MT, NCOL, CON, REF, XPMAX, XPMIN, YPMAX,	21000241
1 YPMIN, A, IREFU, IREFL, JKR)	21000242
GO TO 118	21000243
C	21000244
300 CONTINUE	21000245
END	21000246
FUNCTION ZL(A,AX,AY,KZ)	22000001
C	22000002
C FUNCTION FOR EVALUATING 1ST DEGREE POLYNOMIAL. IF KZ IS	22000003
C NON-POSITIVE, THE EVALUATION IS UNCONDITIONALLY 0.	22000004
C	22000005
DIMENSION A(10,3)	22000006
IF(KZ)10,10,5	22000007
5 ZL=A(1,1)+A(2,1)*AX+A(3,1)*AY	22000008
GO TO 15	22000009
10 ZL=0.0	22000010
15 RETURN	22000011
END	22000012
FUNCTION ZQ(A,AX,AY,KZ)	23000001
C	23000002
C FUNCTION FOR EVALUATING 2ND DEGREE POLYNOMIAL. IF KZ IS	23000003
C NON-POSITIVE, THE EVALUATION IS UNCONDITIONALLY 0.	23000004
C	23000005
DIMENSION A(10,3)	23000006
IF(KZ)10,10,5	23000007
5 ZQ1 = AX * (A(2,2) + A(4,2) * AX + A(5,2) * AY)	23000008
ZQ2=AY * (A(3,2) + A(6,2) * AY)	23000009
ZQ= A(1,2) + ZQ1 + ZQ2	23000010
GO TO 15	23000011
10 ZQ=0.0	23000012
15 RETURN	23000013
END	23000014

C	FUNCTION ZC(A,AX,AY,KZ)	24000001
C	FUNCTION FOR EVALUATING 3RD DEGREE POLYNOMIAL. IF KZ IS	24000002
C	NON-POSITIVE, THE EVALUATION IS UNCONDITIONALLY 0.	24000003
C		24000004
	DIMENSION A(10,3)	24000005
	IF(KZ)10,10,5	24000006
5	ZC1 = AX * (A(2,3) + AX * (A(4,3) + A(7,3) * AX))	24000007
	ZC2=AY * (A(3,3) + AY * (A(6,3) + A(10,3) * AY))	24000008
	ZC3 = AX * AY * (A(5,3) + A(8,3) * AX + A(9,3) * AY)	24000009
	ZC= A(1,3)+ZC1 + ZC2 + ZC3	24000010
	GO TO 15	24000011
10	ZC=0.0	24000012
15	RETURN	24000013
	END	24000014
		24000015
C	SUBROUTINE IREF (IREFU, IREFL)	25000001
C	IREF GENERATES THE DOUBLE DIGIT CODE OF THE PLOTTING SYMBOLS	25000002
C	OF SUBROUTINE CONTUR	25000003
C		25000004
	DIMENSION IREFU(11), IREFL(26)	25000005
	IREFU(1) = 300	25000006
	DO 85 I = 1,10,1	25000007
85	IREFU(I + 1) = 7000 + (I - 1) * 100	25000008
C		25000009
	DO 115 I = 1,26,1	25000010
	IF (I - 9) 100, 100, 109	25000011
100	J = I	25000012
	GO TO 115	25000013
109	IF (I - 18) 111, 111, 112	25000014
111	J = I + 1	25000015
	GO TO 115	25000016
112	J = I + 3	25000017
115	IREFL(I) = 4000 + J * 100 *	25000018
	RETURN	25000019
	END	25000020
		25000021
C	SUBROUTINE RANGE(LL,LU,N,NER)	26000001
C	RANGE DETERMINES WHETHER OR NOT N FALLS IN THE CLOSED	26000002
C	INTERVAL (LL,LU)	26000003
C		26000004
	NER = 0	26000005
	IF(LL - N) 5, 15, 10	26000006
5	IF (LU-N) 10, 15, 15	26000007
10	NER = 1	26000008
15	RETURN	26000009
	END	26000010
		26000011
C	PROGRAM - SUBROUTINE ORDR3A	27000001
C	LANGUAGE - FORTRAN II	27000002
C	NECESSARY SUBROUTINES - RANGE	27000003
C	COMPUTER - IBM 1620 60K CORE	27000004
C	PROGRAMMER - DONALD I GOOD	27000005
C	DATE COMPLETED - APRIL 1964	27000006
C		27000007
C		27000008
	SUBROUTINE ORDR3A(A, B, IC, NF, NL, KD, KR)	27000009
	DIMENSION A(300), B(300), IC(300)	27000010
C		27000011
C	INITIALIZATION STEPS	27000012
C		27000013
	KR=0	27000014
	ND=NL-NF	27000015
C	-----	27000016
C	CHECK ARGUMENTS FOR VALIDITY	27000017
C	-----	27000018
	CALL RANGE(1,300,NF,NKR)	27000019
	KAW=1	27000020
	IF(NKR)120,120,140	27000021
C		27000022

120 CALL RANGE(1,300,NL,NKR)	27000023
KAW=2	27000024
IF(NKR)125,125,140	27000025
C	27000026
125 CALL RANGE(0,1,KD,NKR)	27000027
KAW=3	27000028
IF(NKR)130,130,140	27000029
C	27000030
130 IF(ND)135,150,150	27000031
135 KAW=4	27000032
C	27000033
140 PUNCH 145,KAW	27000034
145 FORMAT(1X, 23HSUBROUTINE ORDR3A ERROR 12)	27000035
KR=1	27000036
GO TO (120,125,130,110),KAW	27000037
150 IF(KR)155,155,110	27000038
C	27000039
C CALCULATE ORDERING PARAMETERS	27000040
C	27000041
155 IF(ND)110,110,15	27000042
15 NP = NF + 1	27000043
NE = NL + 1	27000044
C	27000045
C ORDER ARRAYS IN ASCENDING ORDER ON A	27000046
C	27000047
DO 90 K = 1,ND,1	27000048
C	27000049
30 NE = NE - 1	27000050
AMAX = A(NF)	27000051
J = NF	27000052
DO 50 I = NP,NE,1	27000053
IF(AMAX - A(I)) 40, 50, 50	27000054
40 AMAX = A(I)	27000055
J = I	27000056
50 CONTINUE	27000057
C	27000058
BAMAX=B(J)	27000059
ICAMAX = IC(J)	27000060
C	27000061
A(J)=A(NE)	27000062
B(J)=B(NE)	27000063
IC(J) = IC(NE)	27000064
C	27000065
A(NE) = AMAX	27000066
B(NE) = BAMAX	27000067
IC(NE) = ICAMAX	27000068
C	27000069
90 CONTINUE	27000070
C	27000071
C INVERT ARRAYS IF DESCENDING ORDER IS DESIRED	27000072
C	27000073
IF(KD) 110, 110, 100	27000074
100 NS2 = (NL - NF + 1) / 2 + NF - 1	27000075
NT = NL + NF	27000076
DO 105 I = NF, NS2, 1	27000077
AMAX = A(I)	27000078
BAMAX = B(I)	27000079
ICAMAX = IC(I)	27000080
K = NT - I	27000081
A(I) = A(K)	27000082
B(I) = B(K)	27000083
IC(I) = IC(K)	27000084
A(K) = AMAX	27000085
B(K) = BAMAX	27000086
105 IC(K) = ICAMAX	27000087
110 RETURN	27000088
END	27000089
C	28000001
C PROGRAM - SUBROUTINE CONTUR	28000002
C LANGUAGE - FORTRAN II	28000003
C NECESSARY SUBROUTINES - RANGE, ZL, ZQ, ZC. ALSO NECESSARY TO	28000004
C GENERATE ARRAYS IREFU AND IREFL WITH SUBROUTINE IREF BEFORE	28000005
C ENTERING CONTUR	28000006
C COMPUTER - IBM 1620 60K CORE	28000007
C PROGRAMMER - DONALD I GOOD	28000008
C DATE COMPLETED - APRIL 1964	

C		28000009
C		28000010
	SUBROUTINE CONTUR (LM,M2,MT,NCOL,R1,R2,XPMAX,XPMIN,YPMAX,	28000011
	1 YPMIN, A, IREFU,IREFL,KERR)	28000012
	DIMENSION A(10,3), IREFU(11), IREFL(26), MAP(110)	28000013
C	-----	28000014
C	CALCULATE X AND Y PLOTTING DIMENSIONS	28000015
C	-----	28000016
	DX = XPMAX - XPMIN	28000017
	DY = YPMAX - YPMIN	28000018
	NC = NCOL - 11	28000019
	FNC = NC	28000020
	NC = NC + 1	28000021
C	-----	28000022
C	CHECK ARGUMENTS	28000023
C	-----	28000024
	KERR=0	28000025
C		28000026
	CALL RANGE(1,3,LM,NKR)	28000027
	KEW=1	28000028
	IF(NKR)5,5,50	28000029
C		28000030
	5 CALL RANGE(1,4,M2,NKR)	28000031
	KEW=2	28000032
	IF(NKR)10,10,50	28000033
C		28000034
	10 CALL RANGE(0,1,MT,NKR)	28000035
	KEW=3	28000036
	IF(NKR)15,15,50	28000037
C		28000038
	15 CALL RANGE(12,120,NCOL,NKR)	28000039
	KEW=4	28000040
	IF(NKR)20,20,50	28000041
C		28000042
	20 IF(R1)25,25,30	28000043
	25 KEW=5	28000044
	GO TO 50	28000045
C		28000046
	30 IF(DX)35,35,40	28000047
	35 KEW=6	28000048
	GO TO 50	28000049
C		28000050
	40 IF(DY)45,45,125	28000051
	45 KEW=7	28000052
C		28000053
	50 PUNCH 55,KEW	28000054
	55 FORMAT (1X, 23H SUBROUTINE CONTUR ERROR 12)	28000055
	KERR=1	28000056
	GO TO (5,10,15,20,30,40,574),KEW	28000057
C		28000058
	125 IF(KERR)130,130,574	28000059
C	-----	28000060
C	PUNCH PLOTTING LIMITS	28000061
C	-----	28000062
	130 PUNCH 60, XPMAX, XPMIN, YPMAX, YPMIN	28000063
	60 FORMAT (1H0 15HPLOTTING LIMITS / 1X, 11HMAXIMUM X = F15.6, 5X,	28000064
	1 11HMINIMUM X = F15.6/ 1X, 11HMAXIMUM Y = F15.6, 5X,	28000065
	2 11HMINIMUM Y = F15.6)	28000066
C	-----	28000067
C	CHOOSE ORIENTATION	28000068
C	-----	28000069
	GO TO (135, 165, 195, 196), M2	28000070
C		28000071
	135 EXL = XPMIN	28000072
	EXR = XPMAX	28000073
	EXT = YPMAX	28000074
	EXB = YPMIN	28000075
	M6 = 0	28000076
	GO TO 200	28000077
C		28000078
	165 EXL = YPMIN	28000079
	EXR = YPMAX	28000080
	EXT = XPMIN	28000081
	EXB = XPMAX	28000082
	M6 = 1	28000083
	GO TO 200	28000084

C	195 IF (DX - DY) 135, 135, 165	28000085
C	196 IF (DX - DY) 165, 135, 135	28000086
C	-----	28000087
C	CALCULATE VERTICAL AND HORIZONTAL PLOTTING INCREMENTS	28000088
C	-----	28000089
C	200 HINC = (EXR - EXL) / FNC	28000090
C	IF (MT) 201, 202, 201	28000091
C	201 VINC = HINC * 1.6666667	28000092
C	GO TO 214	28000093
C	202 VINC = HINC	28000094
C	214 IF (M6) 220, 215, 220	28000095
C	215 VINC = - VINC	28000096
C	-----	28000097
C	PUNCH MAP PARAMETERS AND SCALES	28000098
C	-----	28000099
C	220 IF (M6) 300, 280, 300	28000100
C	280 PUNCH 285, EXL, HINC	28000101
C	285 FORMAT (1H0 21HX-SCALE IS HORIZONTAL / 1X, 9HX-VALUE = F8.2,	28000102
C	1 2H + F8.4, 16H X (SCALE VALUE))	28000103
C	PUNCH 295	28000104
C	295 FORMAT (1H0 19HY-SCALE IS VERTICAL)	28000105
C	GO TO 320	28000106
C	300 PUNCH 305, EXL, HINC	28000107
C	305 FORMAT (1H0 21HY-SCALE IS HORIZONTAL / 1X, 9HY-VALUE = F8.2,	28000108
C	1 2H + F8.4, 16H X (SCALE VALUE))	28000109
C	PUNCH 315	28000110
C	315 FORMAT (1H0 19HX-SCALE IS VERTICAL)	28000111
C	320 PUNCH 325, R1, R2	28000112
C	325 FORMAT (1H0 18HCONTOUR INTERVAL = F29.2/ 1X, 17HREFERENCE CONTOUR	28000113
C	1 10H (.....) = F20.2)	28000114
C	IF (NCOL - 80) 340, 340, 330	28000115
C	330 PUNCH 335	28000116
C	335 FORMAT (1H0 9X, 10H0123456789 10H 123456789 10H 123456789	28000117
C	1 10H 123456789 10H 123456789 10H 123456789 2H 1 / 1H9 23X,	28000118
C	2 8H23456789 10H 123456789 10H 123456789 10H 123456789	28000119
C	3 10H 123456789 /)	28000120
C	GO TO 344	28000121
C	340 PUNCH 341	28000122
C	341 FORMAT (1H0 9X, 10H0123456789 10H 123456789 10H 123456789	28000123
C	2 10H 123456789 10H 123456789 10H 123456789 10H 123456789 /)	28000124
C	-----	28000125
C	CHOOSE CHARACTERS FOR LINE BY LINE PLOTTING	28000126
C	-----	28000127
C	344 VERT = EXT - VINC	28000128
C	INCREMENT VERTICAL INDEX BY ONE LINE	28000129
C	345 VERT = VERT + VINC	28000130
C	ZERO PLOTTING ARRAY, MAP	28000131
C	DO 347 I = 1, NC, 1	28000132
C	347 MAP(I) = 0	28000133
C	HOR = EXL - HINC	28000134
C	I = 0	28000135
C	INCREMENT HORIZONTAL INDEX BY ONE	28000136
C	352 I = I + 1	28000137
C	HOR = HOR + HINC	28000138
C	DETERMINE X AND Y VALUES OF THE PLOTTING POSITION	28000139
C	IF (M6) 380, 365, 380	28000140
C	365 AX = HOR	28000141
C	AY = VERT,	28000142
C	GO TO 390	28000143
C	380 AX = VERT	28000144
C	AY = HOR	28000145
		28000146
		28000147
		28000148
		28000149
		28000150
		28000151
		28000152
		28000153
		28000154
		28000155
		28000156
		28000157
		28000158
		28000159
		28000160

C		28000161
C	SELECT PLOTTING FUNCTION AND CALCULATE VALUE OF SURFACE AT THE	28000162
C	PLOTTING POSITION	28000163
C		28000164
C	390 GO TO (395, 405, 415), LM	28000165
C		28000166
C	395 C = ZL(A, AX, AY, 1)	28000167
C	GO TO 420	28000168
C		28000169
C	405 C = ZQ(A, AX, AY, 1)	28000170
C	GO TO 420	28000171
C		28000172
C	415 C = ZC(A, AX, AY, 1)	28000173
C		28000174
C	DETERMINE OF SURFACE VALUE LIES ABOVE OR BELOW REFERENCE CONTOUR	28000175
C	(DELZ IS + OR -)	28000176
C		28000177
C	420 DELZ = C - R2	28000178
C	IF (DELZ) 480, 421, 421	28000179
C		28000180
C	DETERMINE IF SURFACE VALUE LIES IN REFERENCE BAND	28000181
C		28000182
C	421 IF (DELZ - R1) 425, 430, 430	28000183
C	425 MAP(I) = IREFU(1)	28000184
C	GO TO 535	28000185
C		28000186
C	SCALE DELZ SO THAT IT FALLS IN RANGE OF PLOTTING SYMBOLS(IREFU)	28000187
C		28000188
C	430 DELZ = DELZ - R1	28000189
C	431 IF (DELZ - 20. * R1) 445, 435, 435	28000190
C	435 DELZ = DELZ - 20. * R1	28000191
C	GO TO 431	28000192
C		28000193
C	CHOOSE PLOTTING SYMBOL	28000194
C		28000195
C	445 MOD = DELZ / R1	28000196
C	J = -1	28000197
C	K = 1	28000198
C	460 J = J + 2	28000199
C	K = K + 1	28000200
C	IF (MOD - J) 535, 475, 460	28000201
C	475 MAP(I) = IREFU(K)	28000202
C	GO TO 535	28000203
C		28000204
C	SCALE DELZ SO THAT IT FALLS IN RANGE OF PLOTTING SYMBOLS(IREFL)	28000205
C		28000206
C	480 DELZ = - DELZ	28000207
C	485 IF (DELZ - 52. * R1) 500, 490, 490	28000208
C	490 DELZ = DELZ - 52. * R1	28000209
C	GO TO 485	28000210
C		28000211
C	CHOOSE PLOTTING SYMBOL	28000212
C		28000213
C	500 MOD = DELZ / R1	28000214
C	J = -1	28000215
C	K = 0	28000216
C	515 J = J + 2	28000217
C	K = K + 1	28000218
C	IF (MOD - J) 535, 530, 515	28000219
C	530 MAP(I) = IREFL(K)	28000220
C		28000221
C	DETERMINE IF LAST HORIZONTAL POSITION HAS BEEN PROCESSED	28000222
C		28000223
C	535 IF (I - NC) 352, 540, 540	28000224
C		28000225
C	PUNCH PLOTTING ARRAY	28000226
C		28000227
C	540 PUNCH 545, VERT, (MAP(I), I = 1, NC, 1)	28000228
C	545 FORMAT (1X, F8.2, 1X, 62A1/ 1H9 23X, 48A1)	28000229
C		28000230
C	DETERMINE IF LAST LINE HAS BEEN PROCESSED	28000231
C		28000232
C	IF (M6) 565, 560, 565	28000233
C	560 IF (VERT - EXB) 570, 570, 345	28000234
C	565 IF (VERT - EXB) 345, 570, 570	28000235
C		28000236

C	PUNCH FINAL SCALES	28000237
C		28000238
C	570 IF (NCOL - 80) 571, 571, 572	28000239
C		28000240
C	571 PUNCH 341	28000241
	GO TO 574	28000242
C	572 PUNCH 335	28000243
		28000244
C	574 RETURN	28000245
	END	28000246
C	PROGRAM - TREND SURFACE PART III	31000001
C	LANGUAGE - FORTRAN II	31000002
C	COMPUTER - IBM 1620 60K CORE	31000003
C	PRECISION - DECIMAL 08, INTEGER 04	31000004
C	PROGRAMMER - DONALD I GOOD	31000005
C	DATE COMPLETED - APRIL 1964	31000006
C	FOR DOCUMENTATION SEE KANSAS GEOLOGICAL SURVEY SPECIAL	31000007
C	DISTRIBUTION PUBLICATION 14	31000008
C		31000009
C		31000010
	DIMENSION X(300), Y(300), IND(300), ID(40), A(30), MTD(4),	31000011
	1 R(300), JREF(12), RED(300)	31000012
	COMMON X, Y, R, IDI, ID, N, A, MTD, SUMZ, FN, XMAX, XMIN, YMAX,	31000013
	1 YMIN, IPLOT, RED	31000014
	EQUIVALENCE (MTD(4), JREF), (IDI, IND)	31000015
C		31000016
C	CHECK PART III INDICATOR	31000017
C		31000018
	IF (IPLOT - 1) 4, 5, 4	31000019
	4 KAW = 12	31000020
	PUNCH 120, KAW	31000021
	GO TO 105	31000022
C		31000023
C	CALCULATE PLOTTING SYMBOLS FOR SUBROUTINE PLOT3	31000024
C		31000025
	5 CALL ICALC(JREF)	31000026
	REWIND 2	31000027
	MPL = -1	31000028
	KN = N + 1	31000029
	IP = 0	31000030
C	-----	31000031
C	READ IN PLOTTING PARAMETERS	31000032
C	-----	31000033
	READ 10, NUMB	31000034
	10 FORMAT (I5)	31000035
C		31000036
	15 IP = IP + 1	31000037
	IF (NUMB - IP) 105, 19, 19	31000038
	19 READ 20, MP, IOR, M3, MT, NCOL	31000039
	20 FORMAT (1X, 4I1, I4)	31000040
C	-----	31000041
C	CHECK PARAMETERS FOR VALIDITY	31000042
C	-----	31000043
	NERR=0	31000044
	CALL RANGE(0,3,MP,NKR)	31000045
	KAW=9	31000046
	IF(NKR)110,110,115	31000047
	110 CALL RANGE(0,1,M3,NKR)	31000048
	KAW=10	31000049
	IF(NKR)125,125,115	31000050
	115 PUNCH 120,KAW	31000051
	120 FORMAT (1X, 13HPROGRAM ERROR I3)	31000052
	NERR=1	31000053
	IF(KAW-10)110,125,125	31000054
	125 IF(NERR)25,25,130	31000055
	130 TYPE 135	31000056
	135 FORMAT(12HINVALID DATA)	31000057
	PAUSE	31000058
	GO TO 15	31000059
C		31000060

25	IF(M3)40,30,40	31000061
30	READ 35,XPMAX,XPMIN,YPMAX,YPMIN	31000062
35	FORMAT (1X, 4F15.6)	31000063
	GO TO 50	31000064
C		31000065
40	XPMAX=XMAX	31000066
	XPMIN=XMIN	31000067
	YPMAX=YMAX	31000068
	YPMIN=YMIN	31000069
C		31000070
50	IF (MP) 51, 52, 51	31000071
51	IF(MTD(MP))15,15,52	31000072
C	-----	31000073
C	PLACE RESIDUAL ARRAY FROM TAPE 2 INTO R ARRAY	31000074
C	-----	31000075
52	DX = XMAX - XMIN	31000076
	DY = YMAX - YMIN	31000077
	GO TO (140, 145, 150, 155), IOR	31000078
140	NTAPE = 1	31000079
	K = 0	31000080
	GO TO 165	31000081
145	NTAPE = 3	31000082
	K = 2	31000083
	GO TO 165	31000084
150	IF (DX - DY) 140, 140, 145	31000085
155	IF (DX - DY) 145, 140, 140	31000086
165	REWIND NTAPE	31000087
	READ TAPE NTAPE, X, Y, IND	31000088
C		31000089
	MDF = MP - MPL	31000090
	IF(MDF) 170, 183, 180	31000091
170	MDF = - MDF + 1	31000092
	DO 171 I = 1,MDF,1	31000093
171	BACKSPACE 2	31000094
	READ TAPE 2, RED	31000095
	GO TO 183	31000096
180	DO 181 I = 1,MDF,1	31000097
181	READ TAPE 2, RED	31000098
C		31000099
183	DO 190 I = 1,N,1	31000100
	J = KN - I	31000101
	L = IND(J)	31000102
190	R(J) = RED(L)	31000103
	MPL = MP	31000104
C	-----	31000105
C	PUNCH MAP TITLES AND CALL PLOTTING SUBROUTINE PLOT3	31000106
C	-----	31000107
54	PUNCH 55,(ID(I),I=1,40,1)	31000108
55	FORMAT (1H1 39A2, A1)	31000109
C		31000110
	IF (MP) 59, 60, 59	31000111
59	GO TO (70, 80, 90), MP	31000112
C		31000113
60	PUNCH 65	31000114
65	FORMAT (1H0 37HPLOT OF ORIGINAL DATA (Z-COORDINATES))	31000115
	GO TO 160	31000116
C		31000117
70	PUNCH 75	31000118
75	FORMAT (1H0 24HPLOT OF LINEAR RESIDUALS)	31000119
	GO TO 160	31000120
C		31000121
80	PUNCH 85	31000122
85	FORMAT (1H0 25HPLOT OF QUADRIC RESIDUALS)	31000123
	GO TO 160	31000124
C		31000125
90	PUNCH 95	31000126
95	FORMAT (1H0 23HPLOT OF CUBIC RESIDUALS)	31000127
C		31000128
160	CALL PLOT3(X,Y,R,N,IOR,XPMAX,XPMIN,YPMAX,YPMIN,NCOL,MT,K,J,JREF,	31000129
	1 MER)	31000130
	GO TO 15	31000131
C		31000132
105	CONTINUE	31000133
	END	31000134

C	SUBROUTINE ICALC(JREF)	32000001
C	GENERATES PLOTTING SYMBOLS FOR SUBROUTINE PLOT3	32000002
C	DIMENSION JREF(12)	32000003
C	JREF(1)=1000	32000004
C	JREF(2)=2000	32000005
C	DO 10 I=3,12,1	32000006
10	JREF(I)=7000+(I-3)*100	32000007
C	RETURN	32000008
C	END	32000009
		32000010
		32000011
		32000012
		32000013
		32000014
C	SUBROUTINE RANGE(LL,LU,N,NER)	33000001
C	RANGE DETERMINES WHETHER OR NOT N FALLS IN THE CLOSED	33000002
C	INTERVAL (LL,LU)	33000003
C	NER = 0	33000004
	IF (LL - N) 5, 15, 10	33000005
5	IF (LU - N) 10, 15, 15	33000006
10	NER = 1	33000007
15	RETURN	33000008
	END	33000009
		33000010
		33000011
C	PROGRAM - SUBROUTINE PLOT3	34000001
C	LANGUAGE - FORTRAN II	34000002
C	NECESSARY SUBROUTINES - RANGE, ORDER3. ALSO THE ARRAY JREF MUST	34000003
C	BE GENERATED BY SUBROUTINE ICALC BEFORE ENTERING PLOT3	34000004
C	COMPUTER - IBM 1620 60K CORE	34000005
C	PRECISION - DECIMAL 08, INTEGER 04	34000006
C	PROGRAMMER - DONALD I GOOD	34000007
C	DATE COMPLETED - APRIL 1964	34000008
C		34000009
C		34000010
C	SUBROUTINE PLOT3(X, Y, Z, N, IOR, XMAX, XMIN, YMAX, YMIN, NCOL,	34000011
1	MT, M1, M2, JREF,NKR)	34000012
C	DIMENSION X(300), Y(300), Z(300), JREF(12), IER(300), ITAB(300),	34000013
1	MAP(110), IZD(5)	34000014
C	DETERMINE NUMBER OF CHARACTERS, NCC, IN PLOTTING ARRAY	34000015
C	NCD=NCOL-10	34000016
C	NCC=NCD-5	34000017
C	FNC=NCC	34000018
C	CALCULATE PLOTTING DIMENSIONS	34000019
C	DX=XMAX-XMIN	34000020
C	DY=YMAX-YMIN	34000021
C	-----	34000022
C	CHECK ARGUMENTS FOR VALIDITY	34000023
C	-----	34000024
C	NKR=0	34000025
C	CALL RANGE(1,300,N,NAR)	34000026
C	KAR=1	34000027
C	IF (NAR)720,720,759	34000028
720	CALL RANGE(1,4,IOR,NAR)	34000029
	KAR=2	34000030
	IF (NAR)725,725,759	34000031
725	CALL RANGE(16,120,NCOL,NAR)	34000032
	KAR=3	34000033
	IF (NAR)730,730,759	34000034
730	CALL RANGE(0,1,MT,NAR)	34000035
	KAR=4	34000036
	IF (NAR)735,735,759	34000037
735	CALL RANGE(0,2,M1,NAR)	34000038
		34000039
		34000040
		34000041
		34000042
		34000043
		34000044
		34000045
		34000046
		34000047

KAR=5	34000048
IF(NAR)740,740,759	34000049
C 740 IF(DX)745,745,750	34000050
745 KAR=6	34000051
GO TO 759	34000052
C	34000053
750 IF(DY)755,755,765	34000054
755 KAR=7	34000055
759 PUNCH 760,KAR	34000056
760 FORMAT(1X, 22HSUBROUTINE PLOT3 ERROR I2)	34000057
NKR=1	34000058
GO TO (720,725,730,735,740,750,710),KAR	34000059
765 IF(NKR)5,5,710	34000060
C -----	34000061
C PUNCH PLOTTING LIMITS	34000062
C -----	34000063
5 PUNCH 770, XMAX, XMIN, YMAX, YMIN	34000064
770 FORMAT (1H0 15HPLOTTING LIMITS / 1X, 11HMAXIMUM X = F15.6, 5X,	34000065
1 11HMINIMUM X = F15.6/ 1X, 11HMAXIMUM Y = F15.6, 5X,	34000066
2 11HMINIMUM Y = F15.6)	34000067
C	34000068
C ZERO CARRIAGE CONTROL ARRAY FOR OVERPRINT VALUES	34000069
C	34000070
DO 10 I=1,N,1	34000071
10 ITAB(I)=0	34000072
C -----	34000073
C SCALE PLOTTED VALUES TO 4-DIGIT MAXIMUM	34000074
C -----	34000075
AZMAX=ABSF(Z(1))	34000076
DO 20 I=2,N,1	34000077
IF(AZMAX-ABSF(Z(I)))15,20,20	34000078
15 AZMAX=ABSF(Z(I))	34000079
20 CONTINUE	34000080
C	34000081
IF (AZMAX) 21, 66, 21	34000082
21 M=(LOGF(9999.0/AZMAX))/LOGF(10.0)	34000083
IF(M)30,66,40	34000084
C	34000085
30 ND=-M	34000086
CON=0.1	34000087
GO TO 50	34000088
C	34000089
40 ND=M	34000090
CON=10.0	34000091
C	34000092
50 DO 60 I=1,ND,1	34000093
DO 60 J=1,N,1	34000094
60 Z(J)=Z(J)*CON	34000095
C	34000096
C PUNCH SCALE FACTOR	34000097
C	34000098
61 PUNCH 65,M	34000099
65 FORMAT (1H0 40HPLOTTED VALUES HAVE BEEN MULTIPLIED BY A 20H FACTOR	34000100
1 OF 10 TO THE 15, 6H POWER)	34000101
C -----	34000102
C SELECT MAP ORIENTATION, CALCULATE HORIZONTAL PLOTTING INCREMENTS.	34000103
C PUNCH PLOTTING PARAMETERS	34000104
C -----	34000105
66 GO TO (70,80,90,100),IOR	34000106
C	34000107
70 EXT=YMAX	34000108
M3=0	34000109
HINC = DX / FNC	34000110
PUNCH 75, XMIN, HINC	34000111
75 FORMAT (1H0 21HX-SCALE IS HORIZONTAL / 1X, 9HX-VALUE = F8.2, 2H +	34000112
1 F8.4, 16H X (SCALE VALUE) / 1H0 19HY-SCALE IS VERTICAL)	34000113
GO TO 110	34000114
C	34000115
80 EXT=XMIN	34000116
M3=1	34000117
HINC = DY / FNC	34000118
PUNCH 85,YMIN,HINC	34000119
85 FORMAT (1H0 21HY-SCALE IS HORIZONTAL / 1X, 9HY-VALUE = F8.2, 2H +	34000120
1 F8.4, 16H X (SCALE VALUE) / 1H0 19HX-SCALE IS VERTICAL)	34000121
GO TO 110	34000122
	34000123

C	90 IF(DX-DY)70,70,80	34000124
	100 IF(DX-DY)80,70,70	34000125
C		34000126
C	PUNCH HORIZONTAL SCALE	34000127
C		34000128
	110 IF(NCOL-80)120,120,130	34000129
C		34000130
	120 PUNCH 125	34000131
	125 FORMAT (1H0 9X, 10H0123456789 10H 123456789 10H 123456789 10H 1234	34000132
	156789 10H 123456789 10H 123456789 10H 123456789 /)	34000133
	GO TO 140	34000134
		34000135
C		34000136
	130 PUNCH 135	34000137
	135 FORMAT (1H0 9X, 10H0123456789 10H 123456789 10H 123456789 10H 1234	34000138
	156789 10H 123456789 10H 123456789 2H 1 / 1H9 23X,8H23456789 10H 1234	34000139
	23456789 10H 123456789 10H 123456789 10H 123456789 /)	34000140
C		34000141
C	CALCULATE VERTICAL PLOTTING INCREMENT	34000142
C		34000143
	140 IF(MT)160,150,160	34000144
	150 VINC=HINC	34000145
	GO TO 170	34000146
	160 VINC=HINC*1.6666667	34000147
C	-----	34000148
C	PLOTTING ROUTINE	34000149
C	-----	34000150
C		34000151
C	ORDER X, Y, AND Z ARRAYS ON ARRAY CORRESPONDING TO VERTICAL SCALE	34000152
C		34000153
	170 IF(M3)200,180,200	34000154
C		34000155
	180 VINC=-VINC	34000156
	IF(M1-1)220,190,190	34000157
	190 CALL ORDER3(Y,X,Z,1,N,1,LK)	34000158
	M2=0	34000159
	IF(LK)220,220,710	34000160
C		34000161
	200 IF(M1-1)210,210,220	34000162
	210 CALL ORDER3(X,Y,Z,1,N,0,LK)	34000163
	M2=2	34000164
	IF(LK)220,220,710	34000165
		34000166
C		34000167
C	INITIALIZATION STEPS FOR PLOTTING	34000168
C		34000169
	220 PLIM=EXT	34000170
	KER=0	34000171
C		34000172
C	DETERMINE INDEX OF FIRST DATA POINT THAT FALLS IN VERTICAL	34000173
C	PLOTTING RANGE	34000174
C		34000175
	IF (M3) 805, 800, 805	34000176
	800 IF (YMIN - Y(1)) 221, 221, 226	34000177
	221 DO 222 I = 1,N,1	34000178
	IF (YMAX - Y(I)) 222, 228, 228	34000179
	222 CONTINUE	34000180
	GO TO 226	34000181
	805 IF (X(1) - XMAX) 223, 223, 226	34000182
	223 DO 224 I = 1,N,1	34000183
	IF (XMIN - X(I)) 228, 228, 224	34000184
	224 CONTINUE	34000185
	226 PUNCH 227	34000186
	227 FORMAT (1X, 27HNO POINTS IN VERTICAL RANGE)	34000187
	GO TO 650	34000188
	228 NL = I - 1	34000189
C		34000190
C	CALCULATE UPPER (TOWARD TOP OF PAGE) BOUND OF VERTICAL PLOTTING	34000191
C	INTERVAL	34000192
C		34000193
	225 VERT=PLIM	34000194
C		34000195
C	INCREMENT OVERPRINT INDEX. ZERO PLOTTING ARRAY	34000196
C		34000197
	KERF=KER+1	34000198
	DO 230 I=1,NCD,1	34000199
	230 MAP(I)=0	

C		34000200
C	CALCULATE LOWER (TOWARD BOTTOM OF PAGE) BOUND OF VERTICAL PLOTTING	34000201
C	INTERVAL	34000202
C		34000203
C	PLIM=VERT+VINC	34000204
C		34000205
C	DETERMINE INDEX OF NEXT DATA POINT, NF	34000206
C		34000207
C	NF=NL+1	34000208
C	I=NL	34000209
C		34000210
C	SET UP VALUES FOR VERTICAL INTERVAL	34000211
C		34000212
C	IF(M3)270,240,270	34000213
C		34000214
C	COUNT NO. OF DATA POINTS IN VERTICAL PLOTTING INTERVAL	34000215
C		34000216
C	240 I=I+1	34000217
C	IF (I - N) 245, 245, 250	34000218
C	245 IF(Y(I)-PLIM)250,240,240	34000219
C		34000220
C	DETERMINE INDEX OF LAST DATA POINT IN VERTICAL PLOTTING INTERVAL,	34000221
C	NL. ORDER DATA POINTS IN VERTICAL PLOTTING INTERVAL	34000222
C		34000223
C	250 NL=I-1	34000224
C	IF(NL-NF)590,300,260	34000225
C	260 CALL ORDER3(X,Y,Z,NF,NL,1,LK)	34000226
C	IF(LK)300,300,710	34000227
C		34000228
C	COUNT NO. OF DATA POINTS IN VERTICAL PLOTTING INTERVAL	34000229
C		34000230
C	270 I=I+1	34000231
C	IF (I - N) 275, 275, 280	34000232
C	275 IF(X(I)-PLIM)270,270,280	34000233
C		34000234
C	DETERMINE INDEX OF LAST DATA POINT IN VERTICAL PLOTTING INTERVAL,	34000235
C	NL. ORDER DATA POINTS IN VERTICAL PLOTTING INTERVAL	34000236
C		34000237
C	280 NL=I-1	34000238
C	IF(NL-NF)590,300,290	34000239
C	290 CALL ORDER3(Y,X,Z,NF,NL,1,LK)	34000240
C	IF(LK)300,300,710	34000241
C		34000242
C	PLACE Z-VALUES FOR VERTICAL INTERVAL IN PLOTTING ARRAY FROM	34000243
C	RIGHT TO LEFT	34000244
C		34000245
C	300 I = NF - 1	34000246
C	305 I = I + 1	34000247
C		34000248
C	DETERMINE POSITION, IDX, IN PLOTTING ARRAY TO PLACE SIGN OF	34000249
C	PLOTTED VALUE	34000250
C		34000251
C	IF(M3)320,310,320	34000252
C	310 IDX=(X(I)-XMIN)/HINC + 1.0	34000253
C	GO TO 330	34000254
C	320 IDX=(Y(I)-YMIN)/HINC + 1.0	34000255
C		34000256
C		34000257
C	DETERMINE IF PLOTTED VALUE LIES IN HORIZONTAL PLOTTING RANGE	34000258
C		34000259
C	330 IF(IDX) 580, 580, 334	34000260
C	334 IF (IDX - NCC - 1) 335, 335, 580	34000261
C		34000262
C	DETERMINE IF THIS POSITION IN THE PLOTTING ARRAY IS ALREADY	34000263
C	OCCUPIED	34000264
C		34000265
C	335 IF(MAP(IDX))470,340,470	34000266
C		34000267
C	BREAK PLOTTED VALUE INTO 4 SEPARATE DIGITS AND CODE THESE DIGITS	34000268
C	IN THE DOUBLE DIGIT CODE	34000269
C		34000270
C	340 LAZ=ABS(Z(I))	34000271
C	DVD=LAZ	34000272
C	DSR=10000.0	34000273
C	J=1	34000274
C		34000275

350 J=J+1	34000276
DSR=DSR*0.1	34000277
K=DVD/DSR	34000278
IZD(J)=JREF(K+3)	34000279
FK=K	34000280
REM=DVD-FK*DSR	34000281
IF(J-4)360,370,370	34000282
360 DVD=REM	34000283
GO TO 350	34000284
370 K = REM	34000285
IZD(5) = JREF(K+3)	34000286
C	34000287
C DETERMINE LEFT-MOST NON-ZERO DIGIT OF PLOTTED VALUE (EXCEPT ZERO)	34000288
C	34000289
J=1	34000290
380 J=J+1	34000291
IF (J - 5) 385, 390, 390	34000292
385 IF(IZD(J)-7000)386,386,390	34000293
386 IZD(J) = 0	34000294
GO TO 380	34000295
390 K=J-1	34000296
C	34000297
C PLACE SIGN OF PLOTTED VALUE	34000298
C	34000299
IF(Z(I))400,410,410	34000300
400 IZD(K)=JREF(2)	34000301
GO TO 420	34000302
410 IZD(K)=JREF(1)	34000303
C	34000304
C PLACE DIGITIZED VALUE IN PLOTTING ARRAY	34000305
C	34000306
420 IMP=IDX-1	34000307
J = K - 1	34000308
430 J = J + 1	34000309
IF (J - 5) 435, 435, 580	34000310
435 IMP = IMP + 1	34000311
IF(MAP(IMP))450,440,450	34000312
440 MAP(IMP)=IZD(J)	34000313
GO TO 430	34000314
C	34000315
C ERROR ROUTINE FOR OVERLAP PLOTTING	34000316
C	34000317
450 MAP(IDX)=1400	34000318
L=IDX+1	34000319
IMP = IMP - 1	34000320
J = IDX	34000321
455 J = J + 1	34000322
IF(J - IMP) 460, 460, 465	34000323
460 MAP(J)=0	34000324
GO TO 455	34000325
C	34000326
465 KER=KER+1	34000327
IER(KER)=Z(I)	34000328
ITAB(KER)= 14	34000329
GO TO 580	34000330
C	34000331
C ERROR ROUTINES FOR MULTIPLE PLOTTING	34000332
C	34000333
470 IF(MAP(IDX)-2000)480,480,530	34000334
480 IF (MAP(IDX) - 1400) 490, 510, 490	34000335
C	34000336
C IF 2 VALUES ARE TO OCCUPY MAP(IDX)	34000337
C	34000338
490 KER=KER+2	34000339
IER(KER-1)=Z(I-1)	34000340
IER(KER) = Z(I)	34000341
ITAB(KER) = 42	34000342
MAP(IDX) = 4200	34000343
IMP=IDX	34000344
495 IMP=IMP+1	34000345
IF(MAP(IMP)-7000)580,500,500	34000346
500 MAP(IMP)=0	34000347
GO TO 495	34000348
C	34000349
C IF MAP(IDX) IS OCCUPIED BY AN *	34000350
C	34000351

510	KER=KER+1	34000352
520	IER(KER)=Z(I)	34000353
	ITAB(KER-1) = 0	34000354
	ITAB(KER) = 42	34000355
	MAP(IDX)=4200	34000356
	GO TO 580	34000357
C		34000358
C	IF 3-9 VALUES ARE TO OCCUPY MAP(IDX)	34000359
C		34000360
530	IF (MAP(IDX)-4900)540,550,550	34000361
540	MAP(IDX)=MAP(IDX)+100	34000362
	KER = KER + 1	34000363
	ITAB(KER) = ITAB(KER-1) + 1	34000364
	ITAB(KER-1) = 0	34000365
	IER(KER) = Z(I)	34000366
	GO TO 580	34000367
C		34000368
C	IF MORE THAN 9 VALUES ARE TO OCCUPY MAP(IDX)	34000369
C		34000370
550	MAP(IDX)=6900	34000371
560	KER=KER+1	34000372
	IER(KER)=Z(I)	34000373
	ITAB(KER-1)=0	34000374
	ITAB(KER)= 69	34000375
C		34000376
C	DETERMINE IF FINAL VALUE FOR THIS VERTICAL PLOTTING INTERVAL	34000377
C	IS PROCESSED	34000378
C		34000379
580	IF (I - NL) 305, 590, 590	34000380
C		34000381
C	PUNCH PLOTTING ARRAY	34000382
C		34000383
590	PUNCH 595,VERT,(MAP(I),I=1,NCD,1)	34000384
595	FORMAT (1X, F8.2, 1X, 62A1 / 1H9 23X, 48A1)	34000385
C		34000386
C	INVERT LIST OF OVERPRINT AND CARRIAGE CONTROL VALUES IN LAST	34000387
C	VERTICAL PLOTTING INTERVAL	34000388
C		34000389
	IF (KER - KERF) 620, 601, 600	34000390
601	ITAB(KER) = ITAB(KER) + 7000	34000391
	GO TO 620	34000392
600	ITAB(KER) = ITAB(KER) + 7000	34000393
	KF=(KER-KERF+1)/2+KERF-1	34000394
	J=KER+KERF	34000395
	DO 610 I=KERF,KF,1	34000396
	IED=IER(I)	34000397
	ITB=ITAB(I)	34000398
	K=J-I	34000399
	IER(I)=IER(K)	34000400
	ITAB(I)=ITAB(K)	34000401
	IER(K)=IED	34000402
610	ITAB(K)=ITB	34000403
C		34000404
C	DETERMINE IF LAST VERTICAL PLOTTING INTERVAL IS PLOTTED	34000405
C		34000406
620	IF (M3)640,630,640	34000407
630	IF (PLIM-YMIN)650,225,225	34000408
640	IF (PLIM-XMAX)225,225,650	34000409
C		34000410
C	PUNCH FINAL SCALE	34000411
C		34000412
650	IF (NCOL-80)660,660,670	34000413
660	PUNCH 125	34000414
	GO TO 680	34000415
670	PUNCH 135	34000416
C		34000417
C	PUNCH OVERPRINT VALUES	34000418
C		34000419
680	IF (KER)710,710,690	34000420
690	PUNCH 695	34000421
695	FORMAT (1H0 16HOVERPRINT VALUES)	34000422
	PUNCH 700, (ITAB(I), IER(I), I = 1,KER,1)	34000423
700	FORMAT (A2, I6)	34000424
710	RETURN	34000425
	END	34000426

C	PROGRAM - SUBROUTINE ORDER3	35000001
C	LANGUAGE - FORTRAN II	35000002
C	NECESSARY SUBROUTINES - RANGE	35000003
C	COMPUTER - IBM 1620 60K CORE	35000004
C	PROGRAMMER - DONALD I GOOD	35000005
C	DATE COMPLETED - APRIL 1964	35000006
C		35000007
C		35000008
C	SUBROUTINE ORDER3(A,B,C,NF,NL,KD,KR)	35000009
C	DIMENSION A(300), B(300), C(300)	35000010
C		35000011
C	INITIALIZATION STEPS	35000012
C		35000013
C	KR=0	35000014
C	ND=NL-NF	35000015
C	-----	35000016
C	CHECK ARGUMENTS FOR VALIDITY	35000017
C	-----	35000018
C	CALL RANGE(1,300,NF,NKR)	35000019
C	KAW=1	35000020
C	IF(NKR)120,120,140	35000021
C		35000022
C	120 CALL RANGE(1,300,NL,NKR)	35000023
C	KAW=2	35000024
C	IF(NKR)125,125,140	35000025
C		35000026
C	125 CALL RANGE(0,1,KD,NKR)	35000027
C	KAW=3	35000028
C	IF(NKR)130,130,140	35000029
C		35000030
C	130 IF(ND)135,150,150	35000031
C	135 KAW=4	35000032
C		35000033
C	140 PUNCH 145,KAW	35000034
C	145 FORMAT(1X, 23H SUBROUTINE ORDER3 ERROR I2)	35000035
C	KR=1	35000036
C	GO TO (120,125,130,110),KAW	35000037
C	150 IF(KR)155,155,110	35000038
C		35000039
C	CALCULATE ORDERING PARAMETERS	35000040
C		35000041
C	155 IF(ND)110,110,15	35000042
C	15 NP = NF + 1	35000043
C	NE = NL + 1	35000044
C	-----	35000045
C	ORDER ARRAYS IN ASCENDING ORDER ON A	35000046
C	-----	35000047
C	DO 90 K = 1,ND,1	35000048
C		35000049
C	30 NE = NE - 1	35000050
C	AMAX = A(NF)	35000051
C	J = NF	35000052
C	DO 50 I = NP,NE,1	35000053
C	IF(AMAX - A(I)) 40, 50, 50	35000054
C	40 AMAX = A(I)	35000055
C	J = I	35000056
C	50 CONTINUE	35000057
C		35000058
C	BAMAX=B(J)	35000059
C	CAMAX = C(J)	35000060
C		35000061
C	A(J)=A(NE)	35000062
C	B(J)=B(NE)	35000063
C	C(J)=C(NE)	35000064
C		35000065
C	A(NE) = AMAX	35000066
C	B(NE) = BAMAX	35000067
C	C(NE) = CAMAX	35000068
C		35000069
C	90 CONTINUE	35000070
C		35000071
C	INVERT ARRAYS IF DESCENDING ORDER IS DESIRED	35000072
C		35000073
C	IF(KD) 110, 110, 100	35000074
C	100 NS2 = (NL - NF + 1) / 2 + NF - 1	35000075
C	NT = NL + NF	35000076

DO 105 I = NF, NS2, 1	35000077
AMAX = A(I)	35000078
BAMAX = B(I)	35000079
CAMAX = C(I)	35000080
K = NT - I	35000081
A(I) = A(K)	35000082
B(I) = B(K)	35000083
C(I) = C(K)	35000084
A(K) = AMAX	35000085
B(K) = BAMAX	35000086
105 C(K) = CAMAX	35000087
110 RETURN	35000088
END	35000089

INPUT DATA PREPARATION

Throughout this section on input data, all numbers are fixed point unless mention is made of a decimal point.

Part I

If the Kansas Geological Survey systems tape is used, the first two cards of the input must contain the following information beginning in column 1:

..I

..LOAD TREND-SURFACE-1

(The ..I card may contain any additional information; the (-) symbols in the load card are minus punches.) These two cards call the object program from tape drive 0, load the program into core, and ready the program for execution. The remainder of the input for Part I is now described, beginning with card 1. This part of the input is the same whether or not the Kansas Geological Survey systems tape is used.

Card 1 This card is a 79 character title card that is used to identify the program. This card is echoed in each different segment of the output. Column 1 is left blank and the title placed in columns 2-80.

Card 2	Column 1	Blank.
	Columns 2-4	Contain the number of sets of xyz-coordinates that are read in as data. This value may range from 1-300 and is right justified.
	Column 5	Blank.
	Column 6	Contains the indicator for calculation of the linear equation. If it is desired to fit the data to the linear trend surface, this column contains a 1. Otherwise, this column must be punched 0 (zero) or left blank.
	Column 7	Contains the indicator for calculation of the quadric equation. If it is desired to fit the data to the quadric trend surface, this column

contains a 1. Otherwise, this column must be punched 0 (zero) or left blank.

Column 8 Contains the indicator for calculation of the cubic equation. If it is desired to fit the data to the cubic trend surface, this column contains a 1. Otherwise, this column must be punched 0 (zero) or left blank.

Column 9 Contains the indicator for punching of the coefficient matrix. If it is desired to punch the coefficient matrix, this column contains a 1. Otherwise, this column must be punched 0 (zero) or left blank.

Card 3 This is the first of a set of N cards containing the xyz-coordinates where N is the value specified in columns 2-4 on card 2.

Columns 1-11 These columns are ignored.

Columns 12-26 Contain the x-coordinate. If no decimal point is punched, it is assumed to be between columns 20 and 21.

Columns 27-41 Contain the y-coordinate. If no decimal point is punched, it is assumed to be between columns 35 and 36.

Columns 42-56 Contain the z-coordinate. If no decimal point is punched, it is assumed to be between columns 50 and 51.

Part II

If the Kansas Geological Survey systems tape is used, the first two cards of the Part II input must be

..I

..LOAD TREND-SURFACE-2

(The ..I card may contain any additional information; the (-) symbols in the load card are minus punches.)

The remainder of the Part II input that controls the trend-surface contouring is prepared as follows:

Card 1 Columns 1-5 Contain the total number of contour maps to be printed. This value must be right justified.

Column 6 Blank.

Column 7 If Part III is to be used, this column contains a 1; otherwise it must be 0 (zero) or blank.

Card 2 This is the first of a set of M cards which contain the contouring parameters of each map to be contoured. (M is the number specified in columns 1-5 of card 1.)

Column 1 Blank.

Column 2 Contains the contour map indicator, MP. If MP is 1, the linear sur-

face is contoured. If MP is 2, the quadric surface is contoured. If MP is 3, the cubic surface is contoured.

Column 3 Contains the orientation indicator, IOR. This variable controls the orientation of the printed map on the paper. If IOR is 1, the x-axis is horizontal. If IOR is 2, the y-axis is horizontal. If IOR is 3, the contoured map is oriented so that it occupies as much space as possible. For instance, if an interval of 10 units on the x-axis and an interval of 5 units on the y-axis is to be contoured, the map is oriented with the x-axis vertical. If IOR is 4, the contoured map is oriented so that it occupies as little space as possible. In the instance above, the y-axis is oriented vertically.

Column 4 Contains the plotting limit indicator, M3. If M3 is 1, the x plotting interval is the interval between the maximum and minimum values of the X data array, and the y plotting interval is the interval between the maximum and minimum values of the Y data array. If M3 is 0 (zero), the plotting limits are read in on a card that immediately follows this card (not this set of cards). These limits are on the card in the form:

Column 1 Blank.

Columns 2-16 Contain the maximum x plotting limit. If no decimal point is punched, it is assumed to be between columns 10 and 11.

Columns 17-31 Contain the minimum x plotting limit. If no decimal point is punched, it is assumed to be between columns 25 and 26.

Columns 32-46 Contain the maximum y plotting limit. If no decimal point is punched, it is assumed to be between columns 40 and 41.

Columns 47-61 Contain the minimum y plotting limit. If no decimal point is punched, it is assumed to be between columns 55 and 56.

Column 5 Contains the card tabulator indicator, MT. If MT is 1, the output is to be listed at 6 lines per inch. If MT is 0 (zero) the output is to be listed at 10 lines per inch.

Columns 6-9 Contain the program variable NCOL which indicates the number of horizontal columns of output. The value of NCOL may range from 12-120 inclusive and must be right justified. The contour map occupies NCOL - 10 columns.

Columns 10-19 Contain the program variable CON which is the contour interval of the contour map. This value must not be zero or negative. If no decimal point is punched, it is assumed to be between columns 17 and 18.

Columns 20-29 Contain the program variable REF which is the reference contour. This value regulates the placement of the reference symbol (.....) on the contour map. If no decimal point is punched, it is assumed to be between columns 27 and 28.

Part III

If the Kansas Geological Survey systems tape is used, the first two cards of the Part III input must be

..I

..LOAD TREND-SURFACE-3

(The ..I card may contain any additional information; the (-) symbols in the load card are minus punches.) The remainder of the input controls the plotting of the original data and the residuals. If this output is not desired, Part III need not be loaded.

Card 1 Columns 1-5 Contain the total number of plots to be made. This value must be right justified.

Card 2 This is the first of a set of M cards that contain the plotting parameters for each set of values to be plotted. (M is the number specified on card 1.)

Column 1 Blank.

Column 2 Contains the residual plot indicator, MP. If MP is 0, the original data are plotted. If MP is 1, the linear residuals are plotted. If MP is 2, the quadric residuals are plotted. If MP is 3, the cubic residuals are plotted.

Column 3 Contains the orientation indicator, IOR. IOR has the same function here as described in Part II, card 2, column 3.

Column 4 Contains the plotting limit indicator, M3. M3 has the same function here as described in Part II, card 2, column 4.

Column 5 Contains the card tabulator indicator, MT. MT has the same function here as described in Part II, card 2, column 5.

Columns 6-9 Contain the value of the program variable NCOL. NCOL has the same function here as described in Part II, card 2, columns 6-9 except that the value of NCOL in Part III may range from 16-120 inclusive and the plot occupies NCOL - 15 columns. (Note: For the contour maps and the residual plots to have the same scale, the value of NCOL for Part III should be 4 greater than NCOL for a corresponding contour map in Part II.)

Before executing the program, the section on operating procedures should be consulted. The output of the three parts of the trend-surface program is described best by examining the sample problem given below.

SAMPLE PROBLEM

As an example consider the input data shown in Figure 1. The input data cards that contain the symbols ".." in the first two columns are the call cards for the tape system mentioned previously. The remainder of the input is as follows. The title of the program is "TOP OF ARBUCKLE IN KANSAS 4 MAY 64." From the card following this title card, it is specified that the 200 xyz-coordinates are to be read; equations of the linear, quadric, and cubic surfaces are to be determined; and coefficient matrix is to be punched. The 200 xyz-coordinates follow, each set being on a separate card.

Following the "..LOAD TREND-SURFACE-2" card is a card having the values 3 and 1. The 3 specifies that three contour maps are to be made, and the 1 specifies that Part III of the trend-surface program is to be used. Interpreting the next card from left to right,

- 1 specifies contouring of the linear surface,
- 4 specifies that the contour map is oriented on the paper so as to occupy as little space as possible,
- 1 specifies that the x plotting limits range from the maximum to the minimum value of the X data array and that the y plotting limits range from the maximum to the minimum value of the Y data array,
- 1 specifies that the output is listed at 6 lines per inch,
- 116 specifies that the total output for the contour map occupies 116 columns,
- 150.0 is the contour interval, and
- 2000.0 is the reference contour for the linear map.

The next two cards make the same specifications except that the quadric and cubic surfaces are to be contoured respectively.

Following the "..LOAD TREND-SURFACE-3" card is a card containing the value 4. This specifies that 4 residual plots are to be made. This value of four includes the plot of the original data. Interpreting the next card from left to right,

- 0 specifies that the original data are plotted on the xy-plane,
- 4 specifies that the plot is oriented on the paper so as to occupy as little space as possible,
- 1 specifies that the x plotting limits range from the maximum to the minimum value of the X data array and that the y plotting limits range from the maximum to the minimum value of the Y data array,
- 1 specifies that the output is listed at 6 lines per inch, and
- 120 specifies that the total output for the plot occupies 120 columns.

The same specifications are made by the following three cards except that the linear, quadric, and cubic residuals are to be plotted respectively.

Now let us examine the output (Fig. 2) from these input data. When listing on the card tabulator, a new page is registered each time the title "TOP OF ARBUCKLE IN KANSAS 4 MAY 64" is printed. The first item output is the coefficient matrix. The line labeled "COLUMN VECTOR" is

the constant column of the matrix. In this instance it contains 10 elements because the 10x10 matrix is generated to solve for the coefficients of the cubic equation. If it is necessary to punch the 10x10 matrix, this output is programmed for 120 column output; otherwise 80 columns are sufficient. If 120 column output facilities as described in the list of necessary hardware are not available, the output is printed as shown in Figure 3.

Figure 1. --Sample input data.

```

..I GOOD
..LOAD TREND-SURFACE-1
TOP OF ARBUCKLE IN KANSAS 4MAY64
200 1111
16.750000 -8.660000 -1709.000000 26.120000 -.500000 -2295.000000
12.130000 -18.020000 -2934.000000 28.250000 -14.350000 -2421.000000
23.360000 -22.100000 -2961.000000 49.860000 -18.600000 -1.000000
29.800000 -10.580000 -2240.000000 10.480000 -19.500000 -3256.000000
13.180000 -3.920000 -1478.000000 27.210000 -10.580000 -2204.000000
22.180000 -16.240000 -1872.000000 14.310000 -17.100000 -2810.000000
12.340000 -4.810000 -1826.000000 42.000000 -17.900000 -885.000000
22.010000 -3.360000 -2584.000000 19.380000 -17.600000 -2348.000000
14.180000 -17.130000 -2810.000000 12.710000 -1.760000 -1313.000000
10.850000 -1.320000 -1477.000000 7.500000 -11.000000 -2270.000000
39.330000 -21.140000 -1119.000000 47.320000 -19.580000 -210.000000
49.300000 -14.850000 -125.000000 32.480000 -2.240000 -1618.000000
46.000000 -2.150000 -1891.000000 4.990000 -18.580000 -2446.000000
15.100000 -18.500000 -3062.000000 18.960000 -14.540000 -1834.000000
28.960000 -10.300000 -2540.000000 32.970000 -11.790000 -1884.000000
4.310000 -8.150000 -1800.000000 23.500000 -1.570000 -2308.000000
18.900000 -16.690000 -2300.000000 41.890000 -15.250000 -1108.000000
5.900000 -8.960000 -2017.000000 31.400000 -12.200000 -2058.000000
7.800000 -1.780000 -1578.000000 31.600000 -22.820000 -2711.000000
5.960000 -1.500000 -1693.000000 35.900000 -9.900000 -1537.000000
2.100000 -2.650000 -1800.000000 11.000000 -21.500000 -3561.000000
21.110000 -12.260000 -1505.000000 4.620000 -13.550000 -2256.000000
29.920000 -4.000000 -1921.000000 21.540000 -14.900000 -1667.000000
41.990000 -5.310000 -2056.000000 33.460000 -12.310000 -1694.000000
21.860000 -4.010000 -2466.000000 44.080000 -10.860000 -978.000000
41.300000 -16.380000 -1077.000000 19.400000 -16.570000 -2300.000000
22.750000 -21.670000 -2780.000000 4.390000 -23.100000 -3782.000000
35.930000 -14.530000 -707.000000 35.180000 -19.790000 -1465.000000
21.590000 -21.160000 -2677.000000 2.800000 -6.200000 -1867.000000
28.200000 -6.400000 -2801.000000 21.200000 -3.500000 -2349.000000
30.500000 -19.830000 -2678.000000 23.500000 -13.020000 -1564.000000
41.200000 -3.500000 -2586.000000 19.090000 -24.400000 -3657.000000
31.380000 -17.740000 -2190.000000 34.450000 -19.450000 -1257.000000
.300000 -.400000 -2029.000000 25.600000 -17.180000 -2337.000000
3.900000 -15.650000 -2208.000000 28.600000 -26.150000 -4373.000000
2.400000 -24.000000 -3167.000000 29.320000 -11.480000 -2109.000000
24.300000 -23.900000 -3367.000000 43.100000 -19.000000 1.000000
43.100000 -15.340000 -399.000000 32.600000 -24.150000 -2923.000000
8.900000 -21.000000 -3603.000000 25.900000 -19.050000 -2607.000000
47.300000 -4.920000 -1400.000000 12.320000 -20.650000 -3292.000000
24.800000 -21.100000 -2959.000000 20.120000 -19.800000 -2751.000000
12.600000 -14.830000 -2545.000000 12.420000 -14.050000 -2435.000000
22.720000 -11.150000 -1431.000000 4.000000 -16.500000 -2333.000000
20.400000 -21.820000 -3022.000000 33.870000 -23.970000 -1626.000000
1.150000 -25.850000 -1923.000000 7.820000 -24.100000 -4272.000000
26.490000 -6.430000 -2431.000000 14.780000 -20.580000 -3431.000000
45.900000 -13.250000 -638.000000 50.650000 -20.980000 145.000000
.850000 -4.200000 -1803.000000 7.210000 -4.020000 -1634.000000
10.500000 -5.500000 -1907.000000 4.710000 -6.130000 -1844.000000
51.200000 -25.010000 134.000000 34.280000 -1.780000 -2305.000000
33.120000 -17.340000 -1792.000000 1.930000 -20.480000 -3075.000000
24.670000 -15.610000 -2146.000000 39.600000 -19.400000 -1135.000000
30.100000 -12.920000 -2131.000000 1.200000 -18.880000 -2802.000000
10.000000 -26.100000 -6242.000000 49.000000 -15.000000 125.000000
39.010000 -9.930000 -1971.000000
44.410000 -8.570000 -1293.000000
24.600000 -20.450000 -2483.000000
25.100000 -22.840000 -3095.000000
24.480000 -24.450000 -3589.000000

```

26.470000	-13.190000	-1490.000000	27.020000	-17.010000	-2407.000000
20.230000	-17.580000	-2307.000000	20.940000	-22.900000	-3044.000000
35.270000	-19.230000	-1037.000000	9.000000	-26.120000	-5211.000000
8.200000	-14.200000	-2133.000000	1.660000	-7.430000	-1819.000000
25.000000	-9.200000	-1407.000000	17.530000	-10.020000	-1657.000000
22.950000	-8.420000	-2133.000000	28.270000	-8.160000	-2540.000000
35.000000	-23.130000	-3090.000000	17.830000	-.100000	-1647.000000
30.070000	-15.180000	-1890.000000	13.920000	-2.200000	-1313.000000
40.000000	-16.820000	-1366.000000	32.580000	-19.860000	-2140.000000
10.820000	-21.420000	-3609.000000	35.450000	-17.030000	-883.000000
8.200000	-12.920000	-2280.000000	21.210000	-14.570000	-1695.000000
18.450000	-9.010000	-1651.000000	36.200000	-16.250000	-1746.000000
38.010000	-26.050000	-1857.000000	11.870000	-2.520000	-1392.000000
29.050000	-21.080000	-2998.000000	13.190000	-13.100000	-2344.000000
35.400000	-20.900000	-1902.000000	49.700000	-25.900000	563.000000
41.180000	-20.140000	-998.000000	28.520000	-17.200000	-2440.000000
26.700000	-12.800000	-1785.000000	29.800000	-13.960000	-2346.000000
15.580000	-4.630000	-1593.000000	30.400000	-10.020000	-2182.000000
20.700000	-20.390000	-2722.000000	37.450000	-7.180000	-1934.000000
9.790000	-9.950000	-1835.000000	25.020000	-17.820000	-2063.000000
20.800000	-11.500000	-1477.000000	34.200000	-26.200000	-2834.000000
41.110000	-5.220000	-2274.000000	16.600000	-1.850000	-1583.000000
6.600000	-19.680000	-2853.000000	17.400000	-1.100000	-1521.000000
22.110000	-21.000000	-2598.000000	41.120000	-19.860000	-835.000000
26.860000	-21.170000	-2951.000000	7.910000	-8.010000	-1998.000000
29.930000	-16.800000	-2435.000000	29.920000	-22.020000	-3061.000000
24.620000	-23.120000	-3177.000000	17.100000	-14.050000	-2402.000000
26.040000	-16.520000	-2241.000000	44.080000	-20.520000	-488.000000
11.120000	-9.500000	-2012.000000	12.580000	-10.680000	-2240.000000
32.860000	-13.520000	-1775.000000	21.700000	-14.210000	-1608.000000
7.500000	-6.620000	-1937.000000	1.600000	-16.250000	-2462.000000
2.000000	-20.430000	-3075.000000	20.600000	-6.280000	-1613.000000
9.010000	-13.890000	-2101.000000	2.580000	-8.140000	-1936.000000
15.100000	-25.850000	-5400.000000	30.320000	-15.550000	-2195.000000
45.020000	-25.080000	-485.000000	39.620000	-18.030000	-1421.000000
36.990000	-25.280000	-1852.000000	.200000	-8.250000	-1609.000000
22.400000	-13.230000	-1500.000000			
27.910000	-16.480000	-2481.000000			
7.000000	-15.680000	-2489.000000	..I		
12.610000	-14.770000	-2545.000000	..LOAD TREND-SURFACE-2		
19.920000	-11.100000	-1599.000000	3 1		
29.620000	-20.270000	-2875.000000	1411 116 150.0	-2000.0	
36.500000	-10.210000	-1353.000000	2411 116 150.0	-2000.0	
16.580000	-5.120000	-1608.000000	3411 116 150.0	-2000.0	
42.860000	-23.480000	-792.000000	..I		
34.450000	-6.220000	-1499.000000	..LOAD TREND-SURFACE-3		
3.880000	-1.060000	-1860.000000	4		
30.260000	-22.270000	-3029.000000	0411 120		
35.600000	-20.950000	-1860.000000	1411 120		
.100000	-16.610000	-2382.000000	2411 120		
23.230000	-11.590000	-1412.000000	3411 120		

The next quantities of the output are the trend-surface and residual values. This section is preceded by the title. The columns labeled "X-COORD," "Y-COORD," and "Z-COORD" contain the xyz-coordinates that were read into the program as data in Part I. The "LN-SURF" column contains the value of the linear surface calculated from the corresponding xy-coordinate, and the "LN-RESD" is the residual corresponding to this calculated value. The residual is that amount by which the z-coordinate predicted by the linear surface differs from the z data coordinate. The columns labeled "QD-SURF," "QD-RESD," "CB-SURF," and "CB-RESD" contain similar values for the quadric and cubic surfaces. This portion of the output also is programmed for 120 column output. If 120 column output is not available, the output is printed as shown in Figure 4. If the equation of a particular surface is not calculated, the columns of surface and residual values for that surface are printed as zeros.

Figure 2. --Sample output

TOP OF ARBUCKLE IN KANSAS 4MAY64

COEFFICIENT MATRIX

2.0000E+02	4.6857E+03	-2.8725E+03	1.4442E+05	-7.0959E+04	5.1209E+04	5.0396E+06	-2.2494E+06	1.2894E+06	-1.0008E+06
4.6857E+03	1.4442E+05	-7.0959E+04	5.0396E+06	-2.2494E+06	1.2894E+06	1.9020E+08	-7.9938E+07	4.1471E+07	-2.5448E+07
-2.8725E+03	-7.0959E+04	5.1209E+04	-2.2494E+06	1.2894E+06	-1.0008E+06	-7.9938E+07	4.1471E+07	-2.5448E+07	2.0678E+07
1.4442E+05	5.0396E+06	-2.2494E+06	1.9020E+08	-7.9938E+07	4.1471E+07	7.5893E+09	-3.0591E+09	1.4915E+09	-8.2724E+08
-7.0959E+04	-2.2494E+06	1.2894E+06	-7.9938E+07	4.1471E+07	-2.5448E+07	-3.0591E+09	1.4915E+09	-8.2724E+08	5.2888E+08
5.1209E+04	1.2894E+06	-1.0008E+06	4.1471E+07	-2.5448E+07	2.0678E+07	1.4915E+09	-8.2724E+08	5.2888E+08	-4.4428E+08
5.0396E+06	1.9020E+08	-7.9938E+07	7.5893E+09	-3.0591E+09	1.4915E+09	3.1567E+11	-1.2355E+11	5.7684E+10	-3.0045E+10
-2.2494E+06	-7.9938E+07	4.1471E+07	-3.0591E+09	1.4915E+09	-8.2724E+08	-1.2355E+11	5.7684E+10	-3.0045E+10	1.7340E+10
1.2894E+06	4.1471E+07	-2.5448E+07	1.4915E+09	-8.2724E+08	5.2888E+08	5.7684E+10	-3.0045E+10	1.7340E+10	-1.1407E+10
-1.0008E+06	-2.5448E+07	2.0678E+07	-8.2724E+08	5.2888E+08	-4.4428E+08	-3.0045E+10	1.7340E+10	-1.1407E+10	9.8328E+09

COLUMN VECTOR

-4.1768E+05	-8.6219E+06	6.3991E+06	-2.3295E+08	1.3247E+08	-1.1977E+08	-7.0912E+09	3.5280E+09	-2.4649E+09	2.4361E+09
-------------	-------------	------------	-------------	------------	-------------	-------------	------------	-------------	------------

TOP OF ARBUCKLE IN KANSAS 4MAY64

X-COORD	Y-COORD	Z-COORD	LN-SURF	LN-RESD	QD-SURF	QD-RESD	CB-SURF	CB-RESD
16.750	-8.660	-1709.000	-2039.556	330.556	-2018.010	309.010	-1955.942	246.942
12.130	-18.020	-2934.000	-2733.367	-200.632	-2806.773	-127.226	-2726.994	-207.005
23.360	-22.100	-2961.000	-2514.279	-446.720	-2991.344	30.344	-3178.087	217.087
29.800	-15.980	-2430.000	-1630.672	-689.327	-1826.025	-414.975	-1807.457	-423.542
13.180	-3.920	-1478.000	-1920.913	442.913	-1937.145	459.145	-1806.165	328.165
22.180	-16.240	-1872.000	-2240.271	368.271	-2345.074	473.074	-2326.012	454.012
12.340	-4.810	-1826.000	-2002.663	176.663	-1885.740	59.740	-1826.089	0.089
22.010	-3.360	-2584.000	-1542.578	-1041.421	-2217.427	-366.572	-1877.458	-706.541
14.180	-17.130	-2810.000	-2603.969	-206.030	-2655.029	-154.970	-2597.664	-212.335
10.850	-1.320	-1477.000	-1870.474	393.474	-1908.325	431.325	-1701.083	224.083
39.330	-21.140	-1119.000	-1832.908	713.908	-1408.743	289.743	-1335.201	216.201
49.300	-14.850	-1259.000	-1096.318	971.318	-75.311	-49.688	-118.004	-6.995
46.000	-2.150	-1891.000	-531.722	-1359.277	-1787.608	-103.391	-2501.793	610.793
15.100	-18.500	-3062.000	-2642.664	-419.335	-2826.222	-235.777	-2789.426	-272.573
28.960	-10.300	-2540.000	-1648.437	-891.562	-1861.683	-678.316	-1832.783	-707.216
4.310	-8.150	-1800.000	-2501.529	701.529	-1578.220	-221.779	-1853.583	53.583
18.900	-16.690	-2300.000	-2394.041	94.041	-2499.682	199.682	-2472.480	172.480
5.900	-8.960	-2017.000	-2483.216	466.216	-1712.792	-304.208	-1900.527	-116.472
7.800	-1.780	-1578.000	-2019.734	437.734	-1690.029	112.029	-1703.628	125.628
5.960	-1.500	-1693.000	-2072.877	379.877	-1561.402	-131.597	-1689.581	-3.418
2.100	-2.650	-1800.000	-2287.769	487.769	-1233.740	-566.259	-1722.176	-77.823
21.110	-12.260	-1505.000	-2064.745	559.745	-2113.580	608.580	-2062.756	557.756
29.920	-4.900	-1921.000	-1266.097	-654.902	-2164.512	243.512	-1967.729	46.729
41.990	-5.310	-2056.000	-862.444	-1193.555	-1555.008	-500.991	-1946.341	-109.658
21.860	-4.010	-2466.000	-1584.032	-881.967	-2174.175	-291.824	-1882.211	-583.788
41.300	-16.380	-1077.000	-1495.016	418.016	-979.185	-97.814	-938.160	-138.839
22.750	-21.670	-2780.000	-2514.783	-265.216	-2965.158	189.155	-3122.630	342.630
35.930	-14.530	-1605.000	-1605.304	898.304	-1452.905	745.905	-1463.968	756.968
21.590	-21.160	-2677.000	-2532.571	-144.428	-2957.601	280.601	-3079.571	402.571
28.200	-6.400	-2801.000	-1465.080	-1335.919	-2015.942	-785.058	-1898.070	-902.929
30.500	-19.830	-2678.000	-2108.976	-569.023	-2176.084	-501.915	-2230.778	-447.221
41.200	-3.500	-2586.000	-794.567	-1791.432	-1844.603	-741.396	-2172.163	-413.836
31.380	-17.740	-2190.000	-1960.024	-229.975	-1933.397	-256.602	-1937.918	-252.081
3.300	-1.400	-2029.000	-2235.600	206.600	-1075.222	-953.777	-1676.332	-352.667
3.900	-15.650	-2208.000	-2927.838	719.838	-2379.423	171.423	-2272.725	54.725
2.400	-24.000	-3167.000	-3443.553	276.553	-4106.357	939.357	-3694.767	527.767
24.300	-23.900	-3367.000	-2575.702	-791.297	-3217.090	-149.099	-3545.232	178.232
43.100	-15.340	-399.000	-1367.260	968.260	-786.979	387.979	-786.996	387.996
8.900	-21.000	-3603.000	-3023.530	-579.469	-3366.317	-236.682	-3230.403	-372.596
47.300	-4.920	-1400.000	-632.018	-767.981	-1234.699	-165.300	-2017.582	617.582
24.800	-21.100	-2959.000	-2402.886	-556.113	-2749.883	-209.117	-2881.806	-77.193
12.600	-14.830	-2545.000	-2540.403	-4.596	-2389.018	-155.981	-2336.237	-208.762
22.720	-11.150	-1431.000	-1940.642	509.642	-2045.249	614.249	-1987.083	596.083
20.400	-21.820	-3022.000	-2615.277	-406.271	-3127.986	105.986	-3272.986	252.986
1.150	-25.850	-1923.000	-3593.950	1670.950	-4622.453	2699.453	-4157.995	2234.995
26.490	-6.430	-2431.000	-1534.057	-896.942	-2042.017	-388.982	-1901.636	-529.363
45.900	-13.250	-638.000	-1142.702	504.702	-542.397	-95.602	-697.614	59.614
1.850	-4.200	-1803.000	-2421.758	618.758	-1153.689	-649.310	-1746.438	-56.561
10.500	-5.500	-1907.000	-2112.854	205.854	-1803.162	-103.837	-1834.077	-72.923
51.200	-25.010	134.000	-1577.134	1711.134	30.885	103.115	772.344	-638.344
33.120	-17.040	-1792.000	-1859.224	61.224	-1755.353	-36.647	-1747.312	-44.687
24.670	-15.610	-2146.000	-2107.765	-38.234	-2191.948	45.948	-2172.338	26.338
30.100	-12.920	-2131.000	-1746.830	-384.169	-1814.614	-316.385	-1803.124	-327.875
10.000	-26.100	-6242.000	-3259.125	-2982.874	-4504.343	-1737.656	-4670.325	-1571.674
26.120	-4.500	-2295.000	-1224.325	-1070.674	-2539.911	244.911	-1938.921	-356.078
28.250	-14.350	-2421.000	-1897.884	-523.115	-1950.287	-470.712	-1931.306	-489.693
49.860	-18.600	-1.000	-1279.347	1278.347	69.380	-70.380	389.478	-390.478
10.480	-19.500	-3256.000	-2879.280	-376.719	-3066.403	-189.597	-2960.498	-295.501
27.210	-10.580	-2204.000	-1732.662	-471.337	-1921.386	-282.613	-1878.213	-325.786
14.310	-17.100	-2810.000	-2597.209	-212.790	-2649.187	-160.812	-2592.929	-217.070
42.000	-17.900	-885.000	-1550.578	665.578	-931.568	46.568	-829.515	-55.484
19.380	-17.600	-2348.000	-2424.906	76.906	-2585.608	237.608	-2574.004	226.004
12.710	-1.760	-1313.000	-1821.293	508.293	-1994.147	681.147	-1732.271	149.271
7.500	-11.000	-2270.000	-2531.775	261.775	-1930.973	-339.026	-2009.938	-260.061
47.320	-19.580	-210.000	-1432.963	1222.963	-303.512	93.512	2.080	-212.080
32.480	-2.400	-1618.000	-1049.937	-546.962	-2313.891	656.891	-2086.428	462.328
46.990	-18.580	-2446.000	-3045.153	599.153	-2900.972	455.972	-2678.859	232.859
18.960	-14.540	-1834.000	-2274.098	440.098	-2297.196	463.196	-2255.141	421.141
32.970	-11.790	-1884.000	-1572.017	-311.982	-1654.264	-229.735	-1674.625	-209.374
23.500	-1.570	-2308.000	-1386.012	-921.987	-2386.937	78.937	-1883.179	-424.820
41.890	-15.250	-1108.000	-1409.985	301.985	-914.333	-193.666	-918.768	-189.231
31.400	-12.200	-2058.000	-1656.263	-401.736	-1739.807	-318.192	-1740.600	-317.399
31.600	-22.820	-2711.000	-2229.178	-481.021	-2415.908	-295.611	-2597.601	-113.399
39.900	-18.970	-1937.000	-1353.277	-1353.277	-1834.222	1834.222	-1624.732	87.732
11.000	-21.500	-3561.000	-2968.180	-592.819	-3430.204	-130.795	-3369.783	-191.216
4.620	-13.550	-2256.000	-2784.640	528.640	-2104.516	-151.483	-2112.765	-143.234
21.540	-14.900	-1667.000	-2192.190	525.190	-2258.792	591.792	-2224.508	557.508
33.460	-12.310	-1694.000	-1581.159	-112.840	-1620.891	-73.108	-1642.795	-51.204
44.080	-10.860	-978.000	-1083.665	105.665	-859.007	-118.992	-1138.926	160.926
19.400	-16.570	-2300.000	-2367.789	67.789	-2472.255	172.255	-2446.204	146.204
4.390	-23.100	-3782.000	-3315.971	-466.028	-3871.240	89.240	-3568.705	-213.294
35.180	-19.790	-1465.000	-1922.498	457.498	-1751.808	286.808	-1749.560	284.560
2.800	-6.200	-1867.000	-2618.344	437.344	-1977.993	-489.046	-1701.084	-75.915
21.200	-3.500	-2349.000	-1582.131	-766.868	-2195.779	-151.520	-1869.631	-479.368
23.500	-13.020	-1564.000	-2012.195	448.195	-2088.793	524.793	-2046.304	482.304
19.090	-24.400	-3657.000	-2808.207	-848.792	-3670.521	13.521	-3994.401	337.401

34.450	-19.450	-1257.000	-1932.650	675.650	-1795.649	538.649	-1798.217	541.217
29.600	-26.190	-4373.000	-2529.425	-1843.574	-3231.289	-1141.710	-2271.466	-651.533
29.320	-11.480	-2109.000	-1698.794	-410.206	-1840.511	-268.488	-1821.275	-287.724
43.100	-19.000	1.000	-1567.419	1568.419	-836.307	837.307	-677.995	678.995
32.600	-24.150	-2923.000	-2262.536	-660.463	-2492.555	-430.444	-2752.406	-170.593
25.700	-19.050	-2607.000	-2247.458	-359.541	-2429.577	-177.422	-2477.729	-129.270
12.320	-20.670	-3292.000	-2869.716	-422.284	-3240.144	-51.855	-3193.354	-98.645
20.120	-19.800	-2751.000	-2516.481	-234.518	-2836.400	85.400	-2687.242	136.242
12.420	-14.050	-2435.000	-2504.834	69.834	-2306.330	-128.669	-2263.966	-171.033
4.000	-16.500	-2333.000	-2970.385	637.385	-2518.208	185.208	-2366.945	33.945
33.870	-23.970	-1626.000	-2202.682	576.682	-2329.844	703.844	-2542.982	916.982
7.820	-24.100	-4272.000	-3235.593	-1036.407	-4068.714	-203.285	-3978.295	-293.704
14.780	-20.500	-3431.000	-2769.017	-661.982	-3162.227	-268.772	-3166.761	-264.238
50.650	-20.980	145.000	-1378.397	1523.397	149.800	-38.800	-684.888	-539.888
7.210	-4.020	-1634.000	-2161.469	527.469	-1619.608	-14.391	-1771.379	137.379
4.710	-6.130	-1844.000	-2375.307	531.307	-1501.572	-342.427	-1807.411	-36.589
34.280	-1.780	-2305.000	-973.000	-1331.999	-2339.777	34.777	-2152.545	-152.454
1.930	-20.480	-3075.000	-3269.558	194.558	-3250.479	175.479	-2863.058	-211.942
39.600	-19.400	-1135.000	-1727.118	592.118	-1263.095	128.095	-1176.697	41.697
1.200	-18.880	-2802.000	-3210.802	408.802	-2896.925	92.925	-2856.631	-245.368
49.000	-15.000	125.000	-1116.334	1241.334	-107.397	232.397	-134.586	259.586
39.010	-9.930	-1971.000	-1232.452	-738.547	-1329.767	-641.233	-1499.950	-471.049
44.410	-8.570	-1293.000	-945.434	-347.566	-1016.747	-276.252	-1440.087	147.087
24.600	-23.450	-2483.000	-2375.214	-107.785	-2676.961	193.961	-2777.207	294.207
25.100	-23.840	-3095.000	-2486.230	-58.769	-2982.267	-112.732	-3223.671	128.671
24.480	-24.450	-3589.000	-2598.693	-990.306	-3299.135	-289.864	-3679.687	90.687
26.470	-13.190	-1490.000	-1904.539	414.539	-1990.194	500.194	-1958.930	468.930
20.230	-17.580	-2307.000	-2390.341	83.341	-2552.844	245.844	-2545.971	238.971
35.270	-19.230	-1037.000	-1888.329	851.329	-1701.620	664.620	-1689.921	652.921
8.200	-14.200	-2133.000	-2675.213	546.213	-2276.270	143.270	-2238.644	105.644
25.000	-9.200	-1407.000	-1744.218	337.218	-1986.312	579.312	-1909.431	502.431
22.950	-8.420	-2133.000	-1782.286	-350.713	-2023.213	-109.786	-1923.057	-209.942
35.000	-23.130	-3090.000	-2112.246	-977.753	-2098.700	-991.299	-2223.945	-866.054
30.070	-15.180	-1890.000	-1871.607	-18.392	-1881.625	-8.374	-1870.688	-19.311
40.000	-16.820	-1366.000	-1570.271	204.271	-1121.322	-244.677	-1075.046	-290.953
10.820	-21.420	-3609.000	-2970.893	-638.106	-3418.216	-190.783	-3350.195	-258.804
8.200	-22.800	-2280.000	-2409.212	329.212	-2132.908	-147.690	-2137.240	-142.759
18.450	-9.010	-1651.000	-1991.754	340.754	-2036.706	385.706	-1941.233	312.233
38.010	-26.050	-1857.000	-2153.408	296.408	-2111.880	254.880	-2348.329	401.329
29.050	-21.080	-2998.000	-2234.435	-763.564	-2429.687	-568.312	-2545.608	-452.391
35.400	-20.900	-1902.000	-1974.539	72.539	-1822.818	-79.181	-1841.874	-60.125
41.180	-20.140	-998.000	-1705.370	707.370	-1121.642	123.642	-991.707	-6.292
26.700	-12.800	-1785.000	-1874.153	89.153	-1969.023	186.023	-1936.884	151.884
15.580	-12.920	-1593.000	-1865.234	272.234	-2135.688	415.688	-1842.969	249.969
20.700	-20.390	-2722.000	-2525.507	-196.492	-2890.066	170.066	-2970.828	248.828
9.790	-9.950	-1835.000	-2384.176	549.176	-1926.712	91.712	-1984.075	149.075
20.800	-11.500	-1477.000	-2035.389	558.389	-2088.334	611.334	-2032.526	555.526
41.110	-5.220	-2274.000	-892.175	-1381.824	-1619.419	-654.580	-1957.361	-316.638
6.600	-19.680	-2853.000	-3041.911	188.911	-3119.685	266.685	-2914.621	61.621
22.110	-21.000	-2598.000	-2503.344	-94.655	-2704.215	306.215	-3021.539	423.539
26.860	-21.170	-2951.000	-2325.595	-625.404	-2615.968	-338.431	-2745.408	-205.592
29.930	-16.800	-2435.000	-1965.715	-469.284	-1976.119	-458.880	-1974.411	-460.588
24.620	-23.120	-3177.000	-2520.444	-656.555	-3062.813	-114.186	-3325.517	148.517
26.040	-16.520	-2241.000	-2103.584	-137.415	-2191.252	-49.747	-2185.292	-55.707
11.120	-9.300	-2012.000	-2307.193	295.193	-1939.143	-72.856	-1974.061	-37.938
32.860	-13.920	-1775.000	-1670.959	-104.040	-1661.681	-113.318	-1667.465	-107.534
7.500	-6.520	-1937.000	-2292.240	355.240	-1677.968	-259.031	-1844.526	-92.473
2.000	-20.430	-3075.000	-3264.067	189.067	-3240.379	165.379	-2857.677	-217.322
9.010	-13.890	-2101.000	-2630.364	529.364	-2254.081	153.081	-2223.641	122.641
15.100	-25.850	-5400.000	-3044.624	-2355.375	-4212.862	-1187.137	-4580.194	-819.805
45.320	-25.080	-4485.000	-1824.319	1339.319	-988.789	503.789	-743.529	255.529
36.990	-25.270	-1852.000	-2151.463	299.463	-2137.119	285.119	-2349.551	497.551
22.400	-13.230	-1500.000	-2066.995	566.995	-2129.934	629.934	-2086.404	586.404
27.910	-16.480	-2481.000	-2027.759	-453.240	-2083.416	-397.583	-2078.826	-402.173
7.000	-15.680	-2489.000	-2807.406	318.406	-2450.622	-38.377	-2359.793	-129.206
12.610	-14.770	-2545.000	-2536.728	-8.271	-2382.453	-162.546	-2330.429	-214.570
19.920	-11.100	-1999.000	-2448.167	449.167	-2084.805	485.805	-2027.315	428.315
29.620	-20.270	-2875.000	-2167.691	-707.308	-2292.385	-582.614	-2369.270	-505.729
36.500	-10.210	-1353.000	-1346.604	-6.395	-1483.804	130.804	-1583.688	230.688
16.580	-5.120	-1608.000	-1852.653	244.653	-2025.416	417.416	-1861.514	253.514
42.860	-23.480	-792.000	-1821.874	1029.874	-1151.247	359.247	-981.715	189.715
34.450	-6.220	-1499.000	-1209.122	-289.877	-1844.363	345.363	-1880.465	381.465
3.880	-1.060	-1866.000	-2130.721	270.721	-1400.548	-459.451	-1675.833	-184.166
30.260	-21.270	-3029.000	-2251.866	-71.133	-2471.410	-557.589	-2639.247	-389.752
35.600	-20.950	-1860.000	-1969.398	109.398	-1806.592	-93.407	-1822.942	-37.057
1.100	-16.610	-2382.000	-3129.976	747.976	-2421.856	39.856	-2215.081	-166.918
23.230	-11.590	-1412.000	-1944.622	532.622	-2045.573	633.573	-1992.246	580.246
27.020	-17.010	-2407.000	-2091.790	-315.209	-2174.083	-232.916	-2176.152	-230.847
20.940	-22.900	-3344.000	-2653.325	-390.674	-3277.325	233.325	-3551.976	457.976
9.000	-26.120	-3211.000	-3299.597	-1911.402	-4544.695	-666.304	-4656.406	-554.593
1.660	-7.430	-1819.000	-2566.306	747.306	-1977.211	-451.688	-1800.083	-18.916
17.530	-10.320	-1657.000	-2083.217	426.217	-2097.199	400.199	-2002.666	345.666
28.270	-8.160	-2540.000	-1558.575	-981.424	-1934.114	-605.885	-1867.228	-672.771

NOTE: Not all data values shown.

TOP OF ARBUCKLE IN KANSAS 4MAY64

COEFFICIENTS OF LINEAR EQUATION

Z = -2225.53890 + 39.37817 X + 54.68844 Y

COEFFICIENTS OF QUADRIC EQUATION

Z = -1050.91450 + -104.39353 X + -18.33512 Y + 1.72471 X2 + -4.09006 XY + -6.05983 Y2

COEFFICIENTS OF CUBIC EQUATION

Z = -1667.84560 + 11.47826 X + 30.11917 Y + -85551 X2 + 3.52750 XY + 3.92234 Y2 + -00089 X3 + -16738 X2Y + -01073 XY2 + 24530 Y3

ERROR MEASURES

SURFACE	LINEAR	QUADRIC	CUBIC
STANDARD DEVIATION	730.37	461.12	398.99
VARIATION EXPLAINED BY SURFACE	.67719760E+08	.13156113E+09	.14219545E+09
VARIATION NOT EXPLAINED BY SURFACE	.10615534E+09	.42313972E+08	.31679659E+08
TOTAL VARIATION	.17387510E+09	.17387510E+09	.17387510E+09
COEFFICIENT OF DETERMINATION	.38947359	.75664157	.81780226
COEFFICIENT OF CORRELATION	.62407819	.86985146	.90432420

TOP OF ARBUCKLE IN KANSAS 4MAY64

CONTOURED LINEAR SURFACE

PLOTING LIMITS

MAXIMUM X = 51.200000 MINIMUM X = .100000
 MAXIMUM Y = -.100000 MINIMUM Y = -26.200000

X-SCALE IS HORIZONTAL

X-VALUE = .10 + .4866 X (SCALE VALUE)

Y-SCALE IS VERTICAL

CONTOUR INTERVAL = 150.00
 REFERENCE CONTOUR (.....) = -2000.00

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0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
-10 AAAAA ..... 00000000 1111111 22222222 3333333 4444444
-91 AAAAA ..... 00000000 1111111 22222222 3333333 4444444
-1.72 AAAAAA ..... 00000000 1111111 22222222 3333333 4444444
-2.53 AAAAAA ..... 00000000 1111111 22222222 3333333 4444444
-3.34 AAAAAA ..... 00000000 1111111 22222222 3333333 4444444
-4.15 AAAAAA ..... 00000000 1111111 22222222 3333333 4444444
-4.96 BBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-5.77 BBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-6.58 BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-7.39 BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-8.21 BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-9.02 BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-9.83 C BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-10.64 CCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-11.45 CCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-12.26 CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-13.07 CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-13.88 CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-14.69 CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-15.51 DD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-16.32 DDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-17.13 DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-17.94 DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-18.75 DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-19.56 DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-20.37 DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-21.18 EE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-21.99 EEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-22.81 EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-23.62 EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-24.43 EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-25.24 EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-26.05 EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4
-26.86 FFF EEEEE DDDDD DDDDD CCCCCC BBBBBB AAAAAA ..... 00000000 1111111 22222222 3333333 4

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0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

4MAY64

CONTOURED QUADRIC SURFACE

PLOTTING LIMITS

MAXIMUM X =	51.200000	MINIMUM X =	.100000
MAXIMUM Y =	-.100000	MINIMUM Y =	-26.200000

X-SCALE IS HORIZONTAL
X-VALUE = .10 + .4866 X (SCALE VALUE)

Y-SCALE IS VERTICAL

CONTOUR INTERVAL = 150.00
REFERENCE CONTOUR (.....) = -2000.00

-10	2	1111	0000	.....	AAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-91	22	111	0000	.....	AAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-172	22	1111	00000	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-253	22	1111	0000	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-334	2	1111	00000	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-415	2	1111	00000	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-496	2	1111	00000	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-577	1111	00000	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-658	1111	00000	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-739	1111	00000	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-821	111	000000	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-902	1	000000	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-983	000000	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1064	00000	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1145	000	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1226	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1307	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1388	..	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1469	..	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1551	AAA	RRRRRRRRRRR	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1632	BBB8B	RRRRRRRRRRR	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1713	CCCCC	CCCCCCCCCCC	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1794	DDDDD	DDDDDDDDDD	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1875	EEEEEE	EEEEEEEEEEE	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-1956	FFFFF	FFFFFFFFFFFF	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2037	GGGGGG	GGGGGGGGGG	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2118	HHHHH	HHHHHHHHH	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2199	IIIII	IIIIIIIIII	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2281	JJJJJJ	JJJJJJJJJJ	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2362	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2443	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2524	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2605	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....
-2686	.....	.....	.....	.....	AAAAAAAAA	B8B8B8B8B8B8B8B8	B8B8B8B8B8B8B8B8	AAAAAA	.....

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

CONTOURED CUBIC SURFACE

PLOTTING LIMITS

```

FLOPPING LIMITS
MAXIMUM X = 51.200000
MAXIMUM Y = -100000
MINIMUM X = 100000
MINIMUM Y = -26.200000

```

X-SCALE IS HORIZONTAL
X-VALUE = .10 + .4866 X (SCALE VALUE)

Y-SCALE IS VERTICAL

```
CONTOUR INTERVAL = 150.00
REFERENCE CONTOUR (.....) = -2000.00
```

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

[illegible][illegible]

0123456789 123456789 123456789 123456789 123456789

PLOT OF LINEAR RESIDUALS

PLOTTING LIMITS

MAXIMUM X =	51.20000	MINIMUM X =	•10000
MAXIMUM Y =	-1.10000	MINIMUM Y =	-26.20000

X-SCALE IS HORIZONTAL
X-VALUE = .10 + .4866 X (SCALE VALUE)

Y-SCALE IS VERTICAL

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

[illegible]

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

OVERPRINT VALUES

* 503
* 508
* -766

NOTE: all overprint values not shown; quadric cubic residuals are omitted.

Figure 3. --10x10 coefficient matrix printed in 80 columns.

```

1TOP OF ARBUCKLE IN KANSAS      4MAY64
2COEFFICIENT MATRIX
30 2.0000E+02  4.6857E+03 -2.8725E+03  1.4442E+05 -7.0959E+04  5.1209E+04
49      2.0396E+06 -2.2494E+06  1.2894E+06 -1.0008E+06
50 4.6857E+03  1.4442E+05 -7.0959E+04  5.0396E+06 -2.2494E+06  1.2894E+06
69      1.9020E+08 -7.9938E+07  4.1471E+07 -2.5448E+07
70 -2.8725E+03 -7.0959E+04  5.1209E+04 -2.2494E+06  1.2894E+06 -1.0008E+06
89      7.9938E+07  4.1471E+07 -2.5448E+07  2.0678E+07
90 1.4442E+05  5.0396E+06 -2.2494E+06  1.9020E+08 -7.9938E+07  4.1471E+07
99      7.5893E+09 -3.0591E+09  1.4915E+09 -8.2724E+08
00 -7.0959E+04 -2.2494E+06  1.2894E+06 -7.9938E+07  4.1471E+07 -2.5448E+07
09      3.0591E+09  1.4915E+09 -8.2724E+08  5.2888E+08
10 5.1209E+04  1.2894E+06  1.4915E+09 -8.2724E+08  5.2888E+08 -4.4428E+08
19      5.0396E+06  1.9020E+08 -7.9938E+07  7.5893E+09 -3.0591E+09  1.4915E+09
20      3.1567E+11 -1.2355E+11  5.7684E+10 -3.0045E+10  1.7340E+10
29      4.1471E+07 -3.0591E+09  1.4915E+09 -8.2724E+08  5.2888E+08
30 -2.2494E+06 -7.9938E+07  3.1567E+11 -1.2355E+11  5.7684E+10 -3.0045E+10
39      4.1471E+07 -2.5448E+07  1.4915E+09 -8.2724E+08  5.2888E+08
40 1.2894E+06  4.1471E+07 -2.5448E+07  1.4915E+09 -8.2724E+08  5.2888E+08
49      5.7684E+10 -3.0045E+10  1.7340E+10 -1.1407E+10
50 -1.0008E+06 -2.5448E+07  2.0678E+07 -3.0045E+10  1.7340E+10 -1.1407E+10
59      3.0045E+10  1.7340E+10 -1.1407E+10  9.6328E+09
60 COLUMN VECTOR
69 -4.1768E+05 -8.6219E+06  6.3991E+06 -2.3255E+08  1.3247E+08 -1.1977E+08
70      -7.0912E+09  3.5280E+09 -2.4649E+09  2.4361E+09

```

Figure 4. --Partial table of surface and residual values printed in 80 columns.

```

1TOP OF ARBUCKLE IN KANSAS      4MAY64
20 X-COORD      Y-COORD      Z-COORD      LN-SURF      LN-RES      QD-SURF
30      16.750      -8.660      -1709.000      -2039.556      330.556      -2018.010
49      12.130      -18.020      -2934.000      -2733.367      -200.632      -2806.773
50      23.360      -22.100      -2961.000      -2514.279      -446.720      -2991.344
69      29.800      -10.580      -2240.000      -1630.672      -609.327      -1825.025
70      13.180      -3.920      -1478.000      -1807.457      -432.542      -1937.145
79      22.180      -16.240      -1872.000      -2240.271      368.271      -2345.074
80      12.340      -4.810      -1826.000      -2002.663      176.663      -1885.740
89      22.010      -3.360      -2584.000      -1542.578      -1041.421      -2217.427
90      14.180      -17.130      -2810.000      -2603.969      -206.030      -2655.029
99      10.850      -1.320      -1477.000      -1870.474      393.474      -1908.325
00      39.330      -21.140      -1119.000      -1832.908      713.908      -1408.743
09      49.300      -14.850      -125.000      -1096.318      971.318      -75.311
10      46.000      -2.150      -1891.000      -531.722      -1359.277      -1787.608
19      15.100      -18.500      -3062.000      -2642.664      -419.335      -2826.222
20      28.960      -10.300      -2540.000      -1648.437      -891.562      -1861.683
29      4.310      -8.150      -1800.000      -2501.529      701.529      -1578.220
30      18.900      -16.690      -2300.000      -2394.041      94.041      -2499.682
39      5.900      -8.960      -2017.000      -2483.216      466.216      -1712.792
40      7.800      -1.780      -1578.000      -2015.734      437.734      -1690.029
49      5.960      -1.500      -1693.000      -2072.877      379.877      -1561.402
50      -131.597      -1689.581      -3.418

```

The next section of the output is the printing of the equations of the surfaces and printing of the error measures. These form a single page headed by the title. The coefficients of the calculated equations are self-explanatory except that the exponents of the algebraic terms can not be printed as superscripts. The error measures are computed from the following formulas. The "TOTAL VARIATION," V, is given by

$$V = \sum_{i=1}^N (z_i - \bar{z})^2$$

where z_i is the i th z data coordinate,

$$\bar{z} = \frac{\sum_{i=1}^N z_i}{N}$$

V is calculated entirely from the input data and hence is the same for each surface. The "VARIATION NOT EXPLAINED BY SURFACE," S, is given by

$$S = \sum_{i=1}^N (z_i \text{ observed} - z_i \text{ calculated})^2$$

This value is found by squaring the appropriate order of residuals and summing. The "VARIATION EXPLAINED BY SURFACE," E, is given by

$$E = V - S.$$

The "COEFFICIENT OF DETERMINATION," T, is given by

$$T = \frac{E}{V}$$

It should be noted that E, and hence T, may be negative if S is sufficiently large. The "COEFFICIENT OF CORRELATION," L, is given by

$$L = T^{\frac{1}{2}}.$$

If T is negative, L also is output as a negative number (Spiegel, 1961; p. 252-253). The "STANDARD DEVIATION," D, is given by

$$D = \left(\frac{S}{N} \right)^{\frac{1}{2}}$$

where N is the number of sets of data coordinates. Each of these quantities is calculated for each of the three surfaces. If the equation of a particular surface is not calculated, the corresponding error measures are printed as zeros.

The next section of the output is the printing of the contoured trend surfaces. First, the program title is punched. The next line tells which surface is contoured. Following this are the plotting limits. These plotting limits are in the units of the original x and y data coordinates. Next is printed a sequence of three statements which indicate the orientation of the contour map. These statements tell which of the x and y scales is horizontal and which is vertical. Also the formula is given for converting the horizontal scale reading into the units of the corresponding coordinates. Next the contour interval and the reference contour for the contour map are printed. The contour map follows this preliminary information. The scale on the left edge of

the contour map reads directly in terms of whichever scale is specified as vertical, but the horizontal scales do not read directly. First of all, on the horizontal scales only the units digits of the scale values are shown. The blanks in the scales represent increments of ten. For instance, the leftmost blank represents ten and the next blank to the right represents twenty. After the reading is made on the horizontal scale, the reading must be substituted for "SCALE VALUE" in the formula for the horizontal scale. The value given by this substitution corresponds directly to the original units of whichever axis (x or y) is horizontal. On the contour maps the scales are positioned so that any character on the map is in direct line with the scales both vertically and horizontally. Any given character is selected from a calculation of the value of the surface of the center of the small region in which the character is plotted.

The contours are read in the following manner. The reference contour runs along the "letter-edge" of the band of dots. From this reference contour each edge of each band of characters represents an increment of one contour interval--the letter bands proceeding downward (A, B, C, ...) from the reference contour and the number bands upward (0, 1, 2, ...). Both the letter and number bands feature "wrap-around" character selection. For instance, if a surface reaches a greater value above the reference contour than can be contoured by using 10 different bands of digits, the next higher band of digits is a band of 0's, the next a band of 1's, the next a band of 2's, etc. The same is true of the letter bands. The next band lower than Z is A, the next lower is B, etc. The character selection may "wrap around" any number of times, but the reference band is printed only once. It should be noted that as a consequence of this "wrap-around" feature that unless the reference band is printed on the contour map, the specific values represented by the other band are not uniquely determined by the character in the band.

The contour maps are printed in the order in which they are encountered in the input data for Part II. If it is specified that a surface is to be contoured but the equation of that surface has not been determined, the contouring of that surface is bypassed.

The next section of the output is the plotting of the original data and the linear, quadric, and cubic residuals on the xy-plane. Here again, if a certain order of residual is specified to be plotted but the equation of the corresponding surface has not been determined, the plotting of these residuals is bypassed.

Each residual plot also is preceded by the program title, name of the plot, plotting limits, and orientation of the scales. The plots, however, may contain one additional preliminary statement. The plotting routine is designed so that the number of digits in the largest plotted value is always four. If the values to be plotted do not have this property, the entire set of values is multiplied successively either by 10 or 0.1 until this property is attained. If the plotted values are scaled, the scale factor is printed.

The scales for the axes residual plots are interpreted somewhat differently from the scales of the contour maps. The conversion of the horizontal scale reading, however, is the same. The position at which the plotted number is located is indicated by the sign of the number. (A zero

is preceded by a plus sign.) In addition, the horizontal scale should be shifted half a space to the left, and the vertical scale should be shifted half a line upward while the plotted values remain stationary. Thus the scales establish horizontal and vertical limits on the location of the sign of the number rather than defining a unique central position. These limits, however, may be made as small as possible by enlarging the printing area. (It should be noted that by proper manual selection of plotting limits, the total width of the plots and contour maps may be made to occupy more than one page by specifying identical plots with adjacent plotting limits.)

Several symbols other than numbers may occur on the plots. These are the "overprint characters"; their meaning is explained below.

- * An attempt was made to write a number, but before it was completely written another number to the right was encountered.
- B Two numbers fall within the limits of the region of this position.
- C Three numbers fall within the limits of the region of this position.
- D Four numbers fall within the limits of the region of this position.

I Nine numbers fall within the limits of the region of this position.

Z Ten or more numbers fall within the limits of the region of this position.

The "overprint characters" are printed on the plot, and the "OVERPRINT VALUES" that they represent are listed in a single column following the plot. Each time a new line containing overprint values is encountered on the plot a double space is made in the column of overprint values. The overprint values for this line are then read from left to right across the plot.

In addition to the output described above, there are also 37 programmed error messages that may be encountered during the running of the program. The errors that may be encountered in the various parts of the program are listed below.

Part I

Program Errors 1-6.

Subroutine EMSLVR Errors 1-3.

Part II

Program Errors 7, 8, 11.

Subroutine ORDR3A Errors 1-4.

Subroutine CONTUR Errors 1-7.

Part III

Program Errors 9, 10, 12.

Subroutine PLOT3 Errors 1-7.

Subroutine ORDER3 Errors 1-4.

ERROR MESSAGES

Program Errors

- 1 Number of sets of data points outside allowable range (1-300).
- 2 Indicator for calculation of linear equation outside allowable range (0-1).
- 3 Indicator for calculation of quadric equation outside allowable range (0-1).
- 4 Indicator for calculation of cubic equation outside allowable range (0-1).
- 5 Indicator for punching of coefficient matrix outside allowable range (0-1).
- 6 Indicators for calculation of linear, quadric, and cubic equations are all zero.
- 7 Contour map indicator outside allowable range (1-3).
- 8 Plotting limit indicator for contour map outside allowable range (0-1).
- 9 Residual plot indicator outside allowable range (0-3).
- 10 Plotting limit indicator for residual map outside allowable range (0-1).
- 11 Indicator for use of Part III outside allowable range (0-1).
- 12 Use of Part III attempted without proper specification in Part II.

Subroutine EMSLVR Errors

- 1 Indicator for ordering of matrix outside allowable range (0-1).
- 2 Indicator for punching of ordered columns outside allowable range (0-1).
- 3 Order of matrix outside allowable range (1-10).

Subroutine ORDR3A and ORDER3 Errors

- 1 Index of first orderable element outside allowable range (1-300).
- 2 Index of last orderable element outside allowable range (1-300).
- 3 Indicator for ascending or descending order option outside allowable range (0-1).
- 4 Index of first orderable element greater than index of last orderable element.

Subroutine CONTUR Errors

- 1 Indicator for evaluation subroutines outside allowable range (1-3).
- 2 Indicator for orientation outside allowable range (1-4).
- 3 Card tabulator indicator outside allowable range (0-1).
- 4 Number of columns of output outside allowable range (12-120).
- 5 Contour interval negative or zero.
- 6 Maximum x plotting limit less than or equal to minimum x plotting limit.
- 7 Maximum y plotting limit less than or equal to minimum y plotting limit.

Subroutine PLOT3 Errors

- 1 Number of points to be plotted outside allowable range (1-300).
- 2 Orientation indicator outside allowable range (1-4).
- 3 Number of columns of output outside allowable range (16-120).
- 4 Card tabulator indicator outside allowable range (0-1).

- 5 Indicator for previous ordering of elements outside allowable range (0-2).
- 6 Maximum x plotting limit less than or equal to minimum x plotting limit.
- 7 Maximum y plotting limit less than or equal to minimum y plotting limit.

The occurrence of errors is treated in several different ways. Consider first Part I. In the first error checking sequence, program errors 1-6 are tested. If after testing all six of these, any errors are found, the appropriate error messages are punched, the message "INVALID DATA" is typed on the console typewriter, and the 1620 executes a PAUSE. If this PAUSE is terminated by pressing the START key, control is transferred back to the first executable statement of Part I. This allows the program to be restarted after the data have been corrected. If any of the subroutine EMSLVR errors are encountered, the message is punched, and an immediate exit is made from EMSLVR. All three of the possible EMSLVR errors are checked before the exit is made from the subroutine. If EMSLVR, the matrix solution routine, is not completed for any of the three matrices, use of the equations corresponding to the unsolved matrices is bypassed in all subsequent calculations and all corresponding output is either set equal to zero or bypassed.

In Part II the first check made is for Program Error 11. If this error is encountered, the "INVALID DATA" message is typed, and a PAUSE is executed. At this point the START key should not be pressed, but instead the data corrected and the program either restarted manually or reloaded. If Program Error 11 is not encountered, the program tests both Program Errors 7 and 8. If either of these errors is encountered the message "INVALID DATA" is typed and a PAUSE is executed. Pressing START to terminate this PAUSE causes the 1620 to branch back and read in the control card for the next contour map. In the subroutine ORDR3A all the possible errors are tested each time the subroutine is entered. If any errors are encountered an immediate exit is made from ORDR3A and the mainline program proceeds to the next statement. An identical procedure is used for errors in subroutine CONTUR.

In Part III the first check is the testing of Program Error 12. If this error is encountered a branch to the end of Part III is made immediately. If Program Error 12 is not encountered, tests are made for Program Errors 9 and 10. If these errors are encountered, the "INVALID DATA" message is typed and a PAUSE is executed. Termination of this PAUSE by pressing START causes the 1620 to branch back and read in the next residual plot control card. In subroutines PLOT3 and ORDER3 all the possible errors are tested each time the subroutine is entered and the encountering of any error causes an exit from the subroutine. Because ORDER3 is called by PLOT3, any error in ORDER3 also causes an immediate exit from PLOT3.

The error messages do not comprise a complete set of checks on all possible variables that conceivably might cause the program to compute nonsensical answers or to cease computing completely. However, the error messages included should greatly reduce the possibility of wasted computer time. Even with this fairly comprehensive set of error messages, the input data should be checked very carefully if trouble is encountered in the program.

REQUIREMENTS OF COMPUTATIONAL FACILITIES

List of Necessary Hardware

- (1) IBM 1620 computer with 57,000 bit memory. (The 1620 used at The University of Kansas has a 60,000 bit memory; however, 3,000 of these locations are occupied by a systems monitor and are not available to FORTRAN programs.)
- (2) Three magnetic tape units for intermediate output. (Four units are required if the Kansas Geological Survey systems tape is used.)
- (3) Card read-punch unit.
- (4) Card tabulator (preferably wired for carriage control as described below).

The following are the carriage control characters used by the program. These characters are located in column one of the output card.

Blank	Normal operation (single space before printing)
0 (zero)	Double space before printing
1	Skip to beginning of next page before printing
5	Skip to beginning of next 1/5 page before printing
9	Nonspace, and print columns 25 to 72 of the card as columns 73-120 of the printed page (Mailloux, Csontos, and Davis; 1963).

These are a portion of the carriage control characters used by the University of Alberta 407 Utility Board. The character "9" allows for tabulation of 120 column output. A complete documentation of the University of Alberta 407 Utility Board and FORTRAN II compiler may be obtained by writing to the 1620 Users Group.

Program Language

The programs are written in FORTRAN II which has provisions for the following magnetic tape commands:

WRITE TAPE N, list

For dimensioned variables that are not subscripted in the output list the whole array is written as one record on tape drive N, provided information has already been stored in the entire array. Otherwise, the whole array may or may not be output.

READ TAPE N, list

This statement operates in the manner described under "WRITE TAPE N, list," except that tape records are input instead of output.

REWIND N

This causes the computer to rewind tape N to the load point.

BACKSPACE N

The computer moves the tape on drive N back one record (Mailloux, Csontos, and Davis, 1963).

Operating Procedures

First compile each of the three source programs and then treat the object deck as follows:

1. Place magnetic scratch tapes on drives 1, 2, and 3.
2. If the Kansas Geological Survey systems tape is used, place it on drive 0. If this tape is used, the remainder of the operating procedures may be ignored because they are executed automatically.
3. Load object deck for Part I. Enter data for Part I. (Note: If Alberta card object decks are loaded, the monitor must be in core.)
4. When the run for Part I is complete, reset the machine (DO NOT ZERO CORE!), and load object deck for Part II. Enter data for Part II.
5. When the run for Part II is complete, reset the machine (DO NOT ZERO CORE!), and load object deck for Part III. Enter data for Part III.

Modifications for Machines Other Than the IBM 1620

Several portions of the program involve certain numeric codes that are unique for the IBM 1620. These portions must be modified to satisfy the particular computer on which the program is to be run. In Part I no such modifications are necessary.

In Part II subroutine IREF is the only major segment that needs to be modified. In order to explain these modifications, let us first examine this subroutine as it is used on the IBM 1620. The function of this subroutine is to generate the numeric code of the symbols that are used in the contouring subroutine, CONTUR. These symbols are the digits 0-9, the letters A-Z, and the decimal point. The 1620 numeric codes of the symbols ., 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 are stored as elements 1-11 of the fixed point array IREFU. The codes of the symbols A-Z are stored as elements 1-26 of the fixed point array IREFL. Let us now look at the value of IREFU(1) which from card 25000007 is found to be 300. When this number, 300, which is stored internally as 0300, is punched under an A1 format specification when operating with four places of fixed point precision, the resulting punch is a "." punch. Likewise the value of IREFL(1) is 4100. When 4100 is punched under the A1 format at four places of fixed point precision, the resulting punch is an "A" punch. It is these numeric codes, such as the 300 and the 4100 which will have to be modified to satisfy a computer other than an IBM 1620. The subroutine IREF generates the arrays IREFU and IREFL by placing in them the values such that when these values are punched under an A1 format (using four places of fixed point accuracy), the punches for the appropriate contouring symbols are made. There is also one statement in subroutine CONTUR that may have to be modified. On card 28000143 MAP(I) is set equal to zero. On the 1620, zero (0000) is that value which, when punched under an A1 format (using four places of fixed point precision), is punched as a blank (no punch at all).

In Part III the subroutine ICALC is analogous to IREF in Part II. ICALC generates the array JREF which contains the numeric codes of the symbols necessary in the plotting subroutine PLOT3. JREF is a 12 element array containing the codes of the following symbols: +, -, 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. For instance, JREF(1) is 1000. When the value 1000 is punched under an A1 format at four places of fixed point precision, a "+" punch results.

Also in Part III, subroutine PLOT3 will require several modifications. All of these modifications involve the arrays ITAB, MAP, and IZD. The array ITAB contains the carriage control and overprint characters for the overprint column. This array is punched under an A2 format with four place fixed point precision. To illustrate the A2 format, let us suppose that ITAB(1) contains the number 7042. When this number is punched under the A2 format the characters 0B are punched. (The numeric code for 0 (zero) is 70, and the code for B is 42.) Thus for each element of the ITAB array two characters are punched. For purposes of explanation the left two digits of an element of ITAB represent the "first" character and the right two digits represent the "second" character. The elements of the other two arrays, MAP and IZD, are punched under an A1 format in the same manner as described in the discussion of Part II. The modifications to be made in subroutine PLOT3 are now listed according to card number.

- 34000073 Both the first and second characters of ITAB(I) are set equal to that number which will punch as two blanks under the A2 format. (Each character is punched as a single blank.)
- 34000199 MAP(1) is set equal to that value which will punch as a blank under the A1 format.
- 34000293 At this point in the subroutine the number that is to be plotted has been broken into separate digits and these digits in turn converted into their numeric codes. For example, 0 is represented by 7000; 1, by 7100; 2, by 7200; ...; 9, by 7900. It is these codes of the digits of the number to be plotted that are contained in the array IZD - the leftmost digit in IZD(2), and the rightmost digit in IZD(5). The purpose of this FORTRAN statement is to determine the index of the position in the IZD array of the code of the first nonzero digit (from the left) so that the numeric code of the sign of the number can be placed in the position of the next lowest index. This is done by interrogating successively higher elements of the IZD array for the numeric code of zero (7000). This interrogation begins with the second element of the IZD array and continues through the fourth element.
- 34000294 IZD(J) is set equal to the numeric code for a blank.
- 34000318 MAP(IDX) is set equal to the numeric code for an asterisk.
- 34000324 MAP(J) is set equal to the numeric code of a blank.
- 34000329 The second character of ITAB(KER) is set equal to the numeric code for an asterisk.
- 34000334 This statement interrogates MAP(IDX) to determine whether MAP(IDX) is occupied by the code for an *, +, or -, or by the code for B, C, D, E, F, G, H, I, or Z.

If it is occupied by the code for an *, +, or -, control is transferred to statement 480; otherwise, control is transferred to 530.

34000335 This statement interrogates MAP(IDX) to determine whether or not MAP(IDX) is occupied by the numeric code for an *. If MAP(IDX) is occupied by this code, control is transferred to statement 510; otherwise control is transferred to 490.

34000342 The second character of ITAB(KER) is set equal to the numeric code for B.

34000343 MAP(IDX) is set equal to the numeric code for B.

34000346 Control is transferred to statement 500 if MAP(IMP) contains the numeric code for any of the digits (0-9); otherwise control is transferred to statement 580.

34000347 MAP(IMP) is set equal to the numeric code for a blank.

34000354 Both the first and second characters of ITAB(KER-1) are set equal to the numeric code for blanks.

34000355 The second character of ITAB(KER) is set equal to the numeric code for B.

34000356 MAP(IDX) is set equal to the numeric code for B.

34000361 This statement interrogates MAP(IDX) to determine if MAP(IDX) is occupied by either the numeric code of an I or a Z. If MAP(IDX) is occupied by the numeric code for either of these characters, control is transferred to statement 550; otherwise control is transferred to 540.

34000362 This statement changes the numeric code for the overprint character in MAP(IDX) to the code of the overprint character representing one more overprint value. Before this statement, MAP(IDX) may be occupied by the code for the letters B-H. After the statement, MAP(IDX) may be occupied by the code for the letters C-I. The statement has the effect of incrementing the existing code by one letter, from B to C, C to D, D to E, ..., H to I.

34000364 The numeric code in the second character of ITAB(KER-1) is "incremented by one letter." This incremented value then is placed in the second character position of ITAB(KER).

34000365 Both of the characters of ITAB(KER-1) are set equal to the numeric code for blanks.

34000371 MAP(IDX) is set equal to the numeric code for a Z.

34000374 Both characters of ITAB(KER-1) are set equal to the numeric code for blanks.

34000375 The second character of ITAB(KER) is set equal to the numeric code for a Z.

34000391 This statement places the numeric code for a zero in the first character of ITAB(KER).

34000393 This statement places the numeric code for a zero in the first character of ITAB(KER)

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KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN II Trend Surface Program for the IBM 1620.

Computer: IBM 1620

Date: August 1, 1964

Programming language: FORTRAN II

Author, organization: Donald I. Good

Kansas Geological Survey, The University of Kansas, Lawrence.

Direct inquiries to: The author or

Name: Daniel F. Merriam

Address: Kansas Geological Survey

University of Kansas, Lawrence

Purpose/description: The purpose of the program is to determine first-, second-, and third-
order trend surfaces. These surfaces are contoured and the residuals plotted.

Mathematical method: The trend surface is determined by fitting by the least-squares criterion,
a polynomial surface of first, second, or third degree.

Restrictions, range: The program is limited to first-, second-, and third-degree surfaces
and to 300 data points.

Storage requirements: The entire program requires core storage of three 1620's and also magnetic
tape.

Equipment specifications:

Memory 20K 40K 60K (bits) K

Automatic divide: Yes x No Indirect addressing: Yes x No

Other special features required The Alberta FORTRAN II system is desirable but not necessary.

Additional remarks (include at author's discretion: fixed/float, relocatability; optional: running time, approximate
number of times run successfully, programming hours) It is necessary for the FORTRAN II compiler used
to accept commands for magnetic tape. Three magnetic tape drives are required. Operating
time for first-, second-, and third-degree surfaces and involving 200 data points is about
1½ hours.



The Kansas Geological Survey has access to several computers on which to test programs and develop new ones. The bigger and faster the machine, of course, the bigger and more complex can be the program run on it. Many ideas can be developed on small, relatively slow computers such as the IBM 1401 (Fig. A), which in this instance is being used to control a high-speed printer. The IBM 1620, however, can handle more data faster, especially when equipped with magnetic tapes (Fig. B). The University of Kansas has recently installed an IBM 7040, a medium-sized, fairly fast computer (Fig. C) that is much more versatile than the IBM 1620. Because of the limitations of the computation facilities at Lawrence, the Survey has cooperative agreements to use the large, high-speed IBM 7090 computers both at Stanford University (Fig. D) and at Continental Oil Company in Ponca City, Oklahoma.

The Editor

