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A SEQUENTIAL LINEAR DISCRIMINANT ANALYSIS PROGRAM FOR GEOLOGICAL AND REMOTELY-SENSED DATA

by

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Statistical evaluation of the composition, physical properties, and surface configuration of terrestrial test sites and their correlation with remotely-sensed data

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CONTENTS

ABSTRACT

A FORTRAN IV Program for CDC 6400 is presented together with sample output illustrating the use of sequential linear discriminant analysis.

INTRODUCTION

In the standard text by Krumbein and Graybill (1965, p. 359 et seq.) the mathematical basis of linear discriminant functions is described. Numerous programs are available for this type of analysis. However, it has been found useful in many situations to examine the effectiveness of all, or many, combinations of measured variables for the samples to be segregated. Thus, in addition to discrimination on the basis of each individual measured variable used on its own, discrimination on the basis of each subset of two, three, four, or more, measured variables can also be calculated. Not infrequently, two variables that are poor discriminators when used individaully prove to be excellent discriminators when used together. Such results emphasize the value of scanning the output from a sequential regression program before the operator decides which subset of variables best serve his particular purposes.

This program has been used extensively in remote-sensing and petrological analyses at Northwestern University (e.g., Beckman and Whitten, 1966). However, in this report, the data set involving the physicochemical conditions and sedimentary textures in a lagoonal environment used by Krumbein and Graybill (1965, p. 363) is utilized; this has been done so that the reader can compare the results obtained with the present program with the worked example given by Krumbein and Graybill.

THE PROGRAM

Instructions for setting up the program are contained in the comment cards at the beginning of the FORTRAN listing. The data deck used for the

sample output is listed at the end of the FORTRAN listing. As written, every possible subset can be processed; alternatively, selected subsets can be called (as in the case illustrated). Selected sample output from the data deck illustrated is appended after the FORTRAN listing.

REFERENCES CITED

Beckmann, W. A., Jr., and Whitten, E. H. T., 1966, Statistical problems involved in remote sensing of the geology of the lithosphere-atmosphere interface: Journ. Geophys. Res., v. 71, pp. 5873-90.

Krumbein, W. C., and Graybill, F. A., 1965, An introduction to statistical models in geology: McGraw-Hill Book Co., New York, 475 pp.

```
      PROGRAM DISCRM1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C                                                                       DISC   1
C                                                                       DISC   2
C  SEQUENTIAL LINEAR DISCRIMINANT ANALYSIS - TWO GROUPS  JULY, 1970     DISC   3
C  HISTORY OF PROGRAM - BMD04M MODIFIED FOR KRUMBEIN BY BENSON TO       DISC   4
C  IBM 709 FEBRUARY 1965 AND TO CDC 3400 IN MARCH 1965                  DISC   5
C  REORGANIZATION OF S MATRICES BY LINK, FALL 1965 AND MODIFIED INTO FORDISC   6
C  S*BETA HAT = G (SEE KRUMBEIN AND GRAYBILL, PP 359 FF) BY WEG TAYLOR  DISC   7
C  JULY, 1967.  REWRITTEN IN FORTRAN IV WITH MODIFICATION INCLUDING     DISC   8
C  LOG10 TRANSFORM BY GARRETT IN AUGUST 1967.  MINOR CHANGES BY WHITTEN DISC   9
C  IN JULY 1968 AND EXTENDED TO SEQUENTIAL ANALYSIS BY MEG BROWN FOR    DISC  10
C  WHITTEN IN OCTOBER 1968.                                             DISC  11
C  PROGRAM COMPUTES FOR UP TO 200 CASES IN EACH GROUP WITH UP TO 25     DISC  12
C  VARIABLES MEASURED ON EACH CASE.                                     DISC  13
C                                                                       DISC  14
C      THE CASE IDENTIFICATION (CONTL) READ FROM THE DATA CARDS MAY BE  DISC  15
C      UP TO SIX ALPHANUMERIC CHARACTERS LONG.                          DISC  16
C                                                                       DISC  17
C                 DECK SET UP IN FOLLOWING MANNER-                      DISC  18
C      TABLE OF CONSTANTS                                               DISC  19
C      PROBLEM CARD                                                     DISC  20
C      4 TITLE CARDS                                                    DISC  21
C      DATA FORMAT CARD                                                 DISC  22
C      DATA OF GROUP 1                                                  DISC  23
C      DATA OF GROUP 2                                                  DISC  24
C      SELECTION CARD(S)                                                DISC  25
C      FINISH CARD (WORD FINISH IN COLUMNS 1-6)                         DISC  26
C                                                                       DISC  27
C      CONSECUTIVE PROBLEMS MAY BE PROCESSED BY PLACING ANY NUMBER OF   DISC  28
C      PROBLEM DECKS, CONSISTING OF THE PROBLEM CARD THROUGH THE SELECT DISC  29
C      CARD(S) (IF NEEDED), BEFORE THE FINISH CARD.                     DISC  30
C                                                                       DISC  31
C                    PROBLEM CARD SET UP AS FOLLOWS-                    DISC  32
C      1-6     PROBLEM NAME                                  A1         DISC  33
C      7-8     PROBLEM NUMBER                                PROB       DISC  34
C      9-10    NUMBER OF VARIABLES (2-25)                    K          DISC  35
C     11-12    LOG10 TRANSFORM OPTION, PUNCH 1 FOR TRANSFORM IFL        DISC  36
C     13-14    MATRIX PRINT OPTION, PUNCH 1 FOR MATRICES     MAT        DISC  37
C     15-17    NUMBER OF SAMPLES IN GROUP 1                  N(1)       DISC  38
C     18-20    NUMBER OF SAMPLES IN GROUP 2                  N(2)       DISC  39
C     21-23    NUMBER OF SELECTION CARDS USED                NUM        DISC  40
C                                                                       DISC  41
C                    SELECTION CARDS SET UP AS FOLLOWS-                 DISC  42
C      1-6     PUNCH SELECT                                             DISC  43
C      7-8     NUMBER OF VARIABLES IN THAT SUBSET                       DISC  44
C      9-10    INDEX OF FIRST VARIABLE                                  DISC  45
C     11-12    INDEX OF SECOND VARIABLE AND SO ON                       DISC  46
C                                                                       DISC  47
      DIMENSION CONTL(2,203),TITL(52),S(25),GID(4),FMT(13),IRANK(2,203) DISC  48
      DIMENSION Z(2,203),MMM(25),LLL(25),LX(25),LY(25),LL(25),DD(25)    DISC  49
      DIMENSION X(2,25,200),SUM(2,25,25),TOTAL(2,25),D(25),C(25)       DISC  50
      DIMENSION N(2),DIV(2),B(25,25),ZBAR(2),VARZ(2),NE(2)             DISC  51
      DIMENSION TABLE(400),XTABLE(400),PRO(2),ZZ(2,25)                 DISC  52
      INTEGER A1,A2,A3,GID,FINISH,SELECT                               DISC  53
      DATA (GID=2HA),2HB),2HC),2HD)),(FINISH=6HFINISH),(SELECT=6HSELECT)DISC  54
      DATA (ZBAR1=4HD(1)),(ZBAR2=4HD(2)),(DZERO=4HD(0))                DISC  55
C                                                                       DISC  56
      READ (5,1000) (TABLE(I),I=1,400)                                 DISC  57
```

```
 1000 FORMAT (10F4.4)                                                    DISC  58
C                                                                        DISC  59
C      READ PROBLEM TITLE AND FORMAT CARDS                               DISC  60
    1  READ (5,101) A1,PROB,K,IFL,MAT,N(1),N(2),NUM                      DISC  61
       IF(A1.EQ.FINISH)GO TO 42                                          DISC  62
       IF(K.LE.1.OR.K.GT.25)GO TO 2                                      DISC  63
       READ (5,102) TITL                                                 DISC  64
       READ (5,102) FMT                                                  DISC  65
       WRITE (6,102) TITL                                                DISC  66
       WRITE (6,103)                                                     DISC  67
       WRITE (6,104) PROB,K                                              DISC  68
       GO TO 5                                                           DISC  69
    2  WRITE (6,105)                                                     DISC  70
       GO TO 1                                                           DISC  71
C                                                                        DISC  72
C      READ IN DATA                                                      DISC  73
    5  DO 7 I=1,2                                                        DISC  74
       WRITE (6,106) I                                                   DISC  75
       NN=N(I)                                                           DISC  76
       DO 7 J=1,NN                                                       DISC  77
       READ (5,FMT) CONTL(I,J),(X(I,L,J),L=1,K)                          DISC  78
       WRITE (6,107) J,CONTL(I,J),(X(I,L,J),L=1,K)                       DISC  79
       IF(IFL.NE.1)GO TO 7                                               DISC   0
       DO 6 L=1,K                                                        DISC   1
    6  X(I,L,J)=ALOG10(X(I,L,J))                                         DISC   2
    7  CONTINUE                                                          DISC   3
C                                                                        DISC   4
C      COMPUTE MEANS OF GROUPS ETC. AND MATRIX S (SUM) FOR GROUPS 1 AND 2DISC   5
       NSEL=0                                                            DISC   6
       DO 10 M=1,2                                                       DISC   7
       DIV(M)=N(M)                                                       DISC   8
       DO 9 I=1,K                                                        DISC   9
       LL(I)=I                                                           DISC  90
       TOTAL(M,I)=0.0                                                    DISC  91
       DO 9 L=1,K                                                        DISC  92
       SUM(M,I,L)=0.0                                                    DISC  93
       NN=N(M)                                                           DISC  94
       DO 8 J=1,NN                                                       DISC  95
    8  SUM(M,I,L)=SUM(M,I,L)+X(M,I,J)*X(M,L,J)                           DISC  96
    9  SUM(M,L,I)=SUM(M,I,L)                                             DISC  97
       DO 10 I=1,K                                                       DISC  98
       NN=N(M)                                                           DISC  99
       DO 10 J=1,NN                                                      DISC 100
   10  TOTAL(M,I)=TOTAL(M,I)+X(M,I,J)                                    DISC 101
       DO 11 I=1,2                                                       DISC 102
       DO 11 J=1,K                                                       DISC 103
   11  Z(I,J)=TOTAL(I,J)/DIV(I)                                          DISC 104
       DO 12 J=1,K                                                       DISC 105
       D(J)=Z(1,J)-Z(2,J)                                                DISC 106
       DD(J)=D(J)                                                        DISC 107
   12  S(J)=Z(1,J)+Z(2,J)                                                DISC 108
       WRITE (6,108)                                                     DISC 109
       WRITE (6,109)                                                     DISC 110
       DO 13 I=1,K $ ZZ(1,I)=Z(1,I) $ ZZ(2,I)=Z(2,I)                     DISC 111
   13  WRITE (6,110) I,Z(1,I),Z(2,I),D(I),S(I)                           DISC 112
       IF(MAT.NE.1)GO TO 201                                             DISC 113
       DO 14 M=1,2                                                       DISC 114
       WRITE (6,111) GID(M),M                                            DISC 115
       DO 14 I=1,K                                                       DISC 116
```

```
   14 WRITE (6,112) (SUM(M,I,L),L=1,K)                                  DISC 117
C                                                                       DISC 118
C      COMPUTE MATRIX S* FOR GROUPS ONE AND TWO                         DISC 119
  201 DO 15 M=1,2                                                       DISC 120
      DO 15 I=1,K                                                       DISC 121
      DO 15 L=1,K                                                       DISC 122
   15 SUM(M,I,L)=SUM(M,I,L)-TOTAL(M,I)*TOTAL(M,L)/DIV(M)                DISC 123
      IF(MAT.NE.1)GO TO 202                                             DISC 124
      DO 16 M=1,2                                                       DISC 125
      WRITE (6,113) GID(M+2),M                                          DISC 126
      DO 16 I=1,K                                                       DISC 127
   16 WRITE (6,112) (SUM(M,I,L),L=1,K)                                  DISC 128
C                                                                       DISC 129
C      COMPUTE SUMS OF S* FOR GROUPS ONE AND TWO                        DISC 130
  202 DO 17 I=1,K                                                       DISC 131
      DO 17 L=1,K                                                       DISC 132
      B(I,L)=SUM(1,I,L)+SUM(2,I,L)                                      DISC 133
   17 SUM(1,I,L)=B(I,L)                                                 DISC 134
      IF(MAT.NE.1)GO TO 203                                             DISC 135
      WRITE (6,114)                                                     DISC 136
      DO 18 I=1,K                                                       DISC 137
   18 WRITE (6,112) (SUM(1,I,L),L=1,K)                                  DISC 138
C                                                                       DISC 139
C      COMPUTE MATRIX B (KRUMBEIN AND GRAYBILL PAGE 360)                DISC 140
  203 DIVTOT=DIV(1)+DIV(2)-2.0                                          DISC 141
      FB=1.0/DIVTOT                                                     DISC 142
      DO 19 I=1,K                                                       DISC 143
      DO 19 L=1,K                                                       DISC 144
   19 B(I,L)=SUM(1,I,L)*FB                                              DISC 145
      IF(MAT.NE.1)GO TO 21                                              DISC 146
      WRITE (6,115)                                                     DISC 147
      DO 20 I=1,K                                                       DISC 148
   20 WRITE (6,112) (B(I,L),L=1,K)                                      DISC 149
C                                                                       DISC 150
   21 CALL INVERT (B,K,LX,LY)                                           DISC 151
      IF(MAT.NE.1)GO TO 204                                             DISC 152
      WRITE (6,116)                                                     DISC 153
      DO 22 I=1,K                                                       DISC 154
   22 WRITE (6,112) (B(I,J),J=1,K)                                      DISC 155
C                                                                       DISC 156
C      COMPUTE DISCRIMINANT COEFFICIENTS                                DISC 157
  204 DO 23 I=1,K                                                       DISC 158
      C(I)=0.0                                                          DISC 159
      DO 23 L=1,K                                                       DISC 160
   23 C(I)=C(I)+B(I,L)*D(L)                                             DISC 161
      WRITE (6,117)                                                     DISC 162
      WRITE (6,112) (C(I),I=1,K)                                        DISC 163
C                                                                       DISC 164
C      COMPUTE MAHALANOBIS DSQUARE                                      DISC 165
      DSQ=0.0                                                           DISC 166
      DO 24 I=1,K                                                       DISC 167
      DO 24 J=1,K                                                       DISC 168
   24 DSQ=DSQ+D(I)*D(J)*B(I,J)                                          DISC 169
      WRITE (6,118) DSQ                                                 DISC 170
C                                                                       DISC 171
C      COMPUTE Q FOR F TEST OF KRUMBEIN AND GRAYBILL PAGES 361 AND 362  DISC 172
      IDF=N(1)+N(2)-K-1                                                 DISC 173
      DK=IDF                                                            DISC 174
      FK=K                                                              DISC 175
```

```
      VAL = (DIV(1) * DIV(2) * DK) / (FK * (DIV(1) + DIV(2)) * DIVTOT)
      VAL=VAL*DSQ                                                    DISC 177
      WRITE (6,119) K,IDF,VAL                                        DISC 178
C                                                                    DISC 179
C     COMPUTE INDIVIDUAL CASE DISCRIMINANT VALUES                    DISC 180
      DO 25 M=1,2                                                    DISC 181
      NN=N(M)                                                        DISC 182
      DO 25 J=1,NN                                                   DISC 183
      Z(M,J)=0.0                                                     DISC 184
      DO 25 I=1,K                                                    DISC 185
      LI=LL(I)                                                       DISC 186
   25 Z(M,J)=Z(M,J)+C(I)*X(M,LI,J)                                   DISC 187
C                                                                    DISC 188
C     COMPUTE MEANS, VARIANCES AND STD. DEVIATIONS OF DISCRIMINANTS  DISC 189
      WRITE (6,120)                                                  DISC 190
      DO 27 M=1,2                                                    DISC 191
      NN=N(M)                                                        DISC 192
      SUMZ=0.0                                                       DISC 193
      SUMZSQ = DSUBZ = 0.0                                           DISC 194
      ZBAR(M)=0.0                                                    DISC 195
      DIVN=N(M)                                                      DISC 196
      VARZ(M)=0.0                                                    DISC 197
      DO 26 I=1,NN                                                   DISC 198
      SUMZ=SUMZ+Z(M,I)                                               DISC 199
   26 SUMZSQ=SUMZSQ+Z(M,I)**2                                        DISC 200
      ZBAR(M)=SUMZ/DIVN                                              DISC 201
      VARZ(M)=(SUMZSQ-SUMZ**2/DIVN)/(DIVN-1.0)                       DISC 202
      STDVZ=SQRTF(VARZ(M))                                           DISC 20
   27 WRITE (6,121) M,NN,ZBAR(M),VARZ(M),STDVZ                       DISC 204
C                                                                    DISC 205
C     COMPUTE D(0)                                                   DISC 206
      DO 43  I = 1,K                                                 DISC 207
      LI = LL(I)
   43 DSUBZ = DSUBZ + (ZZ(1,LI) + ZZ(2,LI)) * C(I) * 0.5
      WRITE (6,122) DSUBZ                                            DISC 209
C                                                                    DISC 210
C     COMPUTE PROBABILITY OF ERROR                                   DISC 211
      M=1                                                            DISC 212
      PRO(M)=ABS(ZBAR(M)-DSUBZ)                                      DISC 213
      PRO(M)=PRO(M)/SQRT(VARZ(M))                                    DISC 214
      XTABLE(400)=3.99                                               DISC 215
      DO 29 I=1,400                                                  DISC 216
      XTABLE(I)=(I-1)/100.0                                          DISC 217
      IF(PRO(M).LE.XTABLE(400))GO TO 28                              DISC 218
      PRO(M)=0.0                                                     DISC 219
      GO TO 30                                                       DISC 220
   28 IF(PRO(M).GT.XTABLE(I))GO TO 29                                DISC 221
      PRO(M)=0.5-TABLE(I)                                            DISC 222
      GO TO 30                                                       DISC 223
   29 CONTINUE                                                       DISC 224
   30 CONTINUE                                                       DISC 225
      WRITE (6,123) PRO(M)                                           DISC 226
C                                                                    DISC 227
C     RANK DISCRIMINANT VALUES OF CASES                              DISC 228
      WRITE (6,124)                                                  DISC 229
      WRITE (6,125)                                                  DISC 230
      DO 31 I=1,2                                                    DISC 231
      DO 31 J=1,203                                                  DISC 232
   31 IRANK(I,J)=0                                                   DISC 233
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```
      NN=N(1)                                                          DISC 234
      NE(1)=2                                                          DISC 235
      Z(1,NN+1)=ZBAR(1)                                                DISC 236
      Z(1,NN+2)=DSUBZ                                                  DISC 237
      CONTL(1,NN+1)=ZBAR1                                              DISC 238
      CONTL(1,NN+2)=DZERO                                              DISC 239
      NN=N(2)                                                          DISC 240
      NE(2)=1                                                          DISC 241
      Z(2,NN+1)=ZBAR(2)                                                DISC 242
      CONTL(2,NN+1)=ZBAR2                                              DISC 24
      NTOTAL=N(1)+N(2)+3                                               DISC 244
      DO 37 I=1,NTOTAL                                                 DISC 245
      HOLD=-(10.0**35.)                                                DISC 246
      DO 34 M=1,2                                                      DISC 247
      NN=N(M)+NE(M)                                                    DISC 248
      DO 34 J=1,NN                                                     DISC 249
      IF(Z(M,J)-HOLD)34,34,32                                          DISC 250
   32 IF(IRANK(M,J))33,33,34                                           DISC 251
   33 MM=M                                                             DISC 252
      JJ=J                                                             DISC 253
      HOLD=Z(M,J)                                                      DISC 254
   34 CONTINUE                                                         DISC 255
      IRANK(MM,JJ)=999                                                 DISC 256
      IF(MM-1)35,35,36                                                 DISC 257
   35 WRITE (6,126) I,HOLD,CONTL(MM,JJ)                                DISC 258
      GO TO 37                                                         DISC 259
   36 WRITE (6,127) I,HOLD,CONTL(MM,JJ)                                DISC 260
   37 CONTINUE                                                         DISC 261
C                                                                      DISC 262
C     CARRY OUT SELECT OPTION                                          DISC 263
   38 IF(NUM.EQ.0)GO TO 1                                              DISC 264
      NSEL=NSEL+1                                                      DISC 265
      WRITE (6,128) NSEL                                               DISC 266
      READ (5,134) A1,K,(LL(I),I=1,25)                                 DISC 267
      IF(A1.EQ.SELECT)GO TO 39                                         DISC 268
      WRITE (6,130) NSEL                                               DISC 269
      NUM=NUM-1                                                        DISC 270
      GO TO 38                                                         DISC 271
   39 WRITE (6,131)                                                    DISC 272
      WRITE (6,132) (LL(I),I=1,K)                                      DISC 27
      DO 41 I=1,K                                                      DISC 274
      LLI=LL(I)                                                        DISC 275
      DO 40 L=1,K                                                      DISC 276
      LLLL = LL(L)                                                     DISC 277
   40 B(I,L)=SUM(1,LLI,LLLL)/DIVTOT                                    DISC 278
   41 D(I)=DD(LLI)                                                     DISC 279
      NUM=NUM-1                                                        DISC 280
      GO TO 21                                                         DISC 281
C                                                                      DISC 282
   42 WRITE (6,133)                                                    DISC 283
      STOP                                                             DISC 284
C                                                                      DISC 285
  101 FORMAT (A6,A2,3I2,3I3)                                           DISC 286
  102 FORMAT (13A6)                                                    DISC 287
  103 FORMAT (23H0 COMPUTED BY DISCRIM 1)                              DISC 288
  104 FORMAT (15H0 PROBLEM NO.  ,A2/21H  NUMBER OF VARIABLES,I4)       DISC 289
  105 FORMAT (37H0ERROR ON PROBLEM CARD OR DECK SET-UP)                DISC 290
  106 FORMAT (//10X19HINPUT DATA OF GROUP,I2//)                        DISC 291
  107 FORMAT (1H ,I4,6X,A6,7F16.5/(17X,7F16.5))                        DISC 292
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  108 FORMAT (49H1 VARIABLE MEANS BY GROUP AND DIFFERENCE IN MEANS/)     DISC 293
  109 FORMAT (58H  VARIABLE        MEAN 1           MEAN2          DIFFEREDISC 294
     1NCE,10X,3HSUM/)                                                   DISC 295
  110 FORMAT (1H ,I5,2X,4F16.5)                                         DISC 296
  111 FORMAT (1H0,A3,48HMATRIX OF UNCORRECTED SUMS OF SQUARES AND CROSS-DISC 297
     1  15HPRODUCTS, GROUP,I2/)                                         DISC 298
  112 FORMAT (1H ,7F16.5)                                               DISC 299
  113 FORMAT (1H0,A3,46HMATRIX OF CORRECTED SUMS OF SQUARES AND CROSS-  DISC 300
     1  15HPRODUCTS, GROUP, I2)                                         DISC 301
  114 FORMAT (41H0E) MATRIX OF SUMS OF ELEMENTS IN C AND D)             DISC 302
  115 FORMAT (21H0 COVARIANCE MATRIX B)                                      303
  116 FORMAT (32H0 INVERSE OF COVARIANCE MATRIX C)                           304
  117 FORMAT (36H1 DISCRIMINANT FUNCTION COEFFICIENTS/)                      305
  118 FORMAT (23H0 MAHALANOBIS DSQUARE =,F16.5)                              306
  119 FORMAT (4H0 F(,I2,1H,,I3,3H) =,F16.5)                                  307
  120 FORMAT (78H0 POP NO.     SAMPLE SIZE      MEAN Z             VARIANC   308
     1E Z          STD. DEV. Z)                                            309
  121 FORMAT (1H ,I6,I14,F17.5,2F20.5)                                       310
  122 FORMAT (9H0 D(0) = , F11.5)                                            311
  123 FORMAT (26H0 PROBABILITY OF ERROR = (, F6.4,24H) FOR GROUPS ONE AN     312
     1D TWO//)
  124 FORMAT (68H          FIRST GROUP      SECOND GROUP    FIRST GROUP DISC 314
     1 SECOND GROUP)                                                    DISC 315
  125 FORMAT (66H  RANK       VALUES           VALUES          CASE NO.  DISC 316
     1   CASE NO./)                                                     DISC 317
  126 FORMAT (1H ,I4,F17.5,25X,A6)                                      DISC 318
  127 FORMAT (1H ,I4,17X,F17.5,19X,A6)                                  DISC 319
  128 FORMAT (1H1//15H  SELECTION NO.,I4)                               DISC 320
  129 FORMAT (A6,26I2)                                                  DISC 321
  130 FORMAT (40H0 ERROR ON SELECTION CARD OR DECK SET-UP,I4)           DISC 322
  131 FORMAT (28H  VARIABLES USED IN FUNCTION)                          DISC 323
  132 FORMAT (1H ,10I5)                                                 DISC 324
  133 FORMAT (1H1)                                                      DISC 325
  134 FORMAT (A6,I2,25I2)                                               DISC 326
      END                                                               DISC 327
      SUBROUTINE INVERT (A,N,L,M)                                       INVT   0
C     PROGRAM FOR FINDING THE INVERSE OF A NXN MATRIX                   INVT   1
      DIMENSION A(25,25),L(25),M(25)                                    INVT   2
C     SEARCH FOR LARGEST ELEMENT                                        INVT   3
      DE=1.0                                                            INVT   4
      DO80 K=1,N                                                        INVT   5
      L(K)=K                                                            INVT   6
      M(K)=K                                                            INVT   7
      BIGA=A(K,K)                                                       INVT   8
      DO20 I=K,N                                                        INVT   9
      DO20 J=K,N                                                        INVT  10
      IF(ABSF(BIGA)-ABSF(A(I,J))) 10,20,20                              INVT  11
   10 BIGA=A(I,J)                                                       INVT  12
      L(K)=I                                                            INVT  13
      M(K)=J                                                            INVT  14
   20 CONTINUE                                                          INVT  15
C     INTERCHANGE ROWS                                                  INVT  16
      J=L(K)                                                            INVT  17
      IF(L(K)-K) 35,35,25                                               INVT  18
   25 DO30 I=1,N                                                        INVT  19
      HOLD=-A(K,I)                                                      INVT  20
      A(K,I)=A(J,I)                                                     INVT  21
   30 A(J,I)=HOLD                                                       INVT  22
C     INTERCHANGE COLUMNS                                               INVT  23
```

```
   35 I=M(K)                                                          INVT  24
      IF(M(K)-K) 45,45,37                                             INVT  25
   37 DO40 J=1,N                                                      INVT  26
      HOLD=-A(J,K)                                                    INVT  27
      A(J,K)=A(J,I)                                                   INVT  28
   40 A(J,I)=HOLD                                                     INVT  29
C     DIVIDE COLUMN BY MINUS PIVOT                                    INVT  30
   45 DO55 I=1,N                                                      INVT  31
   46 IF(I-K)50,55,50                                                 INVT  32
   50 A(I,K)=A(I,K)/(-A(K,K))                                         INVT  33
   55 CONTINUE                                                        INVT  34
C     REDUCE MATRIX                                                   INVT  35
      DO65 I=1,N                                                      INVT  36
      DO65 J=1,N                                                      INVT  37
   56 IF(I-K) 57,65,57                                                INVT  38
   57 IF(J-K) 60,65,60                                                INVT  39
   60 A(I,J)=A(I,K)*A(K,J)+A(I,J)                                     INVT  40
   65 CONTINUE                                                        INVT  41
C     DIVIDE ROW BY PIVOT                                             INVT  42
      DO75 J=1,N                                                      INVT  43
   68 IF(J-K)70,75,70                                                 INVT  44
   70 A(K,J)=A(K,J)/A(K,K)                                            INVT  45
   75 CONTINUE                                                        INVT  46
C     CONTINUED PRODUCT OF PIVOTS                                     INVT  47
      DE=DE*A(K,K)                                                    INVT  48
C     REPLACE PIVOT BY RECIPROCAL                                     INVT  49
      A(K,K)=1.0/A(K,K)                                               INVT  50
   80 CONTINUE                                                        INVT  51
C     FINAL ROW AND COLUMN INTERCHANGE                                INVT  52
      K=N                                                             INVT  53
  100 K=(K-1)                                                         INVT  54
      IF(K) 150,150,103                                               INVT  55
  103 I=L(K)                                                          INVT  56
      IF(I-K) 120,120,105                                             INVT  57
  105 DO110 J=1,N                                                     INVT  58
      HOLD=A(J,K)                                                     INVT  59
      A(J,K)=-A(J,I)                                                  INVT  60
  110 A(J,I)=HOLD                                                     INVT  61
  120 J=M(K)                                                          INVT  62
      IF(J-K) 100,100,125                                             INVT  63
  125 DO130 I=1,N                                                     INVT  64
      HOLD=A(K,I)                                                     INVT  65
      A(K,I)=-A(J,I)                                                  INVT  66
  130 A(J,I)=HOLD                                                     INVT  67
      GO TO 100                                                       INVT  68
  150 RETURN                                                          INVT  69
       END                                                            INVT  70
```

```
00000040008001200160019902390279031903590
03980438047805170557059606360675071407540
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50005000500050005000500050005000500050000
DISCRI0104    015015005                ------------BEGINNING OF DATA DECK
1  WCK  PROJECT NO. 01 0303
0  LINK'S CARBONATE DATA, K AND G DISCRIMINANT, PAGES 359 FF
0  X1 = EH BELOW INTERFACE, X2 = PH BELOW INTERFACE, X3 = PHI MEAN DIAM.
0  X4 = PHI STANDARD DEVIATION
(6X,A4,F4.0,3F4.2)
010303 U01-2617.560.821.30
010303 U02 1104.442.310.94
010303 U03  834.302.510.56
010303 U04 -454.282.140.79
010303 U05-2146.562.410.10
010303 U06   07.080.131.57
010303 U07-1585.532.381.01
010303 U08-1075.861.931.13
010303 U09-2647.221.901.20
010303 U10  436.291.911.21
010303 U11 1045.650.781.41
010303 U12  745.861.521.13
010303 U13  348.360.881.23
010303 U14-2004.861.931.55
010303 U15-1585.191.721.67
010303 V01  487.921.681.08
010303 V02 -767.972.170.97
010303 V03-3835.422.121.51
010303 V04-2254.891.371.78
010303 V05-1934.601.701.60
010303 V06-2244.342.011.64
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010303 V07-2144.743.142.79
010303 V08-2354.803.162.84
010303 V09-1706.922.852.86
010303 V10-2136.103.522.72
010303 V11-1575.862.902.22
010303 V12 -795.422.312.91
010303 V13 -368.931.221.33
010303 V14-2146.862.592.43
010303 V15-1745.545.303.20
SELECT 3 1 2 3
SELECT 2 1 2
SELECT 1 1
SELECT 3 1 3 4
SELECT 2 1 4
FINISH
```

OUTPUT

WCK PROJECT NO. 01 0303

LINK#S CARBONATE DATA, K AND G DISCRIMINANT, PAGES 359 FF

X1 = EH BELOW INTERFACE, X2 = PH BELOW INTERFACE, X3 = PHI MEAN DIAM.

X4 = PHI STANDARD DEVIATION

COMPUTED BY DISCRIM 1

PROBLEM NO. 01
NUMBER OF VARIABLES 4

INPUT DATA OF GROUP 1

1	U01	-261.00000	7.56000	.82000	1.30000
2	U02	110.00000	4.44000	2.31000	.94000
3	U03	83.00000	4.30000	2.51000	.56000
4	U04	-45.00000	4.28000	2.14000	.79000
5	U05	-214.00000	6.56000	2.41000	.10000
6	U06	0.00000	7.08000	.13000	1.57000
7	U07	-158.00000	5.53000	2.38000	1.01000
8	U08	-107.00000	5.86000	1.93000	1.13000
9	U09	-264.00000	7.22000	1.90000	1.20000
10	U10	43.00000	6.29000	1.91000	1.21000
11	U11	104.00000	5.65000	.78000	1.41000
12	U12	74.00000	5.86000	1.52000	1.13000
13	U13	34.00000	8.36000	.88000	1.23000
14	U14	-200.00000	4.86000	1.93000	1.55000
15	U15	-158.00000	5.19000	1.72000	1.67000

INPUT DATA OF GROUP 2

1	V01	48.00000	7.92000	1.68000	1.08000
2	V02	-76.00000	7.97000	2.17000	.97000
3	V03	-383.00000	5.42000	2.12000	1.51000
4	V04	-225.00000	4.89000	1.37000	1.78000
5	V05	-193.00000	4.60000	1.70000	1.60000
6	V06	-224.00000	4.34000	2.01000	1.64000
7	V07	-214.00000	4.74000	3.14000	2.79000
8	V08	-235.00000	4.80000	3.16000	2.84000
9	V09	-170.00000	6.92000	2.85000	2.86000
10	V10	-213.00000	6.10000	3.52000	2.72000
11	V11	-157.00000	5.86000	2.90000	2.22000
12	V12	-79.00000	5.42000	2.31000	2.91000
13	V13	-36.00000	8.93000	1.22000	1.33000
14	V14	-214.00000	6.86000	2.59000	2.43000
15	V15	-174.00000	5.54000	5.30000	3.20000

VARIABLE MEANS BY GROUP AND DIFFERENCE IN MEANS

VARIABLE	MEAN 1	MEAN2	DIFFERENCE	SUM
1	-63.93333	-169.66667	105.73333	-233.60000
2	5.93600	6.02067	-.08467	11.95667
3	1.68467	2.53600	-.85133	4.22067
4	1.12000	2.12533	-1.00533	3.24533

DISCRIMINANT FUNCTION COEFFICIENTS

.00537 -.51317 -.61105 -2.50228

MAHALANOBIS DSQUARE = 3.64695

F(4, 25) = 6.10539

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-7.22140	1.91562	1.38406
2	15	-10.86835	5.37829	2.31911

D(0) = -9.04487

PROBABILITY OF ERROR = (.0934) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	-4.69603		U03	
2	-5.45157		U02	
3	-5.72242		U04	
4	-6.23820		U05	
5	-6.34588		U11	
6	-6.36625		U12	
7	-7.19184		U10	
8	-7.22140		D(1)	
9		-7.53563		V01
10	-7.58855		U08	
11	-7.64125		U06	
12	-7.66772		U07	
13	-7.72308		U13	
14		-8.25119		V02
15		-8.43921		V05
16	-8.62564		U14	
17	-8.74145		U15	
18		-8.76174		V06
19		-8.84940		V13
20		-9.00859		V04
21	-9.03487		U01	
22	-9.04487		D(0)	
23	-9.28620		U09	
24		-9.91153		V03
25		-10.86835		D(2)
26		-11.17720		V11
27		-11.89868		V12
28		-12.33245		V14
29		-12.48142		V07
30		-12.76230		V08
31		-13.23101		V10
32		-13.36186		V09
33		-15.02301		V15

SELECTION NO. 1
VARIABLES USED IN FUNCTION
1 2 3
DISCRIMINANT FUNCTION COEFFICIENTS

.00648 -.44233 -1.18794

MAHALANOBIS DSQUARE = 1.73370

F(3, 26) = 4.02467

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-5.04109	1.70933	1.30741
2	15	-6.77480	1.75808	1.32593

D(0) = -5.90795

PROBABILITY OF ERROR = (.2514) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	-2.75206		U11	
2	-3.28612		U06	
3	-3.91836		U12	
4	-3.99553		U02	
5	-4.34609		U03	
6	-4.52301		U13	
7	-4.72686		U04	
8	-4.77267		U10	
9	-5.04109		D(1)	
10		-5.18805		V01
11		-5.24797		V04
12		-5.30443		V05
13	-5.36244		U15	
14	-5.57790		U08	
15		-5.63248		V13
16		-5.65331		V12
17	-5.73800		U14	
18		-5.75849		V06
19	-5.90795		D(0)	
20	-6.00882		U01	
21	-6.29687		U07	
22		-6.59550		V02
23		-6.77480		D(2)
24		-7.05409		V14
25	-7.15086		U05	
26	-7.16084		U09	
27		-7.21302		V07
28		-7.39685		V03
29		-7.39936		V08
30		-7.49739		V14
31		-7.54777		V09
32		-8.25953		V10
33		-9.87373		V15

SELECTION NO. 2
VARIABLES USED IN FUNCTION
1 2
DISCRIMINANT FUNCTION COEFFICIENTS

.00750 -.15279

MAHALANOBIS DSQUARE = .80627

F(2, 27) = 2.91553

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-1.38665	1.20480	1.09764
2	15	-2.19292	.40773	.63854

D(0) = -1.78979

PROBABILITY OF ERROR = (.3557) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	.14697		U02	
2	-.03423		U03	
3	-.08293		U11	
4	-.34011		U12	
5	-.63840		U10	
6		-.84993		V01
7	-.99158		U04	
8	-1.02220		U13	
9	-1.08174		U06	
10	-1.38665		D(1)	
11		-1.42086		V12
12		-1.63451		V13
13	-1.69818		U08	
14		-1.78796		V02
15	-1.78979		D(0)	
16	-1.97847		U15	
17	-2.03042		U07	
18		-2.07333		V11
19		-2.15093		V05
20		-2.15200		V15
21		-2.19292		D(2)
22	-2.24318		U14	
23		-2.32989		V07
24		-2.33283		V09
25		-2.34381		V06
26		-2.43534		V04
27		-2.49662		V08
28		-2.53018		V10
29	-2.60797		U05	
30		-2.65380		V14
31	-3.08396		U09	
32	-3.11340		U01	
33		-3.70182		V03

SELECTION NO. 3
VARIABLES USED IN FUNCTION
1
DISCRIMINANT FUNCTION COEFFICIENTS

.00725

MAHALANOBIS DSQUARE = .76618

F(1, 28) = 5.74637

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-.46328	.99014	.99506
2	15	-1.22947	.54222	.73636

D(0) = -.84638

PROBABILITY OF ERROR = (.3483) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	.79710		U02	
2	.75362		U11	
3	.60145		U03	
4	.53623		U12	
5		.34783		V01
6	.31159		U10	
7	.24638		U13	
8	0.00000		U06	
9		-.26087		V13
10	-.32609		U04	
11	-.46328		D(1)	
12		-.55072		V02
13		-.57246		V12
14	-.77536		U08	
15	-.84638		D(0)	
16		-1.13768		V11
17	-1.14493		U07	
18	-1.14493		U15	
19		-1.22947		D(2)
20		-1.23188		V09
21		-1.26087		V15
22		-1.39855		V05
23	-1.44927		U14	
24		-1.54348		V10
25	-1.55072		U05	
26		-1.55072		V07
27		-1.55072		V14
28		-1.62319		V06
29		-1.63043		V04
30		-1.70290		V08
31	-1.89130		U01	
32	-1.91304		U09	
33		-2.77536		V03

SELECTION NO. 4
VARIABLES USED IN FUNCTION
1 3 4
DISCRIMINANT FUNCTION COEFFICIENTS

.00490 -.34548 -2.43188

MAHALANOBIS DSQUARE = 3.25702

F(3, 26) = 7.56094

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-3.61897	1.26981	1.12686
2	15	-6.87599	5.24423	2.29003

D(0) = -5.24748

PROBABILITY OF ERROR = (.0735) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	-1.82233		U03	
2	-2.12432		U05	
3	-2.54506		U02	
4	-2.88099		U04	
5	-2.91058		U12	
6		-2.97165		V01
7	-3.12864		U13	
8	-3.18886		U11	
9	-3.39175		U10	
10		-3.48098		V02
11	-3.61897		D(1)	
12		-3.83227		V13
13	-3.86296		U06	
14	-3.93906		U08	
15	-4.05258		U07	
16	-4.72354		U01	
17	-4.86817		U09	
18	-5.24748		D(0)	
19	-5.41611		U14	
20		-5.42395		V05
21	-5.42960		U15	
22		-5.78021		V06
23		-5.90447		V04
24		-6.28111		V03
25		-6.87599		D(2)
26		-7.16990		V11
27		-7.85277		V14
28		-8.26189		V12
29		-8.77272		V09
30		-8.87441		V10
31		-8.91826		V07
32		-9.14966		V08
33		-10.46558		V15

SELECTION NO. 5
VARIABLES USED IN FUNCTION
1 4
DISCRIMINANT FUNCTION COEFFICIENTS

.00520 -2.61490

MAHALANOBIS DSQUARE = 3.17822

F(2, 27) = 11.49268

POP NO.	SAMPLE SIZE	MEAN Z	VARIANCE Z	STD. DEV. Z
1	15	-3.26088	1.68975	1.29990
2	15	-6.43910	4.66670	2.16025

D(0) = -4.84999

PROBABILITY OF ERROR = (.1093) FOR GROUPS ONE AND TWO

RANK	FIRST GROUP VALUES	SECOND GROUP VALUES	FIRST GROUP CASE NO.	SECOND GROUP CASE NO.
1	-1.03309		U03	
2	-1.37340		U05	
3	-1.88647		U02	
4	-2.29959		U04	
5	-2.57035		U12	
6		-2.57469		V01
7		-2.93134		V02
8	-2.94061		U10	
9	-3.03967		U13	
10	-3.14665		U11	
11	-3.26088		D(1)	
12	-3.46199		U07	
13	-3.51079		U08	
14		-3.66487		V13
15	-4.10540		U06	
16	-4.50958		U09	
17	-4.75549		U01	
18	-4.84999		D(0)	
19	-5.09227		U14	
20		-5.18664		V05
21	-5.18783		U15	
22		-5.45231		V06
23		-5.82359		V04
24		-5.93851		V03
25		-6.43910		D(2)
26		-6.62083		V11
27		-7.46612		V14
28		-8.01984		V12
29		-8.21925		V10
30		-8.36191		V09
31		-8.40749		V07
32		-8.64734		V08
33		-9.27176		V15

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NASA Grant NGR-14-007-027

N.U. Report #	Title	MSC Data Bank #	STAR #
1	Interim progress report 3-31-65	NR-09-00-000-00009	
2	Semi-annual status report 9-30-65		
3	Semi-annual status report 3-31-66	NR-06-00-000-00020	
4	Aspects of geological sampling at test sites	NR-09-00-000-00011	
5	Preliminary details of sampling locations at NASA Sonora Pass Test Site, California	NR-08-DK-019-00010	
6	Semi-annual status report 9-30-66	NR-06-00-000-00030	
7	Statistical problems involoved in remote-sensing of the geology of the lithosphere-atmosphere interface	NR-09-00-000-00035	
8	The general linear equation in prediction of gold content in Witwatersrand rocks, South Africa	NR-09-00-000-00036	
9	Semi-annual status report 3-31-67	NR-06-00-000-00031	
10	FORTRAN IV programs to determine surface roughness in topography for the CDC 3400 computer	NR-09-00-000-00284	
11	A program for the rapid screening of multivariate data from the earth sciences and remote-sensing	NR-09-00-000-00052	

N.U. Report #	Title	MSC Data Bank #	STAR #
12	Two programs for the factor analysis of geologic data	NR-09-DL-019-00067	
13	The geology of the lower Precambrain rocks of the Champion-Republic area of Upper Michigan (NASA Test Site 126)	NR-09-CN-126-00068	
14	The geochemistry of the Fremont Lake quartz monzonites and associated gruss, NASA Sonora Pass Geologic Test Site, Sierra Nevada, California	NR-09-DL-019-00073	N68-10180*CSCL 08D
15	Semi-annual status report		
16	Variance of some selected attributes in granitic rocks	NR-09-DK-998-00181 (NASA-CR-101747)	N69-30686*#CFSTICL08G
17	FORTRAN IV CDC 6400 program to analyze subsurface fold geometry	NR-08-00-000-00080	
18	Semi-annual status report 9-30-68		
19	NASA Geological Test Site #126 Marquette-Republic Trough, Michigan: Report on photographic imagery obtained on Mission 72, May, 1968	(NASA-CR-97790)	N69-12097*#CFSTICSCL08G
20	Relict diagenetic textures and structures in regional metamorphic rocks, Northern Michigan (NASA Geological Test Site #126)		
21	A FORTRAN IV program for two-dimensional autocorrelation analysis of geologic and remotely-sensed data		