1973/121
Copy 3

504702

DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/121

COMPUTER PROCESSING OF SEISMIC REFRACTION DATA

by

J.P. Cull

Record 1973/121

COMPUTER PROCESSING OF SEISMIC REFRACTION DATA

by

J.P. Cull

CONTENTS

APPENDICES

TABLES

ILLUSTRATIONS

SUMMARY

With the increase in upper mantle seismic refraction data held by BMR, it is increasingly necessary to formulate machine methods for statistical interpretation. The computer programs presented here provide a basis for such techniques and can be combined to standardize data processing and presentation.

Rationalization of survey data decks has enabled the ready combination of results from different surveys and has provided a means of indexing individual surveys on a magnetic tape for library purposes.

1. INTRODUCTION

With the increasing frequency of seismic refraction surveys and the advent of remote automatic recorders the quantity of travel-time data available for upper mantle studies can be expected to proliferate. Surveys of a type similar to the 1969 Rabaul Crustal Study Project (Brooks, 1971) which produced a large quantity of data, may be interpreted on a statistical basis by machine methods, and compatability of format with other survey data greatly simplifies the data handling. The work presented here represents preliminary efforts to compile all known Australian refraction data in a self compatible format so that a library of results can be maintained and data relevant to any new interpretation can be easily accessed.

The computer programs presented here were developed on a CDC3600 computer using the Fortran IV language and employing Calcomp plotters and magnetic scratch tapes. To date each of these programs has been used independently of the others; ROBBINS 2 has been adapted from a previous program (ROBBINS) to calculate shot-to-station distances and azimuths from latitudes and longitudes; these were used to compile a data deck which was listed by REFDAT. Selected data were then plotted with PLOTIT so that refractors could be defined and interpreted by the time-term technique using TERMAT (Finlayson & Cull, 1973). By employing standard data formats in a library tape it may be possible to combine these individual functions, thereby rationalizing interpretational techniques.

2. COMPILATION OF DATA

At the completion of a refraction survey all resultant data should ideally be documented to facilitate a complete interpretation. For computer applications a completed data deck consists of three files: survey description, location description, and time/distance files (Plate 1).

Survey description file (file 1)

The first card of this file includes an essential serial number in the first six columns. This serial number has application in the plotting program (PLOTIT) when two or more surveys are combined. Any unique number may be used to identify a particular survey but for convenience the date of survey start is usually chosen.

The remainder of the first card is free format and contains the title of the survey. Any relevant data or comments may be specified in free format on any number of following cards which precede an EOF card.

1st card format	:	F6.0, A2, 9A8
subsequent format	:	10A8.

Location description file (file 2)

Each card in the second file is designed to give a total description of a particular shot or recording station site. The file consists of one card for each shot and for each station and is terminated by an EOF card.

The first column (A1 format) specifies the type of site described by the card; S if a shot, R if a recording site. Columns 2, 3 (I2 format) give the number assigned to the shot or station. Note that no alphabetic identifiers may be used to number sites. The name of the site is given in columns 6-20 (format A8, A7) with blank fill where appropriate.

The co-ordinates of the site are given to tenths of minutes in columns 21-37. Latitude is specified in columns 21-27 (format I2, X, F4.1), and longitude is specified in columns 30-37 (format I3, X, F4.1).

To enable corrections to be made to the observed travel-time date, site elevation in metres is specified in columns 41-45 (format F5). For the special case of a marine shot the depth of water is still specified as a positive elevation and columns 46-50 are used to specify the depth at which the shot is detonated (also positive). For all recorders and any land shots columns 46-50 are left blank.

A location name abbreviation is given in columns 51-55 (format A5). Usually permanent recording stations have an acknowledged three-letter abbreviation while temporary recorders are assigned arbitrary two-letter abbreviations related to their name. The location abbreviation is used to label arrivals on time-distance (t/d) curves produced from the plotting program (PLOTIT).

The institution responsible for each shot or recording station is specified in abbreviated form in columns 56-60 (format A5).

The remaining columns 61-80 are free format and may be used to make comments on quality of recording site, type of shot, etc.

2nd File contents: TYPE, NO., LOCATION, LAT., LONG., ELEVATION, SHOT DEPTH, ABBREVIATION, INSTITUTION, COMMENTS.

format: A1, I2, 2X, A15, (I2, X, F4.1), 2X, (I2, X, F4.1), 3X, F5, F5, A5, A5, A20.

Time/distance file (file 3)

For each particular recording station in a survey this file contains a card for each shot successfully recorded by that station. Although the cards may appear in any sequence it is usual to group the cards according to shot numbers. The cards within each shot group are then placed in order of ascending station numbers. This procedure ensures that any card can be easily found if changes are required in the data.

Columns 1-2 and 3-4 are used to specify the shot and station numbers respectively. Alphabetic identifiers may not be used and the numbers must correspond to those used previously in file 2.

Shot/station distances (km), specified in columns 6-11, are obtained using the program ROBBINS 2 (APPENDIX 1). This version of ROBBINS has been modified to use file 2 described above as its sole input data. The entire file 2 with its EOF card is placed between the RUN and EOD cards of ROBBINS 2.

Columns 12-16 are used to specify the azimuth also obtained from the program ROBBINS 2. Azimuth can be used in the plotting program PLOTIT to limit the data to particular lines. The shot-to-station forward azimuth is used and is specified to one decimal place of degrees.

The remaining columns are used to specify seismic arrivals. Up to seven arrivals may be selected off each recording. Each of these arrivals is then described in terms of travel time, quality, and accuracy. The travel time is computed to two decimal places from a knowledge of arrival time and shot instant. Quality is a subjective assessment assigned to the arrival; A for good, B for fair, C for poor. Accuracy is a measure of the reading precision; 1 for better than 0.01 seconds, 2 for between 0.1 and 0.01 seconds, 3 for between 0.5 and 0.1 seconds, and 4 for worse than 0.5 seconds.

3rd file contents: SHOT NO., RECORDER NO., DISTANCE, AZIMUTH, 7(TRAVEL TIME, QUALITY, ACCURACY).

format: I2, I2, X, F6, F5, X, 7(X, F6, A1, I1).

Water corrections

Subroutine MODIT alters the travel times for submarine slots to correct for water depth, and substitutes a 4.0-km/s layer for the water layer. Both the uncorrected and corrected travel times are listed on output. The water velocity is assumed to be 1.52 km/s, but can be altered if necessary in Subroutine MODIT. The substitution layer velocity of 4.0 km/s can be altered in statement number 98 + 2 of the main program if required (VCOR = 4.0).

3. PRESENTATION OF DATA

Listing of data

Having compiled a survey data deck, a listing of data may be obtained using the Fortran IV program REFDAT (APPENDIX 2). The first card following the RUN card of this program is used to specify the number of recording stations in the survey (format I3). The three refraction data files then follow immediately and are terminated by an EOD card. The resultant computer print-out, an example of which is given in Table 1, provides convenient and systematic access to the data in the interpretational stage.

Time/distance plots

Another method of data presentation is the time/distance plot. Such plots are also used to identify just which arrivals are associated with each particular refractor - a crucial step in any interpretation. The refraction data may be plotted by hand from the REFDAT print-out, but this technique is both subject to error and laborious, especially for large-scale surveys which involve many recorders and shots. To avoid these drawbacks the Fortran program PLOTIT (APPENDIX 3) was written to enable machine plotting of the refraction data deck.

As with REFDAT, the first card after the RUN card of program PLOTIT is used to specify the number of recording stations contributing to the data deck (format I3). The three data files of the survey then follow on immediately after this card. If it is desired to combine two or more surveys then the EOF card of the third data file is followed immediately by the three data files of the second and subsequent surveys; however, it should be noted that the first mentioned data card must be changed to include the total number of recorders in these subsequent surveys. When no further surveys are to be included, the EOF of the third data file is followed by a second EOF card and then the plot specifications.

Plot specifications

Card A: TSCALE, DSCALE, DMAX, VREDUCE, AZR, RA, REVERSAL, PLOTTER

Format: 7F5, 43X, A2.

TSCALE (sec/inch) and DSCALE (km/inch) are respectively the scale on the time and distance axes of the desired plot. DMAX is the maximum shot/station distance in the data and is used to limit the length of the plot. If DMAX is left blank then a plot length of 30 inches is assumed. VREDUCE (km/sec) is the velocity used to produce a reduced time plot; if it is left blank reduction does not occur and a normal t/d plot results. AZR and RA, azimuth and azimuth range respectively, are used to apply azimuth restrictions to the plotted data. Only those data lying in the range (AZR-RA) to (AZR+RA) will be plotted. If both AZR and RA are left blank then all specified points will be plotted. REVERSAL (km) is the distance between two shots or stations when a reversed plot is required; if only a one-way plot is required it is left blank. PLOTTER is used to specify which CALCØMP plotter is required, PB for 30-inch or PL for 10-inch. If PLOTTER is left blank then PB (30 inch) is assumed.

Essential data on this card are TSCALE and DSCALE for a normal, unreversed 30-inch plot.

Having specified scales and plot type, the next step is to specify which data are to be plotted; this is done by using cards (type B) as follows:

Card B: TIPE, LORIG, (LPTS(K),K=1,34), DATE, REV, TIN

Format: A1, I2, 34I2, X, F6, A1, A1.

TIPE is an identifier, either S or R, which indicates whether the plot origin is a shot or recorder position; LORIG then is the number of the shot or recorder which is used as origin. LPTS(K) is the list of recorder or shot numbers whose data are to be plotted.

DATE is the serial number of the data deck which is being used in the plot (ch.2, Survey description file). If only one survey data deck is being used then DATE may be left blank.

REV is a flag to indicate a reverse plot. If REV is left blank then a normal plot results from that card; however, if REV is read to be R then the data from the list LPTS (on that card) are plotted in a reverse direction. Note that if REV is read to be R then REVERSAL on the card A must be non-zero.

TIN is a flag to indicate plot continuation. If TIN is read as C then the next card must be type B and the data specified on it are superimposed in the same plot as the present card. Any number of continuations may be made and REV may be non-blank on any or all of them.

If TIN is left blank and the next card is type B then new axes are taken with the same specifications as given by the previous card type A. However if TIN is blank and the next card is an EOF then a new card type A must be specified before cards type B.

To indicate the end of plotting, two EOF cards follow immediately after a card of type B.

An example of deck structure for plotting is shown in Plate 2.

4. INTERPRETATION

After obtaining a time/distance plot of the data it is then possible to determine which refractors are present in the survey area and which of the observed arrivals can be attributed to each of these refractors. This process is essential to, and forms the first part of any interpretational technique.

Structural variations in each of the detected refractors may be obtained by several methods; wavefronts, intercept times, delay times, time depths, and time terms. However, in regional crustal surveys station and shot spacings are usually too large to enable the construction of sufficiently detailed wavefronts, and the method if intercepts can give only approximate solutions. In small-scale surveys which involve only one or two shots with several recorders a combination of the delay time and time depth methods can be used effectively, but when large amounts of data are involved the time term method is most convenient for handling the data in a statistical manner. The time term method and its limitations are described by Scheidegger & Willmore (1957) and Willmore & Bancroft (1960), while early examples are given with the Lake Superior data by Berry & West (1966) and Smith et al. (1966).

The Fortran IV program TERMAT (Appendix 4) was written to facilitate the compilation and inversion of the coefficient matrix of a set of travel time-equations according to the time term method. The matrix inversion is achieved using SCIRO system subroutine MATINV (Knight, 1964). Input consists of shot-to-station travel times and distances, and output, an example of which is given in Appendix 4, is the coefficient matrix, the resultant time terms, refractor velocity, and travel time residuals.

TERMAT data input

CARD type A: Shot or recorder label. Format A8.

CARD type B: Recorder or shot label, distance, travel time.

Format A8, F7.2, F5.2

For each card of type A there is a series of cards (B) which define a particular refractor and time/distance curve at the location specified on card (A). At the end of one series of (B) cards, the next location (card type A) is specified immediately (no EOF). After all series are specified the data is terminated by an EOF card.

The cards type (A) must be consistent throughout the data deck, and similarly with type (B). For example, if a recorder name is specified on the first card (A) then all cards (A) must contain recorder names while all cards (B) contain shot names.

N.B. Consistency must be maintained if a particular shot or recorder name appears on more than one card in the data deck. Blanks included in the location label are significant (including spaces before and after).

Discussion

If for any given set of data no recorders and shots are coincident, the matrix inversion is not unique, therefore the output time-terms are determined only to within an additive constant (Sheidegger & Willmore, 1957). This constant (ALPHA) is the time-term of the last specified recorder (or shot) on output (see Appendix 4, output listing); it is determined by equating time terms of sufficiently close recorder/shot pairs provided this is acceptable in geological structure.

If on input a recorder and shot can be considered as coincident then the time terms for all other locations can be determined uniquely. The labels of the coincident pair must be specified in columns 65-72 and 73-80 on the first card (A) of the data. The order is irrelevant, but only one pair may be specified to be coincident.

5. DEVELOPMENT

The refraction data deck described in chapter 2 has been designed to enable all available refraction data to be documented in a library of surveys. The format is such that surveys may be readily combined for joint interpretations; currently this is achieved by stacking the relevant data card decks. While this stacking procedure is adequate with small-scale surveys a more attractive system could be based on the use of a magnetic tape input. As each survey is completed its three data files could be added to a master magnetic tape; all data could then be accessed via a search of serial numbers (ch. 2) and then combined on a scratch tape equivalent to the stacked card deck.

Magnetic scratch tapes would also allow greater amounts of data to be handled. At present the capacity is limited by core space for the storage of travel-time matrices, but if scratch tapes are used, relevant travel times could be read as desired.

The programs PLOTIT and REFDAT could be conveniently modified to provide automatic determination of the number of recording stations in each survey under consideration (ch. 3). This, however, would not be necessary if scratch tapes were used to obviate the need for travel-time storage matrices.

A further program could be written to include both REFDAT and ROBBINS 2 so that the data could be written directly onto the library tape. At present data file 2 must first be run with ROBBINS 2 so that distances and azimuths can be obtained and inserted by hand during compilation of the travel-time data (file 3). However, the ROBBINS 2 output could be stored on a scratch tape and subsequently incorporated by machine with the travel times so that the complete data deck could be written immediately.

6. REFERENCES

BERRY, M.J., & WEST, G.F., 1966 - An interpretation of the first arrival data of the Lake Superior Experiment by the time-term method. Bull. seismol. Soc. Amer., 56, 141.

BROOKS, J.A., (editor), 1971 - Investigations of crustal structure in the New Britain/New Ireland region, 1969; geophysical and geological data. Bur. Miner. Resour. Aust. Rec. 1971/131 (unpubl.).

FINLAYSON, D.M., & CULL, J.P., 1973 - Time-term analysis of New Britain/New Ireland island are structures. Geophys. J.R. astr. Soc. (in press).

KNIGHT, D.C., 1964 - Matrix inversion with accompanying solution of linear equations. C.S.I.R.O., DCR Library Subroutine ref. 1D, F1, CSIR MATINV.

SCHEIDEGGER, A.E., & WILLMORE, P.L., 1957 - Use of a least square mthod for the interpretation of data from seismic surveys. Geophysics, 22, 9.

SMITH, T.J., STEINHART, J.S., & ALDRICH, L.T., 1966 - Crustal structure under Lake Superior. Amer. geophys. Un., geophys. Morogr 10, 181.

WILLMORE, P.L., & BANCROFT, A.M., 1960 - The time term approach to refraction seismology. Geophys. J.R. astr. Soc., 3, 419.

APPENDIX 1

PROGRAM ROBBINS 2

```
      PROGRAM ROBBINS2
C
C^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C       ROBBINS MODIFIED TO CALCULATE DISTANCES USING DATA FROM FILE 2
C       OF REGIONAL CRUSTAL STUDIES SEISMIC REFRACTION DATA DECK
C             BUREAU OF MINERAL RESOURCES    ROOM 104
C              D.M.FINLAYSON     J.P.CULL
C^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C     REQUIRES SUBROUTINES  ROBIN,RHONU,RADFORM AND DEGFORM
      COMMON/4/A,E,E2,EDASH2,EDASH/8/SINLAT(5),COSLAT(5)
      COMMON                           /7/RADLAT(5),RADLON(5)
      COMMON/9/RHO(5),ANU(5)
      COMMON/19/FWDAZ,REVAZ,DIST,Z
      COMMON/P/PI,TWOPI,SINONE,COSECONE
C
      DIMENSION STATION(4),DES(4),CRIPTION(4),NS(4),EW(4),SPHEROID(5),
     1DEGLAT(4),MINLAT(4),SECLAT(4),DEGLON(4),MINLON(4),SECLON(4),
     2TASK(10), GEOD(2)
C
      TYPE REAL MINLAT,MINLON,MINFWD,MINREV,MIN
      TYPE INTEGER NS,EW,UNIT,TASK,SPHEROID,STATION,Z,GEOD,FIGURE,TIPE
C
       CALL DATE (JDAY,JMONTH,JYEAR)
      Z=1H  $ FIGURE=3HANS
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C
C      PUT REFRACTION DATA FILE 2 ONTO MAGNETIC TAPE
C
   20 FORMAT(A1,A7,9A8)
   10 READ(60,20)TIPE,(TASK(KH),KH=1,10) $ IF(EOF,60)55,50
   50 IF(TIPE.EQ.1HS)70,80
   70 WRITE(6,20)TIPE,(TASK(KH),KH=1,10) $ GOTO10
   80 WRITE(7,20)TIPE,(TASK(KH),KH=1,10) $ GOTO10
   55 REWIND 6 $ REWIND 7
   60 CONTINUE
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C
C            DEFINE CONSTANTS
   40 A = 6378160. $ FINVERT =298.25   $ SPHEROID(5)= 8H
      SPHEROID(1)= 8HAUSTRALI        $ SPHEROID(2) = 8HAN NATIO
      SPHEROID(3)= 8HNAL SPHE        $ SPHEROID(4) = 8HROID
   90 UNIT=2HMS
  140 GEOD(1)= 8HNORMAL S     $GEOD(2)= 8HECTION
      PI=3.1415926536  $ TWOPI=2.*PI  $SINONE= TWOPI/(360.*3600.)
      COSECONE=1./SINONE
      B=A-A/FINVERT  $A2=A*A   $B2=B*B
      E2=(A2-B2)/A2 $EDASH2=(A2-B2)/B2 $ E=SQRTF(E2)$EDASH=SQRTF(EDASH2)
  191 IDENT=3
      NS(IDENT)=1HS $ EW(IDENT)=1HE
      READ(6,210)STATION(IDENT),DES(IDENT),
     1DEGLAT(IDENT),MINLAT(IDENT),SECLAT(IDENT),DEGLON(IDENT),
     2MINLON(IDENT),SECLON(IDENT),CRIPTION(IDENT)
      IF(EOF,6)260,239
  239 SECLAT(IDENT)=6.0*SECLAT(IDENT)$SECLON(IDENT)=6.0*SECLON(IDENT)
C.............................................................
      WRITE(61,30)JDAY,JMONTH,JYEAR
   30 FORMAT (1H1,4(/),12X,*PROGRAM ROBBINS - DISTANCE AND AZIMUTH FROM
     1LATITUDE AND LONGITUDE*,22X,*COMPUTED *,2(R2,1H/),R2)
  170 WRITE(61,180)(SPHEROID(KH),KH=1,5),A,UNIT,FINVERT,GEOD(1),GEOD(2)
  180 FORMAT (1H ,12X,5A8,F14.3,2X,A2,F9.3,7X,2A8)
```

```
 240 FORMAT (1H0,12X,*FROM*,2X,3A8,2(4X,A1,F4,F3,F3))
     WRITE(61,240)STATION(3),DES(3),CRIPTION(3),NS(3),DEGLAT(3),MINLAT
    1(3),SECLAT(3),EW(3),DEGLON(3),MINLON(3),SECLON(3)
     WRITE(61,190)
 190 FORMAT (1H ,18X,*STATION*,24X,*LATITUDE*, 5X,*LONGITUDE*,8X,*FWD
    1AZIMUTH*,6X,*DISTANCE KMS*,/)
     GO TO 211
C,..........................................................
 200 IDENT=4 $  READ(7,210)STATION(IDENT),DES(IDENT)
    1,DEGLAT(IDENT),MINLAT(IDENT),SECLAT(IDENT),DEGLON(IDENT)
    2,MINLON(IDENT),SECLON(IDENT),CRIPTION(IDENT)
     IF(EOF,7)201,202
 210 FORMAT(5X,A8,A7,F2,X,F2,X,F1,2X,F3,X,F2,X,F1,13X,A5)
 201 REWIND 7 $ GOTO60
C
 202 SECLAT(IDENT)=SECLAT(IDENT)*6,0$SECLON(IDENT)=SECLON(IDENT)*6,0
 211 CONTINUE
     RADLAT(IDENT)=RADFORM(DEGLAT(IDENT),MINLAT(IDENT),SECLAT(IDENT))
     RADLON(IDENT)=RADFORM(DEGLON(IDENT),MINLON(IDENT),SECLON(IDENT))
     RADLAT(IDENT)=-RADLAT(IDENT)
     NS(IDENT) = 1HS
 220 RADLON(IDENT) = -RADLON(IDENT)
     EW(IDENT)=1HE
 230 CONTINUE
     SINLAT(IDENT)=SINF(RADLAT(IDENT))
     COSLAT(IDENT)=COSF(RADLAT(IDENT))
     CALL RHONU(IDENT)
     IF(IDENT,NE,4)GO TO 200
     CALL ROBIN(3,4)
     CALL DEGFORM(FWDAZ,DEGFWD,MINFWD,SECFWD)
     CALL DEGFORM(REVAZ,DEGREV,MINREV,SECREV)
     DEGFWD=DEGFWD + MINFWD/60,0
     DIST = DIST/1000,0
C
C
     WRITE(61,250)STATION(4),DES(4),CRIPTION(4),NS(4),DEGLAT(4),MINLAT
    1(4),SECLAT(4),EW(4),DEGLON(4),MINLON(4),SECLON(4),DEGFWD,DIST
 250 FORMAT (1H ,12X,*TO*,4X,3A8,2(4X,A1,F4,F3,F3), 10X,F5,1,13X,F7,2)
C
     GO TO 200
 260 CONTINUE
     END
```

```
      SUBROUTINE RORIG (IAT,ITO)
C
C     COMPUTES FORWARD AND REVERSE AZIMUTH AND DISTANCE GIVEN THIS
C     COMMON
      COMMON/4/A,E,E2,EDASH2,EDASH/8/SINLAT(5),COSLAT(5)
      COMMON                            /7/RADLAT(5),RADLON(5)
      COMMON/9/RHO(5),ANU(5)
      COMMON/19/FWDAZ,REVAZ,DIST,Z
      COMMON/P/PI,TWOPI,SINONE,COSECONE
      DIMENSION TANPSI(2), AZ(2),FOUR(2),ELR(2),G1(2),G2(2),QRS(2)
      TYPE INTEGER  Z
C
      DELON = RADLON(ITO)-RADLON(IAT)
C
      IF(DELON)50,10,60
   10 IF(RADLAT(ITO)-RADLAT(IAT))20,40,30
   20 FWDAZ = REVAZ = 0,              $ GO TO 70
   30 FWDAZ = -PI   $ REVAZ= PI       $ GO TO 70
C
   40 DIST=FWDAZ=REVAZ=0,   $GO TO 140
   50    FWDAZ=0,   $    REVAZ=PI        $GO TO 70
   60    FWDAZ=PI   $    REVAZ=0,
C
   70 SINLON =SINF(DELON)$COSLON=COSF(DELON) $ J=IAT $ K=ITO
C
      DO 80 I=1,2
      TANPSI(I)=(1,-E2)*SINLAT(K)/COSLAT(K) + E2*ANU(J)*SINLAT(J)/
     1(ANU(K)*COSLAT(K))
      FOUR(I)=COSLAT(J)*TANPSI(I)-SINLAT(J)*COSLON
      AZ(I)=ATANF(SINLON/FOUR(I))
      J=ITO   $ K=IAT
   80 CONTINUE
C
C
      PSI=ATANF(TANPSI(1))
      IF(ABSF(AZ(1)),GT,0,3)90,100
   90 TWO = SINLON/SINF(AZ(1))$GO TO 110
  100 TWO = FOUR(1)/ COSF(AZ(1))
  110 SIGMA=ASINF(COSF(PSI)*TWO)      $ SIG2 =SIGMA**2
      G=EDASH*SINLAT(IAT)   $ H=EDASH*COSLAT(IAT)*COSF(AZ(1))    $ H2=H**2
      DIST=ANU(IAT)*SIGMA*(1,-SIG2/6,*H2*(1,-H2)   +SIG2*SIGMA*0,125*
     1G*H*(1,-2,*H2)   + SIG2**2/120,*(H2*(4,-7,*H2) -3,*G**2*(1,-7,*H2))
     2-SIG2**2*SIGMA/48,*G*H)        $AZ(1) = -AZ(1)
C
      DO 120 I=1,2
      IF(AZ(I),LT,0,) AZ(I)=AZ(I)+PI
  120 CONTINUE   $  IF(DIST,LT,0,) DIST=-DIST
C
        FWDAZ=   FWDAZ + AZ(1)    $     REVAZ=   REVAZ + AZ(2)
      IF((Z,EQ,1H ),OR,(DELON,EQ,0))GO TO 140
      J=IAT $ AZ(1)=FWDAZ $ AZ(2)=REVAZ $ DO 130 I=1,2
      ELR(I)=EDASH2 *DIST*DIST/(12,*ANU(J)**2)
      G1(I) =-ELR(I)*SINF(2,*AZ(I))* COSLAT(J)**2
      G2(I) = ELR(I)*SINF(AZ(I)) *SINF(2,*RADLAT(J))*DIST/(4,*ANU(J))
      AZ(I) = AZ(I)+G1(I)+G2(I)   $ J=ITO
  130 CONTINUE          $ FWDAZ=AZ(1)          $REVAZ =AZ(2)
  140 RETURN
      END
```

```
      SUBROUTINE RHONU(IAT)
C
C     COMPUTES RHO AND NU  GIVEN A, E SQUARED  AND  SINLAT (PLUS OR
C     MINUS) IN SPECIAL NUMBERED COMMON.
C
      COMMON/4/A,E,E2,EDASH2,EDASH/8/SINLAT(5),COSLAT(5)
      COMMON                                /7/RADLAT(5),RADLON(5)
      COMMON/9/RHO(5),ANU(5)
      COMMON/19/FWDAZ,REVAZ,DIST,Z
      COMMON/P/PI,TWOPI,SINONE,COSECONE
C
      BOT=SQRTF(1.-E2*SINLAT(IAT)*SINLAT(IAT))
      ANU(IAT)=A/BOT
      RHO(IAT)=ANU(IAT)*(1.-E2)/(BOT*BOT)
      END
```

```
      FUNCTION RADFORM (D,M,S)
C
C     CONVERTS POSITIVE REAL DEGREES, MINUTES AND SECONDS TO REAL
C     RADIANS, FOR NEGATIVE ANGLES, ALL THREE QUANTITIES MUST BE
C     NEGATIVE, THERE IS NO COMMON
C
      TYPE REAL M
      DATA(SINONE = 4.848136811E-6),(SIXTY=60.)
      RADFORM =(S+SIXTY*(M+SIXTY*D))*SINONE
      END
```

```
      SUBROUTINE  DEGFORM (RADIANS,D,M,S)
C
C     CONVERTS A POSITIVE REAL QUANTITY IN RADIANS INTO POSITIVE REAL
C     DEGREES,MINUTES AND SECONDS, REQUIRES INTF, THERE IS NO COMMON,
C
      TYPE REAL M
      DATA (HEINZ= 57.295779513),(SIXTY=60.)
      ALLDEG = RADIANS * HEINZ
      D =INTF(ALLDEG)
      ALLMIN =(ALLDEG-D   )*SIXTY
      M= INTF(ALLMIN)
      S= (ALLMIN-M)*SIXTY
      END
```

PROGRAM ROBBINS - DISTANCE AND AZIMUTH FROM LATITUDE AND LONGITUDE   COMPUTED 31/01/73
AUSTRALIAN NATIONAL SPHEROID   6378160.000 MS 298.250   NORMAL SECTION

FROM	MT. ITTON	S FIT	S 30 0 24	E 139 33 48		
	STATION		LATITUDE	LONGITUDE	FWD AZIMUTH	DISTANCE KMS
TO	PARTACOONA	PNA	S 32 0 24	E 138 9 54	210.7	258,84
TO	ISLAND LAGOON	ILN	S 31 23 36	E 136 52 12	238.5	300,34
TO	HALLET	HTT	S 33 25 48	E 138 55 18	188.9	384,43
TO	KINGOONYA	KA	S 30 57 42	E 135 20 6	254.3	419,53
TO	SEVENHILL	SNL	S 33 53 12	E 138 38 24	191.2	439,00
TO	MT.BRADY	BY	S 29 14 48	E 134 59 0	279.6	451,45
TO	OODNADATTA	//D	S 27 33 42	E 135 27 0	303.0	484,43
TO	TARCOOLA	TR	S 30 37 12	E 134 30 18	260.8	491,20
TO	UMBERETANA	UMB	S 30 14 24	E 139 7 42	238.2	49,26
TO	CLEVE	CLV	S 33 41 30	E 136 29 42	214.6	501,23
TO	ADELAIDE	ADE	S 34 58 0	E 138 42 30	188.1	555,88
TO	MT.WILLOUGHBY	WY	S 28 0 12	E 134 9 12	291.5	571,59
TO	GRANITE DOWNS	GD	S 26 58 6	E 133 23 54	297.6	691,05
TO	OOLDEA	OA	S 30 29 0	E 131 52 0	264.0	742,53
TO	BELLFIELD	BFD	S 37 10 36	E 142 32 42	161.6	841,91
TO	MILL RIDGE	MLD	S 24 51 18	E 133 9 30	310.5	852,27
TO	COOK	CK	S 30 41 24	E 130 25 30	262.8	881,64
TO	ALICE SPRINGS	ASP	S 23 41 0	E 133 53 48	319.9	898,60
TO	TOOLANGI	TOO	S 37 34 18	E 145 29 24	148.4	1002,13
TO	DEAKIN	DN	S 30 46 18	E 128 57 12	262.6	1022,84
TO	TALBINGO	TAO	S 35 36 42	E 148 17 18	129.6	1025,92
TO	KHANCOBAN	KHA	S 36 12 48	E 148 7 42	133.0	1054,12
TO	CABRAMURRA	CAB	S 35 55 36	E 148 26 0	130.7	1056,84
TO	CAMBERRA	CAN	S 35 19 12	E 148 59 54	126.1	1062,44
TO	JENOLAN	JEN	S 33 49 30	E 150 1 18	115.9	1075,24
TO	INVERALOCHY	INV	S 34 57 54	E 149 40 0	122.7	1096,46
TO	WAMBROOK	WAM	S 36 11 18	E 148 53 0	130.7	1106,71
TO	WEROMBI	WER	S 33 57 0	E 150 34 48	115.6	1128,51
TO	FORREST	FT	S 30 53 0	E 127 46 36	262.1	1135,78
TO	RIVERVIEW	RIVCO	S 33 49 48	E 151 9 30	114.1	1174,82
TO	WARRAMUNGA	WRA	S 19 56 42	E 134 20 30	333.5	1232,50
TO	CHARTERS TOWERS	CTA	S 20 5 18	E 146 15 18	33.0	1288,86
TO	BRISBANE	BRS	S 27 23 30	E 152 46 30	80.6	1322,32
TO	RAWLINNA	RA	S 31 1 24	E 125 19 42	261.7	1370,04
TO	ZANTHUS	ZS	S 31 1 48	E 123 33 6	261.7	1539,67
TO	KALGOORLIE	KLG	S 30 47 0	E 121 27 30	262.6	1740,17
TO	KUNUNURRA	KNA	S 15 45 0	E 128 46 0	322.7	1926,14
TO	MANTON DAM	MTN	S 12 50 48	E 130 7 48	330.9	2134,50
TO	MUNDARING	MUN	S 31 58 42	E 116 12 30	258.4	2237,02
TO	MEEKATHARRA	MEK	S 26 36 48	E 118 32 42	275.2	2092,34
TO	OFFICER BASIN	OF	S 27 5 42	E 124 44 36	278.9	1484,52
TO	KOWEN FORREST	KF	S 35 17 18	E 149 17 36	125.2	1083,77
TO	COOBER PEDY	CP	S 29 15 42	E 134 58 24	279.4	452,06
TO	SANDSTONE	SS	S 28 1 12	E 119 18 0	271.3	1983,82

APPENDIX 2

PROGRAM REFDAT

```
      PROGRAM REFDAT
      INTEGER QQ,QUALITY,AC,TIP
      DIMENSION DESCRIP(10),RABR(100),RNAME1(100),RNAME2(100),RTT(7)
     1,DIS(1200),AZ(1200),TT(8500),QUAL(8500),RQUAL(7)
     2,STERH(100),SDEP(100),RTERH(100),RWINS(100)
      COMMON TO,VCOR,SDEPTH,STERD,RTERD
  109 FORMAT(11X,*LOCATION          ABREVIATION        LATITUDE   LONGITUDE
     1  ELEVATION    INSTITUTION*/)
  108 FORMAT(6X,A1,I2,2X,A8,A7,5X,A5,8X,A8,3X,A8,5X,F6.1,8X,A5,12X,F6.1)
  107 FORMAT(*  SHOT      RECORDER     LOCATION         ABREV   DISTANCE
     1  AZIMUTH        TRAVEL TIME          REMARKS          TT MSL     INST*/
     2)
  106 FORMAT(76X,F6.2, 9X,A4,2X,A4,7X,F6.2)
  105 FORMAT(A1,I1,6X)
  104 FORMAT(/,4XI2,9XI2,6XA8,A7,XA5,2XF6.1,9X,F5.1,10X,F6.2, 9X,A4,2X,
     1A4,7X,F6.2,5XA5)
  103 FORMAT(2I2,X,F6,F5,X,7(X,F6.2,A2))
  102 FORMAT(A1,I2,2X,A8,A7,A8,X,A8,3X,2F5.1,2A5)
  101 FORMAT(1X,10A8)
  100 FORMAT(10A8)
   99 FORMAT(1H1,* *)
   98 FORMAT(I3,F5.2)
      NAS=0 $ NAR=0 $ READ(60,98)NOST,VCOR
      IF(VCOR.LE.0.0)VCOR=4.0
    1 READ(60,100)(DESCRIP(I),I=1,10) $ IF(EOF,60)3,2
    2 WRITE(61,101)(DESCRIP(I),I=1,10) $ GOTO1
    3 WRITE(61,99)
      WRITE(61,109)
C-----------------------------------------------------------------------
C      POSSIBLE READ WATER CORRECTION DATA
C  TERH=HEIGHT ABOVE SEA LEVEL (OR DEPTH OF WATER)  (M.)
C     PTHT=DEPTH OF SHOT
    4 READ(60,102)TIP,MNO,ANAME1,ANAME2,ALAT,ALONG,TERH,PTHT,ABR,WINS
      IF(EOF,60)14,6
    6 WRITE(61,108)TIP,MNO,ANAME1,ANAME2,ABR,ALAT,ALONG,TERH,WINS,PTHT
      IF(TIP.EQ.1HS)GOTO7 $ RABR(MNO)=ABR
      RTERH(MNO)=TERH*0.001 $ RWINS(MNO)=WINS
      RNAME1(MNO)=ANAME1 $ RNAME2(MNO)=ANAME2 $ GOTO4
    7 STERH(MNO)=TERH*0.001 $ SDEP(MNO)=PTHT*0.001 $ GOTO4
C-----------------------------------------------------------------------
   14 WRITE(61,99)
    5 READ(60,103)NSH,NOR,RDIS,RAZ,(RTT(I),RQUAL(I),I=1,7)
      IF(EOF,60)9,8
    8 NSNR=((NSH-1)*NOST)+NOR $ DIS(NSNR)=RDIS $ AZ(NSNR)=RAZ
      DO10I=1,7
      NSNRI=(NSNR*7)+I $ TT(NSNRI)=RTT(I) $ QUAL(NSNRI)=RQUAL(I)
   10 CONTINUE
      IF(NSH.GT.NAS)NAS=NSH $ IF(NOR.GT.NAR)NAR=NOR $ GOTO5
C***********************************************************************
C  START PRINTOUT OF DATA
    9 NPR=2 $ WRITE(61,107) $ NPR=NPR+2
      DO11I=1,NAS
      DO11J=1,NAR
      NSNR=((I-1)*NOST)+J
      IF(DIS(NSNR).LE.0.0)GOTO11 $ NSNRI=(NSNR*7)+1 $ K=1 $ GOTO12
   13 WRITE(61,104)I,J,RNAME1(J),RNAME2(J),RABR(J),DIS(NSNR),AZ(NSNR)
     1,TT(NSNRI),QUALITY,AC,TO,RWINS(J)
      NPR=NPR+2 $ IF(NPR.LT.61)GOTO15 $ NPR=2
      WRITE(61,99) $ WRITE(61,107) $ NPR=NPR+2
   15 DO11K=2,7
```

```
      NSNRI=(NSNR*7)+K $ IF(TT(NSNRI).GT.0.0)GOTO12 $ K=7 $ GOTO11
   12 DECODE(2,105,QUAL(NSNRI))QU,JACC $ QUALITY=4H     $ AC=4H
      IF(QU.EQ.1HA)QUALITY=4HGOOD $ IF(QU.EQ.1HB)QUALITY=4HFAIR
      IF(QU.EQ.1HC)QUALITY=4HPOOR $ IF(QU.EQ.1HD)QUALITY=4HBAD
      IF(JACC.EQ.1)AC=4H0.01 $ IF(JACC.EQ.2)AC=4H0.10
      IF(JACC.EQ.3)AC=4H0.50 $ IF(JACC.EQ.4)AC=4H1.00

      TO=TT(NSNRI) $ SDEPTH=SDEP(I) $ STERD=STERH(I) $ RTERD=RTERH(J)
      CALL MODIT
      IF(K.EQ.1)GOTO13
      WRITE(61,106)TT(NSNRI),QUALITY,AC,TO
      NPR=NPR+1 $ IF(NPR.LT.61)GOTO11
      NPR=2 $ WRITE(61,99) $ WRITE(61,107) $ NPR=NPR+2
   11 CONTINUE
      END
```

```
      SUBROUTINE MODIT
      COMMON TO,VCOR,SDEPTH,STERD,RTERD
      TO=TO-RTERD/VCOR
      IF(SDEPTH.GT.0.0)GOTO1
      TO=TO-STERD/VCOR $ GOTO2
    1 TO=TO+SDEPTH/1.52 $ TO=TO-STERD/1.52 $ TO=TO+STERD/VCOR
    2 CONTINUE
      RETURN
      END
```

APPENDIX 3

PROGRAM PLOTIT

```
      PROGRAM PLOTIT
C           J.P.CULL       REGIONAL CRUSTAL STUDIES
C                        BUREAU OF MINERAL RESOURCES
C****
      DIMENSION  RTT(7),RQUAL(7),RACC(7),DIS(1200),AZ(1200),TT(8500),
     1QUAL(8500),SURVDATE(10),NSAD(10),NRAD(10),ERROR(5),LPTS(35),
     2SABR(150),RABR(150)
      INTEGER TIPE,UM,OU,TIP,TIN,REV
   99 FORMAT(I3)
  100 FORMAT(F6.0)
  101 FORMAT (2I2,X,F5,F5,X,7(X,F6.2,A2))
  102 FORMAT(7F5,43X,A2)
  103 FORMAT(A1,I2,34I2,X,F6,A1,A1)
  104 FORMAT(A8)
  108 FORMAT(1X,F6.0,3X,I3)
      NADS=0 $ NADR=0 $ NAS=0 $ NAR=0  $   NG=0
      READ(60,99)NOST $ READ(60,100)DATE
      PRINT 108,DATE,NOST
    1 READ (60,104)BAF $ IF(EOF,60)19,1
C000000000000000000000000000000000000000000000000000000000000000000
   19 READ(60,110)TIP,MNO,ABR $ IF(EOF,60)2,27
  110 FORMAT(A1,I2,47X,A5)
   27 IF(TIP.EQ.1HS)GOTO28 $MNX=MNO+NADR $ RABR(MNX)=ABR $ GOTO19
   28 MNX=MNO+NADS $ SABR(MNX)=ABR $ GOTO19
C000000000000000000000000000000000000000000000000000000000000000000
    2 READ (60,101)NSH,NOR,RDIS,RAZ,(RTT(I),RQUAL(I),I=1,7)
      IF(EOF,60)6,7
    7 NS=NSH $IF(NS.GT.NAS)NAS=NS
      NR=NOR $IF(NR.GT.NAR)NAR=NR
      NS=NS+NADS $ NR=NR+NADR $ NSNR=((NS-1)*NOST)+NR
      DIS(NSNR)=RDIS $ AZ(NSNR)=RAZ
      DO 8 I=1,7
      NSNRI=(NSNR*7)+I
      TT(NSNRI)=RTT(I)
      QUAL(NSNRI)=RQUAL(I)
    8 CONTINUE
      GOTO 2
    6 NG=NG+1 $SURVDATE(NG)=DATE $ NSAD(NG)=NADS $ NRAD(NG)=NADR
       NADS=NADS+NAS $ NADR=NADR+NAR $ NAS=0 $ NAR=0
      READ(60,100)DATE
      IF (EOF,60)9,1
C
C*****************************************************************************
C*****************************************************************************
C    READ PLOT SPECIFICATIONS
C
    9 READ(60,102)TSCALE,DSCALE,DMAX,VREDUCE,AZR,RA,REVERSAL,PLOTTER
      IF(EOF,60)10,26
   26 IF(DMAX.LE.0.0)DMAX=DSCALE*30.0 $ DMAXH=-(DMAX*0.5)
      IF(RA.LE.0.0)GOTO30 $ AZMAX=AZR+RA $AZMIN=AZR-RA
   30 CONTINUE
      AXILENTH=23.0 $ IF(PLOTTER.EQ.2HPL)AXILENTH=10.0
      TORD=0.0 $ IF(VREDUCE.GT.0.0)TORD=-(AXILENTH*0.5)+2.0
      TMAX=(AXILENTH+TORD)*TSCALE $ TMIN=TORD*TSCALE
      TMEN=TMIN+TSCALE+TSCALE
      ERROR(1)=0.01$ ERROR(2)=0.1 $ ERROR(3)=0.5 $ ERROR(4)=1
      ERROR(5)=0.0  $ LPTS(35)=0  $ DATE1=SURVDATE(1)
C=================================================================
C
C         DRAW AND LABEL AXES
```

```
C
      AXFL=0,0
      CALLPLOT(TSCALE,DSCALE,2) $ CALLPLOT(TMIN,-DMAX,1)
    4 IF(VREDUCE,LE,0,0)GOTO49
      CALLPLOT(0.,(DSCALE*0,5),3)
      CALLTEXT(19HREDUCED TIME  TT-D/,19,2)
      ENCODE(4,113,BUF)VREDUCE $ CALLTEXT(BUF,4,2)
  113 FORMAT(F4,2)
   49 CALLPLOT((TMIN+TSCALE),DMAXH,3) $ CALLTEXT(1HX,0,2)
      CALLPLOT(0.,-DMAX,3) $ CALLPLOT(0.,0.,4)
      CALLPLOT(TMIN,0.,3) $ CALLPLOT(TMAX,0.,4)
      IC=0 $ DPSN=DSCALE*0,5
   35 IC=IC+1
      TSCT=(IC*TSCALE)+TMIN $ IF(TSCT,GT,TMAX)GOTO36
      CALLPLOT(TSCT,DPSN,3) $ ENCODE(3,107,BUF)TSCT
  107 FORMAT(F3,0)
      CALLPLOTSET(4)
      CALLTEXT(BUF,3,2) $ CALLPLOTSET(1) $GOTO35
   36 IC=0
   37 IC=IC+2 $ DSCT=IC*DSCALE $ IF(DSCT,GT,DMAX)GOTO38
      DSCO=-DSCT $ CALLPLOT(0,0,DSCO,3)
      ENCODE(4,109,BUF)DSCT $ CALLTEXT(BUF,4,2) $ GOTO37
  109 FORMAT(F4,0)
   38 IF(REVERSAL,LE,0,0)GOTO381
      CALLPLOT(TMIN,-REVERSAL,3) $ CALLPLOT(TMAX,-REVERSAL,4)
  381 IF(AXFL,EQ,1,0)GOTO5
C=====================================================================
C
C   READ WHICH POINTS ARE TO BE PLOTTED
C
    3 READ(60,103)TIPE,LORIG,(LPTS(K),K=1,34),DATE,REV,TIN
      IF(EOF,60)9,20
   20 IF(AXFL,EQ,1,0)GOTO4
    5 AXFL=0,0
      IF(DATE,EQ,0)DATE=DATE1  $ DATE1=DATE
      PRINT106,DATE,TIPE,LORIG,(LPTS(K),K=1,34),REV,TIN
  106 FORMAT(X,F5,X,A1,I2,X,34I2,X,A1,A1)
      TMEN=TMEN+0,3*TSCALE
C
      DO40 LIK=1,NG
      IF(SURVDATE(LIK),EQ,DATE)39,40
   39 NI=NSAD(LIK) $ NJ=NRAD(LIK) $ LIK=NG
   40 CONTINUE
      PRINT601,NI,NJ
  601 FORMAT(1X,2I8)
   11 IF(TIPE,EQ,1HS) 12,13
   12 I=LORIG+NI $ K=0 $ TABR=SABR(I)
   14 K=K+1$ J=LPTS(K) $ IF(J,EQ,0)GOTO17 $ J=J+NJ $ GOTO 21
   13 J=LORIG+NJ $ K=0 $ TABR=RABR(J)
   15 K=K+1$ I=LPTS(K) $ IF(I,EQ,0)GOTO17 $ I=I+NI
   21  IJ=((I-1)*NOST)+J
      DS=DIS(IJ) $ AZZ=AZ(IJ)
      PRINT602,I,J
  602 FORMAT(20X,I2,2X,I2)
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C       APPLY AZIMUTH RESTRICTIONS
C
      IF(RA,LE,0,0)GOTO31 $ AZS=AZZ $ IF(TIPE,NE,1HS)AZS=AZS-180,0
      IF(AZS,LT,0,0)AZS=AZS+360,0$IF(AZS,GT,AZMAX,OR,AZS,LT,AZMIN)33,31
   33 AZS=AZS+360,0 $ IF(AZS,GT,AZMAX,OR,AZS,LT,AZMIN)34,31
```

```
   34 AZS=AZS-720.0 $ IF(AZS.GT.AZMAX.OR.AZS.LT.AZMIN)32,31
   31 CONTINUE
C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      DO 16 M=1,7
      IJM=(IJ*7)+M
      TP=TT(IJM)   $ IF(TP.GT.0)GOTO22 $ M=7 $ GOTO16
   22 DECODE(2,105,QUAL(IJM))QU,JACC
  105 FORMAT(A1,I1,6X)
       IF(JACC.LE.0)JACC=5 $ TACC=ERROR(JACC)
      TER1=TP+TACC $ TER2=TP-TACC $ IF(VREDUCE.GT.0.0)60,61
   60 TP=TP-DS/VREDUCE $ TER1=TER1-DS/VREDUCE $ TER2=TER2-DS/VREDUCE
   61 IF(TP.GT.TMAX.OR.TP.LT.TMIN)GOTO16 $ IF(DS.GT.DMAX)GOTO16
      PRINT600,TP,DS
  600 FORMAT(1X,F10.4,5X,F10.2)
      XDS=-DS $ IF(REV.EQ.1HR)XDS=-(REVERSAL-DS)
C     START PLOTTING SPECIFIED POINTS
      CALLPLOT(TP,XDS,3) $ CALLTEXT(1H*,0,1)
      IF(QU.EQ.1HA)GOTO23 $ IF(QU.EQ.1HB)GOTO24 $ GOTO46
   23 CALLTEXT(1HO,0,1) $ GOTO46
   24 CALLTEXT(1H=,0,1)
C      LABEL PLOTTED POINTS
   46 IF(M.GT.1)GOTO41
      ABR=SABR(I) $IF(TIPE.EQ.1HS)ABR=RABR(J)
      TSHIF=TER2-TSCALE $IF(TSHIF.LT.TMIN)TSHIF=TMIN
      CALLPLOT(TSHIF,XDS,3) $ENCODE(10,111,BUF)LPTS(K),ABR,LORIG
  111 FORMAT(I2,X,A5,I2)
      CALLTEXT(BUF,10,1)
   41 IF(TER1.GT.TMAX.OR.TER2.LT.TMIN)GOTO16
      CALLPLOT(TER1,XDS,3) $ CALLPLOT(TER2,XDS,4)
   16 CONTINUE
   32 IF(TIPE.EQ.1HS)14,15
   17 CALLPLOT(TMEN,DMAXH,3)
      CALLPLOTSET(4)
      IF(TIPE.EQ.1HS)GOTO47
      CALLTEXT(8HSTATION ,8,2) $ GOTO48
   47 CALLTEXT(5HSHOT ,5,2)
   48 ENCODE(8,112,BUF)LORIG,TABR $ CALLTEXT(BUF,8,2)
      CALLPLOTSET(1)
      CALLPLOT((TMIN+TSCALE),DMAXH,3) $ CALLTEXT(1HO,0,2)
  112 FORMAT(I2,X,A5)
      IF(TIN.EQ.1H )18,3
   18 CALLPLOT(TMIN,DSCALE,3) $CALLPLOT(TMIN,-DMAX,1) $AXFL=1.0 $GOTO3
   10 CONTINUE
      END
```

APPENDIX 4

PROGRAM TERMAT

```
*JOB,CCDMR*CA,TERMAT,4
*EQUIP,6=(TEMPTAPE),MT
*KTN,X,L
```

```
      PROGRAM TERMAT
      DIMENSION CARD(10),AMAT(140),A(140,140),B(140,2),TT2(140)
     1,D(100),T(100),W(100)
      COMMON A,B,N,L,D,AMAT,IRROR,ISTOP,JEND,MFLAG,IOPS,ALOC,BLOC,V,TT2
     1,SUMD2,SW,SWD,SWT,SWTD,SWDD,NMAX,T,W
      EQUIVALENCE (DEL,IDEL)
C     -----------------------------------------------------------------
C     PROGRAM TERMAT  SETS UP AND INVERTS MATRICES TO OBTAIN TIME TERMS
C     AND REFRACTOR VELOCITIES
C     MAXIMUM MATRIX SIZE(140,140)    SHOTS+STATIONS.LE.140

C     IF A SHOT IS COINCIDENT WITH A STATION (THEREBY PROVIDING UNIQUE
C     SOLUTIONS) THEIR LABELS ARE PLACED IN COLUMNS 65-72 AND 73-80 OF
C     THE FIRST DATA CARD  (ANY ORDER)

C      J.P.CULL   REGIONAL CRUSTAL STUDIES   BUREAU MINERAL RESOURCES
C                              4/7/1972
C     -----------------------------------------------------------------
   16 FORMAT(2X,60F2.0)
  160 FORMAT(1H1,1X,* *)
  106 FORMAT(1X,60F2.0)
  102 FORMAT(10A8)
  101 FORMAT(A8,F7.2,F5.2)
C
C     READ DATA ONTO MAGNETIC TAPE
      READ(60,102)(CARD(JB),JB=1,10)
      IF(EOF,60)999,109
  109 DECODE(16,110,CARD(9))ALOC,DEL $ BLOC=DEL
  110 FORMAT(2A8)
      MFLAG=1 $ N=0
      IF(IDEL.NE.60606060606060606060B)MFLAG=0 $ GOTO105

   21 SW=0 $ SWD=0 $ SWT=0 $ SWTD=0 $ SWDD=0
      UT=0 $ UD=0 $ N=1
  103 READ(60,102)(CARD(JB),JB=1,10) $ IF(EOF,60) 25,105
  105 WRITE(6,102)(CARD(JB),JB=1,10)
  111 FORMAT(F7.2,F5.2,F2.0)
      IF(N.EQ.0)GOTO24 $ DECODE(14,111,CARD(2))D(N),T(N),W(N)
      IF(W(N).LE.0.0)W(N)=1.0
      IF(D(N).GT.0.0)GOTO20 $ CALL VELIT
   24 WRITE(61,122)(CARD(JB),JB=1,10) $GOTO21
   20 SW=SW+W(N) $ SWD=SWD+W(N)*D(N) $ SWT=SWT+W(N)*T(N)
      SWTD=SWTD+W(N)*(T(N)*D(N)) $ SWDD=SWDD+W(N)*(D(N)*D(N))
      NMAX=N $ UD=UD+D(N) $ UT=UT+T(N) $ N=N+1
      WRITE(61,122)(CARD(JB),JB=1,10)
  122 FORMAT(1X,10A8)
      GOTO103
   25 CALL VELIT
  104 ENDFILE 6 $ REWIND 6 $ J=0
      WRITE(61,160)

C     ASSIGN MATRIX NUMBERS TO EACH SHOT AND STATION
  100 FORMAT(2A8)
       KES=0
    1 READ(6,100)STN,DEL $ IF(EOF,6)4,3
    3 IF(IDEL.EQ.60606060606060606060B)2,1
    2 J=J+1 $ AMAT(J)=STN $ GOTO1
    4 REWIND 6 $ JEND=J $ ISTOP=JEND
    5 READ(6,100)SHOT,DEL
      IF(EOF,6)10,176
```

```
  178 IF(IDEL.EQ.6060606060606060B)5,6
    6 IF(SHOT.EQ.ALOC.OR.SHOT.EQ.BLOC)GOTO5
      DO7JE=JEND,ISTOP $ IF(SHOT.EQ.AMAT(JE))8,7
    8 JE=ISTOP $ KES=2
    7 CONTINUE
      IF(KES.GT.1)GOTO9 $ISTOP=ISTOP+1 $J=J+1 $AMAT(J)=SHOT
    9 KES=0 $ GOTO5
   10 DO23IYX=1,ISTOP
      DO22IXY=1,ISTOP
      A(IXY,IYX)=0 $B(IXY,1)=0 $B(IXY,2)=0
   22 CONTINUE
   23 CONTINUE
      REWIND 6
C     SET UP MATRIX FOR INVERSION
   13 READ(6,102)SHOT,(CARD(JC),JC=1,9)
      IF(EOF,6)99,113
  113 DECODE(12,107,CARD(1))DEL,TT
  107 FORMAT(F7.2,F5.2)
      IF(DEL.LE.0.1)11,12
   11 DO14JO=1,JEND
      IF(SHOT.EQ.AMAT(JO))15,14
   15 JOP=JO $JO=JEND
   14 CONTINUE
      GOTO13
   12 IF(SHOT.EQ.ALOC.OR.SHOT.EQ.BLOC)30,31
   30 DO32IO=1,JEND
      IF(AMAT(IO).EQ.ALOC.OR.AMAT(IO).EQ.BLOC)33,32
   33 IOP=IO $ IO=JEND
      IOPS=IOP
   32 CONTINUE
       GOTO19
   31 DO18IO=JEND,ISTOP
      IF(SHOT.EQ.AMAT(IO))17,18
   17 IOP=IO $IO=ISTOP
   18 CONTINUE
   19 A(JOP,IOP)=1 $A(IOP,JOP)=1
      A(JOP,JOP)=A(JOP,JOP)+1 $A(IOP,IOP)=A(IOP,IOP)+1
      B(JOP,1)=B(JOP,1)+TT $B(JOP,2)=B(JOP,2)+DEL
      B(IOP,1)=B(IOP,1)+TT $B(IOP,2)=B(IOP,2)+DEL
       GOTO13
   99 NTOT=ISTOP
      WRITE(61,108)(AMAT(JF),B(JF,1),B(JF,2),JF=1,NTOT)
  108 FORMAT(1X,A8,2F10.2)
C         PRINT MATRIX
      WRITE(61,160)
      N=NTOT
      IF(N.GT.60)GOTO42
      DO45I=1,N
   41 WRITE(61,16)(A(I,J),J=1,N)
   45 CONTINUE
      GOTO60
   42 WRITE(61,16)((A(I,J),J=1,60)I=1,N)
      WRITE(61,160)
      IF(N.LE.120)46,50
   46 DO47I=1,N
   47 WRITE(61,16)(A(I,J),J=61,N)
      GOTO60
   50 WRITE(61,16)((A(I,J),J=61,120)I=1,N)
```

```
      WRITE(61,160)
      DO52 I=1,N
   52 WRITE(61,16)(A(I,J),J=121,N)
   60 CONTINUE
      WRITE(61,160)
      N=NTOT-MFLAG $ CALL TIMETERM
      CALL RESIDUAL
  999 CONTINUE
      END
```

```
      SUBROUTINE TIMETERM
      DIMENSION CARD(10),AMAT(140),A(140,140),B(140,2),TT2(140)
     1,D(100),T(100),W(100)
      COMMON A,B,N,L,D,AMAT,IRROR,ISTOP,JEND,MFLAG,IOPS,ALOC,BLOC,V,TT2
     1,SUMD2,SW,SWD,SWT,SWTD,SWDD,NMAX,T,W
C     ------------------------------------------------------------------
      L=2 $ CALLMATINV $ IF(IRROR,GT,0,1)37,38
   37 WRITE(61,101)
  102 FORMAT(10A8)
  101 FORMAT(1X,*MATRIX SINGULAR*)
      GOTO90
   38 REWIND 6 $SUMDT=0$SUMD2=0

   13 READ(6,102)SHOT,(CARD(JC),JC=1,9) $ FLEM=0
      IF(EOF,6)40,113
  113 DECODE(12,107,CARD(1))DEL,TT
  107 FORMAT(F7.2,F5,2)
      IF(DEL,LE,0,1)11,12
   11 DO14JO=1,JEND
      IF(SHOT,EQ,AMAT(JO))15,14
   15 JOP=JO $JO=JEND
   14 CONTINUE
      GOTO13
   12 IF(SHOT,EQ,ALOC,OR,SHOT,EQ,BLOC)30,31
   30 IOP=IOPS
       GOTO19
   31 DO18IO=JEND,ISTOP
      IF(IO,EQ,ISTOP)FLEM=1
      IF(SHOT,EQ,AMAT(IO))17,18
   17 IOP=IO $IO=ISTOP
   18 CONTINUE
   19 IF(FLEM,GT,0)GOTO13
      SUMD=DEL-B(JOP,2)-B(IOP,2)
      SUMD2=SUMD2+SUMD*SUMD
      SUMT=TT-B(JOP,1)-B(IOP,1)
      SUMDT=SUMDT+SUMD*SUMT
      GOTO13
   40 V=SUMD2/SUMDT
      WRITE(61,119)(V)
  119 FORMAT(9X,*   TIME      DISTANCE    V=*,F5.2)
      DO65I=1,N
      TT1=B(I,1)-B(I,2)/V
      TT2(I)=TT1
       IF(MFLAG.LT,1)GOTO43 $ IF(I.LE,JEND)41,42
   41 WRITE(61,124)AMAT(I),B(I,1),B(I,2),TT1 $ GOTO65
   42 WRITE(61,123)AMAT(I),B(I,1),B(I,2),TT1 $ GOTO65
  124 FORMAT(2X,A8,2(F8,2,2X),F8.2,*-ALPHA*)
  123 FORMAT(2X,A8,2(F8,2,2X),F8.2,*+ALPHA*)
   43 WRITE(61,120)AMAT(I),B(I,1),B(I,2),TT1
  120 FORMAT(2X,A8,3(F8,2,2X))
   65 CONTINUE
      IF(MFLAG.GT,0,1)GOTO89
      CTT=B(IOPS,1)-B(IOPS,2)/V
      IF(AMAT(IOPS),EQ,ALOC)CLOC=BLOC
      IF(AMAT(IOPS),EQ,BLOC)CLOC=ALOC
      WRITE(61,122)(CLOC,CTT)
  122 FORMAT(2X,A8,20X,F8,2)
      GOTO90
   89 WRITE(61,121)AMAT(N+1)
  121 FORMAT(2X,A8,24X,* ALPHA*)
```

```
      TT2(N+1)=0.0
   90 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATINV
      COMMON A,B,N,L,D,AMAT,IRROR,ISTOP,JEND,MFLAG,IOPS,ALOC,BLOC,V,TT2
     1,SUMD2,SW,SWD,SWT,SWTD,SWDD,NMAX,T,W
      DIMENSION CARD(10),AMAT(140),A(140,140),B(140,2),TT2(140)
     1,D(100),T(100),W(100),IPIV(140),IND(140,2)
C     A IS AN NXN MATRIX TO BE INVERTED,OR CONTAINING EQUATION COEFFS   MA
C     B IS AN NXM RHS MATRIX FOR EQUATIONS                              MA
C     IF L=0,INVERSE ONLY GIVEN,L POSITIVE,SOLUTIONS ONLY,L NEGATIVE    MA
C      BOTH.   M=ABS(L),                                                MA
C     D CONTAINS THE DETERMINANT OF THE A MATRIX ON EXIT                MA
C     A IS REPLACED BY THE INVERSE ,B BY THE SOLUTIONS.                 MA
C     METHOD OF GAUSS-JORDON PIVOTAL ELIMINATION                        MA
C     ------------------------------------------------------------------
      M=IABS(L)                                                         MA
      D=1.0                                                             MA
      DO 10 I=1,N                                                       MA
   10 IPIV(I)=0                                                         MA
      DO 220 I=1,N                                                      MA
      AMAX=0.0                                                          MA
C     SEARCH SUB-MATRIX FOR LARGEST ELEMENT AS PIVOT                    MA
      DO  70 J=1,N                                                      MA
      IF(IPIV(J)) 80,30,70                                              MA
   30 DO  60 K=1,N                                                      MA
      IF(IPIV(K)-1) 40,60,80                                            MA
C     THIS ROW COLUMN HAS NOT BEEN A PIVOT                              MA
   40 IF(ABS (A(J,K))-AMAX) 60,60,50                                    MA
   50 IROW=J                                                            MA
      ICOL=K                                                            MA
      AMAX=ABS (A(J,K))                                                 MA
   60 CONTINUE                                                          MA
   70 CONTINUE                                                          MA
C     PIVOT FOUND                                                       MA
      IPIV(ICOL)=IPIV(ICOL)+1                                           MA
      IF(AMAX-1.0E-90 ) 80,80,90                                        MA
C     MATRIX SINGULAR,ERROR RETURN                                      MA
   80 IRROR=1                                                           MA
      RETURN                                                            MA
   90 IF(IROW-ICOL) 95,130,95                                           MA
C     MAKE PIVOT A DIAGONAL ELEMENT BY ROW INTERCHANGE.                 MA
   95 D=-D                                                              MA
      DO 100 K=1,N                                                      MA
      AMAX=A(IROW,K)                                                    MA
      A(IROW,K)=A(ICOL,K)                                               MA
  100 A(ICOL,K)=AMAX                                                    MA
      IF(M) 130,130,110                                                 MA
  110 DO 120 K=1,M                                                      MA
      AMAX=B(IROW,K)                                                    MA
      B(IROW,K)=B(ICOL,K)                                               MA
  120 B(ICOL,K)=AMAX                                                    MA
  130 IND(I,1)=IROW                                                     MA
      IND(I,2)=ICOL                                                     MA
      AMAX=A(ICOL,ICOL)                                                 MA
      D=D*AMAX                                                          MA
      A(ICOL,ICOL)=1.0                                                  MA
C     DIVIDE PIVOT ROW BY PIVOT                                         MA
      DO 140 K=1,N                                                      MA
  140 A(ICOL,K)=A(ICOL,K)/AMAX                                          MA
      IF(M) 170,170,150                                                 MA
  150 DO 160 K=1,M                                                      MA
```

```
  160 B(ICOL,K)=B(ICOL,K)/AMAX                                         MAT
C     REDUCE NON-PIVOT ROWS                                            MAT
  170 DO 220 J=1,N                                                     MAT
      IF(J-ICOL) 180,220,180                                           MAT
  180 AMAX=A(J,ICOL)                                                   MAT
      A(J,ICOL)=0.0                                                    MAT
      DO 190  K=1,N                                                    MAT
  190 A(J,K)=A(J,K)-A(ICOL,K)*AMAX                                     MAT
      IF(M)  220,220,200                                               MAT
  200 DO  210 K=1,M                                                    MAT
  210 B(J,K)=B(J,K)-B(ICOL,K)*AMAX                                     MAT
  220 CONTINUE                                                         MAT
C     AFTER N PIVOTAL CONDENSATIONS,SOLUTIONS LIE IN B MATRIX          MAT
      IF(L) 230,230,270                                                MAT
C     FOR INVERSE OF A, INTERCHANGE COLUMNS                            MAT
  230 DO 260 I=1,N                                                     MAT
      J=N+1-I                                                          MAT
      IF(IND(J,1)-IND(J,2)) 240,260,240                                MAT
  240 IROW=IND(J,1)                                                    MAT
      ICOL=IND(J,2)                                                    MAT
      DO 250  K=1,N                                                    MAT
      AMAX=A(K,IROW)                                                   MAT
      A(K,IROW)=A(K,ICOL)                                              MAT
  250 A(K,ICOL)=AMAX                                                   MAT
  260 CONTINUE                                                         MAT
  270 IRROR=0                                                          MAT
      RETURN                                                           MAT
      END                                                              MAT
```

```
      SUBROUTINE RESIDUAL
      DIMENSION CARD(10),AMAT(140),A(140,140),B(140,2),TT2(140)
     1,D(100),T(100),W(100)
      COMMON A,B,N,L,D,AMAT,IRROR,ISTOP,JEND,MFLAG,IOPS,ALOC,BLOC,V,TT2
     1,SUMD2,SW,SWD,SWT,SWTD,SWDD,NMAX,T,W
C     ----------------------------------------------------------------
  102 FORMAT(10A8)
  103 FORMAT(///,1X,*VELOCITY=*,F5.2)
  104 FORMAT(2X,2A8,F8.2,2F6.2)
  105 FORMAT(*    LOC1    LOC2      DIST    TT   RESID*)
  106 FORMAT(/,12X,*ST,DEV, OF RESIDUALS=*,F5,3)
  107 FORMAT(F7.2,F5.2)
  108 FORMAT(1X,*ST,DEV,=*,F5,3)
  160 FORMAT(1H1,1X,* *)

      RS2=0.0 $ TNOBS=0.0
      IF(IRROR.GT.0.1)40,10
   10 REWIND 6
      WRITE(61,160)
      WRITE(61,105)
   13 READ(6,102)SHOT,(CARD(JC),JC=1,9)
      IF(EOF,6)40,113
  113 DECODE(10,107,CARD(1))DEL,TT
      IF(DEL.LE.0.1)11,12
   11 DO14JO=1,JEND
      IF(SHOT.EQ.AMAT(JO))15,14
   15 JOP=JO $JO=JEND
   14 CONTINUE
      STN=SHOT
      GOTO13
   12 IF(SHOT.EQ.ALOC.OR.SHOT.EQ.BLOC)30,31
   30 IOP=IOPS
       GOTO19
   31 DO18IO=JEND,ISTOP
      IF(SHOT.EQ.AMAT(IO))17,18
   17 IOP=IO $IO=ISTOP
   18 CONTINUE
   19 RESID=TT-DEL/V-TT2(IOP)-TT2(JOP)
      RS2=RS2+RESID*RESID
      WRITE(61,104)STN,SHOT,DEL,TT,RESID
      TNOBS=TNOBS+1.0
      GOTO13
   40 CONTINUE
      STOD=RS2/(TNOBS-1.0) $ STED=SQRT(STOD)
      WRITE(61,106)STED
      VSTI=STOD/SUMD2 $ VST=SQRT(VSTI) $ STDV=VST*(V*V)
      WRITE(61,103)V $ WRITE(61,108)STDV
      RETURN
      END
```

```
      SUBROUTINE VELIT
      DIMENSION CARD(10),AMAT(140),A(140,140),B(140,2),TT2(140)
     1,D(100),T(100),W(100)
      COMMON A,B,N,L,D,AMAT,IRROR,ISTOP,JEND,MFLAG,IOPS,ALOC,BLOC,V,TT2
     1,SUMD2,SW,SWD,SWT,SWTD,SWDD,NMAX,T,W
   13 FORMAT(X,*APPARENT VELOCITY = *,F4.2,*(+-*,F4.2,*)*)
   14 FORMAT(X,*INTERCEPT = *,F5.2,*(+-*,F4.2,*)*,/)
      BOT=(SW*SWDD-SWD**2)
      VA=(SW*SWTD-SWD*SWT)/BOT $ V=1.0/VA
      VB=(SWT*SWDD-SWD*SWTD)/BOT
      SRES=0.0
      DO60 N=1,NMAX
      RES=VA*D(N)+VB-T(N) $ SRES=SRES+W(N)*RES*RES
   60 CONTINUE
      ALP=SRES/(NMAX-2)
      ERRA=SQRT((SW*ALP)/BOT) $ ERRB=SQRT((SWDD*ALP)/BOT)
      ERRV=ERRA/(VA**2)
      WRITE(61,13)V,ERRV $ WRITE(61,14)VB,ERRB
      CONTINUE
      RETURN
       END
```

TABLE 1

DATA LIST EXAMPLE (REFDAT)

```
251072    TRANS-AUSTRALIA SEISMIC SURVEY ,1972

PARTICIPATING ORGANISATIONS - BMR,ANU,UNI,OF ADELAIDE,UNI,OF QLD,UNI,OF TAS,
                              RIVERVIEW OBS

THREE LARGE SHOTS FIRED, 1 MT,FITTON(NORTH FLINDERS RANGES),80 TONS
                           DETONATED 25/10/72 , 01HR 05M 00,04S UT
                           LAT, 30DEG 00,4MIN  LONG, 139DEG 33,8MIN

                         2 KUNANALLING(NEAR KALGOORLIE),80 TONS
                           DETONATED 25/10/72 , 04HR 05M 01,23S UT
                           LAT, 30DEG 40,5MIN  LONG, 121DEG 04,0MIN

                         3 BASS STRAIT (40 MILES SOUTH OF ORBOST),10 TONS
                           DETONATED 19/12/72 , 07HR 50M 00,77S UT
                           LAT, 38DEG 17,6MIN  LONG, 148DEG 48,6MIN
COMPLEMENTARY DATA AVAILABLE FROM 1970,71 ORD RIVER BLASTS AND 1956 ATOMIC TEST
DATA FROM MARALINGA ,
```

	LOCATION	ABREVIATION	LATITUDE	LONGITUDE	ELEVATION	INSTITUTION	
S 1	MT,FITTON	S FIT	30 00,4	139 33,8	-0,0		-0,0
S 2	KUNANALLING	S KUN	30 40,5	121 04,0	-0,0		-0,0
S 3	BASS STRAIT	S BAS	38 17,6	148 48,6	25,2		22,7
R 1	PARTACOONA	PNA	32 00,4	138 09,9	-0,0	UA	-0,0
R 2	ISLAND LAGOON	ILN	31 23,6	136 52,2	-0,0	UA	-0,0
R 3	HALLET	HTT	33 25,8	138 55,3	-0,0	UA	-0,0
R 4	KINGOONYA	KA	30 57,7	135 20,1	-0,0	UA	-0,0
R 5	SEVENHILL	SNL	33 53,2	138 38,4	-0,0	UA	-0,0
R 6	MT.BRADY	BY	29 14,8	134 59,0	-0,0	BMR	-0,0
R 7	OODNADATTA	OOD	27 33,7	135 27,0	-0,0	UA	-0,0
R 8	TARCOOLA	TR	30 37,2	134 30,3	-0,0	UA	-0,0
R 9	UMBERETANA	UMB	30 14,4	139 07,7	-0,0	UA	-0,0
R10	CLEVE	CLV	33 41,5	136 29,7	-0,0	UA	-0,0
R11	ADELAIDE	ADE	34 58,0	138 42,5	-0,0	UA	-0,0
R12	MT,WILLOUGHBY	WY	28 00,2	134 09,2	-0,0	BMR	-0,0
R13	GRANITE DOWNS	GD	26 58,1	133 23,9	-0,0	BMR	-0,0
R14	OOLDEA	OA	30 29,0	131 52,0	-0,0	BMR	-0,0
R15	BELLFIELD	BFD	37 10,6	142 32,7	-0,0	BMR	-0,0
R16	MILL RIDGE	MLD	24 51,3	133 09,5	-0,0	BMR	-0,0
R17	COOK	CK	30 41,4	130 25,5	-0,0	BMR	-0,0
R18	ALICE SPRINGS	ASP	23 41,0	133 53,8	-0,0	BMR	-0,0
R19	TOOLANGI	TOO	37 34,3	145 29,4	-0,0	BMR	-0,0
R20	DEAKIN	DN	30 46,3	128 57,2	-0,0	BMR	-0,0
R21	TALBINGO	TAO	35 36,7	148 17,3	-0,0	ANU	-0,0
R22	KHANCOBAN	KHA	36 12,8	148 07,7	-0,0	ANU	-0,0
R23	CABRAMURRA	CAB	35 55,6	148 26,0	-0,0	ANU	-0,0
R24	CANBERRA	CAN	35 19,2	148 59,9	-0,0	ANU	-0,0
R25	JENOLAN	JEN	33 49,5	150 01,3	-0,0	ANU	-0,0
R26	INVERALOCHY	INV	34 57,9	149 40,0	-0,0	ANU	-0,0
R27	HAMBROOK	HAM	36 11,3	148 53,0	-0,0	ANU	-0,0
R28	WEROMBI	WER	33 57,0	150 34,8	-0,0	ANU	-0,0
R29	FORREST	FT	30 53,0	127 46,6	-0,0	BMR	-0,0
R30	RIVERVIEW	RIV	33 49,8	151 09,5	-0,0	COL	-0,0
R31	WARRAMUNGA	WRA	19 56,7	134 20,5	-0,0	BMR	-0,0
R32	CHARTERS TOWERS	CTA	20 05,3	146 15,3	-0,0	QU	-0,0
R33	BRISBANE	BRS	27 23,5	152 46,5	-0,0	QU	-0,0
R34	RAWLINNA	RA	31 01,4	125 19,7	-0,0	BMR	-0,0
R35	ZANTHUS	ZS	31 01,8	123 33,1	-0,0	BMR	-0,0
R36	KALGOORLIE	KLG	30 47,0	121 27,5	-0,0	BMR	-0,0
R37	KUNUNURRA	KNA	15 45,0	128 46,0	-0,0	BMR	-0,0
R38	MANTON DAM	MTN	12 50,8	130 07,8	-0,0	BMR	-0,0
R39	MUNDARING	MUN	31 58,7	116 12,5	-0,0	BMR	-0,0
R40	MEEKATHARRA	MEK	26 36,8	118 32,7	-0,0	BMR	-0,0
R41	OFFICER BASIN	OF	27 05,7	124 44,6	-0,0	BMR	-0,0
R42	KOWEN FORREST	KN	35 17,3	149 17,6	780,0	BMR	-0,0
R43	COOBER PEDY	CP	29 15,7	134 58,4	-0,0	UA	-0,0
R44	SANDSTONE	SS	28 01,2	119 18,0	-0,0	BMR	-0,0
R45	MT.CAVENAGH	CV	25 54,6	133 07,9	-0,0	BMR	-0,0
R46	HOBART	TAU	42 54,6	147 19,2	-0,0	TU	-0,0
R47	MOORLANDS	MOO	42 26,5	147 11,4	-0,0	TU	-0,0
R48	TARRALEAH	TRR	42 18,2	146 27,0	-0,0	TU	-0,0
R49	SAVANNAH	SAV	41 43,2	147 11,3	-0,0	TU	-0,0
R50	SHEFFIELD	SFF	41 20,2	146 18,4	-0,0	TU	-0,0
R51	SILVERTON	SN	31 49,3	141 11,6	-0,0	ANU	-0,0
R52	KARS	KS	32 11,0	142 03,2	-0,0	ANU	-0,0
R53	ASHMONT	AT	32 28,8	142 57,4	-0,0	ANU	-0,0
R54	BEILPAJAH	BH	32 52,3	143 48,1	-0,0	ANU	-0,0
R55	MOSSGIEL	ML	33 19,0	144 22,9	-0,0	ANU	-0,0
R56	BOOLIGAL	BL	33 50,2	144 53,3	-0,0	ANU	-0,0
R57	FERNDALE	FE	35 14,2	147 05,6	-0,0	ANU	-0,0
R58	MEADOWS	MS	35 58,3	147 07,3	-0,0	ANU	-0,0
R59	SCOTTS PEAK	SPK	43 02,3	146 16,5	-0,0	TU	-0,0
R60	STRATH GORDON	SGO	42 50,9	146 12,4	-0,0	TU	-0,0
R61	HOBART	TAU	42 54,6	147 19,2	-0,0	TU	-0,0
R62	TARRALEAH	TRR	42 18,2	146 27,0	-0,0	TU	-0,0
R63	BELLFIELD	BFD	37 10,6	142 32,7	-0,0	BMR	-0,0
R64	UMBERETANA	UMB	30 14,4	139 07,7	-0,0	UA	-0,0
R65	HALLET	HTT	33 25,8	138 55,3	-0,0	UA	-0,0
R66	HOBART	TAU	42 54,6	147 19,2	-0,0	TU	-0,0
R67	SAVANNAH	SAV	41 43,2	147 11,3	-0,0	TU	-0,0
R68	TARRALEAH	TRR	42 18,2	146 27,0	-0,0	TU	-0,0

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS	TT MSL	INST
1	1	PARTACOONA	PNA	258.8	210.7	39.56	GOOD 0.10	39.56	UA
						44.16	FAIR 0.10	44.16	
						70.66	FAIR 0.10	70.66	
						71.96	GOOD 0.10	71.96	
1	2	ISLAND LAGOON	ILN	300.3	238.5	44.96	GOOD 0.10	44.96	UA
						49.86	GOOD 0.50	49.86	
						81.76	GOOD 0.50	81.76	
1	3	HALLET	HTT	384.4	188.9	55.96	GOOD 0.10	55.96	UA
						64.46	GOOD 0.10	64.46	
						96.66	GOOD 0.10	96.66	
						109.46	GOOD 0.10	109.46	
1	4	KINGOONYA	KA	419.5	254.3	58.81	GOOD 0.10	58.81	UA
						66.62	GOOD 0.10	66.62	
						72.93	GOOD 0.10	72.93	
						115.54	FAIR 0.10	115.54	
						117.25	FAIR 0.10	117.25	
1	6	MT,BRADY	BY	451.4	279.6	62.30	GOOD 0.10	62.30	BMR
						62.89	GOOD 0.10	62.89	
1	8	TARCOOLA	TR	491.2	268.8	67.70	GOOD 0.10	67.70	UA
						68.00	GOOD 0.10	68.00	
						70.46	GOOD 0.10	70.46	
						76.60	FAIR 0.10	76.60	
						79.06	FAIR 0.50	79.06	
						120.46	GOOD 0.50	120.46	
1	9	UMBERETANA	UMB	49.3	238.2	8.16	GOOD 0.10	8.16	UA
1	10	CLEVE	CLV	501.2	214.6	68.16	GOOD 0.10	68.16	UA
						76.06	GOOD 0.50	76.06	
						85.56	FAIR 0.10	85.56	
						136.96	GOOD 0.50	136.96	
1	11	ADELAIDE	ADE	555.9	188.1	79.76	FAIR 0.10	79.76	UA
						135.46	GOOD 0.10	135.46	
						154.36	GOOD 0.10	154.36	
1	12	MT,WILLOUGHBY	WY	571.9	291.5	77.86	GOOD 0.01	77.86	BMR
						78.98	GOOD 0.01	78.98	
						99.68	FAIR 0.50	99.68	
						116.50	POOR 0.50	116.50	
						124.70	POOR 0.50	124.70	
						135.40	POOR 0.10	135.40	
						140.10	FAIR 0.10	140.10	
1	14	COLDEA	OA	742.5	264.0	97.20	POOR 0.50	97.20	BMR
						97.79	GOOD 0.10	97.79	
						100.75	FAIR 0.10	100.75	
						102.17	GOOD 0.10	102.17	
						173.64	FAIR 1.00	173.64	
1	15	BELLFIELD	BFD	841.8	161.6	110.76	GOOD 0.10	110.76	BMR

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS	TT MSL	INST
						196.66	GOOD 0.10	196.66	
						241.96	FAIR 0.10	241.96	
1	16	MILL RIDGE	MLD	852.3	318.5	112.00	GOOD 0.10	112.00	BMR
						112.70	GOOD 0.10	112.70	
						115.00	FAIR 0.10	115.00	
						119.70	GOOD 0.10	119.70	
						127.20	FAIR 0.10	127.20	
						176.40	FAIR 0.10	176.40	
						195.60	GOOD 0.10	195.60	
1	17	COOK	CK	881.7	262.8	114.68	GOOD 0.10	114.68	BMR
						115.64	GOOD 0.10	115.64	
						203.00	FAIR 0.50	203.00	
1	18	ALICE SPRINGS	ASP	898.6	319.9	117.86	GOOD 0.10	117.86	BMR
						129.80	FAIR 0.10	129.80	
						143.00	POOR 0.10	143.00	
						149.16	FAIR 0.10	149.16	
						205.46	GOOD 0.10	205.46	
1	19	TOOLANGI	TOO	1002.1	148.4	129.96	FAIR 0.10	129.96	BMR
1	29	FORREST	FI	1135.7	262.1	145.46	GOOD 0.10	145.46	BMR
						147.53	FAIR 0.10	147.53	
						157.60	FAIR 0.10	157.60	
						184.76	FAIR 0.10	184.76	
						254.16	POOR 0.50	254.16	
1	32	CHARTERS TOWERS	CTA	1288.9	33.0	164.00	GOOD 0.10	164.00	CU
						288.46	FAIR 0.50	288.46	
1	34	RAWLINNA	RA	1370.0	261.7	172.86	FAIR 0.10	172.86	BMR
						177.00	FAIR 0.10	177.00	
						307.00	FAIR 0.50	307.00	
1	38	MANTON DAM	MTN	2134.5	330.9	257.50	POOR 0.50	257.50	BMR
						260.66	GOOD 0.10	260.66	
						265.76	FAIR 0.10	265.76	
						272.16	FAIR 0.10	272.16	
1	40	MEEKATHARRA	MEK	2092.3	275.2	255.66	FAIR 0.10	255.66	BMR
1	41	OFFICER BASIN	OF	1484.5	278.9	187.27	FAIR 0.10	187.27	BMR
						188.92	GOOD 0.10	188.92	
1	42	KOWEN FORREST	KN	1083.8	125.2	139.70	GOOD 0.10	139.50	BMR
						140.80	FAIR 0.10	140.61	
1	43	COOBER PEDY	CP	452.1	279.4	62.36	GOOD 0.10	62.36	UA
1	44	SANDSTONE	SS	1983.8	271.3	248.46	FAIR 0.10	248.46	BMR
1	45	MT.CAVENAGH	CV	778.6	308.6	103.10	GOOD 0.10	103.10	BMR
						111.40	FAIR 0.10	111.40	
						128.10	GOOD 0.10	128.10	
						173.60	FAIR 0.50	173.60	

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS	TT MSL	INST
						179.10	GOOD 0.50	179.10	
2	2	ISLAND LAGOON	ILN	1509.6	97.1	189.47	POOR 0.10	189.47	UA
						192.97	FAIR 0.50	192.97	
2	8	TARCOOLA	TR	1287.4	93.2	163.42	FAIR 0.10	163.42	UA
						175.01	FAIR 0.10	175.01	
						289.80	POOR 0.50	289.80	
2	17	COOK	CK	896.4	92.5	116.05	FAIR 0.10	116.05	BMR
						116.67	GOOD 0.10	116.67	
						118.47	FAIR 0.10	118.47	
2	29	FORREST	FT	642.7	93.8	84.93	POOR 0.10	84.93	BMR
						86.01	FAIR 0.50	86.01	
						151.70	FAIR 1.00	151.70	
						180.80	FAIR 1.00	180.80	
2	34	RAWLINNA	RA	409.5	96.5	56.79	GOOD 0.01	56.79	BMR
						66.77	GOOD 0.01	66.77	
						71.51	POOR 0.10	71.51	
						79.42	FAIR 0.50	79.42	
						97.60	POOR 0.50	97.60	
						115.77	FAIR 0.50	115.77	
2	36	KALGOORLIE	KLG	39.4	107.9	6.37	GOOD 0.10	6.37	BMR
						10.97	GOOD 0.10	10.97	
						12.77	GOOD 0.10	12.77	
2	39	MUNDARING	MUN	484.4	251.4	64.57	FAIR 0.10	64.57	BMR
						80.97	POOR 0.10	80.97	
						112.77	GOOD 0.10	112.77	
						132.77	GOOD 0.10	132.77	
						135.27	GOOD 0.10	135.27	
						147.57	GOOD 0.10	147.57	
2	40	MEEKATHARRA	MEK	513.2	330.7	68.87	GOOD 0.10	68.87	BMR
						81.07	GOOD 0.10	81.07	
						121.77	FAIR 0.10	121.77	
						140.27	GOOD 0.10	140.27	
2	41	OFFICER BASIN	OF	534.8	43.0	72.21	FAIR 0.10	72.21	BMR
						72.97	GOOD 0.10	72.97	
2	44	SANDSTONE	SS	340.6	329.3	47.97	GOOD 0.10	47.97	BMR
						53.47	FAIR 0.10	53.47	
						67.77	FAIR 0.50	67.77	
						83.47	GOOD 0.10	83.47	
						94.37	GOOD 0.50	94.37	
3	1	PARTACOONA	PNA	1193.4	302.5	153.70	POOR 0.50	153.70	UA
						169.40	FAIR 0.10	169.40	
3	3	HALLET	HTT	1042.6	298.1	135.20	FAIR 0.10	135.20	UA
						289.70	FAIR 0.10	2[illegible].70	
3	9	UMBERETANA	[illegible]MB	1260.7	312.2	162.60	FAIR 0.50	162.60	UA

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS	TT MSL	INST
						166.70	GOOD 0.10	166.70	
						185.60	GOOD 0.10	185.60	
						214.40	FAIR 0.10	214.40	
						230.20	FAIR 0.10	230.20	
						281.30	FAIR 0.10	281.30	
						293.00	FAIR 0.10	293.00	
3	11	ADELAIDE	ADE	975.3	289.1	134.30	POOR 0.10	134.30	UA
						149.80	POOR 0.50	149.80	
						199.40	FAIR 0.50	199.40	
						222.70	FAIR 0.10	222.70	
						262.40	FAIR 0.10	262.60	
3	15	BELLFIELD	BFD	565.9	280.7	77.00	GOOD 0.10	77.00	BMR
						79.00	FAIR 0.10	79.30	
						84.20	GOOD 0.10	84.20	
						93.20	GOOD 0.50	93.20	
						101.70	GOOD 0.10	101.70	
						111.20	GOOD 0.10	111.20	
						154.20	GOOD 0.10	154.20	
3	18	ALICE SPRINGS	ASP	2151.0	314.5	270.20	FAIR 0.50	270.20	BMR
						275.00	FAIR 0.10	275.00	
3	19	TOOLANGI	TOO	302.6	284.3	45.10	GOOD 0.10	45.10	BMR
						49.20	GOOD 0.10	49.20	
						54.20	GOOD 0.10	54.20	
						82.70	GOOD 0.10	82.70	
						89.40	GOOD 0.10	89.40	
						94.40	GOOD 0.50	94.40	
3	30	RIVERVIEW	RIV	538.5	28.3	88.70	POOR 0.10	88.70	COL
						92.80	FAIR 0.10	92.80	
						147.80	FAIR 0.10	147.80	
						152.20	GOOD 0.10	152.20	
						158.50	GOOD 0.10	158.50	
						165.10	FAIR 0.10	165.10	
						174.10	FAIR 0.10	174.10	
3	46	HOBART	TAU	927.9	193.3	72. .0	FAIR 0.10	72.10	TU
						74.50	FAIR 0.10	74.50	
						77.90	GOOD 0.10	77.90	
						143.40	FAIR 0.10	143.40	
						151.30	GOOD 0.10	151.30	
3	47	MOORLANDS	MOO	480.7	196.1	66.90	GOOD 0.10	66.90	TU
						67.20	GOOD 0.10	67.20	
						82.30	GOOD 0.50	82.30	
						111.20	FAIR 0.10	111.20	
						138.10	FAIR 0.10	138.10	
3	48	TARRALEAH	TRR	488.3	203.5	68.20	GOOD 0.50	68.20	TU
						75.40	FAIR 0.50	75.40	
						80.40	FAIR 0.50	80.40	
						87.60	GOOD 0.10	87.60	
						102.40	FAIR 0.10	102.40	
						136.20	FAIR 0.10	136.20	

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS		TT MSL	INST
3	49	SAVANNAH	SAV	40[illegible].9	199.3	57.10	GOOD	0.10	57.10	TU
						64.50	GOOD	0.10	64.50	
						72.40	GOOD	0.10	72.40	
						79.70	FAIR	0.50	79.70	
						125.30	FAIR	0.10	125.30	
3	50	SHEFFIELD	SEF	400.1	211.6	55.70	GOOD	0.10	55.70	TU
						62.40	GOOD	0.10	62.40	
						66.00	GOOD	0.50	66.00	
						70.40	GOOD	0.50	70.40	
3	59	SCOTTS PEAK	SPK	568.8	201.3	96.00	FAIR	0.10	96.00	TU
						124.90	FAIR	0.10	124.90	
						159.80	GOOD	0.10	159.80	
3	60	STRATH GORDON	SGO	551.7	202.7	75.40	GOOD	0.10	75.40	TU
						81.90	FAIR	0.50	81.90	
						95.80	GOOD	0.10	95.80	
						100.90	FAIR	0.10	100.90	
						123.70	GOOD	0.10	123.70	
						146.70	GOOD	0.10	146.70	

TABLE 2

PROGRAM TERMAT OUTPUT

6	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0
0	7	0	0	0	0	0	1	1	1	1	1	1	1	0	0
0	0	8	0	0	0	1	1	1	1	1	1	1	1	0	0
0	0	0	7	0	0	1	1	1	0	0	0	1	1	1	1
0	0	0	0	7	0	1	0	0	1	1	1	0	1	1	1
0	0	0	0	0	8	1	1	1	1	0	1	0	1	1	1
1	0	1	1	1	1	5	0	0	0	0	0	0	0	0	0
1	1	1	1	0	1	0	5	0	0	0	0	0	0	0	0
1	1	1	1	0	1	0	0	5	0	0	0	0	0	0	0
1	1	1	0	1	1	0	0	0	5	0	0	0	0	0	0
1	1	1	0	1	0	0	0	0	0	4	0	0	0	0	0
1	1	1	0	1	1	0	0	0	0	0	5	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	3	0	0	0
0	1	1	1	1	1	0	0	0	0	0	0	0	5	0	0
0	0	0	1	1	1	0	0	0	0	0	0	0	0	3	0
0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	3

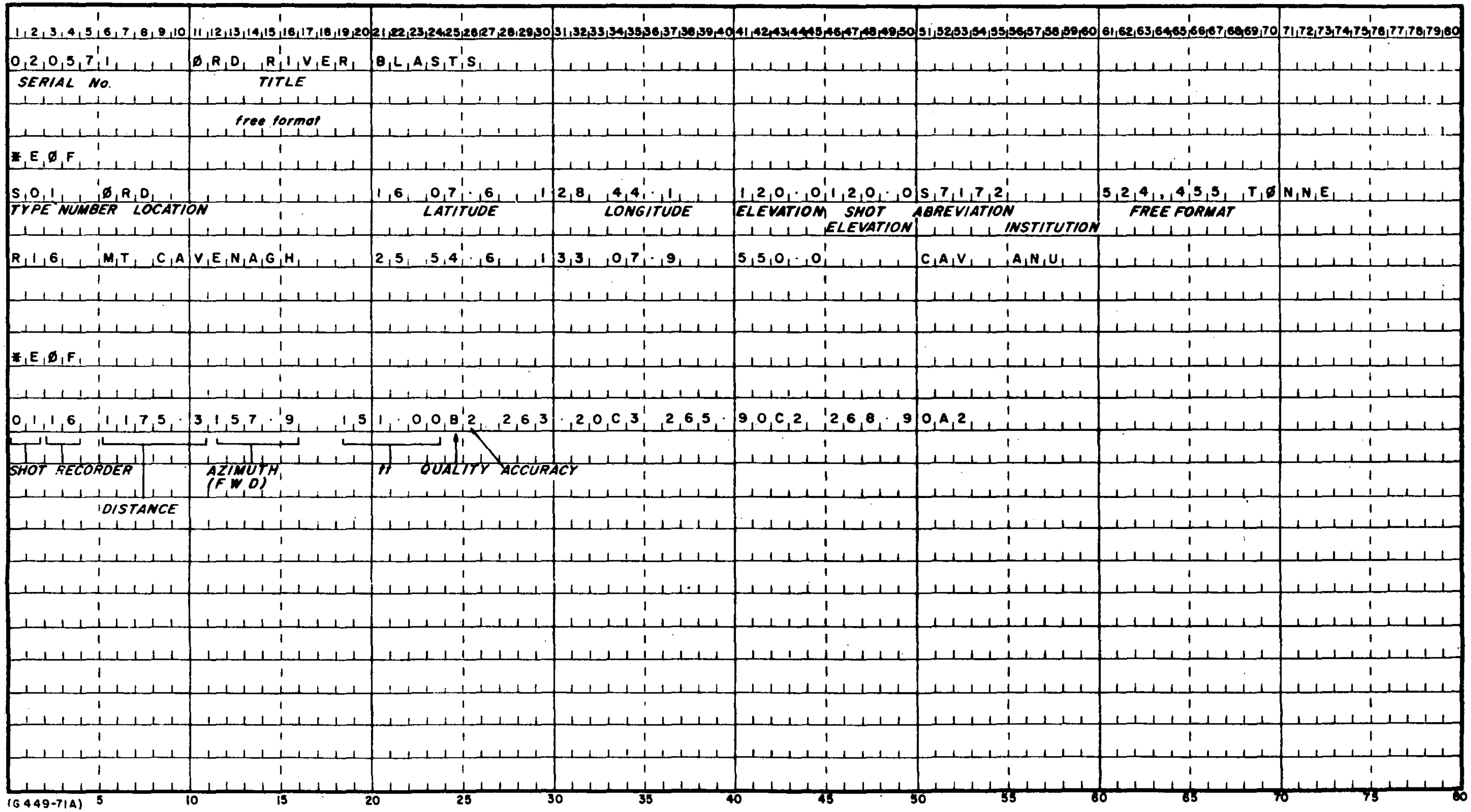
NAM 2	66,05	328,98
NAM 4	70,98	345,97
ULUPUTUR	78,46	386,95
MULIAMA	105,23	572,82
PALIE	84,19	431,66
LONDOL	80,53	435,91
67 25A	59,20	314,02
67 38	44,10	214,19
67 40	57,85	271,98
67 43	58,70	314,76
67 47	60,36	335,29
67 48	48,15	241,49
67 25	24,55	117,86
67 26	54,40	275,14
67 27	40,33	222,47
67 37	37,80	195,09

	TIME	DISTANCE	V= 5,92
NAM 2	10,73	50,27	2,24-ALPHA
NAM 4	10,62	49,77	2,21-ALPHA
ULUPUTUR	10,22	48,15	2,08-ALPHA
MULIAMA	16,01	86,23	1,44-ALPHA
PALIE	11,39	54,34	2,21-ALPHA
LONDOL	10,40	54,52	1,19-ALPHA
67 25A	0,09	4,10	-0,60+ALPHA
67 38	-2,78	-14,95	-0,25+ALPHA
67 40	-0,03	-3,39	0,55+ALPHA
67 43	1,07	11,54	-0,88+ALPHA
67 47	4,35	33,19	-1,26+ALPHA
67 48	-1,04	-3,11	-0,52+ALPHA
67 25	-4,10	-22,10	-0,37+ALPHA
67 26	-0,85	-3,57	-0,24+ALPHA
67 27	0,84	9,13	-0,70+ALPHA
67 37			ALPHA

LOC1	LOC2	DIST	TT	RESID
NAM 2	67 25A	30.21	6,18	-0,56
NAM 2	67 38	22.65	5,92	0,11
NAM 2	67 40	46.89	11,11	0,40
NAM 2	67 43	84.58	15,44	-0,21
NAM 2	67 47	75.99	13,89	0,07
NAM 2	67 48	68.66	13,51	0,19
NAM 4	67 25	26.87	6,35	-0,04
NAM 4	67 26	21.04	5,26	-0,26
NAM 4	67 38	22.70	5,92	0,12
NAM 4	67 40	46.78	11,01	0,35
NAM 4	67 43	84.40	15,34	-0,25
NAM 4	67 47	75.53	13,59	-0,13
NAM 4	67 48	68.65	13,51	0,21
ULUPUTUR	67 25	19.25	4,95	-0,02
ULUPUTUR	67 25A	21.70	5,38	0,24
ULUPUTUR	67 26	12.70	3,96	-0,02
ULUPUTUR	67 38	30.10	6,92	0,00
ULUPUTUR	67 40	55.35	12,01	0,03
ULUPUTUR	67 43	93.44	16,34	-0,65
ULUPUTUR	67 47	78.15	14,29	0,26
ULUPUTUR	67 48	76.26	14,61	0,16
MULIAMA	67 25	71.74	13,25	0,06
MULIAMA	67 25A	77.17	14,18	0,31
MULIAMA	67 26	74.89	13,96	0,11
MULIAMA	67 27	75.02	13,11	-0,30
MULIAMA	67 37	82.99	14,80	-0,66
MULIAMA	67 38	90.79	16,92	0,39
MULIAMA	67 40	100.22	19,01	0,09
PALIE	67 25A	85.46	15,98	-0,07
PALIE	67 26	76.23	14,76	-0,09
PALIE	67 27	66.69	13,11	0,33
PALIE	67 37	49.09	11,00	0,50
PALIE	67 43	31.29	6,84	0,23
PALIE	67 47	105.62	18,59	-0,21
PALIE	67 48	17.28	3,91	-0,70
LONDOL	67 25A	99.48	17,48	0,08
LONDOL	67 26	90.28	16,46	0,26
LONDOL	67 27	80.76	14,11	-0,03
LONDOL	67 37	63.01	12,00	0,16
LONDOL	67 38	47.95	8,42	-0,62
LONDOL	67 40	22.74	4,71	-0,87
LONDOL	67 43	21.05	4,74	0,88
LONDOL	67 48	10.64	2,61	0,14

ST,DEV, OF RESIDUALS=0.354

VELCCITY= 5,92
ST,DEV,=0,085



DATA FILE FORMAT

PLATE 1

PROGRAM PLOTIT DECK STRUCTURE