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Computer Programs for Epicentre Determination

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SUMMARY

Four programs for determining the epicentre (and origin time and depth where possible) of a seismic event are described: SPEEDY uses Geiger's classical method of estimating the epicentre, origin time and depth of focus of an event; SPUR is similar to SPEEDY but is more compact and hence suitable for a small machine; JED is an extension of the classical method to estimate the epicentres, origin times and depths of a large number of events and station (time) terms simultaneously; and EFA estimates epicentres, given the azimuth of an event from each of a number of stations.

1. INTRODUCTION

The determination of earthquake (and explosion) epicentres, origin times and depths is now usually made by computer. The first programs (see, for example, Bolt [1] and Flinn [2]) were based on the classical iterative method of Geiger and determine the position of the focus for each event individually. In recent years it has been shown that estimates of an event focus can often be improved if the epicentres of a group of events are determined simultaneously along with station corrections [3-7].

In this report we describe and list computer programs for both classical and joint epicentre determination. A program for obtaining epicentral estimates given only the azimuth of an event from each of a number of stations is also included.

2. GENERAL THEORY

All the four programs described here use the method of non-linear least squares. Starting with trial values of the unknowns, the programs compute corrections for these trial estimates by the method of least squares. These corrections are then added to the trial estimates and corrections to these revised estimates computed. This process of iteration is continued until the computed corrections become small enough to neglect.

Given a set of equations of condition of the form

$$\underline{X} \underline{\beta} = \underline{y},$$

where \underline{X} is the matrix of coefficients of the equations of condition, $\underline{\beta}$ is a vector of corrections to trial estimates and \underline{y} is the vector of residuals; the programs presented here compute estimates $\hat{\underline{\beta}}$ of $\underline{\beta}$ by least squares (see Kempthorne, p55 [8]), thus,

$$\hat{\underline{\beta}} = \underline{S}^{-1} \underline{X}' \underline{y} \text{ where } \underline{S} \text{ is } \underline{X}' \underline{X} \text{ and } \underline{X}' \text{ is the transpose of } \underline{X},$$

$$\underline{S} \hat{\underline{\beta}} = \underline{X}' \underline{y} \text{ are called the normal equations.}$$

In all the programs described here \underline{x} is never explicitly formed in the computer store; the data are simply read in and added directly into the appropriate position in the normal equations.

After the final iteration, the vector \underline{y} is used to estimate the variance $\hat{\sigma}^2$ of the data, thus,

$$\hat{\sigma}^2 = Q_1 / (n - p), \text{ where } Q_1 = \sum_{i=1}^n y_i^2,$$

where n is the number of equations of condition and p is the number of unknowns. The confidence limits on β_q are then given by

$$t \hat{\sigma} (s^{-1})^{1/2}, \text{ where } s^{-1}_{qq}$$

is the q th diagonal element of S^{-1} and t is Student's t for $(n - p)$ degrees of freedom. The computation of joint confidence limits follows the methods described by Flinn [2].

Where options are included to restrain particular unknowns to pre-set values this is done simply by including an equation of condition of the form

$$w^2 \beta_q = 0,$$

where β_q is the unknown being restrained and w is a weight which is set to a large value (usually 2^{24}). This equation effectively sets β_q to zero. To include this equation of condition w is simply added to the q th diagonal element of the matrix of normal equations.

A brief description of the mathematical basis of each program is given below. It is hoped that the detailed working of the program can be deduced from the comments included in the program listing.

3. DESCRIPTION OF PROGRAMS

3.1 SPEEDY and SPUR

SPEEDY (appendix A) computes the epicentre, depth and origin time of a seismic event, given the arrival times of the P signals at four or more stations. If the arrival times are available from only three stations, then either the depth or origin time must be restrained to some initial value. For less than three arrival times no solution is possible.

The program is less comprehensive than some that have been written; for example, there is no option to reject or weight gross errors or to read arrival times of phases other than P (such as pP). Stations outside the P range, ie, beyond 105° , can be included but are not used in the computation.

The program as published here uses the J-B tables but is easily adapted to take any travel time table.

The program uses the equation of condition

$$\delta H + \delta h \frac{\partial T}{\partial h} - x \cos \alpha_j \frac{\partial T}{\partial \Delta_j} - y \sin \alpha_j \frac{\partial T}{\partial \Delta_j} = \delta T_j, \quad \dots \dots (1)$$

where $\delta T_j = A_j - H - T_j$, H is the approximate origin time of the event, h is the approximate depth of the event, Δ_j is the distance from the approximate epicentre to station j , α_j is the azimuth from the approximate epicentre to station j , A_j is the arrival time (of the P waves) at station j , T_j is the travel time (of the P waves) from the approximate epicentre to station j , $\partial T / \partial \Delta_j$ is the partial derivative of the travel time $T (= f(\Delta_j, h))$ with respect to distance at the point Δ_j , h , $\partial T / \partial h$ is the partial derivative of the travel time T with respect to depth at Δ_j , h . T , $\partial T / \partial \Delta_j$ and $\partial T / \partial h$ are obtained from travel time tables. The unknowns x , y , δh and δH are the corrections to latitude, longitude, depth and origin time respectively.

The matrix of normal equations are solved by matrix inversion. In computing the confidence limits we essentially follow Flinn [2].

The program SPUR (appendix B) is a simplified version of SPEEDY which does not allow depth corrections to be computed; the depth of focus of the event is fixed (as published here the depth of focus is taken as zero). The matrix of normal equations is solved using Cramer's rule (see Wylie, p453 [10]). To compute the elements of the inverse matrix that are required for confidence limits, the program uses the relationship

$$s_{ij}^{-1} = \frac{\|S_{ij}\|^T}{\text{Det } S},$$

where s_{ij}^{-1} is the ij th element of the inverse matrix, $\|S_{ij}\|^T$ is the cofactor of s_{ij} in the transpose of S , and $\text{Det } S$ is the determinant of S . The program is designed to give a rough preliminary estimate of an epicentre and is suitable for use on a small computer.

3.2 JED

This program was written to compute station time terms, epicentres, depths and origin times of a series of events simultaneously. The equation of condition (1) is rewritten to include a station correction S_j . Thus, if δS_j is the correction to the approximate value of S_j , equation (1) becomes for the station j recording the i th event

$$\delta S_j + \delta H_i + \delta h_i \frac{\partial T}{\partial h_i} - x_i \cos \alpha_{ij} \frac{\partial T}{\partial \Delta_{ij}} - y_i \sin \alpha_{ij} \frac{\partial T}{\partial \Delta_{ij}} = \delta T_{ij}, \quad \dots \dots (2)$$

where $\delta T_{ij} = A_{ij} - H_i - T_{ij} - S_j$. This is the equation of condition used in JED together with the side condition $\sum S_j = 0$. This side condition must be applied because without it the station terms and origin times are linearly dependent.

As presented here (appendix C) the program has the option to make computations of this type, but to achieve stability in the solution it is necessary to take a rather widely spread group of epicentres (say spread over a region of $20^\circ - 30^\circ$ of arc) with recording stations well distributed in azimuth around this group, otherwise epicentres and station corrections are nearly linearly dependent. Further, in going to such widely spread groups of epicentres, the station terms which are intended to correct for structure on the whole path between epicentre and the recording station are no longer constant for all paths to a single station from each epicentre. Thus, in this mode for determining absolute epicentres, the program will usually only give useful results in ideal circumstances (see Douglas and Lilwall [11] for further discussion).

The linear dependence between epicentres and station terms can be removed if one of the epicentres in the group is restrained to some fixed position. The other epicentres are then determined relative to the restrained epicentre.

The program has the option to apply weights to the residuals to weight out gross errors. The weighting used is based on Jeffreys' method of uniform reduction.

The version of JED published here uses the J-B tables but the program is easily adapted to use any travel time tables.

The normal equation matrices in the JED program are usually large. Many of the elements, however, are zero; in particular for some submatrices of \underline{S} the only non-zero elements are on the principal diagonal. By storing only the diagonal elements of these submatrices very large matrices can be packed into computer store and estimates obtained economically. The submatrices are manipulated using relationships of the following form.

Let the unknowns that comprise $\underline{\beta}$ be divided into two groups $\gamma_1 \dots \gamma_q$ and $\delta_1 \dots \delta_{p-q}$ so that the equation of condition can be written

$$\underline{X}_1 \underline{\gamma} + \underline{X}_2 \underline{\delta} = \underline{y},$$

where \underline{X}_1 is a matrix composed of the first q columns of \underline{X} , \underline{X}_2 is the remaining $p-q$ columns of \underline{X} , $\underline{\gamma} = (\gamma_1 \dots \gamma_q)$ and $\underline{\delta} = (\delta_1 \dots \delta_{p-q})$.

The normal equations can now be written

$$\begin{bmatrix} \underline{X}'_1 \underline{X}_1 \\ \underline{X}'_2 \underline{X}_1 \end{bmatrix}, \begin{bmatrix} \underline{X}'_1 \underline{X}_2 \\ \underline{X}'_2 \underline{X}_2 \end{bmatrix}, \begin{bmatrix} \underline{\gamma} \\ \underline{\delta} \end{bmatrix} = \begin{bmatrix} \underline{X}'_1 \underline{y} \\ \underline{X}'_2 \underline{y} \end{bmatrix}.$$

Now put $\underline{D} = \underline{X}_1' \underline{X}_1$, $\underline{A} = \underline{X}_1' \underline{X}_2$ and $\underline{C} = \underline{X}_2' \underline{X}_2$

The normal equations now become

$$\begin{bmatrix} \underline{D} & \underline{A} \\ \underline{A}' & \underline{C} \end{bmatrix} \begin{bmatrix} \underline{Y} \\ \underline{\delta} \end{bmatrix} = \begin{bmatrix} \underline{X}_1' \underline{y} \\ \underline{X}_2' \underline{y} \end{bmatrix}.$$

Then the inverse of \underline{S} can be written in terms of equivalent submatrices [12], thus,

$$\underline{S}^{-1} = \begin{bmatrix} \underline{K} & \underline{L} \\ \underline{M} & \underline{N} \end{bmatrix}.$$

where $\underline{N} = (\underline{C} - \underline{A}' \underline{D}^{-1} \underline{A})^{-1}$,

$$\underline{M} = -\underline{N} \underline{A} \underline{D}^{-1},$$

$$\underline{K} = \underline{D}^{-1} - \underline{D}^{-1} \underline{A} \underline{M},$$

$$\underline{L} = \underline{M}^T.$$

Also

$$\underline{N} \underline{\delta} = (\underline{X}_2' \underline{y} - \underline{A}' \underline{D}^{-1} \underline{X}_1' \underline{y}) [13].$$

As a measure of the stability of the estimated epicentres when JED is being used to determine absolute epicentres, the sum of squares due to the epicentre shifts and a confidence region on the mean event is computed. The sum of squares due to the epicentre shifts is computed as follows. Let $\underline{Y} = (Y_1 \dots Y_q)$ now be the total shifts between initial and final epicentre estimates. Then the sum of squares Q_2 , due to these shifts, is given by

$$Q_2 = \underline{Y}' \begin{bmatrix} \underline{K}^{-1} \end{bmatrix} \underline{Y}.$$

Q_2 is distributed as Chi-squared with q degrees of freedom where q is now twice the number of epicentres (q latitude shifts and q longitude shifts). Q_2/q can be tested for significance against $Q_1/(n - p)$ using an F test.

To test the stability of absolute estimates of the epicentres to a simultaneous shift of all the group of epicentres (that is the relative positions of the epicentres in the group is kept fixed and the group as a whole is moved) we compute what we call the confidence region on the mean event. We ask what displacements x and y in latitude and longitude can be applied to all the epicentres simultaneously before the sums of squares attributable to these shifts become significant at

some specified level. Thus, if the latitude corrections are the unknowns γ_1 to $\gamma_{q/2}$ and the longitude corrections are the unknowns $\gamma_{q/2+1} \dots \gamma_q$ we set

$$\gamma_1 = \gamma_2 \dots \gamma_{q/2} = x$$

and $\gamma_{q/2+1} = \gamma_{q/2+2} \dots \gamma_q = y$

and compute $\underline{\gamma}' \underline{K}^{-1} \underline{\gamma}$ which gives a quadratic in x and y . $\underline{\gamma}' \underline{K}^{-1} \underline{\gamma}$ is distributed as Chi-squared with q degrees of freedom. Thus,

$$\frac{\underline{\gamma}' \underline{K}^{-1} \underline{\gamma}}{q} / \frac{Q_1}{n-p}$$

is distributed as $F(q, n-p)$, the F statistic with q and $n-p$ degrees of freedom.

Thus, the 95% confidence region can be defined by solving

$$\underline{\gamma}' \underline{K}^{-1} \underline{\gamma} = \frac{q}{n-p} Q_1 F_{95}(q, n-p).$$

This defines an ellipse in the same form as the confidence ellipses on the individual epicentres.

3.3 EFA

The input to this program (appendix D) is simply the azimuths of an epicentre from each of a number (> 2) of stations. Then, starting with a trial epicentre, the program computes corrections to the trial estimates using the equation of condition [14]

$$\frac{\sin B_i}{\sin \Delta_i} \delta x - \frac{\cos B_i}{\sin \Delta_i} \delta y = \delta \alpha_i,$$

where B_i is the azimuth and Δ_i is the distance of station i from the trial epicentre, $\delta \alpha_i$ is the difference between the observed azimuth and the azimuth computed from the trial estimates, and δx and δy are the corrections to latitude and longitude respectively.

This program can be used if several arrays have recorded one event. If the azimuths of the epicentre of this event from each of the arrays is known, EFA can be used to combine these azimuths and derive a single epicentral estimate.

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APPENDIX A

LISTING OF SUBROUTINES UNIQUE TO SPEEDY

SPEEDY (MAIN)
LOCAT4
CONLM4
PRES

THIS PROGRAM COMPUTES THE EPICENTRE OF A SEISMIC EVENT GIVEN ARRIVAL TIMES AT THREE OR MORE STATIONS. THE PROGRAM HAS NO FACILITIES FOR REJECTING INCONSISTANT DATA. IT WILL ACCEPT DATA FROM STATIONS AT MORE THAN 110 DEGREES DISTANCE BUT THIS DATA IS NOT USED IN THE COMPUTATION.

THE PROGRAM IS LESS COMPREHENSIVE THAN MANY OTHERS BUT IT SHOULD BE FAST IN EXECUTION.

THE PROGRAM BEGINS BY READING IN DATA THAT WILL USUALLY BE COMMON TO ALL RUNS, AS FOLLOWS -

- A. CARDS WITH STUDENTS T - 44 VALUES.
- B. CARDS WITH VARIANCE RATIO F(2,NF) - 44 VALUES - WHERE 2 AND NF ARE DEGREES OF FREEDOM.

* A LIBRARY OF STATIONS WITH THEIR LATITUDES AND LONGITUDES ARE NOW READ IN BY SUBROUTINE TREAD (Q.V.).

THE SUCCEEDING CARDS ARE

1. CARD WITH

ICOR ICOR=0 NO STATION CORRECTIONS TO BE READ IN
ICOR=1,2,3 READ IN STATION CORRECTIONS
CODE CODE OF TRAVEL TIMES USED
IMTRX PUNCH 1 FOR DETAILED PRINT OUT OTHERWISE LEAVE BLANK JED
IFORM IFORM=0 READ IN EVENT DATA ON STANDARD FORMAT
IFORM=1 READ IN EVENT DATA ON FORMAT FMT

*1 punch cc 5 by using
STN code produced by*

FORMAT FOR PUNCHING THIS CARD IS GIVEN IN STATEMENT 4
~~* MUST PUT EXTRA STATIONS BEFORE HERE~~

2. IF ICOR=1,2,3 DECK OF CARDS WITH STATION NAMES AND STATION CORRECTIONS NOW FOLLOW - OTHERWISE NOTHING. THE LAST CARD IN THE STATION CORRECTION DECK SHOULD BE A BLANK.

FORMAT FOR PUNCHING STATION CORRECTION CARDS IS GIVEN IN STATEMENT 21, 22, AND 23.

3. CARD WITH

EVENT EVENT NAME -- USE DATE E.G. 29/10/65
MHR APPROXIMATE ORIGIN TIME - HOURS
MINS APPROXIMATE ORIGIN TIME - MINS
SEC APPROXIMATE ORIGIN TIME - SECONDS
ALAT APPROXIMATE LATITUDE
SN N OR S
ALONG APPROXIMATE LONGITUDE
EW E OR W
H DEPTH IN KILOMETRES
OR PUNCH RESTRAIN TO RESTRAIN ORIGIN TIME
HRES PUNCH RESTRAIN TO RESTRAIN DEPTH
IEPIC PUNCH 1 TO RESTRAIN EPICENTRE

FORMAT FOR PUNCHING IS GIVEN IN STATEMENT 101 - THIS IS IDENTICAL TO THE JED FORMAT.

4. CARDS WITH STATION CODE AND ARRIVAL TIMES NOW FOLLOW.

ASTN STATION CODE
MHR ARRIVAL TIME-HRS
MIN ARRIVAL TIME-MINS
ASEC ARRIVAL TIME-SECONDS

THE END OF THE ARRIVAL TIME DATA IS SIGNIFIED BY A BLANK CARD.

N.B. IF IFORM=1 THE SPECIFIED FORMAT MUST PRECEDE THESE CARDS.

REPEAT CARDS 3 ONWARDS FOR NEXT EVENT.

```
COMMON /LOC54/ X(24),EVENT,MHRS,MINS,SEC,ALAT,SN,ALON,EW,
1ELAT,ELON,H,OT,HH,INDO,INDH,IEPIC,CN,CS,CE,CW,STAR,BLANK,
2CODE,IDEPI,IMTRX
```

```
COMMON /ATAB/ NTABLE,STN(3000),SLAT(3000),SLON(3000),CDR(3000),
1ISTN,ESTN(500),INDEX(500),AT(500),TRESID(500),AZ(500),DIST(500),
2ST(44),FD(44)
```

```
COMMON /GRFF/ TITLE(20), XMAX, XMIN, YMAX, YMIN, INDX, INDY, IND,
1IDOT, ANSTR1, XLIMIT, YLIMIT, SCALX, SCALY
```

```
COMMON /CONSTS/ PI,DTOR,RTOD,ZKM,ER,GFACT,HUGE,SECDAY,ROUND
```

```
DIMENSION FMT(10),SFMT(10)
REAL*8 TITLE,EVENT,RESTR,DR,HRES,FMT,SFMT
DOUBLE PRECISION X,AT,OT,SECTM
```

```
DATA S/4HS  /,E/4HE  /,W/4HW  /,EN/4HN  /,ASTAR/4H*  /,
1RESTR/8HRESTRAIN,ABLINK/4H  /,
2SFMT/8H (1X,A4,,8H15X,I2,1,8HX,I2,1X,,8HF4.1) ,6*8H  /
```

```

CN=EN
CS=S
CE=E
CW=W
STAR=ASTAR
BLANK=ABLANK
DO 3 I=1,10
FMT(I)=SFMT(I)
3 CONTINUE
C
READ 7, ST
READ 7, FD
7 FORMAT(16F5.2)
PRINT 7, ST
PRINT 7, FD
C
C          SET UP CONSTANTS
C
DOUBLE PRECISION DPI,A,B,R,ELLIP
A = 6378.160 DO
ELLIP = 1.00/ 298.25 DO
DPI = 4.00*DATAN(1.00)
PI=DPI
DTOP=DPI/180.00
RTOD=180.00/DPI
B=A*(1.00-ELLIP)
R=DEXP(((DLOG10(A)+DLOG10(A)+DLOG10(B))/3.00)*DLOG(10.00))
ZKM=R*DPI/180.00
ER=ELLIP*R
GFACT=(B*B)/(A*A)
HUGE = B**8
SECDAY = 24.*60.*60.
ROUND = 0.5
PRINT 2,           A,B,R,ELLIP,ZKM,ER,GFACT,DPI,
1             PI,DTOP,RTOD,HUGE,SECDAY,ROUND
2 FORMAT(1X,E15.10)
READ 4, ICCR, CODE, IMTRX, IFORM, IDEP
4 FORMAT(1X,I4,1X,A4,I2,[3,I3])
ICCR=ICCR+1
IMTRX=IMTRX+1
IFORM=IFORM+1
IDEP=IDEP+1
PRINT 4, ICCR, CODE, IMTRX, IFORM, IDEP
C
CALL TREAD(CODE, IMTRX, 3)
C
C          READ ANY STATIONS AND D.C. STATION CORRECTIONS
C          AND STORE IN CORRECT POSITION IN ARRAY
C
GO TO (100,121,121,121),ICOR
121 GO TO (100,1211,1212,1213),ICOR
GO TO 100
1211 READ 21, ASTN,ACOR
PRINT 21, ASTN,ACOR
21 FORMAT(1X,A4,61X,F6.3)
GO TO 122
1212 READ 22, ASTN,ACOR
PRINT 22, ASTN,ACOR
22 FORMAT(2X,A4,F9.3)
GO TO 122
1213 READ 23, ASTN,ACOR
PRINT 23, ASTN,ACOR
23 FORMAT(2X,A4,31X,F8.3)
122 IF(ASTN.EQ.ABLANK)GO TO 100
DO 124 I=1,NTABLE
IF(ASTN.NE.STN(I))GO TO 124
CUR(I)=ACOR
GO TO 121
124 CONTINUE
PRINT 126, ASTN
126 FORMAT(4X,37HCORRECTION GIVEN FOR UNKNOWN STATION ,A4)
GO TO 121
C
C          BEGIN PROCESSING EVENTS
C
C          DATIM STORES DATE AND TIME AS AB AND CLOCK STORES
C          TIME IN MINUTES AT START OF PROCESSING
C          DATIM AND CLOCK ARE LIBRARY PROGRAMS
C
100 CALL DATIM(TITLE(16),TITLE(17))
CALL CLOCK(TS)
READ (5,101,END=228) EVENT,MHRS,MINS,SEC,ALAT,SN,ALON,EW,H,
1               OR,HRES,IEPIC
101 FORMAT(2X,AB,2I4,F6.1,2(F10.4,A1),F6.1,2X,A8,2X,A8,2X,I1)
GO TO (120,103),IFORM
103 READ (5,104,END=228) FMT
104 FORMAT(10A8)
C

```

```

120 OT=SECTM(MHRS,MINS*SEC)
   ELAT=ABS(ALAT)
   ELAT=GEOCEN(ELAT)
   IF(SN.EQ.S)ELAT=-ELAT
   ELON=ABS(ALON)
   IF(EW.EQ.W)ELON=-ELON
   INDH=1
   INDO=1
   IF(HRES.EQ.RESTR)INDH=0
   IF(OR.EQ.RESTR)INDO=0
   HH=H
   IF(IMTRX.EQ.2)PRINT 70,EVENT,OT,HH,ELAT,ELON,INDH,INDO
70 FORMAT(2X,A8,4F10.2,2X,I1,2X,I1)
   IEPIC=IEPIC+1
   IF(IEPIC.NE.2)IEPIC=1

C           READ IN ARRIVAL TIME DATA AND IDENTIFY STATION
C
   PRINT 117, TITLE(16),TITLE(17)
117 FORMAT(1H1//4X,23HEPICENTRE DETERMINATION,65X,A8/
1          4X,23H-----,65X,A8)
   PRINT 118, EVENT
118 FORMAT(//4X,A8//4X,7HSTATION,4X,12HARRIVAL TIME/)

C           ISTN=0
111 ISTN=ISTN+1
   READ FMT, ASTN,MHR,MIN,ASEC
   IF(ASTN.EQ.ABLANK)GO TO 114
   PRINT 115, ISTN,ASTN,MHR,MIN,ASEC
115 FORMAT(2X,I3,2X,A4,5X,I2,1X,I2,1X,F4.1)

C           DD 110 I=1,NTABLE
   IF(ASTN.NE.STN(I))GO TO 110
   ESTN(ISTN)=STN(I)
   INDEX(ISTN)=I
   AT(ISTN)=SECTM(MHR,MIN,ASEC)
   GO TO 111

110 CONTINUE
   PPINT 127, ASTN
127 FORMAT(//4X,16HUNKNOWN STATION ,A4,8H IGNORED//)
   ISTN=ISTN-1
   GO TO 111

114 ISTN=ISTN-1
   IF(ISTN.EQ.3)INDH=0
   IF(ISTN.GE.3.OR.ISTN.LE.500)GO TO 116
   PRINT 119, ISTN
119 FORMAT(4X,12HJOB REJECTED,I5,9H STATIONS)
   GO TO 100
116 IF(IMTRX.EQ.2)PRINT 29, (ESTN(I),AT(I),I=1,ISTN)
29 FORMAT(4X,A4,F12.1)
   CALL LOCAT4

C           CALL CLOCK(TF)
   TS=(TF-TS)*60.
   PRINT 227, TS
227 FORMAT(///4X,31HTIME FOR THIS EVENT (SECONDS) =,F6.2)
   GO TO 100

C           228 CALL FINISH
   STOP
   END

```

SUBROUTINE LOCAT4

C THIS SUBROUTINE SETS UP AND SOLVES THE NORMAL EQUATIONS

```

C
C           COMMON /LOC4/ A(4,5),X(4),EVENT,MHRS,MINS,SEC,ALAT,SN,ALON,EW,
1ELAT,ELON,H,OT,HH,INDO,INDH,IEPIC,CN,CS,CE,CW,STAR,BLANK,
2CODE,IDEPI,IMTRX
C
C           COMMON /ATAB/ NTABLE,STN(3000),SLAT(3000),SLON(3000),CUR(3000),
1ISTN,FSTN(500),INDEX(500),AT(500),TRESID(500),AZ(500),DIST(500),
2ST(44),FD(44)
C
C           COMMON /GRFF/ TITLE(20)
C
C           COMMON /CONSTS/ PI,DTOR,RTOD,ZKM,ER,GFACT,HUGE,SECDAY,ROUND
C
C           DOUBLE PRECISION A,X,CELA,ARG,DT,DH,RESID,SUMSQ,AVSQ,HOLD,EPS,
1DF,DCS,DGN,OT,AT
   REAL*8 TITLE,EVENT,REG(13)

C           ITER=0
   HOLD=0.00
   HOLDA=ELAT
   HOLDO=ELON
   NU=2+INDO+INDH
C

```

```

C      COMMENCE ITERATION
C
1  ITER=ITER+1
CELA=DCOS(DBLE(ELAT*DTOR))
SUMSQ=0.00
AVSQ=0.00
DF=0.00
C
C      SET MATRIX OF NORMAL EQUATIONS TO ZERO
C
DO 3 I=1,4
DO 2 J=1,5
A(I,J)=0.00
2  CONTINUE
3  CONTINUE
C
C      DETERMINE DISTANCE AND AZIMUTH OF EACH STATION FROM TRIAL
C      EPICENTRE (BAZDEL) AND USE DISTANCE TO COMPUTE TRAVEL TIME AND
C      DERIVATIVES (DTDD)
C
DO 6 I=1,ISTN
K=INDEX(I)
CALL BAZDEL(ELAT,ELON,SLAT(K),SLON(K),BB,AZ(I),DIST(I),DTOR)
CALL DTDD(HH,DIST(I),COP(K),HEIGHT(ELAT),HEIGHT(SLAT(K)),
1DERIV,DDEP,TT)
ARG=DBLE(AZ(I)*DTOR)
RLSTD=AT(I)-OT-DBLE(TT)
TRESID(I)=RESID
IF(DIST(I).GE.110.)GO TO 6
SUMSQ=SUMSQ+RESID*RESID
DT=-DBLE(DERIV)
DSN=DT*D SIN(ARG)*CELA
DCS=DT*DCOS(ARG)
DH=DBLE(DDEP)
DF=DF+1.00
C
C      ADD INTO APPROPRIATE POSITION IN MATRIX OF NORMAL EQUATIONS
C      (UPPER TRIANGULAR ELEMENTS ONLY)
C
A(1,1)=A(1,1)+DCS*DCS
A(1,2)=A(1,2)+DCS*DSN
A(1,3)=A(1,3)+DCS
A(1,4)=A(1,4)+DCS*DH
A(1,5)=A(1,5)+DCS*RESID
C
A(2,2)=A(2,2)+DSN*DSN
A(2,3)=A(2,3)+DSN
A(2,4)=A(2,4)+DSN*DH
A(2,5)=A(2,5)+DSN*RESID
C
A(3,3)=A(3,3)+1.00
A(3,4)=A(3,4)+DH
A(3,5)=A(3,5)+RESID
C
A(4,4)=A(4,4)+DH*DH
A(4,5)=A(4,5)+DH*RESID
CONTINUE
C
C      COMPLETE FORMATION OF MATRIX OF NORMAL EQUATIONS
C
DO 4 I=1,4
DO 5 J=1,4
A(J,I)=A(I,J)
5  CONTINUE
4  CONTINUE
C
C      RESTRAIN DEPTH AND ORIGIN TIME IF REQUIRED BY ADDING HUGE (=8**8)
C      TO APPROPRIATE DIAGONAL ELEMENT
C
IF(INDU.EQ.0)A(3,3)=A(3,3)+DBLE(HUGE)
IF(INDU.EQ.0)A(3,5)=0.00
IF(INDH.EQ.0)A(4,4)=A(4,4)+DBLE(HUGE)
IF(INDH.EQ.0)A(4,5)=0.00
C
C      PRINT OUT STATION O-C RESIDUAL ON FIRST ITERATION
C      IF IEPIC=2 RETURN FOR PSUEDO-GEDESS
C
IF(ITER.EQ.1)CALL PRES(ESTN,TRESID,AZ,DIST,ISTN,TITLE(16))
GO TU(7,8),IEPIC
C
7  EPS=DABS(HOLD)*1.D-4
HOLD=HOLD-SUMSQ
IT=ITER-1
PRINT 9, IT,SUMSQ
9  FORMAT(//4X,3IHSUM OF SQUARED RESIDUALS AFTER ,I2,
1 13H ITERATIONS =,F10.4)
C
C      INVERT NORMAL EQUATIONS AND DETERMINE CORRECTIONS TO TRIAL VALUES
C      COMPUTE REVISED ESTIMATES AND IF CHANGE IN SUM OF SQUARES LESS
C      THAN 0.01 PERCENT OR ITERATIONS MORE THAN 10 CEASE ITERATING
C

```

```

IF(IMTRX.EQ.2)PRINT 41, A
CALL SMATRX(A,X,4,4)
IF(IMTRX.EQ.2)PRINT 41, A,X
41 FORMAT(1X,4G20.10)
ELAT=ELAT+X(1)
ELON=ELON+X(2)
OT=OT+X(3)
HH=HH+X(4)
IF(DABS(HOLD).LT.EPS.OR.ITER.GT.10)GO TO 11
HOLD=SUMSQ
GO TO 1
C
C WORK OUT TOTAL SHIFT BETWEEN INITIAL AND FINAL EPICENTRE
C AND LOOKUP REGION
C
11 CALL HRTM(OT,MHR,MIN,ASEC)
HOMO=BLANK
HIHI=BLANK
IF(IND0.EQ.0)HOMO=STAR
IF(INDH.EQ.0)HIHI=STAR
SHLA=(ELAT-HOLDA)*ZKM
SHLO=(ELON-HOLD0)*ZKM**CELA
SHIFT=SQRT(SHLA*SHLA+SHLO*SHLO)
AZIM=ATAN2(SHLO,SHLA)*RTOD
IF(AZIM.LT.0.)AZIM=AZIM+360.
SNN=CN
IF(ELAT.LT.0.0)SNN=CS
ELAT=ABS(GEOGRF(ELAT))
EWW=CE
IF(ELON.LT.0.0)EWW=CW
ELON=ABS(ELON)
CALL LOOKUP(ELAT,SNN,ELON,EWW,IGREG,ISREG,REG,3)
IF(IGRFG)26,26,25
26 DO 23 I=1,4
TITLE(I+5)=REG(I)
23 CONTINUE
DO 24 I=1,5
TITLE(I+9)=REG(I+8)
24 CONTINUE
C
C COMPUTE NUMBER OF DEGREES OF FREEDOM AND CONFIDENCE LIMITS
C AND ELLIPSE
C
25 DF=DF-DFLOAT(NU)
MDF#0
CLAT=0.
CLON=0.
COT=0.
CH=0.
CAREA=0.
IF(DF.EQ.0.0)GO TO 10
C
AVSQ=SUMSQ/DF
SD=DSQRT(AVSQ)
MDF=DF
IF(MDF.LE.30)GO TO 45
IF(MDF.GT.300)GO TO 46
MDF=(MDF+5)/20+29
GO TO 45
46 MDF=44
45 T=ST(MDF)
F=FD(MDF)
CALL CONLM4(AVSQ,F,T,CLAT,CLON,COT,CH,CAREA,CELA)
MDF=DF
C
C PRINT OUT RESULTS
C
10 PRINT 12, IT,TITLE(16),TITLE(17)
12 FORMAT(1H1//4X,14HRESULTS AFTER ,I2,1X,10HITERATIONS,6IX,A8/
1 4X,27H-----,6IX,A8///)
IF(IGREG)30,30,20
20 PRINT 13, IGREG,(REG(I),I=1,8),ISREG,(REG(I),I=9,13)
13 FORMAT(12X,20H GEOGRAPHIC REGION ,I4,1X,4A8/37X,4A8//12X,
1 20H SEISMIC REGION ,I4,1X,5A8///)
30 PRINT 31, ALAT,SN,ELAT,SNN,CLAT,CLON,EW,ELON,EWW,CLON,
1MHRS,MINS,SEC,MHR,MIN,ASEC,COT,HOMO,H,HH,CH,HIHI
31 FORMAT(
1 60H          ORIGINAL          RECALCULATED      /
2 60H          EPICENTRE        EPICENTRE      /
3 7X,11H LATITUDE,4X,F7.3,1X,A1,10X,F7.3,1X,A4,4H+OR-,F8.2,3H KM/
4 7X,11H LONGITUDE,4X,F7.3,1X,A1,10X,F7.3,1X,A4,4H+OR-,F8.2,3H KM/
5 7X,11H ORIGIN TIME,4X,I2,1X,I2,1X,F4.1,9X,I2,1X,I2,1X,F4.1,2X,
6 4H+OR-,F8.2,A1,2H S/
7 7X,11H DEPTH (KM).4X,F7.2,12X,F7.2,5X,4H+OR-,F8.2,A1//)
PRINT 14, CODE
14 FORMAT(4X,A4,17HTRAVEL TIMES USED/4X,23H* RESTRAINED PARAMETERS)
IF(DF.EQ.0.0)GO TO 16
PRINT 18
18 FORMAT(4X,32HALL CONFIDENCE LIMITS 95 PERCENT/)
PRINT 15, CAREA
15 FORMAT(//4X,47HAREA OF 95 PERCENT CONFIDENCE REGION (F TEST) =,
1F11.2,6H SQ.KM//)

```

```

GO TO 17
16 PRINT 19
19 FORMAT(//4X,61HCONFIDENCE LIMITS CAN NOT BE COMPUTED - NO DEGREES
10F FREEDOM/)
17 PRINT 21, SHLA,SHLO,SHIFT,AZIM
21 FORMAT(//4X,16HLATITUDE SHIFTED,F7.2,3H KM,6X,17HLONGITUDE SHIFTED,
1 F7.2,3H KM/4X,13HTOTAL SHIFT =,F8.2,3H KM,4X,
2 20HDIRECTION OF SHIFT =,F6.1,5H DEGS//)
CALL PRES(ESTN,TRESID,AZ,DIST,ISTN,TITLE(16))
PRINT 22, TITLE(16),TITLE(17),SUMSQ,AVSQ,SD,MDF,NU,T,F
22 FORMAT(1H1//4X,36HSTATISTICAL AND OTHER VARIABLES USED,52X,A8/
1 4X,36H-----,52X,A8///
2 35H      SUM OF SQUARED RESIDUALS =,F10.5//  

3 35H      AVERAGE SQUARED RESIDUAL =,F10.5//  

4 35H      STANDARD DEVIATION =,F10.5//  

5 35H      NUMBER OF DEGREES OF FREEDOM =,I5//  

6 35H      NUMBER OF UNKNOWNNS =,I5//  

7 35H      STUDENTS T =,F6.2//  

8 35H      VARIANCE RATIO F =,F6.2)  

C  

8 RETURN
END

```

```

SUBROUTINE CONLM4(AVSQ,F,T,CLAT,CLON,COT,CH,CAREA,CELA)
C
C      COMPUTE CONFIDENCE LIMITS AND GRAPH CONFIDENCE ELLIPSE
C
C      COMMON /LOC54/ A(4,6),EVENT
C
C      COMMON /CONSTS/ PI,DTOR,RTOD,ZKM
C
C      REAL*8 EVENT
C      DOUBLE PRECISION A,AVSQ,CELA
C
C      DIMENSION X(19), Y(19)
C      DATA NN/19/
C
C
CLAT = DSQRT(A(1,1)*AVSQ)*T*ZKM
CLON = DSQRT(A(2,2)*AVSQ)*T*CELA*ZKM
COT = DSQRT(A(3,3)*AVSQ)*T
CH = DSQRT(A(4,4)*AVSQ)*T
C
A11 = A(1,1)
A12 = A(1,2)
A22 = A(2,2)
CSQU=2.*AVSQ*F
CALL AREA(NN,X,Y,A11,A12,A22,CSQU,CAREA,1)
CAREA=CAREA*CELA*ZKM*ZKM
C
DO 1 I=1,NN
X(I)=X(I)*CELA*ZKM
Y(I)=Y(I)*ZKM
1 CONTINUE
CALL GRAPH(EVENT,1,X,Y,NN)
C
RETURN
END

```

```

SUBROUTINE PRES(ESTN,TRESID,AZ,DIST,ISTN,TITLE)
C
C      PRINT RESIDUALS
C
C      DIMENSION ESTN(ISTN),TRESID(ISTN),AZ(ISTN),DIST(ISTN),TITLE(4)
C
C      PRINT 1, TITLE
1 FORMAT(1H1//4X,18HTABLE OF RESIDUALS,70X,2A4/
1           4X,18H-----,70X,2A4//)
2 2(4X,7HSTATION,4X,8HRESIDUAL,4X,8HDISTANCE,4X,7HAZIMUTH,8X)//)
C
PRINT 2, (I,ESTN(I),TRESID(I),DIST(I),AZ(I),I=1,ISTN)
2 FORMAT(2(2X,I3,2X,A4,F11.3,F12.2,F11.1,9X))
C
RETURN
END

```



APPENDIX B

LISTING OF SUBROUTINES UNIQUE TO SPUR

SPUR (MAIN)
LOCAT
CONPOS
CONTIM
TTJB : ENTRY DTD
DECODE

C EPICENTRE DETERMINATION AT ZERO DEPTH (SPUR)

C
C THIS PROGRAM IS BASICALLY AN EPICENTRE DETERMINATION PROGRAM
C DESIGNED TO TAKE LITTLE COMPUTER STORAGE AND HENCE IT SHOULD BE
C SUITABLE FOR A SMALL MACHINE. THE PROGRAM COMPUTES ONLY THE
C EPICENTRE AND ORIGIN TIME, THE DEPTH BEING FIXED AT ZERO (OR
C COULD BE ANY OTHER CHOSEN DEPTH). ONLY TRAVEL TIMES FOR A SINGLE
C (ZERO) DEPTH ARE HELD IN STORAGE. (PROVIDED THE FOCUS IS NOT
C DEEPER THAN ABOUT 100 KM THIS SHOULD NOT INTRODUCE TOO GREAT
C AN ERROR).

C THE MAIN PROGRAM PRESENTED HERE IS BASED ON A PROGRAM THAT
C CAN BE OPERATED THROUGH AN ON-LINE SYSTEM. TO SIMPLIFY THE
C OPERATION OF FEEDING IN THE DATA THROUGH A TELETYPE THE INPUT
C FORMAT HAS BEEN MADE VERY GENERAL. IF THE OPTION TO USE THE
C PROGRAM ON AN ON-LINE SYSTEM IS NOT REQUIRED THEN THE MAIN
C PROGRAM CAN BE SIMPLIFIED AND SUBROUTINES CONTIN AND CONPOS
C OMITTED. ALL THAT IS NEEDED IS A ROUTINE TO READ IN THE DATA
C AND PRESENT IT IN THE REQUIRED FORM TO SUBROUTINE LOCAT WHICH
C RETURNS A REVISED EPICENTRE AND ORIGIN TIME WITH CONFIDENCE
C LIMITS.

C INPUT

C THE FIRST BLOCK OF CARDS IS A DIRECTORY OF STATIONS (STN) AND
C THEIR LATITUDES (SLAT) AND LONGITUDES (SLON).
C FORMAT FOR PUNCHING THESE CARDS IS GIVEN IN STATEMENT 9.
C THE END OF THIS BLOCK OF CARDS IS MARKED BY A CARD WITH STARS
C (****) PUNCHED IN THE STN POSITION.

C THE PROGRAM NOW READS IN ANY STATION CORRECTIONS REQUIRED FROM
C CARDS CARRYING THE STATION CODE AND THE TIME CORRECTION.
C FORMAT FOR PUNCHING THESE CARDS IS GIVEN IN STATEMENT 19.
C THE END OF THIS BLOCK OF CARDS IS MARKED BY A CARD WITH STARS
C (****) PUNCHED INSTEAD OF THE STATION CODE.
C THIS LAST CARD WITH STARS MUST STILL BE INCLUDED EVEN IF THERE
C ARE NO CORRECTIONS.

C NOW FOLLOW (FOR EACH EVENT) IN ANY ORDER CARDS CARRYING
C A TITLE FOR EVENT (1 CARD OPTIONAL)
C INITIAL EPICENTRE AND ORIGIN TIME INFORMATION (1 CARD)
C STATION CODE AND ARRIVAL TIMES (UP TO 100 CARDS)

C IF TWO TITLE CARDS OR TWO EPICENTRE CARDS ARE INCLUDED SECOND
C OVERWRITES THE FIRST. SIMILARLY, IF TWO CARDS WITH THE SAME
C STATION CODE ARE INCLUDED SECOND OVERWRITES THE FIRST.
C A BLANK CARD MARKS THE END OF THE BLOCK OF DATA FOR EACH EVENT.

C THE TITLE CARD HAS TITLE PUNCHED AS THE FIRST DATA ON THE
C CARD. THE REMAINDER OF THE CARD UP TO COLUMN 72 CAN THEN BE
C USED FOR THE TITLE.

C THE INITIAL EPICENTRE CARD HAS EVENT PUNCHED AS THE FIRST
C DATA ON THE CARD AND THEN FOLLOWS IN ORDER

C MHR(S) HOURS)
C MINS MINUTES) ORIGIN TIME
C SECS SECONDS)
C INDO PUNCH A STAR (#) TO RESTRAIN ORIGIN TIME
C (PROGRAM SETS INDO = 0)
C ELAT LATITUDE IN DEGREES
C DRCLAT N (NORTH) OR S (SOUTH)
C ELON LONGITUDE IN DEGREES
C DRCLON E (EAST) OR W (WEST)
C INDE PUNCH A STAR (#) TO RESTRAIN EPICENTRE
C (PROGRAM SETS INDE = 0)

C ANY FORMAT CAN BE USED UP TO COLUMN 72 PROVIDED THERE IS A
C BLANK SPACE BETWEEN EACH VARIABLE AND TWO SPACES BETWEEN THE
C ORIGIN TIME AND THE EPICENTRE.

C STATION CODE AND ARRIVAL TIME CARDS HAVE THE STATION CODE
C PUNCHED AS THE FIRST DATA ON THE CARD. THEN FOLLOWS IN ORDER
C MHR(I) HOURS)
C MIN(I) MINUTES) ARRIVAL TIME AT STATION STN(I)
C SEC(I) SECONDS)

C ANY FORMAT CAN BE USED UP TO COLUMN 72 PROVIDED THERE IS A
C BLANK SPACE BETWEEN EACH VARIABLE.

```

DIMENSION ASTN(100),ALAT(100),ALON(100),COR(100),
1      MHR(100),MIN(100),SEC(100),RESID(100),
2      STN(200),SLAT(200),SLON(200),SCOR(200),
3      CARD(74),HEAD(17)
C
DATA   CN/4HN  /,CS/4HS  /,CE/4HE  /,CW/4HW  /,STARS/4H****/,
1      EVENT/4HEVEN/,TITLE/4HTITL/,START/4H(  /,END/4H)  /,
2      BLANK/4H  /
C
C      DEFINE FUNCTIONS TO CONVERT FROM GEOGRAPHIC TO GEOCENTRIC
C      LATITUDE AND VICE VERSA
C
GEOCEN(GLAT)=ATAN(TAN(GLAT)*DTOR)*GC0N)/DTOR
GE0GRF(GLAT)=ATAN(TAN(GLAT)*DTOR)/GC0N)/DTOR
C
C      SET UP CONSTANTS
C
MXSTNS=200
DTOK=ATAN(1.)/45.
GC0N=0.5933054
CON=111.195
CARD(1)=START
CARD(74)=END
C
C      SET UP UNIT NUMBERS FOR INPUT/OUTPUT
C
IN=5
IO=6
IP=8
C
C      READ IN THE DIRECTORY OF JP TO MXSTNS STATIONS WITH LATITUDES
C      AND LONGITUDES
C      A CARD WITH STARS (****) MARKS THE END OF THE STATION CARDS
C
N=0
10 N=N+1
READ (IN,8)  STN(N),SLAT(N),SLON(N)
8 FORMAT(1X,A4,34X,F10.6,5X,F11.6)
IF(STN(N)-STARS)11,20,11
11 WRITE (IO,8)  STN(N),SLAT(N),SLON(N)
GO TO 10
20 NOSTNS=N-1
IF(NOSTNS-MXSTNS)21,400,400
21 DO 22 I=1,NOSTNS
SCOR(I)=0.
22 CONTINUE
C
C      READ IN STATION NAME AND STATION TIME CORRECTION IF ANY
C      IDENTIFY STATION AND STORE CORRECTION IN APPROPRIATE POSITION
C      IN ARRAY SCOR
C      A CARD WITH STARS (****) MARKS THE END OF STATION CORRECTIONS
C
30 READ (IN,9)  CODE,SECC
9 FORMAT(1X,A4,F9.5)
IF(CODE-STARS)31,50,31
31 DO 33 I=1,NOSTNS
IF(CODE-STN(I))33,32,33
32 SCOR(I)=SECC
WRITE (IO,9)  CODE,SECC
33 CONTINUE
GO TO 30
C
C      INITIALISE EVENT VARIABLES
C
50 DO 60 J=1,17
HEAD(J)=BLANK

```

```

60  CONTINUE
    MHRs=0
    MINs=0
    SECs=0
    INDO=0
    ELAT=0.
    ELATS=0.
    DRCLAT=BLANK
    ELON=0.
    ELONS=0.
    DRCLON=BLANK
    INDE=0
    N=0
    WRITE (IO,1)
1   FORMAT(1H1)

C
C      BEGIN READING IN EPICENTRE DATA AND ARRIVAL TIME DATA
C
100 READ  (IN,2,END=400)  (CARD(K),K=2,73)
2   FORMAT(72A1)
    WRITE (IO,3)  CARD
3   FORMAT(1X,74A1)
    DD 101 K=2,73
    IF(CARD(K)=BLANK)110,101,110
101 CONTINUE
    GO TO 200
C
C      IF CARD BLANK DATA INPUT COMPLETE SO BEGIN PROCESSING
C      OTHERWISE DECODE
C
110 CALL DECODE(CARD(K),CODE,4)
    K=K+4
    I=K+2
C
C      IF CARD IS NOT EVENT CARD OR TITLE CARD ASSUME ARRIVAL TIME CARD
C
    IF(CODE-EVENT)120,160,120
120 IF(CODE-TITLE)130,180,130
C
C      IF ARRIVAL TIME CARD IDENTIFY STATION FROM DIRECTORY
C      IF UNKNOWN REJECT AND CONTINUE
C
130 DO 131 I=1,NOSTNS
    IF(CODE-STN(I))131,140,131
131 CONTINUE
    WRITE (IO,4)
4   FORMAT(2X,24UNKNOWN STATION REJECTED)
    GO TO 100
C
C      CHECK THAT STATION HAS NOT ALREADY BEEN USED IN THIS EVENT
C      IF IT HAS OVERWRITE THE READING
C
140 IF(N)144,144,141
141 DO 142 J=1,N
    IF(CODE-ASTN(J))142,150,142
142 CONTINUE
144 N=N+1
    IF(N-100)145,145,400
145 ASTN(N)=STN(I)
    ALAT(N)=GEOCEN(SLAT(I))
    ALON(N)=SLON(I)
    COR(N)=SCOR(I)
    J=N
C
C      FOR STATION CARDS DECODE ARRIVAL TIME AND CONVERT TO SECONDS
C
150 CALL CONTIM(CARD,K,DD,MHR(J),MIN(J),SEC(J),ID)
    GO TO 100
C
C      FOR EVENT CARDS DECODE ORIGIN TIME LATITUDE LONGITUDE AND IF
C      ANY RESTRAINTS ON ORIGIN TIME AND EPICENTRE
C
160 CALL CONTIM(CARD,I,DD,MHRs,MINs,SECs,IND0)
    CALL CONPOS(CARD,I,ELAT,DRCLAT,ELATS,ELON,DRCLON,ELONS,INDE,DD, ID)
    IF(INDE-1)170,100,100

```

```

170 INDO=0
      GO TO 100
C
C      LOAD TITLE INTO HEAD ARRAY FOR PRINTING
C
180 CALL DECODE(CARD(I),HEAD,73-I)
      GO TO 100
C
C      ALL DATA READ IN PRINT OUT INPJT AND BEGIN PROCESSING
C
200 IF(N-2)400,220,230
220 INDO=0
230 WRITE (IO,5) HEAD,MHRS,MINS,SECS,ELAT,DRCLAT,ELON,DRCLON,
1  (ASTN(J),MHR(J),MIN(J),SEC(J),J=1,N)
5  FORMAT(1H /1H /8H TITLE ,17A4/8H EVENT ,2I4,F6.1,2(F9.3,1X,A1)/
1  (1X,A4,15X,I2,1X,I2,1X,F4.1))
      WRITE (IP,1)
      WRITE (IP,12) HEAD
12  FORMAT(38H EPICENTRE DETERMINATION AT ZERO DEPTH/
1  38H -----/1H /
2  1X,17A4/1H )
      WRITE (IP,13) ELAT,DRCLAT,ELON,DRCLON,MHRS,MINS,SECS
13  FORMAT(20H INITIAL EPICENTRE ,11H LATITJDE,3X,F8.3,2X,A1/
1  20X,11H LONGITUDE,3X,F8.3,2X,A1/20X,11H ORIGIN TIME,2I4,F6.1/
2  1H )
      ID=IND0+INDE
      FLATS=GEOGEN(ELATS)
C
C      DETERMINE REVISED EPICENTRE AND ORIGIN TIME BY LOCAT
C
      CALL LOCAT(MHRS,MINS,SECS,ELATS,ELONS,1D,MHRC,MINC,SECC,
1  ELATC,ELONC,N,MHR,MIN,SEC,ALAT,ALON,COR,RESID,SUMSQ,
2  CT,CLAT,CLON,SHIFT,AZ,ITER,CODE,CON,DTOR)
      IF(ITER-20)310,300,300
C
C      PRINT RESULTS
C
300 WRITE (IP,15)
15  FORMAT(15H NO CONVERGENCE/1H )
      GO TO 320
310 WRITE (IP,16) ITER,CODE
16  FORMAT(15H RESULTS AFTER,14,12H ITERATIONS,3X,2H ,A4,1X,
1  19H TRAVEL TIMES USED /1H )
320 ELAT=ABS(GEOGRF(ELATC))
      DRCLAT=CN
      IF(ELATC)330,340,340
330 DRCLAT=CS
340 ELON=ABS(ELONC)
      DRCLON=CE
      IF(ELONC)350,360,360
350 DRCLON=CW
360 WRITE (IP,14) ELAT,DRCLAT,CLAT,ELON,DRCLON,CLON,MHRC,MINC,SECC,CT
14  FORMAT(20H COMPUTED EPICENTRE ,11H LATITJDE,3X,F8.3,2X,A1,
1  7H +/-,F9.1,3H KM/20X,11H LONGITUDE,3X,F8.3,2X,A1,
2  7H +/-,F9.1,3H KM/20X,11H ORIGIN TIME,2I4,F6.1,
3  7H +/-,F9.1,2H S/1H /1H )
C
C      IF SHIFT BETWEEN INITIAL AND FINAL EPICENTRE GREATER THAN 10 KM
C      COMPUTE MORE ACCURATE VALUE BY BAZDEL
C
      IF(SHIFT-10.)380,380,370
370 CALL BAZDEL(FLATS,ELONS,ELATC,ELONC,DD,AZ,DIST,DTOR)
      SHIFT=DIST*CON
380 WRITE (IP,17) SUMSQ,SHIFT,AZ
17  FORMAT(25H SUM SQUARED RESIDUALS =,F12.4/
1  25H SHIFT IN EPICENTRE =,F9.1,3H KM/
2  25H DIRECTION OF SHIFT =,F7.1,5H DEGS/1H )
      WRITE (IP,18)

```

```

18  FORMAT(55H STATION      READING      RESIDUAL   DISTANCE   AZIMUTH /
1     55H          H M S           S          DEGS       DEGS )
C
C DETERMINE DISTANCE AND AZIMUTH OF EACH STATION FROM FINAL
C EPICENTRE AND PRINT WITH O-C RESIDUALS
C
DO 390 I=1,N
CALL BAZDEL(ELATC,ELONGC,ALAT(I),ALON(I),DD,AZ,DIST,DTOR)
WRITE (IP,19) I,ASTN(I),MHR(I),MIN(I),SEC(I),RESID(I),DIST,AZ
19 FORMAT(I3,2X,A4,I5,I3,F5.1,F12.3,F10.2,F10.1)
390 CONTINUE
GO TO 50
C
C
400 WRITE (IP,1)
STOP
END

SUBROUTINE LOCAT(MHRS,MINS,SECS,ALATS,ALONS,IND,MHRC,MINC,SECc,
1 ALATC,ALONGC,ISTN,MHR,MIN,SEC,SLAT,SLON,COR,RESID,
2 SUMSQ,COT,CLAT,CLCN,SHIFT,AZIM,ITER,CODE,ZKM,DTOR)
C
DIMENSION MHR(ISTN),MIN(ISTN),SEC(ISTN),SLAT(ISTN),SLON(ISTN),
1 COR(ISTN),RESID(ISTN)
C
DOUBLE PRECISION A11,A12,A13,A14,A21,A22,A23,A24,A31,A32,A33,A34,
1 D1,D2,D3,X1,X2,X3,A,R,S,T,DT,CELA,ARG,DCS,DSN,DET,DET3,SECTM
C
C DEFINE FUNCTIONS TO CONVERT TIME TO SECONDS AND TO COMPUTE
C THE DETERMINANT
C
SECTM(IHR,IMIN,SEX)=DFLOAT((IHR*60+IMIN)*60)+DBLE(SEX)
DET3(A1,A2,A3,B1,B2,B3,C1,C2,C3)=A1*B2*C3+B1*C2*A3+C1*A2*B3
1 -A1*C2*B3-B1*A2*C3-C1*B2*A3
C
DIMENSION ST(35)
DATA ST(1)/2.7/,ST(2)/4.30/,ST(3)/3.18/,ST(4)/2.78/,ST(5)/2.57/,
1 ST(6)/2.45/,ST(7)/2.36/,ST(8)/2.31/,ST(9)/2.26/,ST(10)/2.23/,
2 ST(11)/2.20/,ST(12)/2.18/,ST(13)/2.16/,ST(14)/2.14/,ST(15)/2.13/,
3 ST(16)/2.12/,ST(17)/2.11/,ST(18)/2.10/,ST(19)/2.09/,ST(20)/2.09/,
4 ST(21)/2.08/,ST(22)/2.07/,ST(23)/2.07/,ST(24)/2.06/,ST(25)/2.06/,
5 ST(26)/2.06/,ST(27)/2.05/,ST(28)/2.05/,ST(29)/2.05/,ST(30)/2.04/,
6 ST(31)/2.02/,ST(32)/2.00/,ST(33)/2.00/,ST(34)/1.99/,ST(35)/1.98/
C
DIMENSION A(3,4)
EQUIVALENCE (A(1,1),A11),(A(1,2),A12),(A(1,3),A13),(A(1,4),A14)
EQUIVALENCE (A(2,1),A21),(A(2,2),A22),(A(2,3),A23),(A(2,4),A24)
EQUIVALENCE (A(3,1),A31),(A(3,2),A32),(A(3,3),A33),(A(3,4),A34)
C
C SET UP CONSTANTS
C
ITER=0.
COT=0.
CLAT=0.
CLON=0.
SHIFT=0.
AZIM=0.
HOLD=0.
C
OT=SECTM(MHRS,MINS,SECS)
ELAT=ALATS
ELON=ALONS
C
C BEGIN ITERATION LOOP BY SETTING NORMAL EQUATION MATRIX A(I,J)
C TO ZERO
C
100 DO 120 J=1,4
DO 110 I=1,3
A(I,J)=0.00
110 CONTINUE
120 CONTINUE
S=0.00
CELA=DCOS(DBLE(ELAT*DTOR))
C
C SET UP NORMAL EQUATIONS
C DETERMINE DISTANCE AND AZIMUTH OF EACH STATION FROM EPICENTRE
C BY BAZDEL AND TRAVEL TIME AND DERIVATIVES BY DTD
C

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DO 130 I=1,ISTN
CALL BAZDEL(ELAT,ELON,SLAT(I),SLON(I),TT,AZIM,DIST,DTOR)
CALL DTD(CODE,DIST,DT,TT,2,ELAT,SLAT(I),DTOR)
ARG=DBLF(AZIM*DTOR)
T=-DBLE(DT)
DCS=T*DCOS(ARG)
DSN=T*DSIN(ARG)*CELA
R=SECTM(MHR(I),MIN(I),SEC(I))-OT-DBLE(TT+COR(I))
RESID(I)=R
S=S+R*R
C
A11=A11+DCS*DCS
A12=A12+DCS*DSN
A13=A13+DCS
A14=A14+DCS*R
C
A22=A22+DSN*DSN
A23=A23+DSN
A24=A24+DSN*R
C
A34=A34+R
130 CONTINUE
C
A33=DFLOAT(ISTN)
SUMSQ=S
C
FOR IND = 0 DO NOT ITERATE
FOR IND = 1 RESTRAIN ORIGIN TIME
C
IF(IND-1)200,140,150
140 A33=1.D10
A34=0.D0
150 DO 152 J=1,3
DO 151 I=1,3
A(I,J)=A(J,I)
151 CONTINUE
152 CONTINUE
C
FORMATION OF NORMAL EQUATIONS NOW COMPLETE
SOLVE FOR CORRECTIONS TO LATITUDE(X1) LONGITUDE(X2) AND
ORIGIN TIME(X3)
C
DET=1.D0/DET3(A11,A12,A13,A21,A22,A23,A31,A32,A33)
X1=DET3(A14,A24,A34,A21,A22,A23,A31,A32,A33)*DET
X2=DET3(A11,A12,A13,A14,A24,A34,A31,A32,A33)*DET
X3=DET3(A11,A12,A13,A21,A22,A23,A14,A24,A34)*DET
C
COMPUTE DIAGONAL ELEMENTS FOR CONFIDENCE LIMITS
C
D1=DET3(1.00,C.D0,0.D0,A21,A22,A23,A31,A32,A33)*DET
D2=DET3(A11,A12,A13,0.D0,1.D0,0.D0,A31,A32,A33)*DET
D3=DET3(A11,A12,A13,A21,A22,A23,0.D0,0.D0,1.D0)*DET
C
ADD CORRECTIONS TO PREVIOUS ESTIMATES AND COMPUTE SHIFT OF
EPICENTRE BETWEEN SUCCESSIVE ITERATIONS
C
ELAT=ELAT+X1
ELON=ELON+X2
OT=OT+X3
C
160 IF(ABS(ELAT)-90.)170,170,161
161 ELAT=SIGN(89.99,ELAT)
170 IF(ABS(ELON)-180.)180,180,171
171 ELON=ELON-SIGN(360.,ELON)
GO TO 170
C
IF CHANGE IN SUM OF SQUARES OF RESIDUALS OR EPICENTRE SHIFT
LESS THAN 0.0001 OR NUMBER OF ITERATIONS 10 (OR MORE) CEASE
ITERATIONS AND PRINT OUT RESULTS
C
180 EPS=HOLD*0.0001
HOLD=HOLD-SUMSQ
IFI(ABS(HOLD)-EPS)200,200,190
190 SHIFT=DSQRT(X1*X1+X2*X2*CELA*X2*CELA)*ZKM
IFI(SHIFT-0.01)200,200,191
191 HOLD=SUMSQ
ITER=ITER+1
IFI(ITER-20)100,200,200
C
CONVERT ORIGIN TIME TO HOURS MINUTES AND SECONDS
COMPUTE SHIFT AND DIRECTION OF SHIFT BETWEEN INITIAL AND FINAL
EPICENTRE
C

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200 MHRC=OT/3600.00
      MINC=(OT-3600.00*DFLOAT(MHRC))/60.00
      SECC=OT-3600.00*DFLOAT(MHRC)-60.00*DFLJAT(MINC)
      ALATC=ELAT
      ALONC=ELON
      IF(ITER)300,300,210
210  ELAT=(ALATC-ALATS)*ZKM
      ELON=(ALONC-ALONS)*ZKM*CELA
      SHIFT=SQRT(ELAT*ELAT+ELON*ELON)
      AZIM=ATAN2(ELCN,ELAT)/DTOR
      IF(AZIM)220,230,230
220  AZIM=AZIM+360.
C
C   COMPUTE CONFIDENCE LIMITS
C
230  I=ISTN-IND-1
      NDF=I
      IF(NDF)300,300,240
240  IF(NDF-30)280,280,250
250  IF(NDF-100)260,260,270
260  NDF=(NDF+5)/20+29
      GO TO 280
270  NDF=35
280  T=S/DFLOAT(I)
      CLAT=DSQRT(D1*S)*T*ZKM
      CLON=DSQRT(D2*S)*T*CELA*ZKM
      COT=DSQRT(D3*S)*T
C
C
300  RETURN
END

```

```

SUBROUTINE COMPOS(CARD,INDEX,ALAT,DRCLAT,ELAT,ALON,DRCLON,ELON,
1     INDE,DEPTH,INDH,IND,INQ,NCHAR,NPROG)
C
C   GIVEN ALPHA-NUMERIC SINGLE CHARACTERS IN CARD STARTING AT INDEX
C   THIS SUBROUTINE DECODES THE LATITUDE(ALAT,DRCLAT,ELAT), AND THE
C   LONGITUDE(ALON,DRCLON,ELON). A STAR(*) RESTRAINS THE EPICENTRE.
C   THIS IS FOLLOWED BY THE DEPTH IF IT IS GIVEN AND A STAR(*) RESTRAINS THE DEPTH.
C   IF DRCLAT/DRCLON IS THE CHARACTER D THEN A DISTANCE(ALAT,D) AND
C   AZIMUTH(ALON,D) ARE DECODED.
C   ALSO DECODES THE VALUE OF AN INDICATOR(IND) GIVEN BETWEEN QUOTES
C   ('N') AND FOR A SINGLE QUOTE(') ASSUMES A COMMENT.
C
C   DIMENSION FIG(10),CARD(INDEX)
C
DATA FIG(1)/4H0    /,FIG(2)/4H1    /,FIG(3)/4H2    /,FIG(4)/4H3    /,
1    FIG(5)/4H4    /,FIG(6)/4H5    /,FIG(7)/4H6    /,FIG(8)/4H7    /,
2    FIG(9)/4H8    /,FIG(10)/4H9   /,POINT/4H.   /,STAR/4H*   /,
3    CE/4HE   /,CN/4HN   /,CS/4HS   /,CW/4HW   /,CD/4HD   /,
4    QUOTE/4H'  /,CEND/4H)  /,BLANK/4H   /
C
C
      DRCLAT=BLANK
      DRCLON=BLANK
      INDE=1
      INDH=1
      IND=0
      NCHAR=0
      LAT=0
      LON=0
      IDEP=0
      DIRLAT=1.
      DIRLON=1.
      IPLAT=0
      IPLON=0
      IPOW=0
      IIND=1
      I=INDEX
      INQ=I
      GO TO 20
C
10   I=I+1
20   IF(CARD(I)=BLANK)30,10,30
30   IF(CARD(I)=CEND)40,500,40
40   GO TO (50,60),NPROG
50   IF(CARD(I)=QUOTE)80,400,80

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60  IF(CARD(I)=STAR)90,70,90
70  INDE=0
    GO TO 10
80  I=I-1
    IADD=0
    GO TO (100,200,500),IIND
90  I=I-1
    IADD=0
    GO TO (100,200,300,500),IIND
C
C
100 I=I+1
    DO 110 J=1,10
    IF(CARD(I)=FIG(J))110,170,110
110 CONTINUE
    IF(CARD(I)=POINT)130,120,130
120 IADD=1
    NCHAR=NCHAR+1
    GO TO 100
130 IF(CARD(I)=CN)140,190,140
140 IF(CARD(I)=CS)150,180,150
150 IF(CARD(I)=CD)160,190,160
160 IF(CARD(I)=CEND)100,500,170
170 LAT=LAT*10+J-1
    IPLAT=IPLAT-IADD
    NCHAR=NCHAR+1
    GO TO 100
180 DIRLAT=-1.
190 DRCLAT=CARD(I)
    NCHAR=NCHAR+1
    IIND=2
    INDEX=I+1
    GO TO 10
C
200 I=I+1
    DO 210 J=1,10
    IF(CARD(I)=FIG(J))210,270,210
210 CONTINUE
    IF(CARD(I)=POINT)230,220,230
220 IADD=1
    NCHAR=NCHAR+1
    GO TO 200
230 IF(CARD(I)=CE)240,290,240
240 IF(CARD(I)=CW)250,280,250
250 IF(CARD(I)=CD)260,290,260
260 IF(CARD(I)=CEND)200,500,200
270 LON=LON*10+J-1
    IPLON=IPLON-IADD
    NCHAR=NCHAR+1
    GO TO 200
280 DIRLON=-1.
290 DRCLON=CARD(I)
    NCHAR=NCHAR+1
    IIND=3
    INDEX=I+1
    GO TO 10
C
300 I=I+1
    DO 310 J=1,10
    IF(CARD(I)=FIG(J))310,370,310
310 CONTINUE
    IF(CARD(I)=PCINT)340,320,340
320 IADD=1
    NCHAR=NCHAR+1
    GO TO 300
330 I=I+1
340 IF(CARD(I)=BLANK)350,330,350
350 IF(CARD(I)=STAR)360,380,360
360 IF(CARD(I)=CEND)390,500,390
370 IDEP=IDEP*10+J-1
    IPOW=IPOW-IADD
    NCHAR=NCHAR+1
    INDEX=I+1
    GO TO 300
380 INDH=0
    NCHAR=NCHAR+1
390 IIND=4
    INDEX=I+1
    GO TO 10
C
400 INQ=I
410 I=I+1
    IF(CARD(I)=BLANK)420,410,420

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```

420 DO 430 J=1,10
430 IF(CARD(I)-FIG(J))430,440,430
430 CONTINUE
430 GO TO 500
440 I=I+1
440 IF(CARD(I)-BLANK)450,440,450
450 IF(CARD(I)-QUOTE)460,470,460
460 IF(CARD(I)-CEND)10,500,10
470 IND=J-1
470 INDEX=I+1
470 INQ=I+1
470 GO TO 10
C
500 ALAT=FLOAT(LAT)*(10.**IPLAT)
500 ELAT=ALAT*DIRLAT
500 ALON=FLOAT(LON)*(10.**IPLONG)
500 ELON=ALON*DIRLON
500 DEPTH=FLOAT(IDEPTH)*(10.**IPDTH)
500 RETURN
500 END

SUBROUTINE CONTIM(CARD,INDEX,TIME,MHR,MIN,SEC,INDO)
C
C GIVEN ALPHA-NUMERIC SINGLE CHARACTERS IN CARD STARTING AT INDEX
C THIS SUBROUTINE DECODES THE TIME IN HOURS(MHR), MINUTES(MIN), AND
C SECONDS(SEC,MSEC), AND ALSO THE TOTAL NUMBER OF SECONDS(TIME),
C PROVIDED THERE IS AT LEAST ONE BLANK SPACE BETWEEN THE CODING AND
C TWO BLANK SPACES AT THE END.
C IF THERE IS A STAR THE TIME IS RESTRAINED BY SETTING INDO=0.
C
C
C DIMENSION FIG(10),CARD(INDEX)
C
C DATA FIG(1)/4H0    /,FIG(2)/4H1    /,FIG(3)/4H2    /,FIG(4)/4H3    /,
1    FIG(5)/4H4    /,FIG(6)/4H5    /,FIG(7)/4H6    /,FIG(8)/4H7    /,
2    FIG(9)/4H8    /,FIG(10)/4H9   /,POINT/4H.  /,STAR/4H*   /,
3    DASH/4H-   /,CEND/4H)  /,BLANK/4H  /
C
C
C TIME=0.
C SGN=1.
C MHR=0
C MIN=0
C SEC=0.
C MSEC=0
C INDO=1
C IPOW=0
C IADD=0
C IND=1
C I=INDEX-1
C
1  I=I+1
1  IF(CARD(I)-CEND)2,40,2
2  IF(CARD(I)-BLANK)3,1,3
3  IF(CARD(I)-STAR)5,4,5
4  INDO=0
4  GO TO 1
5  IF(CARD(I)-DASH)8,6,8
6  SGN=-1.
6  GO TO 1
8  GO TO (10,20,30),IND
C
10 DO 11 J=1,10
11 IF(CARD(I)-FIG(J))11,13,11
11 CONTINUE
11 IF(CARD(I)-BLANK)14,12,14
12 IND=2
12 INDEX=I
12 GO TO 1
13 MHR=MHR*10+J-1
14 I=I+1
14 GO TO 10
C
20 DO 21 J=1,10
21 IF(CARD(I)-FIG(J))21,23,21
21 CONTINUE
21 IF(CARD(I)-BLANK)24,22,24
22 IND=3
22 INDEX=I
22 GO TO 1
23 MIN=MIN*10+J-1

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24  I=I+1
    GO TO 20
C
30  DO 31 J=1,10
    IF(CARD(I)-FIG(J))31,38,31
31  CONTINUE
    IF(CARD(I)-BLANK)33,32,33
32  IF(CARD(I+1)-BLANK)33,40,33
33  IF(CARD(I)-CEND)34,40,34
34  IF(CARD(I)-STAR)36,35,36
35  INDO=0
    GO TO 39
36  IF(CARD(I)-POINT)39,37,39
37  IADD=1
    GO TO 39
38  MSEC=MSEC*10+J-1
    IPOW=IPOW-IADD
39  I=I+1
    INDEX=I+1
    GO TO 30
C
40  SEC=FLOAT(MSEC)*(10.**IPOW)
    TIME=((FLOAT(NHR)*60.+FLOAT(MIN))*60.+SEC)*SGN
    RETURN
    END

```

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SUBROUTINE TTJB(CODE,DELT,DERIV,TRAV,IND,ELAT,SLAT,DTDR)
C
C      JEFFREYS AND BULLEN (1958) TRAVEL TIMES CODE JB      ZERO DEPTH
C
DIMENSION TA(105,3),DIST(105),TT(105),SLOWNS(105),PROG(2)
EQUIVALENCE {TA(1,1),DIST(1)},(TA(1,2),TT(1)),(TA(1,3),SLOWNS(1))
C
DATA PROG(1)/4H&JB /,PROG(2)/4HJB /, N/105/
C
DATA   TA(1,1) / 1.0/,   TA(1,2) / 21.1/,   TA(1,3) /14.30/
DATA   TA(2,1) / 2.0/,   TA(2,2) / 35.4/,   TA(2,3) /14.30/
DATA   TA(3,1) / 3.0/,   TA(3,2) / 49.7/,   TA(3,3) /14.25/
DATA   TA(4,1) / 4.0/,   TA(4,2) / 63.9/,   TA(4,3) /14.20/
DATA   TA(5,1) / 5.0/,   TA(5,2) / 78.1/,   TA(5,3) /14.15/
DATA   TA(6,1) / 6.0/,   TA(6,2) / 92.2/,   TA(6,3) /14.10/
DATA   TA(7,1) / 7.0/,   TA(7,2) /106.3/,   TA(7,3) /14.06/
DATA   TA(8,1) / 8.0/,   TA(8,2) /120.3/,   TA(8,3) /13.95/
DATA   TA(9,1) / 9.0/,   TA(9,2) /134.2/,   TA(9,3) /13.85/
DATA   TA(10,1) / 10.0/,  TA(10,2) /148.0/,  TA(10,3) /13.75/
DATA   TA(11,1) / 11.0/,  TA(11,2) /161.7/,  TA(11,3) /13.66/
DATA   TA(12,1) / 12.0/,  TA(12,2) /175.3/,  TA(12,3) /13.51/
DATA   TA(13,1) / 13.0/,  TA(13,2) /188.7/,  TA(13,3) /13.29/
DATA   TA(14,1) / 14.0/,  TA(14,2) /201.9/,  TA(14,3) /13.14/
DATA   TA(15,1) / 15.0/,  TA(15,2) /215.0/,  TA(15,3) /13.07/
DATA   TA(16,1) / 16.0/,  TA(16,2) /228.0/,  TA(16,3) /12.86/
DATA   TA(17,1) / 17.0/,  TA(17,2) /240.7/,  TA(17,3) /12.59/
DATA   TA(18,1) / 18.0/,  TA(18,2) /253.2/,  TA(18,3) /12.45/
DATA   TA(19,1) / 19.0/,  TA(19,2) /265.5/,  TA(19,3) /11.98/
DATA   TA(20,1) / 20.0/,  TA(20,2) /277.0/,  TA(20,3) /10.91/
DATA   TA(21,1) / 21.0/,  TA(21,2) /287.4/,  TA(21,3) /10.18/
DATA   TA(22,1) / 22.0/,  TA(22,2) /297.5/,  TA(22,3) / 9.99/
DATA   TA(23,1) / 23.0/,  TA(23,2) /307.4/,  TA(23,3) / 9.78/
DATA   TA(24,1) / 24.0/,  TA(24,2) /317.1/,  TA(24,3) / 9.71/
DATA   TA(25,1) / 25.0/,  TA(25,2) /326.8/,  TA(25,3) / 9.57/
DATA   TA(26,1) / 26.0/,  TA(26,2) /336.2/,  TA(26,3) / 9.28/
DATA   TA(27,1) / 27.0/,  TA(27,2) /345.4/,  TA(27,3) / 9.14/
DATA   TA(28,1) / 28.0/,  TA(28,2) /354.5/,  TA(28,3) / 9.04/
DATA   TA(29,1) / 29.0/,  TA(29,2) /363.5/,  TA(29,3) / 9.01/
DATA   TA(30,1) / 30.0/,  TA(30,2) /372.5/,  TA(30,3) / 8.90/
DATA   TA(31,1) / 31.0/,  TA(31,2) /381.3/,  TA(31,3) / 8.79/
DATA   TA(32,1) / 32.0/,  TA(32,2) /390.1/,  TA(32,3) / 8.75/
DATA   TA(33,1) / 33.0/,  TA(33,2) /398.8/,  TA(33,3) / 8.70/
DATA   TA(34,1) / 34.0/,  TA(34,2) /407.5/,  TA(34,3) / 8.66/
DATA   TA(35,1) / 35.0/,  TA(35,2) /416.1/,  TA(35,3) / 8.55/
DATA   TA(36,1) / 36.0/,  TA(36,2) /424.6/,  TA(36,3) / 8.44/
DATA   TA(37,1) / 37.0/,  TA(37,2) /433.0/,  TA(37,3) / 8.39/
DATA   TA(38,1) / 38.0/,  TA(38,2) /441.4/,  TA(38,3) / 8.41/
DATA   TA(39,1) / 39.0/,  TA(39,2) /449.8/,  TA(39,3) / 8.36/
DATA   TA(40,1) / 40.0/,  TA(40,2) /458.1/,  TA(40,3) / 8.24/

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DATA TA(41,1) / 41.0/, TA(41,2) /466.3/, TA(41,3) / 8.19/
DATA TA(42,1) / 42.0/, TA(42,2) /474.5/, TA(42,3) / 8.21/
DATA TA(43,1) / 43.0/, TA(43,2) /482.7/, TA(43,3) / 8.15/
DATA TA(44,1) / 44.0/, TA(44,2) /490.8/, TA(44,3) / 8.11/
DATA TA(45,1) / 45.0/, TA(45,2) /498.9/, TA(45,3) / 8.00/
DATA TA(46,1) / 46.0/, TA(46,2) /506.8/, TA(46,3) / 7.88/
DATA TA(47,1) / 47.0/, TA(47,2) /514.7/, TA(47,3) / 7.92/
DATA TA(48,1) / 48.0/, TA(48,2) /522.6/, TA(48,3) / 7.80/
DATA TA(49,1) / 49.0/, TA(49,2) /530.3/, TA(49,3) / 7.69/
DATA TA(50,1) / 50.0/, TA(50,2) /538.0/, TA(50,3) / 7.65/
DATA TA(51,1) / 51.0/, TA(51,2) /545.5/, TA(51,3) / 7.60/
DATA TA(52,1) / 52.0/, TA(52,2) /553.2/, TA(52,3) / 7.57/
DATA TA(53,1) / 53.0/, TA(53,2) /560.7/, TA(53,3) / 7.38/
DATA TA(54,1) / 54.0/, TA(54,2) /568.0/, TA(54,3) / 7.35/
DATA TA(55,1) / 55.0/, TA(55,2) /575.4/, TA(55,3) / 7.31/
DATA TA(56,1) / 56.0/, TA(56,2) /582.6/, TA(56,3) / 7.20/
DATA TA(57,1) / 57.0/, TA(57,2) /589.8/, TA(57,3) / 7.10/
DATA TA(58,1) / 58.0/, TA(58,2) /596.8/, TA(58,3) / 6.99/
DATA TA(59,1) / 59.0/, TA(59,2) /603.8/, TA(59,3) / 6.96/
DATA TA(60,1) / 60.0/, TA(60,2) /610.7/, TA(60,3) / 6.84/
DATA TA(61,1) / 61.0/, TA(61,2) /617.5/, TA(61,3) / 6.81/
DATA TA(62,1) / 62.0/, TA(62,2) /624.3/, TA(62,3) / 6.70/
DATA TA(63,1) / 63.0/, TA(63,2) /630.0/, TA(63,3) / 6.59/
DATA TA(64,1) / 64.0/, TA(64,2) /637.5/, TA(64,3) / 6.56/
DATA TA(65,1) / 65.0/, TA(65,2) /644.0/, TA(65,3) / 6.44/
DATA TA(66,1) / 66.0/, TA(66,2) /650.4/, TA(66,3) / 6.40/
DATA TA(67,1) / 67.0/, TA(67,2) /656.8/, TA(67,3) / 6.36/
DATA TA(68,1) / 68.0/, TA(68,2) /663.1/, TA(68,3) / 6.25/
DATA TA(69,1) / 69.0/, TA(69,2) /669.3/, TA(69,3) / 6.14/
DATA TA(70,1) / 70.0/, TA(70,2) /675.4/, TA(70,3) / 6.10/
DATA TA(71,1) / 71.0/, TA(71,2) /681.5/, TA(71,3) / 6.06/
DATA TA(72,1) / 72.0/, TA(72,2) /687.5/, TA(72,3) / 5.95/
DATA TA(73,1) / 73.0/, TA(73,2) /693.4/, TA(73,3) / 5.84/
DATA TA(74,1) / 74.0/, TA(74,2) /699.2/, TA(74,3) / 5.80/
DATA TA(75,1) / 75.0/, TA(75,2) /705.0/, TA(75,3) / 5.76/
DATA TA(76,1) / 76.0/, TA(76,2) /710.7/, TA(76,3) / 5.65/
DATA TA(77,1) / 77.0/, TA(77,2) /716.3/, TA(77,3) / 5.54/
DATA TA(78,1) / 78.0/, TA(78,2) /721.3/, TA(78,3) / 5.50/
DATA TA(79,1) / 79.0/, TA(79,2) /727.3/, TA(79,3) / 5.46/
DATA TA(80,1) / 80.0/, TA(80,2) /732.7/, TA(80,3) / 5.35/
DATA TA(81,1) / 81.0/, TA(81,2) /738.0/, TA(81,3) / 5.24/
DATA TA(82,1) / 82.0/, TA(82,2) /743.2/, TA(82,3) / 5.20/
DATA TA(83,1) / 83.0/, TA(83,2) /748.4/, TA(83,3) / 5.16/
DATA TA(84,1) / 84.0/, TA(84,2) /753.5/, TA(84,3) / 5.04/
DATA TA(85,1) / 85.0/, TA(85,2) /758.5/, TA(85,3) / 5.00/
DATA TA(86,1) / 86.0/, TA(86,2) /763.5/, TA(86,3) / 4.96/
DATA TA(87,1) / 87.0/, TA(87,2) /768.4/, TA(87,3) / 4.84/
DATA TA(88,1) / 88.0/, TA(88,2) /773.2/, TA(88,3) / 4.80/
DATA TA(89,1) / 89.0/, TA(89,2) /778.0/, TA(89,3) / 4.76/
DATA TA(90,1) / 90.0/, TA(90,2) /782.7/, TA(90,3) / 4.64/
DATA TA(91,1) / 91.0/, TA(91,2) /787.3/, TA(91,3) / 4.59/
DATA TA(92,1) / 92.0/, TA(92,2) /791.9/, TA(92,3) / 4.60/
DATA TA(93,1) / 93.0/, TA(93,2) /796.5/, TA(93,3) / 4.60/
DATA TA(94,1) / 94.0/, TA(94,2) /801.1/, TA(94,3) / 4.60/
DATA TA(95,1) / 95.0/, TA(95,2) /805.7/, TA(95,3) / 4.61/
DATA TA(96,1) / 96.0/, TA(96,2) /810.3/, TA(96,3) / 4.55/
DATA TA(97,1) / 97.0/, TA(97,2) /814.8/, TA(97,3) / 4.49/
DATA TA(98,1) / 98.0/, TA(98,2) /819.3/, TA(98,3) / 4.49/
DATA TA(99,1) / 99.0/, TA(99,2) /823.8/, TA(99,3) / 4.56/
DATA TA(100,1) /100.0/, TA(100,2) /828.4/, TA(100,3) / 4.56/
DATA TA(101,1) /101.0/, TA(101,2) /832.9/, TA(101,3) / 4.50/
DATA TA(102,1) /102.0/, TA(102,2) /837.4/, TA(102,3) / 4.45/
DATA TA(103,1) /103.0/, TA(103,2) /841.8/, TA(103,3) / 4.40/
DATA TA(104,1) /104.0/, TA(104,2) /846.2/, TA(104,3) / 4.40/
DATA TA(105,1) /105.0/, TA(105,2) /850.6/, TA(105,3) / 4.40/

```

C
C

```

ENTRY DTD(CODE,DFLT,DERIV,TRAV,IND,ELAT,SLAT,DTDR)
ELLIP(ALAT)=21.3613*(0.333333-SIN(ALAT*DTDR)**2)
FD(D)=D*0.0006+0.016
CODE=PROG(IND)
C

```

```

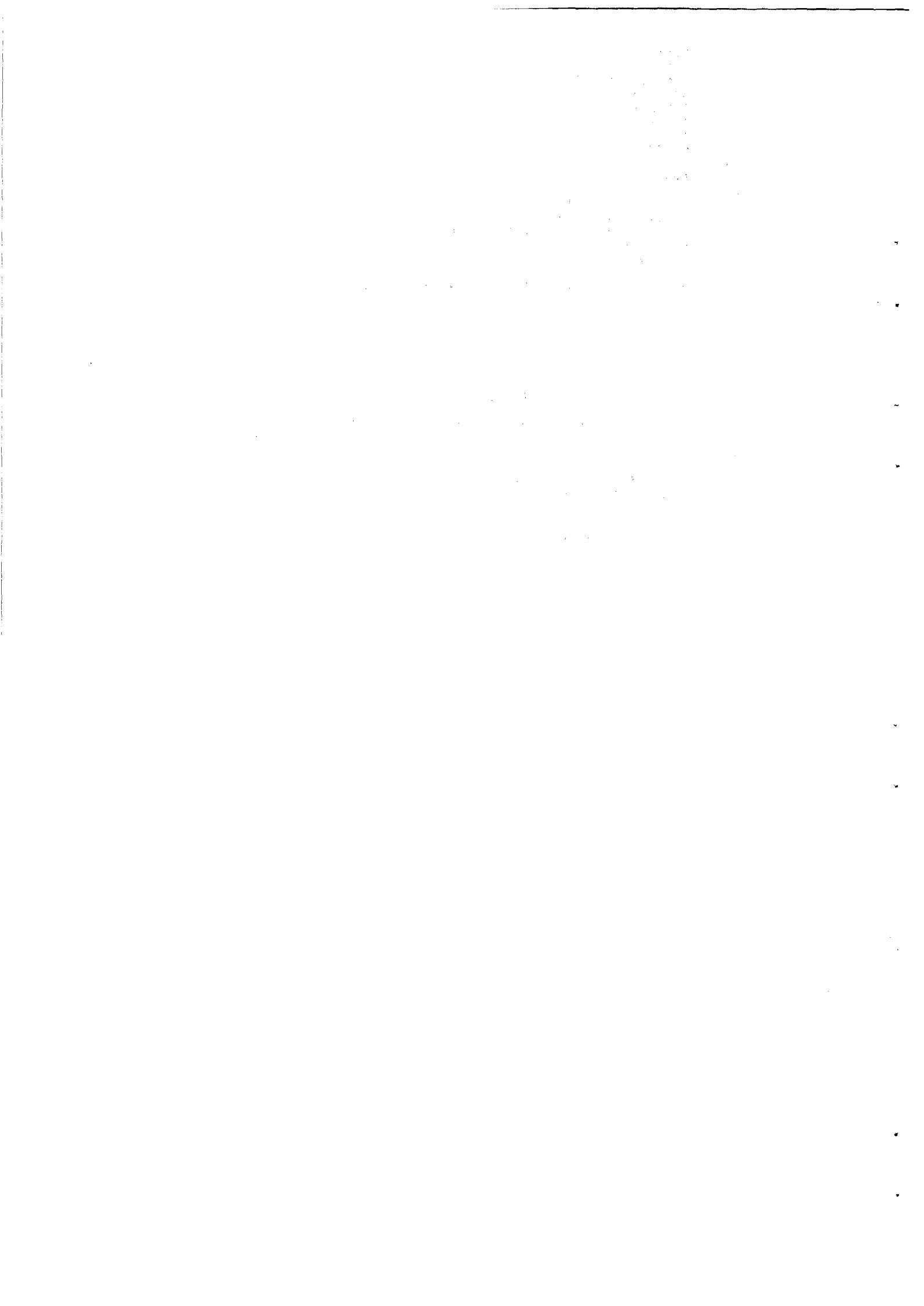
ID=2
I=1
IF(DELT-DIST(1))4,1,1
1 DO 3 I=1,N
IF(DELT-DIST(I))2,3,3
2 I=I-1
ID=1
GO TO 4
3 CONTINUE
I=N-1
C
4 DDIST=DELT-DIST(I)
DERIV=SLOWNS(I)+DDIST*(SLOWNS(I+1)-SLOWNS(I))
TRAV=TT(I)+DDIST*(TT(I+1)-TT(I))
GO TO (5),IO
DERIV=0.
5 GO TO (6),IND
TRAV=TRAV+FD(DELT)*(ELLIP(BLAT)+ELLIP(SLAT))
C
6 RETURN
END

```

```

SUBROUTINE DECODE(ARRAY, CODE, N)
C
C THIS SUBROUTINE TAKES SINGLE ALPHA-NUMERIC CHARACTERS IN ARRAY
C AND DECODES THEM TO FORM N CHARACTERS OF TEXT IN CODE.
C
C DIMENSION ARRAY(4,4),CODE(4)
C LOGICAL*1 ARRAY,CODE
C
DO 4 I=1,N
CODE(I)=ARRAY(1,I)
4 CONTINUE
RETURN
END

```



APPENDIX C

LISTING OF SUBROUTINES UNIQUE TO JED

MAIN
JED
SNORM
ARRTIM
CONF
GAUSS
MSOLVE
WEIGHT

```

C MAIN JED      10 EVENTS + 10 STATIONS
C -----
C GIVES DIMENSION A(31,32),B(32,10),C(10,10)
C ND IS COMPUTED FROM THE FOLLOWING FORMULA INVOLVING N
C ND = (N*3+1)*(N*3+2) + (N*3+2)*N/2 + N*N/2
C
C COMMON N,ND,D(1202)
C DOUBLE PRECISION D
C
C N=10
C ND=1202
C
C CALL JED
C
C CALL FINISH
C STOP
C END

```

C JOINT EPICENTRE DETERMINATION 10/09/73

C THIS PROGRAM COMPUTES STATION CORRECTIONS, EPICENTRES, AND ORIGIN
C TIMES OF SEVERAL EVENTS SIMULTANEOUSLY. IF THE EVENTS OCCUR WITHIN
C A LIMITED REGION (TYPICALLY WITHIN 20 DEGREES), AT LEAST ONE EVENT
C MUST HAVE EPICENTRE AND ORIGIN TIME RESTRAINED OTHERWISE THE
C SOLUTION IS UNSTABLE. IF THE EVENTS ARE WELL SPREAD AND RECORDING
C STATIONS WELL DISTRIBUTED THEN THE SOLUTION WILL BE STABLE WITHOUT
C ANY EPICENTRE BEING RESTRAINED.

C THE PROGRAM BEGINS BY READING IN DATA THAT WILL USUALLY BE
C COMMON TO ALL RUNS, AS FOLLOWS -
C A CARDS WITH STUDENTS T - 44 VALUES
C B CARDS WITH VARIANCE RATIO F(2,NF) - 44 VALUES - WHERE 2 AND
C NF ARE DEGREES OF FREEDOM.

C A LIBRARY OF STATIONS WITH THEIR LATITUDES AND LONGITUDES ARE
C NOW READ IN BY SUBROUTINE TREAD (Q.V.).

C THE SUCCEEDING CARDS MAY DIFFER FOR EACH RUN.

C 1. CARD WITH
C FMT FORMAT FOR READING IN STATION CODES AND ARRIVAL TIMES.
C THE WHOLE CARD CAN BE USED.

C 2. CARD WITH
C NEVENT TOTAL NUMBER OF EVENTS. IF NEVENT.GT.50 THE JOB IS
C REJECTED.

C TTSET THIS IS A CODE FOR SELECTING DIFFERENT TRAVEL TIME
C TABLES. FOUR SETS OF TABLES ARE AVAILABLE. PUNCH -
C JR TO OBTAIN JEFFREYS-BULLEN TABLES
C H61 TO OBTAIN HERRIN 1961 TABLES
C H68 TO OBTAIN HERRIN 1968 TABLES
C DL TO OBTAIN DOUGLAS-LILWALL TABLES
C IMTRX PUNCH 1 TO OBTAIN DETAILED PRINT OUT
C PUNCH 2 TO OBTAIN (MASSIVE) PRINT OUT OF MATRICES.
C OTHERWISE LEAVE BLANK.

C IKON PUNCH 1 TO SUPPRESS CONFIDENCE LIMITS. OTHERWISE
C LEAVE

C IWT PUNCH A DIGIT BETWEEN 2 AND 9 TO APPLY JEFFREYS
C WEIGHTING FOR EACH IWT+1 ITERATIONS AT EACH OF THESE
C ITERATIONS REVISED JEFFREYS PARAMETERS AND VARIANCES ARE COMPUTED.
C AFTER IWT+1 ITERATIONS THE JEFFREYS PARAMETER AND VARIANCE ARE
C HELD AT THE IWT+1 VALUE. IF IWT = 1 WEIGHTING IS APPLIED FOR 10
C ITERATIONS. IF IWT = 0 WEIGHTING IS NOT APPLIED. NOTE THAT THE
C PROGRAM AT PRESENT IS DESIGNED TO RUN FOR 10 ITERATIONS AS A TOTAL.

C FORMAT FOR PUNCHING THIS CARD IS GIVEN IN STATEMENT 4
C THE PROGRAM NOW READS IN TRAVEL TIME TABLES SPECIFIED BY TTSET.

C THIS DATA IS READ IN BY SUBROUTINE TREAD (Q.V.).
C NOW FOLLOWS NEVENT CARDS WITH DATA ON EACH EVENT TO BE PROCESSED.
C THE ITH CARD OF THIS GROUP IS PUNCHED AS FOLLOWS

```

C      EVENT(I)  EVENT NAME -- USF DATE E.G. 29/10/65
C          HR    APPROXIMATE ORIGIN TIME - HOURS
C          MINS APPROXIMATE ORIGIN TIME - MINUTES
C          SECS APPROXIMATE ORIGIN TIME - SECONDS
C          ALAT APPROXIMATE LATITUDE
C              SN  N OR S
C          ALONG APPROXIMATE LONGITUDE
C              EW  E OR W
C          H(I)  DEPTH IN KMS
C              OR  PUNCH RESTRAIN TO RESTRAIN ORIGIN TIME
C          HRES PUNCH RESTRAIN TO RESTRAIN DEPTH
C          IEVIC(I) PUNCH ONE TO RESTRAIN EPICENTRE

```

FORMAT FOR PUNCHING THESE CARDS IS GIVEN IN STATEMENT NUMBER 4

THE NEXT CARD CARRIES A TITLE FOR THE OUTPUT GRAPHS. THE WHOLE CARD MAY BE USED.

THE PROGRAM HAS THE FACILITY FOR READING IN INFORMATION ABOUT THE DATA BEING PROCESSED. THIS INFORMATION IS REPRODUCED ON THE FINAL PRINT OUT.

THERE NOW FOLLOWS UP TO 100 CARDS WITH THIS INFORMATION PUNCHED ON THEM -- THE WHOLE CARD CAN BE USED EXCEPT COLUMNS 1 AND 80. THE FINAL INFORMATION CARD HOWEVER MUST HAVE 1 IN COLUMN 80. FAILURE TO DO THIS WILL RESULT IN SUCCEEDING DATA CARDS BEING READ IN AS COMMENTS

NOW FOLLOWS NEVENT BLOCKS OF ARRIVAL TIME DATA ONE BLOCK FOR EACH EVENT. THE FIRST CARD OF EACH BLOCK IS THE EVENT NAME -- WHICH MUST BE THE SAME AS THE NAME GIVEN IN THE EVENT LIST ABOVE. THE LAST CARD OF EACH BLOCK IS A BLANK. THE REMAINING CARDS IN THE BLOCK HAVE

```

C          ASTN STATION CODE -- ONLY INCLUDE STATIONS SPECIFIED IN THE
C          LIST ABOVE
C          AHPS ARRIVAL TIME AT STATION -- HOURS
C          AMIN ARRIVAL TIME AT STATION -- MINUTES
C          ASECS ARRIVAL TIME AT STATION -- SECONDS

```

A VARIABLE FORMAT IS GIVEN FOR THIS CARD . THIS MUST BE PUNCHED ON FIRST CARD FOLLOWING CARDS CARRYING VARIANCE RATIO F. TO PROCESS SUCCESSIVE BLOCKS OF DATA CARDS 1 ONWARDS (FMT) ARE REPEATED.

CODE EBCDIC (+ =)

SUBROUTINE JED

```

COMMON /JEDS/ N,NO,NSTN,NEVENT,IOT,IDS,NSNE,NS2NE,NS3NE,NS4NE,
1CN,CS,CE,CW,RDATE,RTIME,TTSET,IREL,IFORM,IDEF,IWT,IMTRX,
2EVENT(101),OT(100),H(100),FLAT(101),ELON(101),SN(101),EW(101),
3INDO(100),INDH(100),HOT(100),HH(100),HELAT(101),HELON(101),
4HSN(100),HEW(100),IEVIC(100),AIND(100),
5STN(500),SLAT(500),SLON(500),SCOR(500),ART(500),S(500),PSTN(500),
6)IST(500),AZ(500),X(801),XX(801),LOC(800),EV(800),FV(800)

```

```
COMMON /ATAB/ NTABLE,STA(3000),SLA(3000),SL0(3000),COR(3000)
```

```
COMMON /STAT/ CON(500),
1CX(1900),CY(1900),ST(44),FD(44),T,F,DF,AVSQ,SUMSQ,IKON,NN
```

```
COMMON /GRFF/ TITLE(20), XMAX, XMIN, YMAX, YMIN, INDX, INDY, IND,
1IDOUT, ANSTR1, XLIMIT, YLIMIT, SCALX, SCALY
```

```
COMMON /CONSTS/ PI,DTOR,RTOD,ZKM,FR,GFACT,HUGE,SECDAY,ROUND
```

```
COMMON NX,ND,D(1)
```

```
DIMENSION FMT(10),SFMT(10),AT(1)
EQUIVALENCE (D(1),AT(1))
```

```

REAL*8 TITLF,EVENT,RDATE,RTIME,RESTR,OR,HRES,AEVFNT,FMT,SFNT
DOUBLE PRECISION D,AT,DT,XX,HOT,ART,S,X,SECTM,DF,AVSQ,SUMSQ,EV,FV
INTEGER HR,MINS,AHRS,AMNS

C
DATA SD/4HS /,EN/4HN /,F/4HE /,W/4HW /,BLANK/4H /
1RESTR/8HRESTRAIN/,2SFMT/8H (1X,A4,,8H15X,I2,1,8HX,I2,1X,,8HF4.1) ,6*8H /
C
C
CALL CLOCK(TS)
CALL DATIM(RDATE,RTIME)
C
CN=EN
CS=SD
CE=E
CW=W
TITLE(16)=RDATE
C
READ 7, ST
PRINT 7, ST
READ 7, FD
PRINT 7, FD
7 FORMAT(16F5.2)
C
SET UP CONSTANTS
C
DOUBLE PRECISION DPI,A,B,R,ELLIP
A = 6378.160 DO
ELLIP = 1.00/ 298.25 DO
DPI = 4.00*COS(1.00)
PI=DPI
DTOR=DPI/180.00
RTOD=180.00/DPI
B=A*(1.00-ELLIP)
R=DEXP(((DLOG10(A)+DLOG10(B))/3.00)*DLOG(10.00))
ZKM=R*DPI/180.00
ER=ELLIP*R
GFACT=(B*B)/(A*A)
HUGE = 8**8
SECDAY = 24.*60.*60.
ROUND = 0.5
PRINT 2, A,B,R,ELLIP,ZKM,ER,GFACT,DPI,
1 PI,DTOR,RTOD,HUGE,SECDAY,ROUND
2 FORMAT(1X,E15.10)
C
READ IN STATIONS AND COORDINATES AND FIRST OPTIONS CARD
C
CALL TREAD(BLANK,IMTRX,1)
READ 4, NEVENT,TTSET,IMTRX,IFORM,IDEP,IKON,IWT
IMTRX=IMTRX+1
CALL TREAD(TTSET,IMTRX,2)
GO TO 130
C
C
READ IN OPTIONS CARD AND CHANGE TRAVEL TIMES IF REQUIRED
C
100 READ (5,4,END=31) NEVENT,CODE,IMTRX,IFORM,IDEP,IKON,IWT
IMTRX=IMTRX+1
REWIND 1
C
IF(CODE-BLANK)110,130,110
110 IF(CODE-TTSET)120,130,120
120 CALL TREAD(CODE,IMTRX,2)
TTSET=CODE
C
130 IF((IFORM,NE.0)IFORM=1
IFORM=IFORM+1
IF(IDEP,NE.0)IDEP=1
IDEP=IDEP+1
IF(IKON,NE.0)IKON=1
IKON=IKON+1
IF(IWT.EQ.1)IWT=11
PRINT 1
1 FORMAT(1H1)
PRINT 4, NEVENT,TTSET,IMTRX,IFORM,IDEP,IKON,IWT
4 FORMAT(1X,I4,1X,A4,I2,I3,I3,I3,I3)
IREL=1
NSTN=0
IOT=0
IDS=0
IEXIT=1

```

```

C
      IF(NEVENT.LE.100)GO TO 140
      PRINT 72
      72 FORMAT(//4X,30HJOB REJECTED - TOO MANY EVENTS)
      GO TO 31
C
C      READ EVENT NAME (DATE) ORIGIN TIME LATITUDE AND LONGITUDE
C      DEPTH AND WHETHER DEPTH AND ORIGIN TIME TO BE RESTRAINED
C      CONVERT ORIGIN TIME FROM HOURS MINUTES AND SECONDS TO SECONDS
C      SOUTH LATITUDE AND WEST LONGITUDE ARE CONVERTED TO NEGATIVE
C      LATITUDE IS ALSO CONVERTED TO GEOCENTRIC FROM GEOGRAPHIC
C
14.) DO 66 I=1,NEVENT
      READ 6, EVENT(I),HR,mins,sec,ALAT,SN(I),ALON,EW(I),H(I),OR,HRES,
      1IEPIC(I)
      6 FORMAT(2X,A8,2X,I2,I4,F6.1,F10.4,A1,F10.4,A1,F6.1,2X,A8,2X,A8,I3)
      UT(I)=SECTM(HR,mins,sec)
      HDT(I)=DT(I)
      HH(I)=H(I)
      HSN(I)=SN(I)
      HEW(I)=EW(I)
      ELAT(I)=ABS(ALAT)
      IF(SN(I).EQ.0)ELAT(I)=-ELAT(I)
      HELAT(I)=ELAT(I)
      ELAT(I)=GEOCEN(ELAT(I))
      ELON(I)=ABS(ALON)
      IF(EW(I).EQ.0)ELON(I)=-ELON(I)
      HELON(I)=ELON(I)
      INDO(I)=1
      INDH(I)=1
      IF(OR.EQ.RESTR)INDO(I)=0
      IF(HRES.EQ.RESTR)INDH(I)=0
      IOT=IOT+INDC(I)
      IDS=IDS+INDH(I)
      IF(IEPIC(I).EQ.1)IREL=2
      GO TO (66,70,70),IMTRX
7.0 PRINT 71, EVENT(I),UT(I),H(I),HELAT(I),HELON(I),INDH(I),INDO(I)
71 FORMAT(1X,A8,F12.2,F10.2,F10.2,F10.3,I3,I3)
66 CONTINUE
      HELAT(NEVENT+1)=0.
      HELON(NEVENT+1)=0.

C      SET UP FORMAT OF ARRIVAL TIME DATA
C
      GO TO (80,82),IFORM
80 DO 81 I=1,1C
      FMT(I)=SFMT(I)
81 CONTINUE
      GO TO 83
82 READ (5,5,END=31) FMT
83 PRINT 5, FMT
      5 FORMAT(10A8)

C      SET DIMENSIONS OF A AND B MATRICES AND RESIDUALS MATRIX C
C      IF TOO MANY UNKNOWN (DIMENSIONS TOO SMALL) JOB REJECTED
C      UNKNOWN CAN BE REDUCED BY RESTRAINING DEPTHS
C
      NE=NEVENT
      NF1=IOT+IDS+NE+NE+1
      NF2=NE1+1
      NB=NE1*NE2
      NS=MNU(500,2*(ND-NB)/(NE2+NF1),ND/NE)
      NC=NB+NS*NE2/2
      NA=NC+NS*NE/2
      PRINT 3, NE1,NE2,NE2,NS,NF,NS,NA,NB,NC,ND
      3 FORMAT(//4X,17HUSES DIMENSION A(,I3,1H,,I3,4H),B(,I3,1H,,I3,
      14H),C(,I3,1H,,I3,1H),20X,4I10)
      IF(NS.GE.4)GO TO 150
      IEXIT=2
      PRINT 67
      67 FORMAT(//4X,30HJOB REJECTED - RESTRAIN DEPTHS)
C
C      15. CALL DATIM(RDATE,RTIME)
      PRINT 50, RDATE,RTIME
      50 FORMAT(1H1, 3X,32HMULTIPLE EPICENTRE DETERMINATION,84X,A8/4X,
      132H-----,84X,A8//)
      READ (5,5,END=31) (TITLE(I),I=6,15)
C
C      READ IN COMMENTS - UP TO 100 CARDS
C

```

```

DO 52 I=1,100
READ 53, NC
PRINT 53
53 FORMAT(79H
      ,I1)
IF(NO)52, 52, 54
52 CONTINUE
PRINT 55
55 FORMAT(//4X,59HJOB REJECTED - 1 PUNCH MISSING IN COL.80 OF LAST TI
ITLE CARD)
GO TO 31

C
C   SET MATRIX OF ARRIVAL TIMES TO HUGE
C
54 DO 15 K=1,ND
AT(K)=DBLE(HUGE)
15 CONTINUE

C
C   READ EVENT CARD FOLLOWED BY ARRIVAL TIME DATA IN EVENT ORDER
C
DO 17 I=1,NEVENT
NO=0
READ 18, AEVENT
18 FORMAT(2X,A8)

C
C   FIND OUT WHICH EVENT IT IS
C
DO 19 K=1,NEVENT
IF(AEVENT.NE.EVENT(K))GO TO 19
KEVENT=K
GO TO 20
19 CONTINUE
IEXIT=2
PRINT 68, AEVENT
68 FORMAT(//4X,29HJOB REJECTED - UNKNOWN EVENT ,A8//)
20 PRINT 21, AEVENT
21 FORMAT(//4X,A8//4X,7HSTATION,4X,12HARRIVAL TIME/)

C
C   READ STATION AND ARRIVAL TIME - IF BLANK SWITCH TO NEW EVENT
C
22 READ FMT, ASTN,AHRS,AMNS,ASECS
IF(ASTN.EQ.BLANK)GO TO 17

C
C   FIND OUT WHICH STATION IT IS AND GET STATION COORDINATES FROM
C   LIBRARY LIST CONVERTING LATITUDE TO GEOCENTRIC FROM GEOGRAPHIC
C   CONVERT ARRIVAL TIME IN HOURS MINUTES AND SECONDS TO SECONDS
C
NO=NO+1
PRINT 117, NO,ASTN,AHRS,AMNS,ASECS
117 FORMAT(2X,I3,2X,A4,5X,I2,1X,I2,1X,F4.1)
IF(INSTN.EQ.0)GO TO 32
DO 24 J=1,NSTN
IF(ASTN.NE.STN(J))GO TO 24
CALL ARTTIM(AT,NE,NS,KEVENT,J,SECTM(AHRS,AMNS,ASECS),0)
GO TO 22
24 CONTINUE
IF(INSTN.EQ.NS)GO TO 26
32 DO 25 K=1,NTABLE
IFI(ASTN.NE.STA(K))GO TO 25
NSTN=NSTN+1
STN(NSTN)=STA(K)
SLAT(NSTN)=SLA(K)
SLON(NSTN)=SLO(K)
CALL ARTTIM(AT,NE,NS,KEVENT,NSTN,SECTM(AHRS,AMNS,ASECS),0)
SCOR(NSTN)=COR(K)
GO TO 22
25 CONTINUE
PRINT 69, ASTN
69 FORMAT(//4X,27HREJECTED - UNKNOWN STATION ,A4//)
GO TO 22

C
26 PRINT 73, ASTN
73 FORMAT(//4X,29HREJECTED - TOO MANY STATIONS ,A4//)
GO TO 22
17 CONTINUE

C
C   PRINT TOTAL NUMBER OF STATIONS USED
C   IF AN ERROR OCCURRED IN SETTING UP THE JOB IS TERMINATED
C
PRINT 14, NSTN
14 FORMAT(///4X,31HTOTAL NUMBER OF STATIONS USED =,I4//)
GO TO (30,31),IEXIT
31 RETURN

```

```

C
C      COMPLETE ARRIVAL TIME DATA AND SET A B C MATRICES TO SEND TO SNORM
C
C      30 CALL ARTTIM(AT,NE,NSTN,I,J,O.,IMTRX)
C          CALL SNORM(D(1),D(NB+1),D(NC+1),NE,NE1,NE2,NS)
C
C      COMPUTE TIME FOR JOB
C
C      CALL CLOCK(TF)
C      TS=(TF-TS)*60.
C      PRINT 227, TS
C      227 FORMAT(////22X,20HTIME TAKEN FOR JOB =,F7.2,8H SECONDS)
C      TS=TF
C      GO TO 100
C      END

C
C      SUBROUTINE SNORM(A,B,TRESID,NE,NE1,NE2,NS)
C      DIMENSION A(NE1,NE2),B(NE2,NS),TRESID(NE,NS)
C
C      THE MAIN PURPOSE OF THIS SUBROUTINE IS TO SETUP
C      THE NORMAL EQUATIONS
C
C      COMMON /JEDS/ N,NO,NSTN,NEVENT,IOT,IDS,NSNE,NS2NE,NS3NE,NS4NE,
C      1CN,CS,CE,CW,RDATE,RTIME,TTSET,IREL,IFORM,IDEP,IWT,IMTRX,
C      2EVENT(101),OT(100),H(100),ELAT(101),ELON(101),SN(101),EW(101),
C      3INDO(100),INDH(100),HOT(100),HH(100),HELAT(101),HELO(101),
C      4HSN(100),HEW(100),IEPIC(100),AIND(100),
C      5STN(500),SLAT(500),SLON(500),SCOR(500),ART(500),S(500),PSTN(500),
C      6DIST(500),AZ(500),X(801),XX(801),LOC(800),EV(800),FV(800)
C
C      COMMON /STAT/ COT(100),CH(100),CLAT(100),CLON(100),CAREA(100),
C      1CX(1900),CY(1900),ST(44),FD(44),T,F,DF,AVSQ,SUMSQ,IKON,NN
C
C      COMMON /CONSTS/ PI,DTOR,RTOD,ZKM,ER,GFAC, HUGE, SEC DAY, ROUND
C
C      DIMENSION PHRS(100),PMINS(100),PSECS(100),REG(16)
C      INTEGER PHRS,PMINS,AHRS,AMINS,HHRS,HMINS
C
C      REAL*8 EVENT,RDATE,RTIME,HMEAN
C      DOUBLE PRECISION A,X,ARG,DT,DH,RESID,HOLD,DCS,DSN,OT,W,SUMSQ,AVSQ,
C      1WSUMSQ,WAVSQ,DF,ART,S,XX,SIV,SQEP,HOT,EV,FV,EPS
C
C      DATA HMEAN/8H MEAN /,STAR/4H* /,BLANK/4H /

C
C      SET CONSTANTS
C
C      ITER=0
C      HOLD=0.00
C      CAREAM=0.
C      N1=NEVENT+1
C      N2=NEVENT*2
C      N4=(NEVENT-1)/4+1
C      N9=(NEVENT-1)/9+1
C      EVENT(N1)=HMEAN
C      SIG=0.
C      W=1.00

C
C      DO 774 J=1,NS
C      DO 773 I=1,NE
C          TRESID(I,J)=HUGE
C      773 CONTINUE
C      774 CONTINUE
C      DO 777 I=1,16
C          REG(I)=BLANK
C      777 CONTINUE
C      IF(IWT.LE.0)GO TO 999

C
C      SET UP RESIDUALS FIRST TIME ROUND IF WEIGHTING REQUIRED
C
C      DO 772 I=1,NEVENT
C          READ (1) (ART(J),J=1,NSTN)
C          DO 771 J=1,NSTN
C              IF(ART(J).GE.DBLE(HUGE))GO TO 771
C              CALL BAZDEL(ELAT(I),ELON(I),SLAT(J),SLON(J),BB,AZ(J),DIST(J),DTOR)
C              CALL DTDD(H(I),DIST(J),SCOR(J),HEIGHT(ELAT(I)),HEIGHT(SLAT(J)),
C              1DERIV,DDEP,TT)
C              TRESID(I,J)=ART(J)-OT(I)-DBLE(TT)

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771 CONTINUE
772 CONTINUE
REWIND 1
C
C BEGIN ITERATION LOOP WITH ITER AS THE ITERATION COUNT
C COUNT UP NUMBER OF UNRESTRAINED DEPTHS AND ORIGIN TIMES
C
999 ITER=ITER+1
DF=0.0D0
SUMSQ=0.0D0
WSUMSQ=0.0D0
IRES=0
C
IO=0
IH=IO+IOT
ILA=IH+IDS
IL0=ILA+NEVENT
N=IL0+NEVENT
N=N+1
IF(IREL.EQ.2)N=N-1
NO=N+1
NSNF=NSTN+NEVENT
NS2NE=NSNE+NEVENT
NS3NE=NS2NF+NEVENT
NS4NE=NS3NE+NEVENT
NORE=NS4NE+1
NJ=N+NSTN
NEP=0
C
C IF WEIGHTING REQUIRED FIND JEFFERYS PARAMETER MEAN AND VARIANCE
C OF RESIDUALS SO THAT WEIGHTS CAN BE COMPUTED
C
IF(IWT.NE.0.AND.ITER.LT.IWT)
1CALL WEIGHT(TRESID,NEVENT,NSTN,N,SIG,EMU,SUMW,WMEAN,IMTRX)
C
C XX CONTAINS BOTH RESTRAINED AND UNRESTRAINED PARAMETERS
C X CONTAINS COMPUTED CORRECTIONS TO UNRESTRAINED PARAMETERS
C LOC IS AN ARRAY OF INDICES SUCH THAT THE ITH ELEMENT OF THE X
C ARRAY IS THE CORRECTION TO PARAMETER IN POSITION LOC(I) IN XX
C
IO=NSTN
IH=IO+IOT
DO 40 J=1,NSTN
XX(J)=SCOR(J)
LOC(J)=J
40 CONTINUE
DO 48 I=1,NEVENT
I1=I+NSTN
I2=I+NSNE
I3=I+NS2NE
I4=I+NS3NE
XX(I1)=DT(I)
XX(I2)=H(I)
XX(I3)=ELAT(I)
XX(I4)=ELON(I)
IF(INDO(I).EQ.0)GO TO 41
IO=IO+1
LOC(IO)=I1
41 IF(INDH(I).EQ.0)GO TO 42
IH=IH+1
LOC(IH)=I2
42 ILAI=ILA+I1
LOC(ILAI)=I3
IL0I=IL0+I1
LOC(IL0I)=I4
48 CONTINUE
XX(NORE)=0.0D0
LOC(NJ)=NORE
C
C ZERO MATRIX OF NORMAL EQUATIONS
C
DO 43 I=1,N
DO 44 J=1,NO
A(I,J)=0.0D0
44 CONTINUE
43 CONTINUE
DO 45 J=1,NSTN
S(J)=0.0D0
PSTN(J)=0.0
DO 46 I=1,NO
B(I,J)=0.0
46 CONTINUE
45 CONTINUE

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```

C      SET UP NORMAL EQUATIONS
C
I0=0
IH=I0+IOT
DO 1 I=1,NEVENT
IB=1
IBB=1
ILAI=ILA+I
ILOI=ILO+I
IF(INDO(I).EQ.0)GO TO 2
IB=2
IO=I0+1
2 IF(INDH(I).EQ.0)GO TO 3
IBB=2
IH=IH+1
3 READ (1) (ART(J),J=1,NSTN)
DO 4 J=1,NSTN
IF(ART(J).GE.DBLE(HUGE))GO TO 4
PSTN(J)=PSTN(J)+1.0
CALL BAZDEL(ELAT(I),ELON(I),SLAT(J),SLON(J),BB,AZ(J),DIST(J),DTOR)
CALL DTDD(H(I),DIST(J),SCOR(J),HEIGHT(ELAT(I)),HEIGHT(SLAT(J)),
1DERIV,DDEP,TT)
ARG=DBLE(AZ(J)*DTOR)
RESID=ART(J)-DT(I)-DBLE(TT)
TRESID(I,J)=RESID
IF(DIST(J).GE.110.)GO TO 4
SUMSQ=SUMSQ+RESID*RESID
DT=-DBLE(DERIV)
DSN=DT*DSIN(ARG)
DCS=DT*DCOS(ARG)
DH=DBLE(DDEP)
DF=DF+1.00
IF(IWT.EQ.0)GO TO 24
C      COMPUTE WEIGHT
C
C1=(TRESID(I,J)-WMEAN)**2
C2=2.0*SIG*SIG
C3=C1/C2
IF(C3.GT.100.0)C3=100.0
W=1.00/(1.00+DBLE(EMU*EXP(C3)))
C      SET UP ELEMENTS OF MATRIX OF NORMAL EQUATIONS
C
24 WSUMSQ=WSUMSQ+RESID*RESID*W
S(J)=S(J)+W
B(NO,J)=B(NO,J)+RESID*W
GO TO(20,21),IB
C
21 B(IO,J)=B(IO,J)+W
A(IO,IO)=A(IO,IO)+W
A(IO,ILAI)=A(IO,ILAI)+DCS*W
A(IO,ILOI)=A(IO,ILOI)+DSN*W
A(IO,NO)=A(IO,NO)+RESID*W
20 GO TO(22,23),IBB
C
23 B(IH,J)=B(IH,J)+DH*W
A(IH,IH)=A(IH,IH)+DH*DHS*W
A(IH,ILAI)=A(IH,ILAI)+DH*DCS*W
A(IH,ILOI)=A(IH,ILOI)+DH*DSN*W
A(IH,NO)=A(IH,NO)+DH*RESID*W
GO TO(22,25),IB
25 A(IO,IH)=A(IO,IH)+DH*W
C
22 B(ILAI,J)=B(ILAI,J)+DCS*W
B(ILOI,J)=B(ILOI,J)+DSN*W
A(ILAI,ILAI)=A(ILAI,ILAI)+DCS*DCS*W
A(ILAI,ILOI)=A(ILAI,ILOI)+DCS*DSN*W
A(ILOI,ILOI)=A(ILOI,ILOI)+DSN*DSN*W
A(ILAI,NO)=A(ILAI,NO)+DCS*RESID*W
A(ILOI,NO)=A(ILOI,NO)+DSN*RESID*W
4 CONTINUE
IF(IEPIC(I).EQ.0)GO TO 1
A(ILAI,ILAI)=A(ILAI,ILAI)+DBLE(HUGE)
A(ILOI,ILOI)=A(ILOI,ILOI)+DBLE(HUGE)
A(ILAI,NO)=0.00
A(ILOI,NO)=0.00
IRES=IRES+2

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1 CONTINUE
REWIND 1
GO TO (6,30),IREL
6 DO 7 J=1,NSTN
B(N,J)=B(N,J)+1.
7 CONTINUE
C
30 DO 26 I=1,N
DO 27 J=I,N
A(J,I)=A(I,J)
27 CONTINUE
26 CONTINUE
C
GO TO (32,32,31),IMTRX
31 PRINT 667, (DIST(K),K=1,NSTN)
PRINT 667, (AZ(K),K=1,NSTN)
32 IF(ITER.GT.1)GO TO 1850
C
C PRINT OUT RESIDUALS BEFORE FIRST ITERATION
C
DO 1003 IC=1,N9
NLOW=(IC-1)*9+1
NHY=NLOW+8
IF(NHY.GT.NEVENT)NHY=NEVENT
PRINT 54, RDATE,RTIME,(EVENT(I),I=NLOW,NHY)
PRINT 55
C
DO 1004 J=1,NSTN
DO 1005 I=NLOW,NHY
IF(TRESID(I,J).LT.HUGE)GO TO 1008
AIND(I)=BLANK
COT(I)=0.
GO TO 1005
1008 AIND(I)=STAR
COT(I)=TRESID(I,J)
1005 CONTINUE
PRINT 56, J,STN(J),(COT(I),AIND(I),I=NLOW,NHY)
1004 CONTINUE
1003 CONTINUE
C
C PRINT OUT STATION - EVENT PAIRS FOR WHICH RESIDUALS ARE GREATER
C THAN 100 SECONDS
C
1850 DO 1852 I=1,NEVENT
DO 1851 J=1,NSTN
IF(TRESID(I,J).GE.HUGE)GO TO 1851
IF(ABS(TRESID(I,J)).GT.100.0)PRINT 1854, STN(J),EVENT(I)
1854 FORMAT(4X,21HRESIDUAL FROM STATION,1X,A4,1X,BHTO EVENT,1X,A8,1X,
124HGREATERTHAN 100 SECONDS)
1851 CONTINUE
1852 CONTINUE
C
1002 GO TO (668,668,669),IMTRX
669 DO 666 I=1,N
PRINT 667, (A(I,J),J=1,NO)
667 FORMAT(1X,10F12.3)
666 CONTINUE
DO 671 J=1,NSTN
PRINT 667, (TRESID(I,J),I=1,NEVENT)
671 CONTINUE
PRINT 667, (XX(I),I=1,NORE)
PRINT 677, (LOC(K),K=1,NJ)
677 FORMAT(1X,4CI3)
C
C COMPUTE NUMBER OF DEGREES OF FREEDOM DF
C
668 NU=N+NSTN-IRES
DF=DF-DFLOAT(NU)
IF(IREL-1)404,672,404
672 DF=DF+2.D0
NU=NU-2
C
C FIND APPROPRIATE VALUES OF STUDENT'S T AND VARIANCE RATIO
C F FOR 95 PERCENT POINTS AND DF DEGREES OF FREEDOM
C
404 MDF=DF
IF(MDF.LE.30)GO TO 405
IF(MDF.GT.300)GO TO 406
MDF=(MDF+5)/20+29
GO TO 405

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406 MDF=44
405 T=ST(MDF)
F=FD(MDF)
MDF=DF
C
EPS=DABS(HOLD)*1.0D-4
HOLD=HOLD-WSUMSQ
AVSQ=SUMSQ/DF
WAVSQ=WSUMSQ/DF
SD=DSQRT(AVSQ)
WSD=DSQRT(WAVSQ)
IC=ITER-1
PRINT 1001, IC,SUMSQ
1001 FORMAT(//4X,31HSUM OF SQUARED RESIDUALS AFTER ,I2,13H ITERATIONS =
1,F15.5)
IF(IWT.NE.0) PRINT 1006, WSUMSQ
1006 FORMAT(//15X,35HWEIGHTED SUM OF SQUARED RESIDUALS =,F15.5)
1000 IF(DABS(HOLD).LT.EPS.OR.ITER.GT.10)GO TO 916
HOLD=WSUMSQ
C
C SOLVE MATRIX TO OBTAIN CORRECTIONS (X) TO PREVIOUS ESTIMATES
C
CALL MSOLVE(1,A,B,NE1,NE2,NS)
C
C CORRECT LONGITUDE CORRECTIONS FOR DISTANCE FROM EQUATOR
C
DO 28 I=1,NEVENT
ILOI=ILO+NSTN+I
X(ILOI)=X(ILOI)/DCOS(DBLE(ELAT(I)*DTOR))
28 CONTINUE
C
C ADD CORRECTIONS (X) TO TRIAL ESTIMATES (XX)
C
DO 29 J=1,NJ
I=LOC(J)
XX(I)=XX(I)+X(J)
29 CONTINUE
C
C REVISE EPICENTRE ORIGIN TIME AND DEPTH OF ALL EVENTS
C
DO 60 J=1,NSTN
SCOR(J)=XX(J)
60 CONTINUE
DO 61 I=1,NEVENT
I1=I+NSTN
I2=I+NSNE
I3=I+NS2NE
I4=I+NS3NE
OT(I)=XX(I1)
H(I)=XX(I2)
ELAT(I)=XX(I3)
ELON(I)=XX(I4)
61 CONTINUE
C
C COMPUTE MEAN LATITUDE AND LONGITUDE OF GROUP OF EVENTS
C
CALL AMAX(ELAT,NEVENT,EMA)
CALL AMAX(ELON,NEVENT,EMO)
CALL AMIN(ELAT,NEVENT,EMAN)
CALL AMIN(ELON,NEVENT,EMON)
ELAT(N1)=(EMA-EMAN)/2.+EMAN
ELON(N1)=(EMO-EMON)/2.+EMON
IF((EMO-EMON).GT.180.)ELON(N1)=ELON(N1)-SIGN(180.,ELON(N1))
DO 62 J=1,NSTN
CALL BAZDEL(ELAT(N1),ELON(N1),SLAT(J),SLON(J),BB,AZ(J),DIST(J),
1DTOR)
62 CONTINUE
C
GO TO (999,680,680),IMTRX
680 PRINT 681, (EVENT(I),OT(I),H(I),ELAT(I),ELON(I),I=1,N1)
681 FORMAT(1H1/(4X,A8,F12.2,F10.2,F10.3,F10.3))
PRINT 682, (STN(J),SCOR(J),J=1,NSTN)
682 FORMAT(1D(3X,A4,F6.3))
GO TO (999,999,683),IMTRX
683 PRINT 667, (DIST(K),K=1,NEVENT)
PRINT 667, (AZ(K),K=1,NEVENT)
GO TO 999
C
C ITERATIONS NOW COMPLETE AND PREPARE RESULTS FOR PRINTING OUT
C
916 ITER=ITER-1
DO 160 K=1,NS4NE

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X(K)=0.00
XX(K)=0.00
160 CONTINUE
GO TO(150,151),IKON
152 HOLD=AVSQ
IF(IWT.NE.0)AVSQ=WAVSQ
C
C COMPUTE CONFIDENCE LIMITS AND CONFIDENCE ELLIPSES
C
CALL CONF(ILA,ILO,A,B,NE1,NE2,NS)
AVSQ=HOLD
C
C PRINT OUT INITIAL ESTIMATES AND REVISED ESTIMATES OF EPICENTRES
C ETC AND CONFIDENCE LIMITS
C
151 PRINT 158, ITER,RDATE,RTIME
158 FORMAT(1H1, 3X,14HRESULTS AFTER ,I2,1X,10HITERATIONS,
189X,A8/4X,27H-----,89X,A8//31X,5HEVENT,
26X,11HORIGIN TIME,6X,10HDEPTH (KM),6X,8HLATITUDE,5X,9HLONGITUDE)
C
C COMPUTE EPICENTRE SHIFT BETWEEN INITIAL AND REVISED ESTIMATES BY
C STANDARD SPHERICAL TRIG METHODS
C
DO 920 I=1,N1
CALL BAZDEL(GEOCEN(HELAT(I)),HELON(I),ELAT(I),ELON(I),
188,AZZ,SHIFT,DTOR)
ELAT(I)=GEOGRF(ELAT(I))
SN(I)=CN
IF(ELAT(I).LT.0.0)SN(I)=CS
ELAT(I)=ABS(ELAT(I))
EW(I)=CE
IF(ELON(I).LT.0.0)EW(I)=CW
ELON(I)=ABS(ELON(I))
IF(I.GT.NEVENT)GO TO 923
HELAT(I)=ABS(HELAT(I))
HELON(I)=ABS(HELON(I))
K=I+NEVENT
X(I)=ELAT(I)-HELAT(I)
X(K)=ELON(I)-HELON(I)
HOHO=BLANK
HIHI=BLANK
CALL HRTM(OT(I),AHRS,AMINS,ASECS)
CALL HRTM(HOT(I),HHRS,HMINS,HSECS)
IF(INDO(I).EQ.0)HOHO=STAR
IF(INDH(I).EQ.0)HIHI=STAR
PRINT 921, EVENT(I),HHRS,HMINS,HSECS,HH(I),
1HELAT(I),HSN(I),HELON(I),HEW(I)
921 FORMAT(///8X,18HORIGINAL EPICENTRE,4X,A8,3X,2I3,F6.2,
16X,F8.3,6X,F8.3,1X,A1,4X,F8.3,1X,A1)
PRINT 922, AHRS, AMINS, ASECS, HOHO, HIHI,
IELAT(I),SN(I),ELON(I),EW(I)
922 FORMAT(4X,22HRECALCULATED EPICENTRE,15X,2I3,F6.2,
1A1,5X,F8.3,A1,5X,F8.3,1X,A1,4X,F8.3,1X,A1)
IF(IEPIC(I).NE.0)GO TO 2055
C
C CONVERT SHIFT IN EPICENTRE TO KILOMETRES AND IF LESS THAN 10 KM
C RECOMPUTE BY PYTHAGORAS TO REDUCE ROUNDING ERROR
C
SHIFT=SHIFT*ZKM
IF(SHIFT-10.)928,2050,2050
928 D1=X(I)*ZKM
D2=X(K)*COS(ELAT(I)*DTOR)*ZKM
SHIFT=SQRT(D2*D2+D1*D1)
AZZ=ATAN2(D2,D1)
IF(AZZ.LT.0.0)AZZ=AZZ+2.*PI
AZZ=AZZ*RTOD
2050 PRINT 2051, SHIFT,AZZ
2051 FORMAT(17X,17HEPICENTRE SHIFTED,F9.3,14H KM AZIMUTH,F7.2,
15H DEGS)
NEP=NEP+2
GO TO 2054
2054 PRINT 2052
2052 FORMAT(17X,20HEPICENTRE RESTRAINED)
2054 PHRS(I)=AHRS
PMINS(I)=AMINS
PSECS(I)=ASECS
920 CONTINUE
C
C LOOKUP REGION AND PRINT MEAN EPICENTRE AND TRAVEL TIME CODE

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923 CALL LOOKUP(ELAT(N1),SN(N1),ELON(N1),EW(N1),IGREG,ISREG,REG,2)
      PRINT 924, (REG(I),I=1,8),ELAT(N1),SN(N1),ELON(N1),EW(N1),
      1           (REG(I),I=9,16),TTSET
924 FORMAT(///12X,14HMEAN EPICENTRE,4X,8A4,7X,F12.3,1X,A1,F12.3,1X,A1
1/30X,8A4//4X,23H* RESTRAINED PARAMETERS
2           //4X,A4,17HTRAVEL TIMES USED)
C
      PRINT 925, RDATE,RTIME,(J,STN(J),SCOR(J),XX(J),DIST(J),AZ(J),
      1           PSTN(J),J=1,NSTN)
925 FORMAT(1H1, 3X,30HSTATION CORRECTIONS (SECONDS),86X,A8/
14X,30H-----,6X,13HMEAN DISTANCE,6X,
212HMEAN AZIMUTH,6X,15HNO. OF READINGS,28X,A8//,
3(2X,I3,2X,A4,F10.3,6H +OR-,F7.3,6X,F10.3,10X,F8.2,10X,F6.0))
      PUNCH 926, (STN(J),SCOR(J),J=1,NSTN)
926 FORMAT(1X,A4,60X,1HC,F6.3)
      GO TO (152,153),IKON
153 PRINT 154
154 FORMAT(///4X,30HCONFIDENCE LIMITS NOT COMPUTED)
      GO TO 157
152 PRINT 156, RDATE,RTIME
156 FORMAT(1H1, 3X,42H95 PERCENT CONFIDENCE LIMITS (KILOMETRES),74X,
1A8/4X,42H-----,74X,A8//)
C
      DO 161 IC=1,N4
      NLOW=(IC-1)*4+1
      NHY=NLOW+3
      IF(NHY.GT.NEVENT)NHY=NEVENT
      PRINT 162, (EVENT(I),I=NLOW,NHY)
      PRINT 163, (ELAT(I),SN(I),CLAT(I),I=NLOW,NHY)
      PRINT 164, (ELON(I),EW(I),CLON(I),I=NLOW,NHY)
      PRINT 165, (H(I),CH(I),I=NLOW,NHY)
      PRINT 166, (PHRS(I),PMINS(I),PSECS(I),COT(I),I=NLOW,NHY)
      PRINT 167, (CAREA(I),I=NLOW,NHY)
      PRINT 168
      168 FORMAT(20X,A8,21X,A8,21X,A8,21X,A8)
      163 FORMAT(/1X,12H LATITUDE,3X,4(F10.3,1X,A1,6H +OR-,F9.3,2X))
      164 FORMAT(/1X,12H LONGITUDE,3X,4(F10.3,1X,A1,6H +OR-,F9.3,2X))
      165 FORMAT(/1X,12H DEPTH (KM),3X,4(F10.3,2X, 6H +OR-,F9.3,2X))
      166 FORMAT(/1X,12H ORIGIN TIME, 4(I6,I3,F6.2, 6H +OR-,F6.2,2H S))
      167 FORMAT(/1X,13HAREA OF CONF.,2X,4(F12.2,17X))
      168 FORMAT(1X,13HREGION SQ.KM.//)
      161 CONTINUE
C
C     PRINT RESIDUALS AND WEIGHTED RESIDUALS WHEN REQUIRED
C
      157 NORE=1
      155 DO 819 IC=1,N9
      NLOW=(IC-1)*9+1
      NHY=NLOW+8
      IF(NHY.GT.NEVENT)NHY=NEVENT
      GO TO (182,183),NORE
      182 PRINT 54, RDATE,RTIME,(EVENT(I),I=NLOW,NHY)
      54 FORMAT(1H1, 3X,18HTABLE OF RESIDUALS,98X,A8/4X,18H-----
1--,98X,A8//4X,8HSTATION ,9(5X,A8))
      PRINT 55
      55 FORMAT(1X)
      GO TO 184
      183 PRINT 58, RDATE,RTIME,(EVENT(I),I=NLOW,NHY)
      58 FORMAT(1H1, 3X,27HTABLE OF WEIGHTED RESIDUALS,89X,A8/4X,27H-----
1-----,89X,A8//4X,8HSTATION ,9(5X,A8))
      PRINT 55
      184 DO 57 J=1,NSTN
      DO 65 I=NLOW,NHY
      IF(TRESID(I,J).LT.HUGE)GO TO 66
      AIND(I)=BLANK
      COT(I)=0.
      GO TO 65
      66 GO TO (64,67),NORE
      67 C1=(TRESID(I,J)-WMEAN)**2
      C2=2.0*SIG*SIG
      C3=C1/C2
      IF(C3.GT.100.0)C3=100.0
      W=1.00/(1.00+DBLE(EMU*EXP(C3)))
      TRESID(I,J)=TRESID(I,J)*DSQRT(W)
      64 AIND(I)=STAR
      COT(I)=TRESID(I,J)
      65 CONTINUE
      PRINT 56, J,STN(J),(COT(I),AIND(I),I=NLOW,NHY)
      56 FORMAT(2X,I3,2X,A4,1X,9(F12.4,A1))
      57 CONTINUE
      819 CONTINUE
      NORE=NORE+1
      IF(NORE.EQ.2.AND.IWT.NE.0) GO TO 155
      GO TO (816,817),IKON

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C
C      COMPUTE SUM OF SQUARES DUE TO EPICENTRE SHIFTS
C
816 DO 71 J=1,N2
    IL0I=ILA+J
    DO 70 I=1,N2
        ILAI=ILA+I
        A(I,J)=A(ILAI,IL0I)
70 CONTINUE
71 CONTINUE
    CALL SMATRX(A,ART,N2,NE1)
    DO 73 J=1,N2
        SIV=0.D0
        DO 72 I=1,N2
            SIV=SIV+A(I,J)*X(I)
72 CONTINUE
    XX(J)=SIV
73 CONTINUE
    SQEP=0.D0
    DO 74 I=1,N2
        SQEP=SQEP+X(I)*XX(I)
74 CONTINUE
    VAREP=SQEP/DFLOAT(NEP)
    IF(IREL.FQ.2) GO TO 817
C
C      COMPUTE AREA OF JOINT CONFIDENCE ELLIPSE FOR MEAN EVENT
C
    D1=0.D0
    D2=0.D0
    D3=0.D0
    DO 76 K=1,NEVENT
        I2=K+NEVENT
        DO 75 I=1,NEVENT
            I1=I+NEVENT
            D1=D1+A(I,K)
            D2=D2+A(I,I2)
            D3=D3+A(I1,I2)
75 CONTINUE
76 CONTINUE
    CSQU=AVSQ*DFLOAT(N2)
    IF(IWT.NF.0)CSQU=WAVSQ*DFLOAT(N2)
    IC=NEVENT*NN
    CALL AREA(NN,CX(IC+1),CY(IC+1),D1,D2,D3,CSQU,CAREAM,2)
    CELA=COS(FLAT(N1)*DTOR)
    DO 77 K=1,NN
        I=IC+K
        CX(I)=CX(I)*CELA*ZKM
        CY(I)=CY(I)*ZKM
77 CONTINUE
    CARFAM=CAREAM*CELA*ZKM*ZKM
    NEVENT=NEVENT+1
C
C      PRINT FINAL TABLE
C
817 PRINT 818, RDATE,RTIME,SUMSQ,AVSQ,SD,MDF,NU,T,F
818 FORMAT(1H1, 3X,36HSTATISTICAL AND OTHER VARIABLES USED,80X,A8/
14X,36H-----,80X,A8//)
216X,26HSUM OF SQUARED RESIDUALS =,F15.5// 
316X,26HAVERAGE SQUARED RESIDUAL =,F15.5// 
422X,20HSTANDARD DEVIATION =,F15.5// 
512X,30HNUMBER OF DEGREES OF FREEDOM =,I10// 
622X,20HNUMBER OF UNKNOWNS =,I10// 
730X,12HSTUDENTS T =,F10.2// 
824X,18HVARIANCE RATIO F =,F10.2/// 
169 IF(IWT.NE.0)PRINT 169, WSUMSQ,WAVSQ,WSD
169 FORMAT(//7X,35HWEIGHTED SUM OF SQUARED RESIDUALS =,F15.5// 
17X,35HWEIGHTED AVERAGE SQUARED RESIDUAL =,F15.5// 
213X,29HWEIGHTED STANDARD DEVIATION =,F15.5/// 
17 IF(IKON.EQ.1)PRINT 79, SQEP,VAREP,NEP,CAREAM,N2,MDF
79 FORMAT(//2X,40HSUM OF SQUARES DUE TO EPICENTRE SHIFTS =,F15.5// 
18X,34HVARINACE DUE TO EPICENTRE SHIFTS =,F15.5// 
229X,13HNUMBER USED =,I10/// 
342H AREA OF CONFIDENCE REGION ON MEAN EVENT =,F12.2,7H * F (, 
414,1H,,I5,11H ) SQ.KM.)
C
C      GRAPH CONFIDENCE ELLIPSES IF COMPUTED
C
    GO TO(100,911),IKON
100 CALL GRAPH(EVENT,NEVENT,CX,CY,NN)
911 RETURN
END

```

```

SUBROUTINE ARTTIM(AT,NE,NS,I,J,TIME,IMTRX)
C
C THIS LITTLE SUBROUTINE IS IMPORTANT FOR USING THE VARIABLE
C DIMENSION TECHNIQUE.
C
C IN THE JED PROGRAM THE ARRIVAL TIME MATRIX AT IS STORED AS A
C LINEAR ARRAY. THIS SUBROUTINE ENABLES THE MATRIX TO BE FORMED
C FOR ONLY THE NUMBER OF EVENTS AND STATIONS USED. HENCE SPACE
C IS SAVED BECAUSE THE MAXIMUM DIMENSIONS DO NOT HAVE TO BE GIVEN.
C
C WITH IMTRX=0 EACH SINGLE ARRIVAL TIME READING IS STORED
C IN THE APPROPRIATE (I,J) POSITION IN THE MATRIX AT.
C
C WITH IMTRX=1,2,3 IT ASSUMES THAT ALL DATA HAS BEEN SETUP.
C THE MATRIX IS TRANSFERRED TO DISK STATION BY STATION.
C WITH IMTRX=3 IT ALSO PRINTS OUT THE COMPLETE MATRIX.
C
C
C DIMENSION AT(NE,NS)
C DOUBLE PRECISION AT,TIME
C
C
1 IF(IMTRX)1,1,2
1 AT(I,J)=TIME
GO TO 6
C
2 DO 5 I=1,NE
WRITE (1) (AT(I,J),J=1,NS)
GO TO 5,5,3),IMTRX
3 PRINT 4, (AT(I,J),J=1,NS)
4 FORMAT(1X,10F12.3)
5 CONTINUE
REWIND 1
C
6 RETURN
END

```

```

SUBROUTINE CONF(ILA,ILO,A,B,NE1,NE2,NS)
DIMENSION A(NE1,NE2),B(NE2,NS)
C
C
COMMON /JEDS/ N,NO,NSTN,NEVENT,OT,IDS,NSNE,NS2NE,NS3NE,NS4NE,
1CN,CS,CE,CW,RDATE,RTIME,TTSET,IREL,IFORM,IDEPE,IWT,IMTRX,
2EVENT(101),OT(100),H(100),ELAT(101),ELON(101),SN(101),EW(101),
3INDO(100),INDH(100),HOT(100),HH(100),HELAT(101),HELO(101),
4HSN(100),HEW(100),IEPIC(100),AIND(100),
5STN(500),SLAT(500),SLON(500),SCOR(500),ART(500),S(500),PSTN(500),
6DIST(500),AZ(500),X(801),XX(801),LOC(800),EV(800),FV(800)
C
COMMON /STAT/ COT(100),CH(100),CLAT(100),CLON(100),CAREA(100),
1CX(1900),CY(1900),ST(44),FD(44),T,F,DF,AVSQ,SUMSQ,IKON,NN
C
COMMON /CONSTS/ PI,DTDR,RTOD,ZKM
C
RFAL*8 EVENT,RDATE,RTIME
DOUBLE PRECISION A,X,OT,XX,HOT,ART,S,DF,AVSQ,SUMSQ,EV,FV,P
C
C FORM INVERSE OF A
C
CALL MSOLVE(2,A,B,NE1,NE2,NS)
CALL SMATRX(A,X,N,NE1)
C
C FROM DIAGONAL ELEMENTS OF THE INVERSE OF A COMPUTE CONFIDENCE
C LIMITS ON ALL UNKNOWNNS EXCEPT STATION CORRECTIONS
C
DO 4 I=1,N
K=I+NSTN
J=LOC(K)
P=AVSQ*A(I,I)
XX(J)=T*DSIGN(DSQRT(DABS(P)),P)
4 CONTINUE
C
C FORM INVERSE OF DIAGONAL ELEMENTS EQUIVALENT TO S MATRIX OF
C NORMAL EQUATIONS AND FROM THESE INVERSE ELEMENTS FIND CONFIDENCE
C LIMITS ON STATION CORRECTIONS
C

```

```

      DO 100 J=1,NSTN
      DO 101 I=1,N
      EV(I)=B(I,J)*S(J)
101  CONTINUE
      DO 102 I=1,N
      FV(I)=0.0D0
      DO 103 K=1,N
      FV(I)=FV(I)+EV(K)*A(I,K)
103  CONTINUE
102  CONTINUE
      XX(J)=S(J)
      DO 104 I=1,N
      XX(J)=XX(J)+FV(I)*EV(I)
104  CONTINUE
      P=AVSQ*XX(J)
      XX(J)=T*DSIGN(DSQRT(DABS(P)),P)
105  CONTINUE
C
C   LOAD CONFIDENCE LIMITS INTO APPROPRIATE ARRAYS READY FOR PRINTING
C
3    DO 5 I=1,NEVENT
      I1=I+NSTN
      I2=I+NSNF
      I3=I+NS2NE
      I4=I+NS3NE
      COT(I)=XX(I1)
      CH(I)=XX(I2)
      CLAT(I)=XX(I3)
      CLON(I)=XX(I4)
5    CONTINUE
      CSQU=2.0D0*AVSQ*F
C
C   PICK OUT APPROPRIATE ELEMENTS OF THE INVERSE MATRIX TO ALLOW
C   CONFIDENCE ELLIPSES TO BE COMPUTED FOR EACH OF THE EVENTS
C
      NN=19
      DO 10 I=1,NEVENT
      I1=(I-1)*NN
      I2=ILA+I
      I3=IL0+I
      A22=A(I2,I2)
      A23=A(I2,I3)
      A33=A(I3,I3)
      CALL AREA(NN,CX(I1+1),CY(I1+1),A22,A23,A33,CSQU,CAREA(I),1)
      CELA=COS(CLAT(I)*DTOR)
      DO 11 I4=1,NN
      J=I1+I4
      CX(J)=CX(J)*CELA*ZKM
      CY(J)=CY(J)*ZKM
11    CONTINUE
      CAREA(I)=CAREA(I)*CELA*ZKM*ZKM
      CLAT(I)=CLAT(I)*ZKM
      CLON(I)=CLON(I)*CELA*ZKM
10    CONTINUE
C
      RETURN
      END

```

```

SUBROUTINE GAUSS(A,X,N,N1,NSTN)
DIMENSION A(N1,N1),X(NSTN)

C
C   THIS PROGRAM SOLVES N SIMULTANEOUS LINEAR EQUATIONS IN N
C   VARIABLES X(N) BY THE METHOD OF GAUSS ( OR SUCCESSIVE )
C   ELIMINATION AND BACK SUBSTITUTION. THE PIVOT AT EACH STAGE IS
C   CHOSEN AS THE LARGEST ELEMENT IN THE FIRST COLUMN OF THE
C   APPROPRIATE ARRAY.

C   THE EQUATIONS SOLVED HAVE THE FORM --
C
C   A(1,1)X(1)+A(1,2)X(2)+.....A(1,N)X(N) = B(1)
C
C   A(2,1)X(1)+A(2,2)X(2)+.....A(2,N)X(N) = B(2)
C

```

```

C   *   *   *
C   *   *   *
C   *   *   *
C   *   *   *
C   *   *   *
C   *   *   *
C   *   *   *
C   A(N,1)X(1)+A(N,2)X(2)+.....+A(N,N)X(N) = B(N)
C
C   THE METHOD ( AND BASIC PROGRAM ) OF SUCCESSIVE ELIMINATION
C   IS GIVEN IN NUMERICAL METHODS VOL 1 BY B. NOBLE ( OLIVER AND
C   BOYD ) CHAPTER 4
C
C   DOUBLE PRECISION A,X,C,D
C
C   NO = N+1
C   NA = N-1
C
  DO 17 K = 1,NA
  KQ = K
  4 KP = KQ
  5 IF(KQ-N) 11,10,11
 11 KQ = KQ+1
  IF(DABS(A(KP,K))-DABS(A(KQ,K)))4,5,5
 10 DO 12 J = K,NO
  C = A(K,J)
  A(K,J)= A(KP,J)
  A(KP,J) = C
 12 CONTINUE
  KA = K+1
  DO 18 I = KA,N
  DO 19 J = KA,NO
  A(I,J) = A(I,J)-(A(I,K)*A(K,J))/A(K,K)
 19 CONTINUE
 18 CONTINUE
 17 CONTINUE
  X(N) = A(N,N+1)/A(N,N)
  DO 22 K = 1,NA
  L = N-K
  LO = L+1
  D = 0.00
  DO 20 J = LG,N
  D = D + A(L,J)*X(J)
 20 CONTINUE
  X(L) = (A(L,NO)-D)/A(L,L)
 22 CONTINUE
C
  DO 30 J=1,N
  L=N-J+1
  K=L+NSTN
  X(K)=X(L)
 30 CONTINUE
  IF(NSTN)33,33,31
 31 DO 32 J=1,NSTN
  X(J)=0.00
 32 CONTINUE
C
 33 RETURN
  END

SUBROUTINE MSOLVE(KON,A,B,NE1,NE2,NS)
DIMENSION A(NE1,NE2),B(NE2,NS)
C
C   THE MATRIX OF NORMAL EQUATIONS SAY
C   CX = Y
C
C   IS STORED IN PARTITIONED FORM
C   *   *   *   *   *   *   *   *
C   *           *
C   *           S           B   *
C   *           *           *
C   *   *   *   *   *   *   *   *
C   *           *           *
C   *           T R A N S   B   *   A   *
C   *           *           *   *
C   *   *   *   *   *   *   *   *

```

```

C S IS STORED AS A SINGLE ARRAY WHICH IS THE
C DIAGONAL ELEMENTS OF S ALL OTHER ELEMENTS ARE ZERO. THE VECTOR Y
C IS STORED PARTITIONED INTO SAY Y1 AND Y2 IN THE NO COLUMN OF B AND
C A. LET THE UNKNOWNNS IN VECTOR X BE PARTITIONED IN AN EQUIVALENT
C WAY INTO X1 AND X2. THE PROGRAM NOW FORMS A=A-(TRANS B)*(S**-1)*B
C (IN THIS PROCESS A(I,NO)=Y2 BECOMES Y2-TRANS B*(S**-1)*Y1)
C
C IF KON=2 THIS NEW A IS RETURNED
C IF KON=1 PROGRAM CALLS GAUSS AND SOLVES A BY GAUSSIAN ELIMINATION.
C
C THIS GIVES CORRECTIONS TO X2, ALL ESTIMATES EXCEPT STATION TERMS.
C TO FIND STATION TERMS X1 FORM X1=(Y1-B*X2)*(S**-1)
C
C COMMON /JEDS/ N,NO,NSTN,NEVENT,IOT,IDS,NSNE,NS2NE,NS3NE,NS4NE,
C 1CN,CS,CE,CW,RDATE,RTIME,TTSET,IREL,IFORM,IDEF,IWT,IMTRX,
C 2EVENT(101),OT(100),H(100),ELAT(101),ELON(101),SN(101),EW(101),
C 3INDO(100),INDH(100),HOT(100),HH(100),HELAT(101),HELON(101),
C 4HSN(100),HEW(100),IEPIC(100),AIND(100),
C 5STN(500),SLAT(500),SLON(500),SCOR(500),ART(500),S(500),PSTN(500),
C 6DIST(500),AZ(500),X(801),XX(801),LOC(800),EV(800),FV(800)
C
C REAL*8 EVENT,RDATE,RTIME
C DOUBLE PRECISION A,X,OT,XX,HOT,ART,S,EV,FV,ASUM
C
C INVERT DIAGONAL MATRIX S
C
C DO 1 J=1,NSTN
C S(J)=1.00/S(J)
1 CONTINUE
C
C FORM A-(TRANS B)*(S**-1)*B
C
C DO 2 I=1,N
C DO 3 J=1,NSTN
C EV(J)=S(J)*B(I,J)
3 CONTINUE
C
C DO 4 K=1,N
C ASUM=0.D0
C DO 5 J=1,NSTN
C ASUM=ASUM+EV(J)*B(K,J)
5 CONTINUE
C
C A(I,K)=A(I,K)-ASUM
C
C ASUM=0.D0
C DO 6 J=1,NSTN
C ASUM=ASUM+EV(J)*B(NO,J)
6 CONTINUE
C
C A(I,NO)=A(I,NO)-ASUM
C
C CONTINUE
C
C IF KON=1 A MATRIX SOLVED BY GAUSS
C IF KON=2 A MATRIX RETURNED FOR INVERSION LATER
C
C GO TO (9,10),KON
C
C SOLVE BOTTOM RIGHT HAND MATRIX BY GAUSS
C
C 9 CALL GAUSS(A,X,N,NE1,NSTN)
C
C SUBSTITUTE TO FIND CORRECTIONS TO STATION TERMS X1
C X1=(Y1-B*X2)*(S**-1)
C
C DO 8 J=1,NSTN
C ASUM=C.D0
C DO 7 I=1,N
C K=I+NSTN
C ASUM=ASUM+B(I,J)*X(K)
7 CONTINUE
C
C X(J)=(B(NO,J)-ASUM)*S(J)
8 CONTINUE
C
C 10 RETURN
END

```

```

SUBROUTINE WEIGHT(TRESID,NEVENT,NSTN,N,SIG,EMU,SUMW,AMEAN,IMTRX)
DIMENSION TRESID(NEVENT,NSTN)

C COMPUTE JEFFERYS PARAMETER, MEAN AND VARIANCE TO DEFINE WEIGHTING
C FUNCTION.

C COMMON /CONSTS/ PI,DTOR,RTOD,ZKM,ER,GFACT,HUGE
C
C DIMENSION HIST(101)
C
C FIND MAXIMUM AND MINIMUM RESIDUALS
C
200 AMAX=0.
AMIN=0.
DO 260 J=1,NSTN
DO 250 I=1,NEVENT
AD=TRESID(I,J)
IF(AD-HUGE)210,250,250
210 IF(AD-AMAX)230,220,220
220 AMAX=AD
230 IF(AD-AMIN)240,240,250
240 AMIN=AD
250 CONTINUE
260 CONTINUE
RANGE=AMAX-AMIN

C DIVIDE INTO 100 AND CALCULATE HISTOGRAM
C
RANGE=RANGE/100.0
DO 310 I=1,101
HIST(I)=0.0
310 CONTINUE
DO 340 J=1,NSTN
DO 330 I=1,NEVENT
IF(TRESID(I,J)-HUGE)320,330,330
320 IND=(TRESID(I,J)-AMIN)/RANGE
IND=IND+1
HIST(IND)=HIST(IND)+1.0
330 CONTINUE
340 CONTINUE

C FIND APPROX MODE FROM HISTOGRAM
C
IND=1
AMAX=HIST(1)
DO 360 I=1,101
IF(HIST(I)-AMAX)360,350,350
350 IND=I
AMAX=HIST(I)
360 CONTINUE
AMEAN=FLOAT(IND)*RANGE+AMIN

C COMPUTE MEAN DEVIATION ABOUT MODE
C
ASUMSQ=0.
ASUM=0.
ASUMMD=0.
NRES=0
DO 430 J=1,NSTN
DO 420 I=1,NEVENT
IF(TRESID(I,J)-HUGE)410,420,420
410 DIFF=TRESID(I,J)-AMEAN
ASUM=ASUM+TRESID(I,J)
ASUMMD=ASUMMD+ABS(DIFF)
ASUMSQ=ASUMSQ+DIFF*DIFF
NRES=NRES+1
420 CONTINUE
430 CONTINUE
SIG=ASUMMD/FLOAT(NRES-N)
SSIG=2.0*SIG

C TRUNCATE AT 2 SD ABOUT MODE AND COMPUTE MEAN AND SD
C
ASUMSQ=0.
ASUM=0.
NTRU=0
DO 470 J=1,NSTN
DO 460 I=1,NEVENT
IF(TRESID(I,J)-HUGE)440,460,460

```

```

440 DIFF=TRESID(I,J)-AMEAN
450 IF(ABS(DIFF)-SSIG)450,450,460
450 ASUM=ASUM+TRESID(I,J)
450 ASUMSQ=ASUMSQ+DIFF*DIFF
450 NTRU=NTRU+1
460 CONTINUE
470 CONTINUE
470 AMEAN=ASUM/FLOAT(NTRU)
470 SIG=SQRT(ABS(ASUMSQ/FLOAT(NTRU-N)))
C
C      START ITERATIVE PART
C      COMPUTE FREQUENCIES NEAR MEAN AND FLANKS
C
        ITER=0
500 ITER=ITER+1
500 SSIG=6.0*SIG
500 TSIG=3.0*SIG
500 SIG6=SIG/6.0
500 FLANK=0.0
500 ANMEAN=0.0
500 DO 540 J=1,NSTN
500 DO 530 I=1,NEVENT
500 IF(TRESID(I,J)-HUGE)510,530,530
510 DIFF=ABS(TRESID(I,J)-AMEAN)
510 IF(DIFF.LT.SIG6) GO TO 520
510 IF(DIFF.GT.SSIG.OR.DIFF.LT.TSIG) GO TO 530
510 FLANK=FLANK+1.0
510 GO TO 530
520 ANMFAN=ANMEAN+1.0
530 CONTINUE
540 CONTINUE
C
C      WORK OUT JEFFERYS PARAMETER
C
        EMU=(FLANK/6.0)/(ANMEAN*3.0-FLANK/6.0)
        IF(FLANK.EQ.0.0) EMU=0.001
C
C      COMPUTE WEIGHTS,WEIGHTED MEAN,AND SD
C
        WMEAN=0.0
        SUMW=0.0
        WSUMSQ=0.0
        DO 570 J=1,NSTN
        DO 560 I=1,NEVENT
        IF(TRESID(I,J)-HUGE)550,560,560
550 DIFF=TRESID(I,J)-AMEAN
550 DIFF2=DIFF*DIFF
550 ARG=DIFF2/(12.0*SIG*SIG)
550 IF(ARG.GT.150.0) ARG=150.0
550 W=1.0/(1.0+EMU*EXP(ARG))
550 WMEAN=WMEAN+W*TRESID(I,J)
550 WSUMSQ=WSUMSQ+W*DIFF2
550 SUMW=SUMW+W
560 CONTINUE
570 CONTINUE
        HOLDM=AMEAN
        HOLDS=SIG
        SIG=SQRT(WSUMSQ/SUMW*FLOAT(NRES)/FLOAT(NRES-N))
        AMEAN=WMEAN/SUMW
C
C      CHECK FOR CONVERGENCE
C
        IF(ITER.GT.3) GO TO 600
        IF(ABS(HOLDM-AMEAN).GT.0.01) GO TO 500
        IF(ABS(HOLDS-SIG).GT.0.01) GO TO 500
600 GO TO (620,610,610),IMTRX
610 PRINT 611, EMU,SIG
611 FORMAT(//////4X,20HJEFFREYS PARAMETER =,F10.5,7H    SD =,F10.5)
C
620 RETURN
END

```

APPENDIX D

LISTING OF SUBROUTINES UNIQUE TO EFA

EFA (MAIN)
FEFA
NUMBER
DECODE

C EPICENTRES FROM AZIMUTHS (FEFA)

C
C
C THIS PROGRAM READS IN THE AZIMUTH OF AN EPICENTRE FROM EACH
C OF A NUMBER OF STATIONS AND COMPUTES THE BEST LEAST-SQUARES
C ESTIMATES OF THE EPICENTRE GIVEN AN INITIAL TRIAL ESTIMATE
C FOR THE EPICENTRE.
C

C THE MAIN PROGRAM PRESENTED HERE IS BASED ON A VERSION THAT
C IS OPERATED THROUGH AN ON-LINE SYSTEM. TO SIMPLIFY THE OPERATION
C OF FEEDING IN THE DATA THROUGH A TELETYPE THE INPUT FORMAT
C HAS BEEN MADE VERY GENERAL. IF THE OPTION TO USE THE PROGRAM
C ON-LINE IS NOT REQUIRED THEN THE MAIN PROGRAM CAN BE MUCH
C SIMPLIFIED AND SUBROUTINE NUMBER OMITTED. ALL THAT IS NEEDED
C IS A ROUTINE TO READ IN THE DATA AND PRESENT IT IN THE FORM
C REQUIRED TO SLBROUTINE FEFA WHICH RETURNS A REVISED EPICENTRE
C WITH CONFIDENCE LIMITS.
C

C INPUT

C THE FIRST BLOCK OF CARDS IS A DIRECTORY OF STATIONS (STN) AND
C THEIR LATITUDES (SLAT) AND LONGITUDES (SLONG).
C FORMAT FOR PUNCHING THESE CARDS IS GIVEN IN STATEMENT 9.
C THE END OF THIS BLOCK OF CARDS IS MARKED BY A CARD WITH STARS
C (*****) PUNCHED IN THE STN POSITION.

C NOW FOLLOW IN ANY ORDER CARDS CARRYING
A TITLE FOR JCB (1 CARD OPTIONAL)
INITIAL EPICENTRE (2 CARDS)
STATION CODE AND AZIMUTH (UP TO 100 CARDS)

C IF TWO TITLE CARDS OR TWO EPICENTRE CARDS ARE INCLUDED THE
C SECOND OVERWRITES THE FIRST. IF NO EPICENTRE CARDS ARE
C INCLUDED THE INITIAL EPICENTRE IS TAKEN AS (0.0N, 0.0E).
C IF TWO CARDS WITH THE SAME STATION CODE ARE INCLUDED THE SECOND
C OVERWRITES THE FIRST. UNKNOWN STATIONS ARE REJECTED.
C A BLANK CARD MARKS THE END OF THE BLOCK OF DATA FOR ONE
C EPICENTRE.
C

C THE TITLE CARD HAS TITLE PUNCHED AS THE FIRST DATA ON THE
C CARD. THE REST OF THE CARD UP TO 52 CHARACTERS CAN THEN BE
C USED FOR THE TITLE.

C THE INITIAL EPICENTRE CARD HAS NORTH OR SOUTH AS THE
C FIRST DATA DEPENDING ON WHETHER THE EVENT IS RESPECTIVELY
NORTH OR SOUTH LATITUDE. THE LATITUDE NOW FOLLOWS.
C SIMILARLY, A CARD WITH EAST OR WEST AS THE FIRST DATA
C DEPENDING ON WHETHER THE LONGITUDE IS EAST OR WEST RESPECTIVELY
FOLLOWED BY THE LONGITUDE COMES NEXT.

C STATION/AZIMUTH CARDS HAVE THE STATION CODE AS THE FIRST DATA
C ON THE CARD FOLLOWED BY THE AZIMUTH OF THE EVENT IN DEGREES.

C
C
C DIMENSION ASTN(100),AZIM(100),ALAT(100),ALONG(100),RES(100),
1 STN(200),SLAT(200),SLONG(200),
2 CARC(74),HEAD(13)

C
REAL NORTH
DATA NORTH/4HNORT/,SOUTH/4HSOUT/,EAST/4HEAST/,WEST/4HWEST/,
1 TITLE/4HTITLE/,START/4H /,END/4H /,STARS/4H****/,
2 BLANK/4H /

C
C
C DEFINE FUNCTIONS TO CONVERT FROM GEOGRAPHIC TO GEOCENTRIC
C
LATITUDE AND VICE VERSA

C
GEOCEN(GLAT)=ATAN(TAN(GLAT*DTOR)*GCON)/DTOR
GEOGRF(GLAT)=ATAN(TAN(GLAT*DTOR)/GCON)/DTOR

C
C
SET UP CONSTANTS

```

MXSTNS=200
DTOR=ATAN(1.)/45.
GCON=0.9933054
CON=111.195
CARD(1)=START
CARD(74)=END
C
C      SET UP UNIT NUMBERS FOR INPUT/OUTPUT
C
IN=5
IO=6
IP=8
C
C      READ IN THE DIRECTORY OF UP TO MXSTNS STATIONS WITH LATITUDES
C      AND LONGITUDES
C      A CARD WITH STARS (****) MARKS THE END OF THE STATION CARDS
C
N=0
20 N=N+1
READ (IN,8) STN(N),SLAT(N),SLONG(N)
8 FORMAT(1X,A4,34X,F10.6,5X,F11.6)
IF(STN(N)-STARS)30,40,30
30 WRITE (IO,8) STN(N),SLAT(N),SLONG(N)
GO TO 20
40 NOSTNS=N-1
IF(NOSTNS-MXSTNS)60,500,500
C
C      INITIALISE EVENT VARIABLES
C
60 DO 80 I=1,13
HEAD(I)=BLANK
80 CONTINUE
ELAT=0.
DLAT=NORTH
ELONG=0.
DLONG=EAST
NC=200
N=0
WRITE (IO,1)
1 FORMAT(1H1)
C
C      BEGIN PROCESSING EVENT BY READING IN DATA
C
100 READ (IN,2,END=500) (CARD(K),K=2,73)
2 FORMAT(72A1)
WRITE (IO,3) CARD
3 FORMAT(1X,74A1)
DO 101 K=2,73
IF(CARD(K)-BLANK)110,101,110
101 CONTINUE
GO TO 300
C
C      IF CARD IS BLANK DATA INPUT COMPLETE SO BEGIN PROCESSING
C      OTHERWISE DECODE AND FIND THE FIRST FOUR LETTERS ON THE CARD
C      AND ANY SUCCEEDING NUMBER (LATITUDE LONGITUDE AZIMUTH)
C      IF THE CARD IS NEITHER AN EPICENTRE CARD NOR A TITLE CARD
C      ASSUME STATION/AZIMUTH CARD
C
110 CALL DECODE(CARD(K),AS,4)
K=K+4
CALL NUMBER(CARD(K),AZ,IC)
IF(AS-NORTH)120,220,120
120 IF(AS-SOUTH)130,230,130
130 IF(AS-EAST)140,240,140
140 IF(AS-WEST)150,250,150
150 IF(AS-TITLE)160,260,160
C
C      IF STATION CARD IDENTIFY STATION FROM THE DIRECTORY
C      IF UNKNOWN REJECT
C
160 DO 170 I=1,NOSTNS
IF(AS-STN(I))170,200,170

```

```

170  CONTINUE
      WRITE (IO,4)
4       FORMAT(2X,24HUNKNOWN STATION REJECTED)
      GO TO 100
C
C      CHECK THAT THE STATION HAS NOT ALREADY BEEN READ IN THIS
C      DATA BLOCK
C      IF IT HAS THIS SECOND READING OVERWRITES THE FIRST
C
200  IF(N)203,203,201
201  DO 202 J=1,N
      IF(AS-ASTN(J))202,210,202
202  CONTINUE
203  N=N+1
      IF(N-100)204,204,300
204  ASTN(N)=STN(I)
      ALAT(N)=GEOCEN(SLAT(I))
      ALONG(N)=SLCNG(I)
      J=N
210  AZIM(J)=AZ
211  WRITE (IO,5) AS,AZ
5       FORMAT(2X,A4,F11.3)
      GO TO 100
220  ELAT=ABS(AZ)
      DLAT=NORTH
      GO TO 251
230  ELAT=-ABS(AZ)
      DLAT=SOUTH
      GO TO 251
240  ELONG=ABS(AZ)
      DLONG=EAST
      GO TO 251
250  ELONG=-ABS(AZ)
      DLONG=WEST
251  NC=20
      GO TO 211
C
C      LOAD TITLE INTO HEAD ARRAY FOR PRINTING
C
260  K=K+1
      I=MINO(52,73-K)
      CALL DECODE(CARD(K),HEAD,I)
      WRITE (IO,6) HEAD
6       FORMAT(13A4)
      GO TO 100
C
C      ALL DATA READ IN PRINT OUT INPUT AND BEGIN PROCESSING
C
300  IF(N-2)500,310,310
310  BLAT=ABS(ELAT)
      BLONG=ABS(ELONG)
      WRITE (IO,10) HEAD,BLAT,DLAT,BLONG,DLONG,(ASTN(I),AZIM(I),I=1,N)
10    FORMAT(1H /1H /10H TITLE ,13A4/10H LATITUDE,F10.3,2X,A4,1HH/
1     10H LONGITUDE,F10.3,2X,A4/(1X,A4,1X,F10.3))
      WRITE (IP,1)
      WRITE (IP,11) HEAD
11    FORMAT(3H FINDING EPICENTRES FROM AZIMUTHS/
1     33H -----/20X,13A4/1H )
      WRITE (IP,12) BLAT,DLAT,BLONG,DLONG
12    FORMAT(2H INITIAL EPICENTRE ,9H LATITUDE,3X,F8.3,2X,A4,1HH/
1     22X,9H LONGITUDE,3X,F8.3,2X,A4/1H )
      ELAT=GEOCEN(BLAT)
      FLAT=ELAT
      FLONG=ELONG
C
C      COMPUTE REVISED EPICENTRE BY FEFA
C
      CALL FEFA(N,ASTN,AZIM,RES,ALAT,ALONG,ELAT,ELOWG,CLAT,CLONG,CSQ,
1     IC,NC,CON,DTOR)
      IF(IC)320,320,330
C
C      PRINT RESULTS
C
320  WRITE (IP,15)
15    FORMAT(15H NO CONVERGENCE/1H )
      GO TO 340
330  WRITE (IP,16) IC
16    FORMAT(15H RESULTS AFTER,I4,12H ITERATIONS/1H )

```

```

340 BLAT=GEOGRF(ELAT)
      BLONG=ELONG
      BLAT=ABS(BLAT)
      DLAT=NORTH
      IF(ELAT)350,360,360
350 DLAT=SOUTH
360 BLONG=ABS(BLONG)
      DLONG=EAST
      IF(ELONG)370,380,380
370 DLONG=WEST
380 WRITE (IP,13) BLAT,DLAT,CLAT,BLONG,DLONG,CLONG
13 FORMAT(22H COMPUTED EPICENTRE ,9H LATITUDE,3X,F8.3,2X,A4,
1    7HH +/-,F9.1,3H KM/22X,9H LONGITUDE,3X,F8.3,2X,A4,
2    7H +/-,F9.1,3H KM/1H /1H )
C
C COMPUTE SHIFT BETWEEN INITIAL AND REVISED EPICENTRE AND PRINT
C
CALL BAZDEL(FLAT,FLONG,ELAT,ELONG,AS,AZ,SHIFT,DTOR)
SHIFT=SHIFT*CCN
IF(SHIFT-10.)400,410,410
400 BLAT=(ELAT-FLAT)*CON
BLONG=(ELONG-FLONG)*COS(ELAT*DTOR)*CON
SHIFT=SQRT(BLAT*BLONG+BLONG*BLONG)
410 WRITE (IP,17) CSQ,SHIFT,AZ
17 FORMAT(25H SUM SQUARED RESIDUALS =,F12.4/
1    25H SHIFT IN EPICENTRE =,F9.1,3H KM/
2    25H DIRECTION OF SHIFT =,F7.1,5H DEGS/1H )
WRITE (IP,18) (I,ASTN(I),AZIM(I),RES(I),I=1,N)
18 FORMAT(30H STATION AZIMUTH RESIDUAL,10X,30H STATION AZIMUT
1H RESIDUAL/(I3,2X,A4,F10.2,F11.3,I3,2X,A4,F10.2,F11.3))
GO TO 60
C
C
500 WRITE (IP,1)
STOP
END

```

```

SUBROUTINE FFEA(NS,STNS,BAZ,RES,SLAT,SLONG,ELAT,ELONG,CLAT,CLONG,
1 CSQ,IC,NC,CON,DTOR)
C
C DIMENSION STNS(NS),BAZ(NS),RES(NS),SLAT(NS),SLONG(NS)
C
C DOUBLE PRECISION DLAT,BLONG,COSLAT,S,A,D,SAZD,CAZD,DAZ,DET,
1 A11,A12,A13,A21,A22,A23
C
C DIMENSION ST(35)
DATA ST(1)/12.7/,ST(2)/4.30/,ST(3)/3.18/,ST(4)/2.78/,ST(5)/2.57/,
1ST( 6)/2.45/,ST( 7)/2.36/,ST( 8)/2.31/,ST( 9)/2.26/,ST(10)/2.23/,
2ST(11)/2.20/,ST(12)/2.18/,ST(13)/2.16/,ST(14)/2.14/,ST(15)/2.13/,
3ST(16)/2.12/,ST(17)/2.11/,ST(18)/2.10/,ST(19)/2.09/,ST(20)/2.09/,
4ST(21)/2.08/,ST(22)/2.07/,ST(23)/2.07/,ST(24)/2.06/,ST(25)/2.06/,
5ST(26)/2.06/,ST(27)/2.05/,ST(28)/2.05/,ST(29)/2.05/,ST(30)/2.04/,
6ST(31)/2.02/,ST(32)/2.00/,ST(33)/2.00/,ST(34)/1.99/,ST(35)/1.98/
C
C CLAT=0.
C CLONG=0.
C CSQ=0.
C DLAT=0.D0
C DLONG=0.D0
C HOLD=0.
C
C BEGIN ITERATION LOOP
C
C PROGRAM RUNS FOR UP TO NT ITERATIONS. FIRST STEP IS TO ADD
C CORRECTIONS (DLAT AND DLONG) TO THE EPICENTRE (ELAT AND ELONG)
C FROM THE PREVIOUS ITERATION (CORRECTIONS ZERO ON ITERATION 0).
C CHECK THAT REVISED ELAT STILL LIES BETWEEN +/- 90 AND REVISED
C ELONG BETWEEN +/- 180.
C
C IC=0
100 DO 300 I=1,NC
      ELAT=ELAT+DLAT
110 IF(ABS(ELAT)-90.)1130,130,120
120 ELAT=ELAT-SIGN(90.,ELAT)
130 COSLAT=DCOS(DBLE(ELAT*DTOR))
      ELONG=ELONG+DLONG
140 IF(ABS(ELONG)-180.)200,200,150
150 ELONG=ELONG-SIGN(360.,ELONG)
      GO TO 140

```

```

C
C      ZERO THE ELEMENTS OF NORMAL MATRIX AND RHS OF THE EQUATION -
C      ++++++      ++++++
C      +A11,A12+  +A13+
C      +A21,A22+  = +A23+
C      ++++++      ++++++
C
C      200 A11=0.00
C          A12=0.00
C          A22=0.00
C          A13=0.00
C          A23=0.00
C          S=0.00
C
C      SET UP NORMAL EQUATIONS
C
C      COMPUTE DISTANCE AZIMUTH AND BACKBEARING OF EACH STATION FROM
C      THE REVISED EPICENTRE.
C
DO 230 J=1,NS
CALL BAZDEL(ELAT,ELONG,SLAT(J),SLONG(J),BB,AZ,DELTA,DTOR)
A=DBLE(AZ*DTOR)
D=DSIN(DBLE(DELTA*DTOR))
SAZD = DSIN(A)/D
CAZD = -DCOS(A)/D
AZ   = BAZ(J) - BB
IF(ABS(AZ)-180.1220,220,210
210 AZ=AZ-SIGN(360.,AZ)
220 DAZ=DBLE(AZ)
A11=A11+SAZD*SAZD
A12=A12+SAZD*CAZD*COSLAT
A22=A22+CAZD*CAZD*COSLAT*COSLAT
A13=A13+DAZ*SAZD
A23=A23+DAZ*CAZD
S=S+DAZ*DAZ
230 CONTINUE
CSQ=S
A21=A12
C
C      SOLVE NORMAL EQUATIONS FOR DLAT AND DLONG
C
DET=A11*A22-A12*A21
IF(DABS(DET)-1.D-4)600,240,240
240 DLAT=(A13*A22-A23*A12)/DET
DLONG=(A11*A23-A21*A13)/DET
C
C      TEST IF CORRECTIONS LESS THAN EPS.  IF YES, CEASE ITERATING.
C
EPS=HOLD*0.0001
HOLD=HOLD-CSQ
IF(ABS(HOLD)-EPS)400,400,250
250 DELTA=DSQRT(DLAT*DLAT+DLONG*COSLAT*DLONG*COSLAT)*CON
IF(DELTA-0.01)400,400,260
260 HOLD=CSQ
300 CONTINUE
GO TO 410
C
C      COMPUTE CONFIDENCE LIMITS.
C      STUDENTS T FOR M-2 DEGREES OF FREEDOM USED.
C
400 IC=I
410 IF(NS-3)500,420,420
420 NDF=NS-2
IF(NDF-30)460,460,430
430 IF(NDF-100)440,440,450
440 NDF=(NDF+5)/2C+29
GO TO 460
450 NDF=35
460 A=ST(NDF)
S=S/DFLOAT(NS-2)
CLAT=DSQRT((A22/DET)*S)*A*CON
CLONG=DSQRT((A11/DET)*S)*A*COSLAT*CON
C
C      FORM ARRAY OF RESIDUALS
C
500 DO 520 J=1,NS
CALL BAZDEL(ELAT,ELONG,SLAT(J),SLONG(J),BB,AZ,DELTA,DTOR)
RES(J) = BAZ(J) - BB
IF(ABS(RES(J))-180.)520,520,510
510 RES(J)=RES(J)-SIGN(360.,RES(J))

```

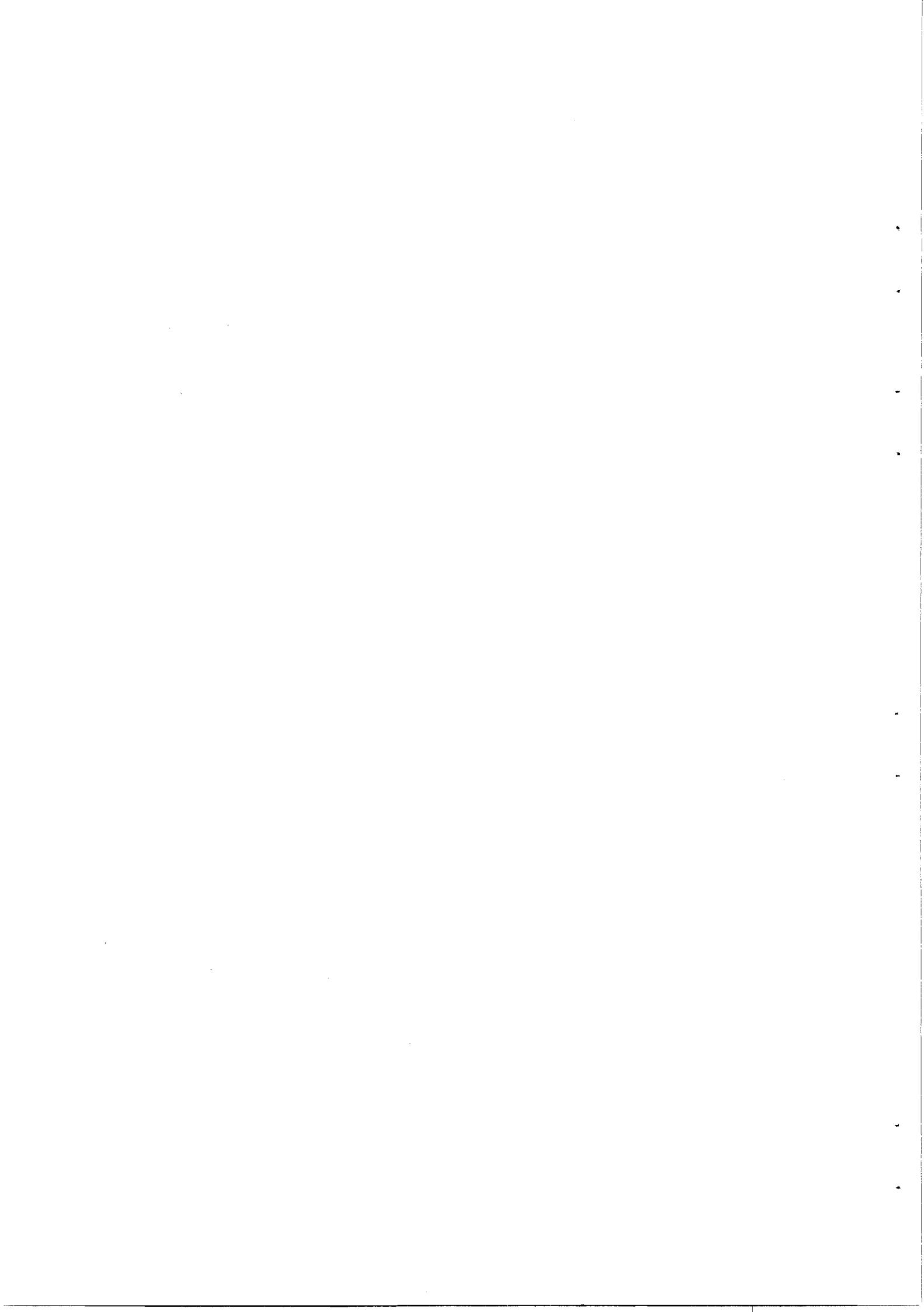
```

520 CONTINUE
IF(IC)600,600,530
530 ELAT=ELAT+DLAT
ELONG=ELONG+DLONG
C
C
600 RETURN
END

SUBROUTINE NUMBER(CARD,RNUM,INUM)
C
C GIVEN ALPHA-NUMERIC SINGLE CHARACTERS IN CARD THIS SUBROUTINE
C ATTEMPTS TO DECODE ANY NUMBER WITH OR WITHOUT SIGN OR DECIMAL
C POINT THE ANSWER BEING RNUM OR INUM AND COMPLETING ON A DOUBLE
C BLANK OR A CLOSE BRACKET
C
C DIMENSION FIG(10),CARD(1)
C
DATA FIG(1)/4H0   /,FIG(2)/4H1   /,FIG(3)/4H2   /,FIG(4)/4H3   /,
1   FIG(5)/4H4   /,FIG(6)/4H5   /,FIG(7)/4H6   /,FIG(8)/4H7   /,
2   FIG(9)/4H8   /,FIG(10)/4H9  /,POINT/4H.  /,CEND/4H)  /,
3   PLUS/4H+   /,DASH/4H-   /,BLANK/4H   /
C
PNUM=0.
INUM=0
IPOW=0
ICHR=0
ISGN=+1
IADD=0
I=0
C
100 I=I+1
DO 110 J=1,10
IF(CARD(I)-FIG(J))110,200,110
110 CONTINUE
IF(CARD(I)-BLANK)130,120,130
120 IF(CARD(I+1)-BLANK)100,240,100
130 IF(CARD(I)-PLLS)140,210,140
140 IF(CARD(I)-DASH)150,220,150
150 IF(CARD(I)-POINT)160,230,160
160 IF(CARD(I)-CEND)100,250,100
C
200 INUM=INUM*10+J-1
IPOW=IPOW-IADD
210 ICHR=ICHR+1
GO TO 100
220 ISGN=-1
GO TO 210
230 IADD=1
GO TO 210
240 IF([ICHR]100,100,250
250 RNUM=FLOAT(INUM*ISGN)*(10.**IPOW)
INUM=IFIX(ABS(RNUM)+0.5)*ISGN
C
RETURN
END

SUBROUTINE DECODE(ARRAY,CODE,N)
C
C THIS SUBROUTINE TAKES SINGLE ALPHA-NUMERIC CHARACTERS IN ARRAY
C AND DECODES THEM TO FORM N CHARACTERS OF TEXT IN CODE.
C
C
DIMENSION ARRAY(4,4),CODE(4)
LOGICAL*1 ARRAY,CODE
C
DO 4 I=1,N
CODE(I)=ARRAY(1,I)
4 CONTINUE
RETURN
END

```



APPENDIX E

LISTING OF SUBROUTINES COMMON TO SPEEDY AND JED

	(GS : ENTRY TABS
GEDESS* routines	(GT : ENTRY DTDD; GTI; GTS
	(GL
	AMAX
	AMIN
	AREA
	BAZDEL**
	ELLIP
	GEOCEN
	GEOGRF
	GRAPH
	HEIGHT
	HRTM
	SECTM
	SMATRX
	TREAD
	(FINISH
	(GC
Dummy routines	(GGS
	(GRIF
	(LOOKUP

*The GEDESS routines are part of another program not described here. As used here parts of these GEDESS routines are redundant; they are never used. To retain compatibility with the GEDESS program the redundant sections have been left intact in the routines published here.

For a full description of GEDESS see AWRE Report 054/68, "GEDESS: A Series of Computer Programs for Deriving Information at Selected Seismic Recording Sites, for Signals from Known Hypocentres" by J B Young and P G Gibbs.

**BAZDEL is also used by SPUR and EFA.

```

C               GEDESS SETUP ROUTINE (GS)
C
C   THIS PROGRAM SETS UP - TABLE 1      P TRAVEL TIMES
C                               TABLE 2      PKP TRAVEL TIMES
C                               TABLE 3      ELLIPTICITY CORRECTIONS
C                               TABLE 4      REGIONS
C                               TABLE 5      STATIONS
C
C   THE TABLES ARE PRINTED OUT IF THE KEY KTAB IS SET TO 2 OR 3
C
C   SUBROUTINE GS(MXSTNS,STN,SLAT,SLONG,ELEV,SA,SB,SC,SD,SE,SG,SH,SK,H
1,TTSET,IP,NP,NPD,P,PDEP,PDIST,PSTART,IPKP,NPKP,NPKD,PKP,PKPDEP)
DIMENSION STN(MXSTNS), SLAT(MXSTNS), SLONG(MXSTNS), ELEV(MXSTNS),
1           SA(MXSTNS), SB(MXSTNS), SC(MXSTNS),
2           SD(MXSTNS), SE(MXSTNS),
3           SG(MXSTNS), SH(MXSTNS), SK(MXSTNS), H(MXSTNS)
DIMENSION P(IP,IP),PDEP(IP),PKP(IPKP,IPKP),PKPDEP(IPKP),FD(180)
C
COMMON /BLANK/ IUNIT,JUNIT,KUNIT,LUNIT,MUNIT,NUNIT,KTAB,
1           LIND,LINE,LINES,LLINES
COMMON /REGNS/ GREG(9,730),NGREG(730),SREG(10,50),NSREG(730)
COMMON /GECS/ NEVENT,NPAGE
COMMON /STNS/ NOSTNS
DIMENSION MINS(14),SECS(14),HNAME(12),BNAME(15),ADIST(112)
C
REAL KM
DATA TO/4HTC/,FROM/4HFROM/,KM/4HKM/,EM/4HM/,ES/4HS/
1     BLANK/4H    /,SET/4H    /
C
C SET UP VARIABLES
C
IF(MXSTNS)2000,2000,1000
1000 DO 1010 I=1,MXSTNS
STN(I)=BLANK
SLAT(I)=0.
SLONG(I)=0.
ELEV(I)=0.
1010 CONTINUE
GO TO 2000
C
ENTRY TABS(MXSTNS
1,TTSET,IP,NP,NPD,P,PDEP,PDIST,PSTART,IPKP,NPKP,NPKD,PKP,PKPDEP)
IF(SET-BLANK)1020,2000,1020
1020 TTSET=SET
GO TO 5000
C
C P AND PKP TRAVEL TIMES
C
2000 READ (JUNIT,911) HNAME,J,NP,NPD
READ (JUNIT,922) (PDEP(IDEPTH),IDEPTH=1,NP)
DO 2010 IDIST=1,NPD
READ (JUNIT,912) (P(IDEPTH,IDL),IDEPTH=1,NP),ADIST(IDL)
2010 CONTINUE
READ (JUNIT,911) HNAME
READ (JUNIT,922) (P(1,IDL),IDL=1,NPD),PDIST,PSTART
DO 2040 IDIST=1,NPD
DO 2020 IDEPTH=2,NP
P(IDEPTH,IDL)=P(1,IDL)-P(IDEPTH,IDL)
2020 CONTINUE
IF(ADIST(IDL)-PDIST*FLOAT(IDL-1))2030,2040,2030
2030 PRINT 902
STOP
2040 CONTINUE
TTSET=HNAME(5)
SET=TTSET
GO TO (2100,2050,2050),KTB
2050 MLIND=LIND-(16+LIND/50)
ND=NPD-IFIX(1./PDIST)
LO=1
N=MIND(NP,11)
LPAGE=0
LINE=0
NPAGE=NPAGE+1
WRITE (LUNIT,916) HNAME,NPAGE
WRITE (LUNIT,923) (PDEP(IDEPTH),KM,IDEPTH=1,N)
WRITE (LUNIT,924) (EM,ES,IDEPTH=1,N)
LINES=LINES+5
DO 2070 IDIST=LO,ND
DIST=PDIST*FLCAT(IDL-1)+PSTART
DO 2060 IDEPTH=1,N
SECS(IDEPTH)=P(IDEPTH,IDL)
MINS(IDEPTH)=SECS(IDEPTH)*0.016666667
SECS(IDEPTH)=ABS(SECS(IDEPTH))-FLOAT(MINS(IDEPTH))*60.0

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```

2060 CONTINUE
LINE=LINE+1
2062 WRITE (LUNIT,925) DIST,(MINS(IDEPTH),SECS(IDEPTH),IDEPTH=1,N)
LPAGE=LPAGE+1
IF(LPAGE-MLINC)2066,2064,2064
2064 LPAGE=0
NPAGE=NPAGE+1
WRITE (LUNIT,916) HNAME,NPAGE
WRITE (LUNIT,923) (PDEP(IDEPTH),KM,IDEPTH=1,N)
WRITE (LUNIT,924) (EM,ES,IDEPTH=1,N)
LINES=LINES+6
GO TO 2062
2066 IF(LINE-5)2070,2068,2068
2068 WRITE (LUNIT,914)
LINES=LINES+6
LINE=0
2070 CONTINUE
LINES=LINES+LINE
IF(NP-11)2100,2100,2075
2075 LPAGE=0
LINE=0
NPAGE=NPAGE+1
WRITE (LUNIT,916) HNAME,NPAGE
WRITE (LUNIT,923) (PDEP(IDEPTH),KM,IDEPTH=12,NP)
WRITE (LUNIT,924) (EM,ES,IDEPTH=12,NP)
LINES=LINES+5
DO 2090 IDIST=LO,ND
DIST=PDIST*FLOAT(IDIST-1)+PSTART
DO 2080 IDEPTH=12,NP
SECS(IDEPTH)=P(IDEPTH,1DIST)
MINS(IDEPTH)=SECS(IDEPTH)*0.016666667
SECS(IDEPTH)=ABS(SECS(IDEPTH)-FLOAT(MINS(IDEPTH))*60.0)
2080 CONTINUE
LINE=LINE+1
2082 WRITE (LUNIT,925) DIST,(MINS(IDEPTH),SECS(IDEPTH),IDEPTH=12,NP)
LPAGE=LPAGE+1
IF(LPAGE-MLINC)2086,2084,2084
2084 LPAGE=0
NPAGE=NPAGE+1
WRITE (LUNIT,916) HNAME,NPAGE
WRITE (LUNIT,923) (PDEP(IDEPTH),KM,IDEPTH=12,NP)
WRITE (LUNIT,924) (EM,ES,IDEPTH=12,NP)
LINES=LINES+6
GO TO 2082
2086 IF(LINE-5)2090,2088,2088
2088 WRITE (LUNIT,914)
LINES=LINES+6
LINE=0
2090 CONTINUE
LINES=LINES+LINE
2100 READ (JUNIT,911) HNAME,J,NPKP,NPKPD
READ (JUNIT,922) (PKPDEP(IDEPTH),IDEPTH=1,NPKP)
DO 2110 IDIST=1,NPKPD
READ (JUNIT,912) (PKP(IDEPTH,1DIST),IDEPTH=1,NPKP),ADIST(IDIST)
2110 CONTINUE
READ (JUNIT,911) HNAME
READ (JUNIT,922) (PKP(1,1DIST),IDIST=1,NPKPD),PKPDST
DO 2140 IDIST=1,NPKPD
DO 2120 IDEPTH=2,NPKP
PKP(IDEPTH,1DIST)=PKP(1,1DIST)-PKP(IDEPTH,1DIST)
2120 CONTINUE
IF(ADIST(IDIST)-PKPDST*FLOAT(IDIST-1)-109.)2130,2140,2130
2130 PRINT 902
STOP
2140 CONTINUE
GO TO (2200,2150,2150),KTAB
2150 ND=NPKPD-1
LO=2
LPAGE=0
LINE=0
NPAGE=NPAGE+1
WRITE (LUNIT,916) HNAME,NPAGE
WRITE (LUNIT,923) (PKPDEP(IDEPTH),KM,IDEPTH=1,11)
WRITE (LUNIT,924) (EM,ES,IDEPTH=1,11)
LINES=LINES+5
DO 2170 IDIST=LO,ND
DIST=FLOAT(IDIST-1)+109.
DO 2160 IDEPTH=1,11
SECS(IDEPTH)=PKP(IDEPTH,1DIST)
MINS(IDEPTH)=SECS(IDEPTH)*0.016666667
SECS(IDEPTH)=ABS(SECS(IDEPTH)-FLOAT(MINS(IDEPTH))*60.0)
2160 CONTINUE
LINE=LINE+1

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2162 WRITE (LUNIT,925) DIST,(MINS(IDEPTH),SECS(IDEPTH),IDEPTH=1,11)
    LPAGE=LPAGE+1
    IF(LPAGE-MLIN)2166,2164,2164
2164 LPAGE=0
    NPAGE=NPAGE+1
    WRITE (LUNIT,S16) HNAME,NPAGE
    WRITE (LUNIT,923) (PKPDEP(IDEPTH),KM,IDEPTH=1,11)
    WRITE (LUNIT,924) (EM,ES,IDEPTH=1,11)
    LINES=LINES+6
    GO TO 2162
2166 IF(LINE-5)2170,2168,2168
2168 WRITE (LUNIT,S14)
    LINES=LINES+6
    LINE=0
2170 CONTINUE
    LINES=LINES+LINE
    LPAGE=0
    LINE=0
    NPAGE=NPAGE+1
    WRITE (LUNIT,916) HNAME,NPAGE
    WRITE (LUNIT,923) (PKPDEP(IDEPTH),KM,IDEPTH=12,NPKP)
    WRITE (LUNIT,924) (EM,ES,IDEPTH=12,NPKP)
    LINES=LINES+5
    DO 219C IDIST=LO,NO
    DIST=FLOAT(IDIST-1)+109.
    DO 2180 IDEPTH=12,NPKP
    SECS(IDEPTH)=PKP(IDEPTH,IDIST)
    MINS(IDEPTH)=SECS(IDEPTH)*0.016666667
    SECS(IDEPTH)=ABS(SECS(IDEPTH)-FLOAT(MINS(IDEPTH))*60.0)
2180 CONTINUE
    LINE=LINE+1
2182 WRITE (LUNIT,925) DIST,(MINS(IDEPTH),SECS(IDEPTH),IDEPTH=12,NPKP)
    LPAGE=LPAGE+1
    IF(LPAGE-MLIN)2186,2184,2184
2184 LPAGE=0
    NPAGE=NPAGE+1
    WRITE (LUNIT,916) HNAME,NPAGE
    WRITE (LUNIT,923) (PKPDEP(IDEPTH),KM,IDEPTH=12,NPKP)
    WRITE (LUNIT,924) (EM,FS,IDEPTH=12,NPKP)
    LINES=LINES+6
    GO TO 2182
2186 IF(LINE-5)2190,2188,2188
2188 WRITE (LUNIT,S14)
    LINES=LINES+6
    LINE=0
2190 CONTINUE
    LINES=LINES+LINE
C
C ELLIPTICITY CORRECTIONS
C
2200 READ (JUNIT,911) HNAME
    READ (JUNIT,926) (FD(JDIST),JDIST=1,180)
    GO TO (2300,2210,2210),KTAB
221^ NPAGE=NPAGE+1
    WRITE (LUNIT,927) HNAME,NPAGE
    WRITE (LUNIT,928) (JDIST,FD(JDIST),JDIST=1,180)
    LINES=LINES+39
C
C SET UP TIME PROGRAM AND RETURN IF REGIONS AND STATIONS NOT REQUIRED
C
2300 CALL GTS(IP,NP,P,PDEP,PDIST,PSTART,IPKP,NPKP,PKP,PKPDEP,FD)
    IF(MXSTNS)5000,5000,3000
C
C GEOGRAPHIC AND SEISMIC REGIONS
C
3000 READ (JUNIT,911) HNAME,KUNIT,ND
    IF(KUNIT) 3010,3010,3020
3010 KUNIT=JUNIT
3020 NG=0
    ND=ND+1
    GO TO (3050,3030),ND
3030 DO 3040 I=1,730
    ICOUNT=NG
    READ (KUNIT,931) NGREG(I),(GREG(J,I),J=1,9),NG,NSREG(I)
    IF(NG-I)3090,3040,3090
3040 CONTINUE
    GO TO 3070
3050 DO 3060 I=2,730,2
    ICOUNT=NG
    IH=I-1
    READ (KUNIT,932) NG,NSREG(IH),NGREG(IH),(GREG(J,IH),J=1,9),
    NG,NSREG(I),NGREG(I),(GREG(J,I),J=1,9)
    IF(NG-I)3090,3060,3090

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```

3060 CONTINUE
3070 GO TO (3080,3100),KTAB
3080 READ (KUNIT,933) ((SREG(J,I),J=1,10),I=1,50)
   GO TO 4000
3090 PRINT 903, NG,ICOUNT
   STOP
3100 ICOUNT=0
   LINE=LIND
   DO 3160 I=1,730
      IF(LINE-LIND)3120,3110,3110
3110 LINES=LINES+LINE
   LINE=1
   NPAGE=NPAGE+1
   WRITE (LUNIT,934) HNAME,NPAGE
3120 IF(ICOUNT-NSREG(I))3130,3150,3150
3130 IF(LINE-(LIND-4))3140,3110,3110
3140 ICOUNT=ICOUNT+1
   READ (KUNIT,933) (SREG(J,ICOUNT),J=1,10)
   WRITE (LUNIT,935) ICOUNT,(SREG(J,ICOUNT),J=1,10)
   LINE=LINE+4
3150 WRITE (LUNIT,936) (GREG(9,I),J=1,4),I,(GREG(J,I),J=1,8)
   LINE=LINE+1
3160 CONTINUE
   LINES=LINES+LINE
C
C STATIONS
C
4000 GO TO (4004,4002,4002),KTAB
4002 LINE=4
   NPAGE=NPAGE+1
   WRITE (LUNIT,944) HNAME,NPAGE
4004 READ (JUNIT,911) HNAME,KUNIT,ND
   LO=1
   N=0
   IF(ND) 4140,4140,4010
4010 READ (JUNIT,941) SA(LO),SD(LO),SH(LO)
   ANAME=SA(LO)
   IF(ANAME=TO)4020,4030,4020
4020 LO=LO+1
   IF(LO-ND)4010,4010,4040
C READ CODE FROM CARDS AND COORDINATES FROM TAPE
4030 IF(KUNIT) 4032,4032,4035
4032 KUNIT=JUNIT
4035 READ (KUNIT,941) (SA(I),SD(I),SH(I),I=LO,ND)
4040 READ (JUNIT,942) ANAME,BNAME,IH
   IF(ANAME=TO)4045,4040,4045
4045 IF(ANAME=FRCM)4050,4200,4050
4050 GO TO (4080,4060,4060),KTAB
4060 IF(LINE=LIND)4080,4070,4070
4070 LINES=LINES+LINE
   LINE=4
   NPAGE=NPAGE+1
   WRITE (LUNIT,944) HNAME,NPAGE
4080 DO 4110 I=1,ND
   IF(ANAME=SA(I))4110,4090,4110
4090 ALAT=SD(I)
   ALONG=SH(I)
   N=N+1
   STN(N)=ANAME
   SLAT(N)=AMAX1(ALAT,-89.999)
   SLONG(N)=ALCNG
   ELEV(N)=FLOAT(IH)*0.001
   GO TO (4040,4100,4100),KTAB
4100 WRITE (LUNIT,945) ANAME,BNAME,IH
   LINE=LINE+1
   GO TO 4040
4110 CONTINUE
   PRINT 905, ANAME,BNAME,IH
   GO TO 4040
C READ CODE AND COORDINATES FROM CARDS
4140 READ (JUNIT,943) ANAME,(BNAME(I),I=1,8),ALAT,ALONG,IH
   IF(ANAME=TO)4145,4140,4145
4145 IF(ANAME=FRCM)4150,4200,4150
4150 GO TO (4180,4160,4160),KTAB
4160 IF(LINE=LIND)4180,4170,4170
4170 LINES=LINES+LINE
   LINE=4
   NPAGE=NPAGE+1
   WRITE (LUNIT,944) HNAME,NPAGE
4180 N=N+1
   STN(N)=ANAME
   SLAT(N)=AMAX1(ALAT,-89.999)
   SLONG(N)=ALONG
   ELEV(N)=FLCAT(IH)*0.001
   GO TO (4140,4190,4190),KTAB

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4190 WRITE (LUNIT,946) ANAME,(BNAME(I),I=1,8),ALAT,ALONG,IH
LINE=LINE+1
GO TO 4140
C CHECK FOR RIGHT NUMBER OF STATIONS
4200 NOSTNS=N
4210 IF(NOSTNS-2)4230,4220,4220
4220 IF(NOSTNS-MXSTNS)4240,4240,4230
4230 PRINT 906
STOP
4240 N=MXSTNS*9
DO 4250 I=1,N
SA(I)=0.
4250 CONTINUE
C SET UP STATION CONSTANTS
DO 4260 I=1,NOSTNS
CALL GC(SLAT(I),SLONG(I),SA(I),SB(I),SC(I),SD(I),SE(I),
      1          SG(I),SH(I),SK(I),H(I))
4260 CONTINUE
GO TO (430C,4270,4270),KTAB
4270 LINES=LINES+LINE
C
C SET UP GEORGE PROGRAM
C
4300 CALL GGS(MXSTNS,STN,SLAT,SLONG,ELEV,SA,SB,SC,SD,SE,SG,SH,SK,H)
C
5100 RETURN
C
C FORMATS
C
902 FORMAT(48H1** JOB HALTED - DEPTH ALLOWANCES OUT OF ORDER)
903 FORMAT(25H1** JOB HALTED - REGION,I4,42H OUT OF SEQUENCE - LAST
1CORRECT REGION WAS,I4)
905 FORMAT(47HC** JOB ERROR - UNKNOWN STATION REJECTED - ,
1A4,4X,15A4,4X,16/)
906 FORMAT(50H1** JOB HALTED - INCOMPATIBLE NUMBER OF STATIONS)
911 FORMAT(1X,12A4,I1,6I5)
912 FORMAT(1X,14F5.1,5X,F4.1)
914 FORMAT(127X)
916 FORMAT(1H1,12A4,12X,9HDEPTH = ,43X,11HPAGE NUMBER,I3/127X)
922 FORMAT(2X,7F1C.2)
923 FORMAT(6H CIST,11(F9.2,A2))
924 FORMAT(6H CEG.,121X/6X,11(4X,A4,A3))
925 FORMAT(1X,F5.1,11(I5,F6.2))
926 FORMAT(2X,1CF7.4)
927 FORMAT(1H1,12A4,63X,11HPAGE NUMBER,I4/127X/127X)
928 FORMAT(1O(I5,1H*,F6.4),7X/127X)
931 FORMAT(1X,I4,1X,8A4,2X,A1,31X,2I4)
932 FORMAT(2(I3,I2,I2,8A4,A1))
933 FORMAT(6X,1CA4)
934 FORMAT(1H1,12A4,63X,11HPAGE NUMBER,I4)
935 FORMAT(127X/127X/41X,I4,2X,10A4,40X/127X)
936 FORMAT(51X,4A1,I5,2X,8A4,33X)
941 FORMAT(1X,A4,31X,3HLAT,F10.6,5H LONG,F11.6)
942 FORMAT(1X,A4,1X,15A4,I6)
943 FORMAT(1X,A4,1X,7A4,A2,3HLAT,F10.6,5H LONG,F11.6,1X,I6)
944 FORMAT(1H1,12A4,63X,11HPAGE NUMBER,I4/127X/
1127H CODE   STATION           REGION    LATITUDE    LONGITUDE
2           ELEVATION       CORRECTIONS      /
3127X)
945 FORMAT(1X,A4,4X,15A4,4X,I6,48X)
946 FORMAT(1X,A4,4X,7A4,A2,3HLAT,F10.6,5H LONG,F11.6,5X,I6,48X)
END

```

```

C               GEDESS TIME SUBROUTINE (GT)
C
C COMPUTES TRAVEL TIME FOR A GIVEN DEPTH AND DISTANCE (DIST)
C ADDS THE ELLIPTICITY CORRECTION FOR THE PARTICULAR DISTANCE
C ADDS THE STATION TIME CORRECTION (CT)
C AND ALSO COMPUTES THE PHASE VELOCITY (PHASEV)
C
C THE TRAVEL TIME OF SURFACE WAVES (RALEY) IS ESTIMATED FROM
C FOR IND = 2 THE FORMULA -- LR. DT/DD = 0.4674 +/- 0.0011 MIN/DEG
C                               WITH VELOCITY = 3.972 +/- 0.009 KM/SEC
C AND A FIXED ARBITRARY POINT AT 60 DEGREES OF 29 MINS
C AND FOR IND = 1 USING A VELOCITY OF 3.1 KM/SEC
C                               CORRESPONDING TO A PERIOD OF 20 SECONDS
C
C
C SUBROUTINE GT(DEPTH,DIST,CT,H0,H1,PHASEV,TIME,RALEY,IND,
1IP,NP,P,PDEP,PDIST,PSTART,IPKP,NPKP,PKP,PKPDEP,FD)
DIMENSION P(IP,IP),PDEP(IP),PKP(IPKP,IPKP),PKPDEP(IPKP), FD(180)
C

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```

COMMON /CCNSTS/ PI,DTOR,RTOO,ZKM,ER,GFACT,HUGE,SECDAY,ROUND
C
C
C      ENTRY GTI(DEPTH,DIST,CT,H0,H1,PHASEV,TIME,RALEY,IND)
N=IND+1
GO TO (10,20,30,40),N
10 GO TO 300
20 RALEY=(DIST*ZKM)/3.1
GO TO 50
30 RALEY=(29.+10.4674*(DIST-60.))/60.
GO TO 50
40 RALEY=0.
GO TO 50
C
C      ENTRY DTDD(DEPTH,DIST,CT,H0,H1,DERIV,DH,TIME)
N=0
C
50 IF(DIST>110.)100,200,200
C
C
C          P VALUES
C
100 DO 110 IDEPTH=1,NP
IF(DEPTH-PDEP(IDEPTH))120,110,110
110 CONTINUE
IDEPTH=NP
120 IDEPTH=MAX0((IDEPTH-1,1)
DDEPTH=(DEPTH-PDEP(IDEPTH))/(PDEP(IDEPTH+1)-PDEP(IDEPTH))
IDIST=MAX0(IFIX((DIST-PSTART)/PDIST),1)
DDIST=((DIST-PSTART)/PDIST)-FLOAT(IDIST)
JDIST=MAX0(IFIX(DIST+ROUND),1)
P2=1./(PDIST*2.)
C
T01 = P ((ICEPTH, IDIST - 1)
T11 = P ((ICEPTH, IDIST + 1)
T21 = P ((ICEPTH, IDIST + 2)
T31 = P ((ICEPTH, IDIST + 3)
T02 = P ((ICEPTH + 1, IDIST - 1)
T12 = P ((ICEPTH + 1, IDIST + 1)
T22 = P ((ICEPTH + 1, IDIST + 2)
T32 = P ((ICEPTH + 1, IDIST + 3)
TIME = GL(T11,T12,T21,T22,DDEPTH,DDIST)+CT+FD(JDIST)*(H0+H1)
F11=(T21-T01)*P2
F12=(T22-T02)*P2
F21=(T31-T11)*P2
F22=(T32-T12)*P2
DERIV = GL(F11,F12,F21,F22,DDEPTH,DDIST)
PHASEV=ZKM/DERIV
IF(N)130,120,300
C
130 IDEPTH=MINC(ICEPTH,NP-2)
D2=1./(PDEP(IDEPTH+2)-PDEP(IDEPTH+1))
D1=1./(PDEP(IDEPTH+1)-PDEP(IDEPTH))
DDEPTH=(DEPTH-PDEP(IDEPTH))*D1
T01 = P ((ICEPTH , IDIST + 1)
T11 = P ((ICEPTH+1, IDIST + 1)
T21 = P ((ICEPTH+2, IDIST + 1)
T02 = P ((ICEPTH , IDIST + 2)
T12 = P ((ICEPTH+1, IDIST + 2)
T22 = P ((ICEPTH+2, IDIST + 2)
F11=(T11-T01)*D1
F12=(T12-T02)*D1
F21=(T21-T11)*D2
F22=(T22-T12)*D2
DH = GL(F11,F12,F21,F22,DDEPTH,DDIST)
GO TO 300
C
C
C          PKP VALUES
C
200 DO 210 IDEPTH=1,NPKP
IF(DEPTH-PKPDEP(IDEPTH))220,210,210
210 CONTINUE
IDEPTH=NPKP
220 IDEPTH=MAX0((IDEPTH-1,1)
DDEPTH=(DEPTH-PKPDEP(IDEPTH))/(PKPDEP(IDEPTH+1)-PKPDEP(IDEPTH))
IDIST=MIN0(IFIX(DIST)-109,70)
DDIST=DIST-FLOAT(IDIST+109)
JDIST=IFIX(DIST+ROUND)
C
T01 = PKP(ICEPTH, IDIST - 1)
T11 = PKP(ICEPTH, IDIST + 1)
T21 = PKP(ICEPTH, IDIST + 2)
T31 = PKP(ICEPTH, IDIST + 3)

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```

T02 = PKP(ICEPTH+1, IDIST )
T12 = PKP(ICEPTH+1, IDIST+1)
T22 = PKP(ICEPTH+1, IDIST+2)
T32 = PKP(ICEPTH+1, IDIST+3)
TIME = GL(T11,T12,T21,T22,DDEPTH,DDIST)+CT+FD(JDIST)*(H0+H1)
DERIV=0.
DH=0.
F11=T21-T01
F12=T22-T02
F21=T31-T11
F22=T32-T12
PHASEV = 2.*ZKM/GL(F11,F12,F21,F22,DDEPTH,DDIST)
N=IFIX(PHASEV+ROUND)
PHASEV=FLOAT(N)
IF(PHASEV-1CO.)1300,230,230
230 PHASEV=100.
GO TO 300
C
C
ENTRY GTS(IF,NP,P,PDEP,PDIST,PSTART,IPKP,NPKP,PKP,PKPDEP,FD)
300 RETURN
END

```

```

C          GEDESS LINEAR INTERPOLATION FUNCTION (GL)
C
C          LINEAR INTERPOLATION ROUTINE FOR THE TABLES
C
C          FINDS T IN THE MATRIX      T11(DDEPTH)      T12
C                                (DDIST)           T
C
C                                T21           T22
C
C          FUNCTION GL(T11,T12,T21,T22,DDEPTH,DDIST)
C          GL = T11+DDEPTH*(T12-T11)+DDIST*(T21-T11)
C          1     +DDEPTH*DDIST*(T11-T12-T21+T22)
C          RETURN
C          END

```

```

SUBROUTINE AMAX (X,N,XMAX)
C
C          FINDS MAXIMUM VALUE OF ARRAY X
C
C
DIMENSION X(N)
C
KQ = 1
2 KP = KQ
5 IF(KQ-N)3,4,4
3 KQ = KQ + 1
IF(X(KP) - X(KQ))2,5,5
4 XMAX = X(KP)
RETURN
END

```

```

SUBROUTINE AMIN (X,N,XMIN)
C
C          FINDS MINIMUM VALUE OF ARRAY X
C
C
DIMENSION X(N)
C
KQ = 1
5 KP = KQ
2 IF(KQ-N)3,4,4
3 KQ = KQ + 1
IF(X(KP) - X(KQ))2,5,5
4 XMIN = X(KP)
RETURN
END

```

```

SUBROUTINE AREA(N,X,Y,A11,A12,A22,CSQU,CAREA,IND)
C
C COMPUTES ORIENTATION OF CONFIDENCE ELLIPSES, LENGTHS OF MAJOR AND
C MINOR AXFS AND AREA OF ELLIPSE. THIS ROUTINE IS BASED CLOSELY ON
C THE THEORY DESCRIBED BY E.A.FLINN, REVIEWS OF GEOPHYSICS, VOL 3, 157-185
C
C
COMMON /CCASTS/ PI
DIMENSION X(N), Y(N), ADASH(2,2)

C
GO TO 1,2,IND
1 DET=1./(A11*A22-A12*A12)
ADASH(1,1)=A22*DET
ADASH(1,2)=-A12*DET
ADASH(2,2)=A11*DET
GO TO 3
2 ADASH(1,1)=A11
ADASH(1,2)=A12
ADASH(2,2)=A22
3 ADASH(2,1)=ADASH(1,2)
C
ALPHA=C.5*ATAN( 2.*ADASH(1,2)/(ADASH(1,1)-ADASH(2,2)))
IF((ADASH(1,1)-ADASH(2,2)).EQ.0.)ALPHA=PI*0.5
C
CALF=COS(ALPHA)
SALF=SIN(ALPHA)
CALF2=CALF*CALF
SALF2=SALF*SALF
SCALF=CALF*SALF
C
HOLD=2.*ADASH(1,2)*SCALF
AD=ADASH(1,1)*SALF2-HOLD+ADASH(2,2)*CALF2
BD=ADASH(1,1)*CALF2+HOLD+ADASH(2,2)*SALF2
C
CAREA=((PI*CSQU)/SQRT(AD*BD))
C=SQRT(CSQU)
A=C/SQRT(AD)
B=C/SQRT(BD)
C
CALL ELLIP(A,X,Y,A,B,CALF,SALF)
C
RETURN
END

```

```

SUBROUTINE EAZDEL(ELAT,FLON,SLAT,SLON,BB,AZ,DIST,DTCR)
C
C THIS PROGRAM COMPUTES BACKBEARING (BB), AZIMUTH (AZ) AND
C DISTANCE (DIST) OF EPICENTRE (COORDINATES - ELAT, ELON) FROM
C STATION (COORDINATES - SLAT, SLON) AND FORMULAE USED ARE
C TAKEN FROM ISS BULLETINS
C
C
SLA=SLAT*DTCR
SLC=SLON*DTCR
ELA=ELAT*DTCR
ELC=ELON*DTCR
C
SLAC=COS(SLA)
SLAS=SIN(SLA)
SLCC=COS(SLC)
SLCS=SIN(SLC)
C
ELAC=COS(ELA)
ELAS=SIN(ELA)
ELCC=COS(ELC)
ELOS=SIN(ELC)
C
AS=SLAC*SLCC
BS=SLAC*SLCS
CS=SLAS
DS=SLOS
ES=-SLOC
GS=SLAS*SLCC
HS=SLAS*SLCS
SK=-SLAC
C

```

```

AE=ELAC*ELCC
BE=ELAC*ELCS
CE=ELAS
DE=ELOS
EE=-ELOC
GE=ELAS*ELOC
HE=ELAS*ELCS
EK=-ELAC
C
CDIST=AE*AS+BE*BS+CE*CS
SDIST=SQRT(1.-CDIST*CDIST)
DIST=ATAN2(SDIST,CDIST)/DTOR
CSDIST=1./SCLIST
SAZ=(AS*DE+BS*EE)*CSDIST
CAZ=(AS*GE+BS*HE+CS*EK)*CSDIST
SBB=(AE*DS+BE*ES)*CSDIST
CBB=(AE*GS+BE*HS+CE*SK)*CSDIST
C
AZ=ATAN2(SAZ,CAZ)/DTOR
IF(AZ.LT.0.) AZ=AZ+360.
BB=ATAN2(SBB,CBB)/DTOR
IF(BB.LT.0.) BB=BB+360.
C
RETURN
END

```

```

SUBROUTINE ELLIP(N,X,Y,A,B,CALF,SALF)
C COMPUTES N POINTS OF X AND Y DEFINING CONFIDENCE ELLIPSE
C
COMMON /CCNSTS/ PI
DIMENSION X(N), Y(N)
C
M4=(N-3)/4+1
M2=M4*2
M=M2*2-1
DEL=PI/FLOAT(M2-1)
C
DO 1 I=1,M4
I1=I-1
THETA=FLOAT(I1)*DEL
HXC=A*COS(THETA)
HYC=B*SIN(THETA)
HXS=HXC*SALF
HYS=HYC*SALF
HXC=HXC*CALF
HYC=HYC*CALF
IM=M2-I1
IMM=M2+I1
IM2=M-I1
X(I)= HXC+HYS
Y(I)=-HXS+HYC
X(IM)= -HXC+HYS
Y(IM)= HXS+HYC
X(IMM)= -HXC-HYS
Y(IMM)= HXS-HYC
X(IM2)= HXC-HYS
Y(IM2)= -HXS-HYC
CONTINUE
1
DO 2 I=M,N
X(I)=X(M)
Y(I)=Y(M)
CONTINUE
2
C
RETURN
END

```

```

FUNCTION GECCEN(ALAT)
C CONVERT LATITUDE FROM GEOGRAPHIC TO GEOCENTRIC
C
COMMON /CCNSTS/ PI,DTOR,RTOD,ZKM,ER,GCON
C
GECEN=RTOD*ATAN(GCON*(SIN(ALAT*DTOR)/COS(ALAT*DTOR)))
C
RETURN
END

```

```

FUNCTION GECGRF(ALAT)
C
C      CONVERT LATITUDE FROM GEOCENTRIC TO GEOGRAPHIC
C
C      COMMON /CCNSTS/ PI,DTOR,RTOD,ZKM,ER,GCON
C      GEOGRF=RTOD*ATAN(SIN(ALAT*DTOR)/(COS(ALAT*DTOR)*GCON))
C
C      RETURN
C      END

SUBROUTINE GRAPH(EVENT,NEVENT,X,Y,NN)
C
C      SETS UP INDICATORS AND MAXIMUM AND MINIMUM VALUES TO ALLOW
C      GRAPHING OF CONFIDENCE ELLIPSES ON A COMMON SCALE
C
C      COMMON /GRFF/ TITLE(20), XMAX, XMIN, YMAX, YMIN, INDX, INDY, IND,
C      IIDCT, ANSTRI, XLIMIT, YLIMIT, SCALX, SCALY
C
C      REAL*8 TITLE,EVENT,BLANK,FN,FS,FE,FW
C      DIMENSION EVENT(NEVENT),X(NN),Y(NN)
C
C      DATA BLANK/8H      /,
C      FN/8HNORTH      /,FS/8HSOUTH      /,FE/8HEAST      /,FW/8HWEST      /
C
C      DO 2 I=18,2C
C      TITLE(I)=BLANK
2     CONTINUE
C      TITLE(1)=FW
C      TITLE(2)=BLANK
C      TITLE(3)=FE
C      TITLE(4)=FN
C      TITLE(5)=FS
C
C      IF=2
NLIM=NN*NEVENT
CALL AMAX(X,NLIM,XMAX)
CALL AMIN(X,NLIM,XMIN)
CALL AMAX(Y,NLIM,YMAX)
CALL AMIN(Y,NLIM,YMIN)
YMAX=AMAX1(YMAX,XMAX)
XMAX=YMAX
YMIN=AMIN1(YMIN,XMIN)
XMIN=YMIN
INDX=1
INDY=1
IND=1
IDOT=44
ANSTRI=1.
C
DO 3 I=1,NEVENT
IXY=(I-1)*NN+1
TITLE(15)=EVENT(I)
CALL GRIF(X(IXY),Y(IXY),NN,0.)
3     CONTINUE
C
RETURN
END

FUNCTION HEIGHT(ALAT)
C
C      COMPUTE HEIGHT ABOVE THE MEAN SPHERE OF POINT OF LATITUDE
C
C      COMMON /CCNSTS/ PI,DTOR,RTOD,ZKM,ER
C
HEIGHT=ER*(1./3.-SIN(ALAT*DTOR)**2)
C
RETURN
END

SUBROUTINE HRTM(TSECS,MHRS,MINS,SECS)
C
C      CONVERT SECONDS TO HOURS MINUTES AND SECONDS
C
C      DOUBLE PRECISION TSECS
C
MHRS=TSECS/3600.00
MINS=(TSECS-DFLOAT(MHRS*3600))/60.00
SECS=TSECS-CFLOAT(MHRS*3600)-DFLOAT(MINS*60)
C
RETURN
END

```

```

FUNCTION SECTM(MHR,MIN,SEC)
C   CONVERT HOURS MINUTES AND SECONDS TO SECONDS
C   DOUBLE PRECISION SECTM
C
C   SECTM=DFLOAT((MHR*60+MIN)*60)+DBLE(SEC)
C
RETURN
END

SUBROUTINE SMATRX(A,X,M,N)
C   MATRIX INVERSION ROUTINE
C
C   THE METHOD USED IS CALLED TRIANGULAR DECOMPOSITION
C   FROM N.P.L. MODERN COMPUTING METHODS
C
C   DIMENSION A(N,N),X(N),C(212),IND(212)
C   DOUBLE PRECISION A,AMAX,STO,W,W1,C,X
C
AMAX=0.0D0
DO 2 I=1,M
IND(I)=I
IF(DABS(A(I,1))-AMAX)2,2,3
3 AMAX=DABS(A(I,1))
I4=I
2 CONTINUE
MM=M-1
DO 111 J=1,MM
IF(I4-J)6,6,4
4 ISTO=IND(J)
IND(J)=IND(I4)
IND(I4)=ISTO
DO 5 K=I,M
STO=A(I4,K)
A(I4,K)=A(J,K)
A(J,K)=STO
5 CONTINUE
6 AMAX=0.0D0
J1=J+1
DO 11 I=J1,M
A(I,J)=A(I,J)/A(J,J)
DO 10 K=J1,M
A(I,K)=A(I,K)-A(I,J)*A(J,K)
IF (K-J1)14,14,10
14 IF(DABS(A(I,K))-AMAX)10,10,17
17 AMAX=DABS(A(I,K))
I4=I
10 CONTINUE
11 CONTINUE
111 CONTINUE
65 DO 140 II=1,MM
I=M+1-II
I2=I-1
DO 41 J1=1,I2
J=I2+1-J1
J2=J+1
W1=-A(I,J)
IF(I2-J2)41,43,43
43 DO 42 K=J2,I2
W1=W1-A(K,J)*C(K)
42 CONTINUE
141 C(J)=W1
41 CONTINUE
DO 40 K=1,I2
A(I,K)=C(K)
40 CONTINUE
140 CONTINUE
DO 150 II=1,M
I=M+1-II
I2=I+1
W=A(I,I)
DO 56 J=1,M
IF (I-J)52,53,54
52 W1=0.0D0
GO TO 55

```

```

53 W1=1.D0
      GO TO 55
54 W1=A(I,J)
55 IF(I1-1)156,156,57
57 DO 58 K=I2,M
      W1=W1-A(I,K)*A(K,J)
58 CONTINUE
156 C(J)=W1
56 CONTINUE
      DO 50 J=1,M
      A(I,J)=C(J)/W
50 CONTINUE
150 CONTINUE
      DO 60 I=1,M
63 IF(IND(I)-I)61,60,61
61 J=IND(I)
      DO 62 K=1,M
      STO=A(K,I)
      A(K,I)=A(K,J)
      A(K,J)=STO
62 CONTINUE
      ISTO=IND(J)
      IND(J)=J
      IND(I)=ISTO
      GO TO 63
60 CONTINUE
C
64   DO 66 J=1,M
      STO=0.D0
      DO 67 I=1,M
      STO=STO+A(I,J)*A(I,M+1)
67   CONTINUE
      X(J)=STO
66   CONTINUE
C
      RETURN
END

SUBROUTINE TREAD(CODE,IMTRX,IND)
C
C THIS ROUTINE SETS UP STATIONS AND TABLES
C
C     FOR IND=1 SET UP STATIONS ONLY
C     FOR IND=2 SET UP TABLES ONLY
C     FOR IND=3 SET UP BOTH STATIONS AND TABLES
C
C
COMMON /BLANK/    IUNIT,JUNIT,KUNIT,LUNIT,MUNIT,NUNIT,KTAB,
1           LIND,LINE,LINES,LLINES
COMMON /GECS/     NEVENT,NPAGE
C
COMMON /TABLES/   IPKP, NPKP, NPKPD, PKP(14,73), PKPDEP(14),
1           IP, NP, NPD, P(21,223), PDEP(21), PDIST, PSTART
C
COMMON /ATAE/     NTABLE,STN(3000),SLAT(3000),SLON(3000),COR(3000)
C
DATA STARS/4H****/
C
GO TO (90,96,90),IND
C
C ANY EXTRA STATIONS AND COORDINATES NOT STORED ON TAPE CAN NOW BE
C READ IN UP TO TOTAL OF 3000 STATIONS. LAST CARD OF THIS BLOCK
C MUST CONTAIN ASTERISKS IN COLUMNS 2 TO 5. IF NO EXTRA STATIONS
C CARD WITH ASTERISKS MUST STILL BE INCLUDED.
C
90 I=0
92 I=I+1
94 READ (5,100) STN(I),SLAT(I),SLON(I)
100 FORMAT(1X,A4,34X,F10.6,5X,F11.6)
      IF(STN(I)=STARS)92,93,92
C
C READ STATION DATA FROM TAPE
C
93 N=I
      READ (16) NTABLE,(STN(I),SLAT(I),SLON(I),I=N,3000)
C
1 NTABLE=MINO(NTABLE+N-1,3000)
DO 91 I=1,NTABLE
      SLAT(I)=GEOCEN(SLAT(I))
      COR(I)=0.
91 CONTINUE
C

```

```

C 96 GO TO (2,95,95),IND
C      READ IN AND SETUP TRAVEL TIMES
C
C 95 KTAB=IMTRX
C      GO TO (98,98,97),KTAB
C 97 PRINT 100, (STN(I),SLAT(I),SLON(I),I=1,NTABLE)
C 98 LIND=47
C      NPAGE=1
C      JUNIT=4
C      LUNIT=6
C      IP=21
C      IPKP=14
C      CALL TABS(0,CODE,IP,NP,NPD,P,PDEP,PDIST,PSTART,IPKP,NPKP,NPKPD,
C      1PKP,PKPDEP)
C
C 2 RETURN
C      END

C      DUMMY SUBROUTINE FINISH
C
C      SUBROUTINE FINISH IS A LIBRARY PROGRAM USED TO CLOSE THE DATASET
C      USED FOR PLCTTING GRAPHS
C
C      SUBROUTINE FINISH
C      STOP
C      END

C      DUMMY SUBROUTINE GC
C
C      SUBROUTINE GC IS A GEDESS ROUTINE NOT USED HERE
C
C      SUBROUTINE CCIALAT,ALONG,AA,AB,AC,AD,AE,AG,AH,AK,H)
C      RETURN
C      END

C      DUMMY SUBROUTINE GGS
C
C      SUBROUTINE GGS IS A GEDESS ROUTINE NOT USED HERE
C
C      SUBROUTINE GGS(M,STN,SLAT,SLONG,ELEV,SA,SB,SC,SD,SE,SG,SH,SK,H)
C      RETURN
C      END

C      DUMMY SUBROUTINE GRIF
C
C      SUBROUTINE GRIF IS A LINK PROGRAM BETWEEN THE GRAPH PROGRAM
C      AND ANY PLOTTING ROUTINE
C
C      SUBROUTINE GRIF(X,Y,N,DT)
C      DIMENSION X(N),Y(N)
C      RETURN
C      END

C      DUMMY SUBROUTINE LOOKUP
C
C      SUBROUTINE LOOKUP IS USED TO FIND THE REGION NAME AND NUMBER
C      OF AN EPICENTRE
C
C      SUBROUTINE LOOKUP(ALAT,DRCLAT,ALONG,DRCLNG,IGREG,ISREG,RNAME,N)
C      IREG=0
C      ISREG=0
C      RETURN
C      END

```

APPENDIX F

EXAMPLES OF INPUT AND OUTPUT FOR EACH PROGRAM

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F1. SAMPLE INPUT AND OUTPUT FOR SPUR WITH STATION COORDINATES	72
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F1. SAMPLE INPUT AND OUTPUT FOR SPUR WITH STATION COORDINATES

Three examples of the use of SPUR are shown.

F1.1 Theoretical stations study

This uses data constructed from the J-B tables for a set of hypothetical stations for a fictitious earthquake with epicentre 10.0S, 45.0W, origin time 01.00 .00 GMT. The arrival times should be error free (apart from rounding error) so that the computed epicentre and origin time should agree with the values used to construct the data.

F1.2 Theoretical stations study - J-B times modified by
2 sin A seconds

This uses the same arrival time data as F1.1 except that a bias in the travel times of $2 \sin A$ seconds (where A is the azimuth of the station from the epicentre) has been included. The epicentral estimate is now displaced from the value used to construct the arrival time data (cf, results obtained from JED).

F1.3 JED test date - LONGSHOT

This uses observed data from the explosion LONGSHOT (cf, results obtained from JED).

BMO	BLUE MOUNTAINS	OREGON	LAT 44.848889	LONG -117.305556	
BRS	BRISBANE	QUEENSLAND	LAT -27.391667	LONG 152.775000	
COL	COLLEGE OUTPOST	*ALASKA	LAT 64.900000	LONG -147.793333	
CPO	CUMBERLAND PLAT.	TENNESSEE	LAT 35.594833	LONG -85.570417	
CTA	CHARTERSTOWERS*	QUEENSLAND	LAT -20.088333	LONG 146.254444	358
DAR	DARWIN/	N.TERRITORY	LAT -12.408333	LONG 130.818333	6
EKA	ESKDALEMUIR	ARRAY SCOTLAND	LAT 55.333189	LONG -3.158756	
GBA	GAURIBIDANUR	ARRAY INDIA	LAT 13.604167	LONG 77.436111	
HNR	HONIARA*	SOLOMON IS.	LAT -9.432194	LONG 159.947111	72
IST	ISTANBUL*	TURKEY	LAT 41.045556	LONG 28.995833	50
KIP	KIPAPA*	HAWAII	LAT 21.423333	LONG -158.015000	
KON	KONGSBERG*	NORWAY	LAT 59.649083	LONG 9.598222	200
KOU	KOUMAC	NEW CALEDONIA	LAT -20.561944	LONG 164.281389	
MAT	MATSUSHIRO*	HONSHU	LAT 36.538333	LONG 138.208333	440
OTT	OTTAWA&	ONTARIO	LAT 45.393889	LONG -75.715833	
PAS	PASADENA	CALIFORNIA	LAT 34.148333	LONG -118.171667	
PMG	PORT MORESBY*	PAPUA	LAT -9.409167	LONG 147.153889	
PPT	PAPEETE	TAHITI	LAT -17.568889	LONG -149.575556	260
QUE	QUETTA*	PAKISTAN	LAT 30.188333	LONG 66.950000	
RIV	RIVERVIEW*	N.S.WALES	LAT -33.829361	LONG 151.158333	
SHL	SHILLONG*	INDIA	LAT 25.566667	LONG 91.883333	
SGJ	SAN JUAN*	PUERTO RICO	LAT 18.111667	LONG -66.150000	
TEH	TEHERAN	IRAN	LAT 35.737778	LONG 51.385556	
TOD	TOOLANGI	VICTORIA	LAT -37.571389	LONG 145.490556	
TRD	TROMSOE	NORWAY	LAT 69.632500	LONG 18.928056	
UBO	JINTA BASIN/	UTAH	LAT 40.321667	LONG -109.568694	
UPP	UPPSALA	SWEDEN	LAT 59.858056	LONG 17.626944	
VUN	VUNIKAWAI	FIJI ISLANDS	LAT -18.042667	LONG 178.463667	
WES	WESTON*	MASSACHUSETTS	LAT 42.384694	LONG -71.322083	
WRA	WARRAMUNGA ARRAY	AUSTRALIA	LAT -19.947778	LONG 134.350833	
YKA	YELLOW KNIFE ARRAY	CANADA	LAT 62.492858	LONG -114.604593	
TS01	DIST = 30	AZ = 30	LAT 35.346	LONG -17.193	10N 35W
TS02	DIST = 30	AZ = 60	LAT 23.447	LONG -6.869	10N 35W
TS03	DIST = 30	AZ = 90	LAT 8.650	LONG -4.624	10N 35W
TS04	DIST = 30	AZ = 120	LAT -5.595	LONG -9.211	10N 35W
TS05	DIST = 30	AZ = 150	LAT -16.191	LONG -19.919	10N 35W
TS06	DIST = 30	AZ = 180	LAT -20.190	LONG -35.000	10N 35W
TS07	DIST = 30	AZ = 210	LAT -16.191	LONG -50.081	10N 35W
TS08	DIST = 30	AZ = 240	LAT -5.595	LONG -60.789	10N 35W
TS09	DIST = 30	AZ = 270	LAT 8.649	LONG -65.376	10N 35W
TS10	DIST = 30	AZ = 300	LAT 23.447	LONG -63.131	10N 35W
TS11	DIST = 30	AZ = 330	LAT 35.346	LONG -52.807	10N 35W
TS12	DIST = 30	AZ = 360	LAT 40.124	LONG -35.000	10N 35W
TS13	DIST = 60	AZ = 30	LAT 55.769	LONG 15.017	10N 35W
TS14	DIST = 60	AZ = 60	LAT 31.019	LONG 25.879	10N 35W
TS15	DIST = 60	AZ = 90	LAT 4.982	LONG 25.373	10N 35W
TS16	DIST = 60	AZ = 120	LAT -20.016	LONG 17.901	10N 35W
TS17	DIST = 60	AZ = 150	LAT -40.921	LONG -0.151	10N 35W
TS18	DIST = 60	AZ = 180	LAT -50.255	LONG -35.000	10N 35W
TS19	DIST = 60	AZ = 210	LAT -40.921	LONG -69.849	10N 35W
TS20	DIST = 60	AZ = 240	LAT -20.016	LONG -87.901	10N 35W
TS21	DIST = 60	AZ = 270	LAT 4.981	LONG -95.373	10N 35W
TS22	DIST = 60	AZ = 300	LAT 31.019	LONG -95.879	10N 35W
TS23	DIST = 60	AZ = 330	LAT 55.769	LONG -85.017	10N 35W
TS24	DIST = 60	AZ = 360	LAT 70.058	LONG -35.000	10N 35W
TS25	DIST = 90	AZ = 30	LAT 58.715	LONG 71.636	10N 35W
TS26	DIST = 90	AZ = 60	LAT 29.671	LONG 60.688	10N 35W
TS27	DIST = 90	AZ = 90	LAT 0.000	LONG 55.000	10N 35W
TS28	DIST = 90	AZ = 120	LAT -29.670	LONG 49.312	10N 35W
TS29	DIST = 90	AZ = 150	LAT -58.715	LONG 38.364	10N 35W
TS30	DIST = 90	AZ = 180	LAT -80.131	LONG -35.000	10N 35W
TS31	DIST = 90	AZ = 210	LAT -58.715	LONG -108.364	10N 35W
TS32	DIST = 90	AZ = 240	LAT -29.671	LONG -119.312	10N 35W
TS33	DIST = 90	AZ = 270	LAT -0.000	LONG -125.000	10N 35W
TS34	DIST = 90	AZ = 300	LAT 29.670	LONG -130.688	10N 35W
TS35	DIST = 90	AZ = 330	LAT 58.715	LONG -141.636	10N 35W
TS36	DIST = 90	AZ = 360	LAT 80.131	LONG 145.300	10N 35W
****	END OF STATIONS				
****	END OF CORRECTIONS				
TITLE THEORETICAL STATIONS STUDY - JB TIMES					
EVENT	1 0 0.	0.ON 45.0W			
TS01	1 9	15.0			10S 45W
TS02	1 8	58.2			10S 45W
TS03	1 8	13.5			10S 45W
TS04	1 7	2.7			10S 45W
TS05	1 5	28.8			10S 45W
TS06	1 3	21.9			10S 45W
TS07	1 1	58.9			10S 45W
TS08	1 3	51.3			10S 45W
TS09	1 5	50.1			10S 45W
TS10	1 7	19.1			10S 45W
TS11	1 8	24.7			10S 45W
TS12	1 9	3.7			10S 45W

TS13	1 12 24.1	10S 45W
TS14	1 12 8.5	10S 45W
TS15	1 11 26.2	10S 45W
TS16	1 10 19.9	10S 45W
TS17	1 8 58.8	10S 45W
TS18	1 7 46.2	10S 45W
TS19	1 7 20.1	10S 45W
TS20	1 7 59.1	10S 45W
TS21	1 9 16.4	10S 45W
TS22	1 10 35.1	10S 45W
TS23	1 11 36.3	10S 45W
TS24	1 12 13.2	10S 45W
TS27	1 13 48.6	10S 45W
TS28	1 12 57.7	10S 45W
TS29	1 12 2.1	10S 45W
TS30	1 11 16.7	10S 45W
TS31	1 11 1.8	10S 45W
TS32	1 11 25.2	10S 45W
TS33	1 12 14.4	10S 45W
TS34	1 13 8.7	10S 45W

TITLE THEORETICAL STATIONS STUDY - JB TIMES ADJUSTED BY 2*SIN(AZ)

EVENT 2 0 0.	10.0S 45.0W	
TS01	2 9 16.0	10S 45W
TS02	2 8 59.9	10S 45W
TS03	2 8 15.5	10S 45W
TS04	2 7 4.4	10S 45W
TS05	2 5 29.8	10S 45W
TS06	2 3 21.9	10S 45W
TS07	2 1 57.9	10S 45W
TS08	2 3 49.6	10S 45W
TS09	2 5 48.1	10S 45W
TS10	2 7 17.4	10S 45W
TS11	2 8 23.7	10S 45W
TS12	2 9 3.7	10S 45W
TS13	2 12 25.1	10S 45W
TS14	2 12 10.2	10S 45W
TS15	2 11 28.2	10S 45W
TS16	2 10 21.6	10S 45W
TS17	2 8 59.8	10S 45W
TS18	2 7 46.2	10S 45W
TS19	2 7 19.1	10S 45W
TS20	2 7 57.4	10S 45W
TS21	2 9 14.4	10S 45W
TS22	2 10 33.4	10S 45W
TS23	2 11 35.3	10S 45W
TS24	2 12 13.2	10S 45W
TS27	2 13 50.6	10S 45W
TS28	2 12 59.4	10S 45W
TS29	2 12 3.1	10S 45W
TS30	2 11 16.7	10S 45W
TS31	2 11 0.8	10S 45W
TS32	2 11 23.5	10S 45W
TS33	2 12 12.4	10S 45W
TS34	2 13 7.0	10S 45W

TITLE JEO TEST DATA - LONGSHOT

EVENT 21 00 00.1	51.44 N 179.18 E	
COL	21 04 50.3	LONGSHOT
MAT	21 06 32.2	LONGSHOT
KIP	21 06 53.9	LONGSHOT
BMO	21 07 48.5	LONGSHOT
PAS	21 08 36.0	LONGSHOT
UBO	21 08 47.2	LONGSHOT
TRO	21 09 53.9	LONGSHOT
HNR	21 10 27.0	LONGSHOT
OTT	21 10 30.8	LONGSHOT
CPO	21 10 45.6	LONGSHOT
PMG	21 10 51.4	LONGSHOT
UPP	21 10 57.7	LONGSHOT
WES	21 10 59.8	LONGSHOT
KON	21 11 04.2	LONGSHOT
SHL	21 11 04.6	LONGSHOT
VUN	21 11 08.6	LONGSHOT
KOU	21 11 31.2	LONGSHOT
PPT	21 11 37.5	LONGSHOT
DAR	21 11 49.0	LONGSHOT
CTA	21 11 52.6	LONGSHOT
QUE	21 12 07.2	LONGSHOT
TEH	21 12 20.0	LONGSHOT
BRS	21 12 20.7	LONGSHOT
IST	21 12 30.0	LONGSHOT
RIV	21 12 53.7	LONGSHOT
SJG	21 13 01.3	LONGSHOT
TOO	21 13 16.3	LONGSHOT

EPICENTRE DETERMINATION AT ZERO DEPTH

THEORETICAL STATIONS STUDY - JB TIMES

INITIAL EPICENTRE	LATITUDE	0.0	N
	LONGITUDE	45.000	W
	ORIGIN TIME	1 C 0.0	

RESULTS AFTER 3 ITERATIONS (JB TRAVEL TIMES USED)

COMPUTED EPICENTRE	LATITUDE	10.003	S	+/-	0.4 KM
	LONGITUDE	45.001	W	+/-	0.4 KM
	ORIGIN TIME	0 59 60.0		+/-	0.0 S

SUM SQUARED RESIDUALS = 0.0765
 SHIFT IN EPICENTRE = 1105.0 KM
 DIRECTION OF SHIFT = 180.0 DEGS

STATION	READING	RESIDUAL			DISTANCE	AZIMUTH
		H	M	S	DEGS	DEGS
1 TS01	1 9 15.0	-0.019			52.20	28.9
2 TS02	1 8 58.2	0.033			49.96	47.8
3 TS03	1 8 13.5	0.040			44.26	66.6
4 TS04	1 7 2.7	0.058			35.71	85.7
5 TS05	1 5 28.8	-0.017			25.18	106.8
6 TS06	1 3 21.9	-0.055			13.99	137.5
7 TS07	1 1 58.9	-0.125			7.89	218.3
8 TS08	1 3 51.3	-0.077			16.24	284.5
9 TS09	1 5 50.1	-0.012			27.47	311.7
10 TS10	1 7 19.1	0.006			37.68	332.1
11 TS11	1 8 24.7	-0.013			45.70	351.1
12 TS12	1 9 3.7	-0.026			50.73	9.9
13 TS13	1 12 24.1	-0.037			82.20	29.6
14 TS14	1 12 8.5	-0.017			79.14	55.7
15 TS15	1 11 26.2	-0.011			71.66	81.4
16 TS16	1 10 19.9	-0.028			61.27	107.3
17 TS17	1 8 58.8	0.042			50.08	135.8
18 TS18	1 7 46.2	0.087			40.97	170.2
19 TS19	1 7 20.1	0.049			37.82	211.3
20 TS20	1 7 59.1	0.023			42.50	251.3
21 TS21	1 9 16.4	0.054			52.34	284.2
22 TS22	1 10 35.1	0.019			63.57	911.9
23 TS23	1 11 36.3	0.049			73.51	337.7
24 TS24	1 12 13.2	-0.047			80.17	3.5
25 TS27	1 13 48.6	-0.121			99.85	91.7
26 TS28	1 12 57.7	-0.018			88.82	119.8
27 TS29	1 12 2.1	0.023			78.08	148.0
28 TS30	1 11 16.7	-0.003			70.29	178.2
29 TS31	1 11 1.8	0.026			67.81	210.2
30 TS32	1 11 25.2	0.048			71.53	242.1
31 TS33	1 12 14.4	0.054			80.15	271.7
32 TS34	1 13 8.7	0.017			91.18	299.8

EPICENTRE DETERMINATION AT ZERO DEPTH

THEORETICAL STATIONS STUDY - JB TIMES ADJUSTED BY 2*SIN(AZ)

INITIAL EPICENTRE	LATITUDE	10.000	S
	LONGITUDE	45.000	W
	ORIGIN TIME	2 C 0.0	

RESULTS AFTER 2 ITERATIONS (JB TRAVEL TIMES USED)

COMPUTED EPICENTRE	LATITUDE	10.006	S	+/-	5.2 KM
	LONGITUDE	45.227	W	+/-	4.8 KM
	ORIGIN TIME	1 59 59.9		+/-	0.2 S

SUM SQUARED RESIDUALS = 13.2826
 SHIFT IN EPICENTRE = 24.9 KM
 DIRECTION OF SHIFT = 268.5 DEGS

STATION	READING	RESIDUAL			DISTANCE	AZIMUTH
		H	M	S	DEGS	DEGS
1 TS01	2 9 16.0	0.253			52.31	29.0
2 TS02	2 8 59.9	0.558			50.13	48.0
3 TS03	2 8 15.5	0.473			44.47	66.7
4 TS04	2 7 4.4	-0.036			35.93	85.7
5 TS05	2 5 29.8	-0.920			25.39	106.7
6 TS06	2 3 21.9	-1.920			14.19	136.9
7 TS07	2 1 57.9	0.895			7.76	217.1
8 TS08	2 3 49.6	1.043			16.03	284.7
9 TS09	2 5 48.1	-0.426			27.31	312.1

10	TS10	2	7	17.4	-0.748	37.58	332.4
11	TS11	2	8	23.7	-0.668	45.67	351.3
12	TS12	2	9	3.7	-0.243	50.77	10.1
13	TS13	2	12	25.1	0.475	82.31	29.7
14	TS14	2	12	10.2	0.777	79.32	55.7
15	TS15	2	11	28.2	0.761	71.88	81.4
16	TS16	2	10	21.6	0.326	61.49	107.3
17	TS17	2	8	59.8	-0.032	50.23	135.7
18	TS18	2	7	46.2	-0.115	41.01	170.0
19	TS19	2	7	19.1	0.124	37.70	211.1
20	TS20	2	7	57.4	0.149	42.29	251.3
21	TS21	2	9	14.4	-0.240	52.12	284.3
22	TS22	2	10	33.4	-0.507	63.41	312.1
23	TS23	2	11	35.3	-0.383	73.42	337.8
24	TS24	2	12	13.2	-0.037	80.19	3.5
25	TS27	2	13	50.6	0.957	100.07	91.8
26	TS28	2	12	59.4	0.855	89.02	119.8
27	TS29	2	12	3.1	0.479	78.19	148.0
28	TS30	2	11	16.7	0.059	70.29	178.1
29	TS31	2	11	0.8	-0.164	67.70	210.2
30	TS32	2	11	23.5	-0.374	71.33	242.1
31	TS33	2	12	12.4	-0.667	79.93	271.8
32	TS34	2	13	7.0	-0.706	90.98	299.8

EPICENTRE DETERMINATION AT ZERO DEPTH

JED TEST DATA - LONGSHOT

INITIAL EPICENTRE LATITUDE 51.440 N
 LONGITUDE 179.180 E
 ORIGIN TIME 21 C 0.1

RESULTS AFTER 2 ITERATIONS (JB TRAVEL TIMES USED)

COMPUTED EPICENTRE LATITUDE 51.644 N +/- 9.8 KM
 LONGITUDE 179.211 E +/- 10.2 KM
 ORIGIN TIME 20 59 57.0 +/- 0.4 S

SUM SQUARED RESIDUALS = 24.4703
 SHIFT IN EPICENTRE = 23.0 KM
 DIRECTION OF SHIFT = 5.4 DEGS

STATION	READING	H M S	RESIDUAL S	DISTANCE DEGS	AZIMUTH
					DEGS
1 COL	21 4 50.3		1.136	21.51	39.3
2 MAT	21 6 32.2		-0.030	32.61	258.7
3 KIP	21 6 53.9		0.968	34.98	141.0
4 BMO	21 7 48.5		0.485	41.62	73.4
5 PAS	21 8 36.0		-0.000	47.57	86.1
6 UBU	21 8 47.2		1.041	48.89	73.9
7 TRU	21 9 53.9		-0.302	58.18	352.0
8 HNR	21 10 27.0		-1.384	63.06	201.4
9 OTT	21 10 30.8		-2.197	63.84	49.3
10 CPO	21 10 45.6		-1.396	65.98	62.7
11 PMG	21 10 51.4		-1.155	66.79	214.7
12 UPP	21 10 57.7		-0.730	67.86	350.1
13 WES	21 10 59.8		-1.072	68.19	48.8
14 KON	21 11 4.2		0.280	68.74	354.4
15 SHL	21 11 4.6		-0.228	68.78	284.6
16 VUN	21 11 8.6		-0.071	69.39	180.8
17 KUU	21 11 31.2		0.397	73.08	194.6
18 PPT	21 11 37.5		0.633	74.11	149.1
19 DAR	21 11 49.0		-0.308	76.28	228.8
20 CTA	21 11 52.6		-0.851	77.03	211.6
21 QUE	21 12 7.2		1.901	79.23	305.3
22 TEH	21 12 20.0		1.578	81.72	319.5
23 BRS	21 12 20.7		0.366	82.06	203.6
24 IST	21 12 30.0		-0.574	84.11	337.8
25 RIV	21 12 53.7		0.921	88.61	203.1
26 SJG	21 13 1.3		0.192	90.31	59.8
27 TDU	21 13 16.3		0.399	93.62	206.2

F2. TRAVEL TIME TABLES (J-B) AND ELLIPTICITY CORRECTIONS
AS INPUT TO SPEEDY AND JED

This is followed by the data given in F3 (for SPEEDY) or F4 (for JED) to complete the input to SPEEDY and JED.

IP DEPTH ALLOWANCES		JEFFREYS AND BULLEN (1958)							14	112	
0.00	33.00	96.38	159.76	223.14	286.52	349.90	PDEPTH	S1			
413.28	476.66	540.04	603.42	666.80	730.18	793.56	PDEPTH	S2			
1.4	-6.7	-14.6	-22.3	-29.8	-37.1	-44.3	-51.2	-57.7	-64.0	-70.0	-76.0
3.4	.7	-4.7	-11.2	-18.0	-24.8	-31.6	-38.2	-44.6	-50.7	-56.6	-62.5
3.4	2.5	-.6	-5.2	-10.4	-16.2	-22.2	-28.0	-33.8	-39.4	-44.9	-50.5
3.4	3.0	1.3	-1.6	-5.5	-10.0	-14.9	-20.0	-25.1	-30.1	-35.0	-40.1
3.4	3.5	2.6	.7	-2.1	-5.5	-9.5	-13.6	-17.8	-22.3	-26.7	-31.2
3.4	4.0	3.7	2.5	.6	-2.0	-5.2	-8.4	-11.8	-15.4	-19.2	-23.3
3.5	4.5	4.6	3.9	2.7	.8	-1.5	-4.1	-6.7	-9.6	-12.6	-16.0
3.5	4.7	5.3	5.2	4.5	3.2	1.5	-.2	-2.1	-4.3	-6.8	-9.6
3.6	5.1	6.0	6.3	6.1	5.4	4.2	3.2	2.0	.5	-1.4	-3.7
3.6	5.5	6.7	7.3	7.6	7.4	6.7	6.3	5.8	4.9	3.5	1.7
3.6	5.8	7.4	8.3	9.0	9.2	9.0	9.4	9.4	9.1	8.1	6.8
3.6	6.1	8.0	9.2	10.3	10.9	11.1	12.4	12.9	13.0	12.6	11.7
3.7	6.4	8.6	10.2	11.5	12.5	13.5	15.4	16.4	16.7	16.7	16.3
3.7	6.6	9.1	11.1	12.7	14.0	15.8	18.2	19.6	20.2	20.6	20.2
3.8	6.9	9.6	11.9	13.8	15.6	18.3	21.0	22.7	23.7	24.3	24.6
3.8	7.1	10.1	12.7	14.9	18.0	21.0	23.9	25.8	27.1	27.9	28.6
3.9	7.5	10.7	13.6	16.7	20.4	23.9	26.8	29.0	30.5	31.6	32.5
4.0	7.8	11.2	14.7	18.8	22.7	26.5	29.5	32.0	33.8	35.2	36.2
4.0	8.0	12.1	16.7	21.0	25.1	28.9	32.1	34.8	36.9	38.5	39.7
4.0	9.0	13.9	18.8	23.2	27.4	31.4	34.7	37.6	39.9	41.7	43.0
4.5	9.9	15.1	20.1	24.8	29.1	33.2	36.7	39.7	42.2	44.2	45.7
4.5	10.1	15.5	20.6	25.4	29.8	34.0	37.7	40.9	43.5	45.6	47.2
4.6	10.3	15.8	21.0	25.8	30.3	34.6	38.5	41.8	44.5	46.7	48.5
4.6	10.5	16.0	21.2	26.2	30.9	35.4	39.3	42.7	45.5	47.8	49.7
4.6	10.6	16.1	21.5	26.6	31.4	36.0	40.0	43.4	46.3	48.7	50.7
4.6	10.6	16.4	21.9	27.2	32.1	36.7	40.7	44.2	47.2	49.7	51.8
4.6	10.7	16.5	22.1	27.5	32.4	37.1	41.2	44.8	47.8	50.4	52.6
4.6	10.7	16.6	22.2	27.6	32.6	37.4	41.5	45.2	48.3	51.0	53.3
4.6	10.7	16.6	22.3	27.7	32.8	37.7	41.9	45.5	48.8	51.6	53.9
4.7	10.8	16.7	22.4	27.9	33.0	38.0	42.1	45.9	49.2	52.1	54.5
4.8	10.9	16.8	22.6	28.1	33.3	38.3	42.5	46.3	49.7	52.6	55.1
4.7	10.9	16.8	22.7	28.2	33.5	38.5	42.7	46.6	50.0	53.0	55.6
4.7	11.0	16.9	22.8	28.4	33.7	38.7	43.0	46.9	50.4	53.4	56.0
4.7	11.0	17.0	22.9	28.5	33.9	38.9	43.3	47.2	50.7	53.8	56.5
4.8	11.1	17.2	23.1	28.7	34.1	39.1	43.6	47.5	51.1	54.2	57.0
4.8	11.2	17.3	23.2	28.9	34.3	39.3	43.8	47.8	51.4	54.6	57.4
4.8	11.2	17.4	23.3	29.0	34.4	39.4	44.0	48.0	51.7	54.9	57.8
4.8	11.2	17.4	23.3	29.0	34.5	39.5	44.1	48.2	51.9	55.1	58.1
4.8	11.3	17.4	23.4	29.1	34.6	39.7	44.3	48.5	52.1	55.4	58.4
4.9	11.4	17.5	23.5	29.3	34.8	39.9	44.5	48.8	52.4	55.8	58.8
4.9	11.4	17.6	23.6	29.4	34.9	40.0	44.7	49.0	52.7	56.1	59.2
4.8	11.4	17.6	23.6	29.4	35.0	40.1	44.8	49.2	52.9	56.4	59.6
4.8	11.4	17.6	23.7	29.5	35.1	40.3	45.0	49.4	53.2	56.7	60.0
4.8	11.4	17.7	23.8	29.7	35.3	40.5	45.3	49.7	53.6	57.2	60.5
4.8	11.4	17.8	23.9	29.8	35.4	40.7	45.5	50.0	53.9	57.5	61.0
4.9	11.5	17.9	24.1	30.0	35.6	40.9	45.8	50.3	54.3	58.0	61.5
4.8	11.5	17.9	24.1	30.1	35.7	41.0	46.0	50.5	54.6	58.3	61.9
4.9	11.5	18.0	24.3	30.2	35.9	41.2	46.2	50.8	54.9	58.7	62.3
4.9	11.6	18.1	24.4	30.4	36.1	41.5	46.5	51.1	55.3	59.2	62.8
4.9	11.6	18.1	24.5	30.5	36.2	41.6	46.7	51.3	55.5	59.5	63.2
4.9	11.6	18.2	24.6	30.7	36.4	41.8	46.9	51.6	55.9	59.9	63.6
4.9	11.6	18.2	24.7	30.9	36.6	42.0	47.1	51.9	56.2	60.3	64.0
5.0	11.7	18.3	24.9	31.1	36.8	42.2	47.4	52.2	56.7	60.8	64.6
5.0	11.7	18.4	25.0	31.3	37.0	42.4	47.7	52.6	57.1	61.2	65.1
4.9	11.7	18.4	25.0	31.4	37.1	42.5	47.9	52.8	57.4	61.5	65.4
5.0	11.8	18.5	25.2	31.6	37.4	42.8	48.2	53.2	57.8	62.0	66.0
5.0	11.8	18.5	25.3	31.7	37.5	43.0	48.4	53.5	58.1	62.4	66.4
5.0	11.9	18.7	25.4	31.9	37.8	43.3	48.8	53.8	58.5	62.8	66.9
5.0	11.9	18.7	25.4	31.9	37.9	43.5	49.0	54.0	58.7	63.1	67.3
5.0	12.0	18.7	25.5	32.0	38.0	43.8	49.3	54.3	59.0	63.5	67.7
5.0	12.0	18.8	25.6	32.1	38.2	44.0	49.5	54.6	59.3	63.8	68.1
5.0	12.0	18.8	25.7	32.2	38.4	44.2	49.7	54.8	59.6	64.1	68.5
5.1	12.1	18.9	25.8	32.4	38.6	44.4	49.9	55.1	59.9	64.5	68.9
5.0	12.0	18.5	25.8	32.5	38.7	44.5	50.0	55.3	60.1	64.7	69.1
5.1	12.1	19.0	25.9	32.6	38.9	44.7	50.2	55.5	60.4	65.0	69.5
5.1	12.1	19.0	26.0	32.7	39.0	44.8	50.4</td				

5.2	12.6	19.9	27.0	34.0	40.7	47.1	53.3	59.0	64.4	69.6	74.7	79.7	P	083
5.2	12.7	20.0	27.1	34.1	40.7	47.2	53.4	59.2	64.6	69.7	74.9	79.9	P	084
5.2	12.7	20.0	27.1	34.1	40.8	47.3	53.5	59.3	64.7	69.9	75.1	80.1	P	085
5.3	12.8	20.1	27.2	34.2	41.0	47.5	53.7	59.5	64.9	70.2	75.4	80.4	P	086
5.3	12.8	20.2	27.3	34.3	41.1	47.6	53.8	59.7	65.1	70.4	75.6	80.6	P	087
5.3	12.8	20.2	27.4	34.4	41.1	47.7	53.9	59.8	65.2	70.5	75.7	80.8	P	088
5.3	12.9	20.3	27.5	34.5	41.3	47.8	54.0	59.9	65.3	70.7	75.9	81.0	P	089
5.3	12.9	20.3	27.5	34.5	41.3	47.9	54.1	60.0	65.4	70.8	76.0	81.1	P	090
5.2	12.8	20.2	27.5	34.5	41.3	47.9	54.1	60.0	65.4	70.8	76.0	81.1	P	091
5.2	12.8	20.2	27.4	34.4	41.2	47.8	54.1	60.0	65.5	70.8	76.0	81.1	P	092
5.2	12.8	20.2	27.4	34.4	41.2	47.8	54.1	60.0	65.5	70.8	76.0	81.2	P	093
5.3	12.9	20.3	27.5	34.5	41.3	47.9	54.1	60.0	65.6	70.8	76.0	81.2	P	094
5.3	12.9	20.3	27.5	34.5	41.3	47.9	54.2	60.1	65.7	70.9	76.1	81.3	P	095
5.4	13.0	20.4	27.6	34.6	41.3	47.9	54.3	60.2	65.8	71.0	76.2	81.4	P	096
5.3	12.9	20.3	27.5	34.5	41.3	47.9	54.2	60.1	65.8	71.0	76.2	81.3	P	097
5.3	12.9	20.3	27.5	34.5	41.3	47.8	54.2	60.1	65.8	71.0	76.2	81.3	P	098
5.3	12.8	20.2	27.4	34.4	41.2	47.8	54.2	60.1	65.8	71.0	76.2	81.3	P	099
5.3	12.9	20.3	27.5	34.5	41.3	48.0	54.3	60.2	65.8	71.1	76.3	81.4	P	100
5.3	12.9	20.3	27.5	34.5	41.4	48.1	54.4	60.3	65.9	71.2	76.4	81.5	P	101
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	102
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	103
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	104
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	105
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	106
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	107
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	108
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	109
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	110
5.3	13.0	20.4	27.6	34.6	41.5	48.2	54.5	60.4	66.0	71.3	76.5	81.6	P	111

TABLE 1	P	JB	JEFFREYS AND RULLEN (1958)	TIMES FOR SURFACE FOCUS
	6.8	21.1	35.4	78.1
	106.3	120.3	134.2	92.2 000-006
	201.9	215.0	228.0	188.7 007-013
	287.4	297.5	307.4	277.0 014-020
	354.5	363.5	372.5	345.4 021-027
	416.1	424.6	433.0	407.5 028-034
	474.5	482.7	490.8	466.3 035-041
	530.3	538.0	545.6	522.6 042-048
	582.6	589.8	596.8	575.4 049-055
	630.9	637.5	644.0	624.3 056-062
	675.4	681.5	687.5	669.3 063-069
	716.3	721.8	727.3	710.7 070-076
	753.5	758.5	763.5	748.4 077-083
	787.3	791.9	796.5	782.7 084-090
	819.3	823.8	828.4	814.8 091-097
	850.6	855.0	859.4	846.2 098-104
	1.0			877.0 105-111

5.3	13.3	21.0	28.6	35.9	43.0	50.0	56.6	63.0	69.1	74.9	80.6	86.3	PKP	141
5.3	13.2	20.9	28.4	35.6	42.6	49.5	56.1	62.4	68.4	74.1	79.8	85.3	PKP	142
5.3	13.2	20.9	28.4	35.7	42.8	49.7	56.3	62.7	68.7	74.5	80.2	85.8	PKP	143
5.3	13.2	21.0	28.5	35.8	42.9	49.9	56.5	62.9	69.0	74.8	80.6	86.2	PKP	144
5.3	13.2	21.0	28.5	35.9	43.1	50.1	56.8	63.2	69.3	75.2	81.0	86.7	PKP	145
5.3	13.2	21.1	28.6	36.0	43.2	50.2	57.0	63.4	69.5	75.4	81.2	87.0	PKP	146
5.3	13.3	21.1	28.7	36.1	43.3	50.4	57.1	63.6	69.7	75.6	81.5	87.3	PKP	147
5.4	13.3	21.2	28.7	36.2	43.5	50.5	57.3	63.7	69.8	75.8	81.7	87.5	PKP	148
5.4	13.4	21.2	28.8	36.3	43.6	50.7	57.4	63.9	70.0	76.0	82.0	87.8	PKP	149
5.4	13.4	21.3	28.9	36.4	43.7	50.8	57.6	64.1	70.2	76.2	82.2	88.1	PKP	150
5.4	13.4	21.3	28.9	36.4	43.7	50.8	57.6	64.1	70.2	76.2	82.2	88.1	PKP	151
5.4	13.4	21.3	28.9	36.4	43.7	50.8	57.6	64.1	70.2	76.2	82.2	88.2	PKP	152
5.4	13.4	21.3	28.9	36.4	43.7	50.8	57.7	64.2	70.3	76.3	82.3	88.2	PKP	153
5.4	13.4	21.3	28.9	36.4	43.7	50.8	57.7	64.2	70.3	76.3	82.3	88.2	PKP	154
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.7	64.2	70.3	76.3	82.3	88.3	PKP	155
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.7	64.2	70.3	76.3	82.3	88.3	PKP	156
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.7	64.2	70.3	76.3	82.3	88.3	PKP	157
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.7	64.2	70.4	76.4	82.4	88.3	PKP	158
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.8	64.3	70.4	76.4	82.4	88.4	PKP	159
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.8	64.3	70.4	76.4	82.4	88.4	PKP	160
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.8	64.3	70.4	76.4	82.4	88.4	PKP	161
5.4	13.4	21.3	29.0	36.5	43.8	50.9	57.8	64.3	70.5	76.5	82.5	88.5	PKP	162
5.4	13.4	21.3	29.0	36.5	43.8	51.0	57.9	64.4	70.5	76.5	82.5	88.5	PKP	163
5.4	13.4	21.3	29.0	36.5	43.8	51.0	57.9	64.4	70.5	76.5	82.5	88.5	PKP	164
5.4	13.5	21.4	29.1	36.6	43.9	51.0	57.9	64.4	70.6	76.6	82.6	88.6	PKP	165
5.4	13.5	21.4	29.1	36.6	43.9	51.0	57.9	64.4	70.6	76.6	82.6	88.6	PKP	166
5.4	13.5	21.4	29.1	36.6	43.9	51.0	57.9	64.4	70.6	76.6	82.6	88.6	PKP	167
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.6	76.6	82.6	88.6	PKP	168
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	169
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	170
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	171
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	172
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	173
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	174
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.7	76.7	82.7	88.7	PKP	175
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	176
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	177
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	178
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	179
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	180
5.4	13.5	21.4	29.1	36.6	43.9	51.1	58.0	64.5	70.8	76.8	82.8	88.8	PKP	181

TABLE 2		PKP	JB	JEFFREYS AND BULLEN (1958)				TIMES FOR SURFACE FOCUS			
1111.2		1113.2		1115.2		1117.1		1119.1		1121.1	
1125.0		1126.9		1128.8		1130.8		1132.7		1134.7	
1138.5		1140.5		1142.4		1144.3		1146.2		1148.2	
1152.0		1153.9		1155.8		1157.7		1159.5		1161.4	
1165.0		1166.9		1168.7		1170.5		1172.3		1174.0	
1177.4		1179.2		1180.9		1182.6		1184.2		1185.8	
1188.9		1190.4		1191.8		1193.2		1194.5		1195.8	
1198.5		1199.7		1200.8		1201.8		1202.8		1203.8	
1205.8		1206.7		1207.4		1208.0		1208.6		1209.2	
1210.4		1210.9		1211.2		1211.5		1211.8		1212.0	
1212.1		1212.2		1212.3		1.0					

TABLE 3 F(0) ELLIPTICITY CORRECTIONS											
.001	.02	.003	.004	.005	.006	.07	.08	.09	.01	001- 1	
.012	.014	.015	.017	.019	.021	.023	.024	.026	.028	011-02	
.029	.029	.030	.031	.032	.032	.033	.034	.034	.035	021-03	
.036	.036	.037	.038	.039	.039	.040	.041	.041	.042	031-040	
.042	.043	.043	.044	.044	.045	.045	.046	.046	.047	041-050	
.047	.048	.048	.048	.048	.049	.049	.049	.050	.050	051-060	
.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	061-070	
.061	.061	.062	.062	.063	.064	.064	.065	.065	.066	071-080	
.066	.066	.066	.066	.066	.066	.066	.066	.066	.066	081-090	
.066	.066	.066	.066	.066	.066	.066	.066	.066	.066	091-100	
.066	.066	.066	.066	.066	.066	.066	.066	.066	.066	101-110	
.	.	.	.	.	.	.	.	.	.	111-120	
.	.	.	.	.	.	.	.	.	.	121-130	
.	.	.	.	.	.	.	.	.	.	131-140	
.	.	.	.	.	.	.	.	.	.	141-150	
.	.	.	.	.	.	.	.	.	.	151-160	
.	.	.	.	.	.	.	.	.	.	161-170	
.	.	.	.	.	.	.	.	.	.	171-180	

F3.

ADDITIONAL INPUT AND OUTPUT FOR SPEEDY

Three examples of the use of SPEEDY are shown. These are the same examples as used for SPUR (appendix F1).

12.70	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26	2.23	2.20	2.18	2.16	2.14	2.13	2.12
2.11	2.10	2.09	2.09	2.08	2.07	2.07	2.06	2.06	2.06	2.05	2.05	2.05	2.04	2.02	2.00
2.00	1.99	1.98	1.98	1.98	1.98	1.98	1.97	1.97	1.97	1.97	1.97	1.97	1.96		
199.51	19.00	9.55	6.94	5.79	5.14	4.74	4.46	4.26	4.10	3.98	3.89	3.81	3.74	3.68	3.63
3.59	3.55	3.52	3.49	3.47	3.44	3.42	3.40	3.39	3.37	3.35	3.34	3.33	3.32	3.23	3.15
3.12	3.09	3.07	3.07	3.06	3.05	3.04	3.03	3.02	3.01	3.01	3.00				

**** PUT EXTRA STATIONS BEFORE HERE

10S 45W	1 CC	CC.	0.	N	45.	W	RESTRAIN
TS01		1	9	15.0			10S 45W
TS02		1	8	58.2			10S 45W
TS03		1	8	13.5			10S 45W
TS04		1	7	2.7			10S 45W
TS05		1	5	28.8			10S 45W
TS06		1	3	21.9			10S 45W
TS07		1	1	58.9			10S 45W
TS08		1	3	51.3			10S 45W
TS09		1	5	50.1			10S 45W
TS10		1	7	19.1			10S 45W
TS11		1	8	24.7			10S 45W
TS12		1	9	3.7			10S 45W
TS13		1	12	24.1			10S 45W
TS14		1	12	8.5			10S 45W
TS15		1	11	26.2			10S 45W
TS16		1	10	19.9			10S 45W
TS17		1	8	58.8			10S 45W
TS18		1	7	46.2			10S 45W
TS19		1	7	20.1			10S 45W
TS20		1	7	59.1			10S 45W
TS21		1	9	16.4			10S 45W
TS22		1	10	35.1			10S 45W
TS23		1	11	36.3			10S 45W
TS24		1	12	13.2			10S 45W
TS27		1	13	48.6			10S 45W
TS28		1	12	57.7			10S 45W
TS29		1	12	2.1			10S 45W
TS30		1	11	16.7			10S 45W
TS31		1	11	1.8			10S 45W
TS32		1	11	25.2			10S 45W
TS33		1	12	14.4			10S 45W
TS34		1	13	8.7			10S 45W

10S 45W	2 CC	CC.	10.	S	45.	W	RESTRAIN
TS01		2	9	16.0			10S 45W
TS02		2	8	59.9			10S 45W
TS03		2	8	15.5			10S 45W
TS04		2	7	4.4			10S 45W
TS05		2	5	29.8			10S 45W
TS06		2	3	21.9			10S 45W
TS07		2	1	57.9			10S 45W
TS08		2	3	49.6			10S 45W
TS09		2	5	48.1			10S 45W
TS10		2	7	17.4			10S 45W
TS11		2	8	23.7			10S 45W
TS12		2	9	3.7			10S 45W
TS13		2	12	25.1			10S 45W
TS14		2	12	10.2			10S 45W
TS15		2	11	28.2			10S 45W
TS16		2	10	21.6			10S 45W
TS17		2	8	59.8			10S 45W
TS18		2	7	46.2			10S 45W
TS19		2	7	19.1			10S 45W
TS20		2	7	57.4			10S 45W
TS21		2	9	14.4			10S 45W
TS22		2	10	33.4			10S 45W
TS23		2	11	35.3			10S 45W
TS24		2	12	13.2			10S 45W
TS27		2	13	50.6			10S 45W
TS28		2	12	59.4			10S 45W
TS29		2	12	3.1			10S 45W
TS30		2	11	16.7			10S 45W
TS31		2	11	0.8			10S 45W
TS32		2	11	23.5			10S 45W
TS33		2	12	12.4			10S 45W
TS34		2	13	7.0			10S 45W

	29/10/65	21	06	00.1	51.44	N	179.18	E	RESTRAIN
COL	29/10/65	21	04	50.3					JED TEST DATA
MAT	29/10/65	21	06	32.2					JED TEST DATA
KIP	29/10/65	21	06	53.9					JED TEST DATA
BMO	29/10/65	21	07	48.5					JED TEST DATA
PAS	29/10/65	21	08	36.0					JED TEST DATA
UBO	29/10/65	21	08	47.2					JED TEST DATA
TRO	29/10/65	21	09	53.9					JED TEST DATA
HNR	29/10/65	21	10	27.0					JED TEST DATA
OTT	29/10/65	21	10	30.8					JED TEST DATA
CPO	29/10/65	21	10	45.6					JED TEST DATA
PMG	29/10/65	21	10	51.4					JED TEST DATA
UPP	29/10/65	21	10	57.7					JED TEST DATA
WES	29/10/65	21	10	59.8					JED TEST DATA
KON	29/10/65	21	11	04.2					JED TEST DATA
SHL	29/10/65	21	11	04.6					JED TEST DATA
VUN	29/10/65	21	11	08.6					JED TEST DATA
KOU	29/10/65	21	11	31.2					JED TEST DATA
PPT	29/10/65	21	11	37.5					JED TEST DATA
DAR	29/10/65	21	11	49.0					JED TEST DATA
CTA	29/10/65	21	11	52.6					JED TEST DATA
QUE	29/10/65	21	12	07.2					JED TEST DATA
TEH	29/10/65	21	12	20.0					JED TEST DATA
RRS	29/10/65	21	12	20.7					JED TEST DATA
IST	29/10/65	21	12	30.0					JED TEST DATA
RIV	29/10/65	21	12	53.7					JED TEST DATA
SJG	29/10/65	21	13	01.3					JED TEST DATA
TOO	29/10/65	21	13	16.3					JED TEST DATA

EPICENTRE DETERMINATION

23/01/74
11.34.46

10S 45W

STATION ARRIVAL TIME

1	TS01	1	9	15.0
2	TS02	1	8	58.2
3	TS03	1	8	13.5
4	TS04	1	7	2.7
5	TS05	1	5	28.8
6	TS06	1	3	21.9
7	TS07	1	1	58.9
8	TS08	1	3	51.3
9	TS09	1	5	50.1
10	TS10	1	7	19.1
11	TS11	1	8	24.7
12	TS12	1	9	3.7
13	TS13	1	12	24.1
14	TS14	1	12	8.5
15	TS15	1	11	26.2
16	TS16	1	10	19.9
17	TS17	1	8	58.8
18	TS18	1	7	46.2
19	TS19	1	7	20.1
20	TS20	1	7	59.1
21	TS21	1	9	16.4
22	TS22	1	10	35.1
23	TS23	1	11	36.3
24	TS24	1	12	13.2
25	TS27	1	13	48.6
26	TS28	1	12	57.7
27	TS29	1	12	2.1
28	TS30	1	11	16.7
29	TS31	1	11	1.8
30	TS32	1	11	25.2
31	TS33	1	12	14.4
32	TS34	1	13	8.7

TABLE OF RESIDUALS

23/01/74
11.34.46

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 TS01	66.405	43.69	33.5	2 TS02	48.980	43.75	55.1
3 TS03	25.584	41.13	76.9	4 TS04	-3.799	36.16	99.4
5 TS05	-39.764	29.51	124.2	6 TS06	-99.178	22.33	154.6
7 TS07	-120.201	16.85	197.1	8 TS08	-6.105	16.72	250.3
9 TS09	51.784	22.04	293.5	10 TS10	73.299	29.21	324.2
11 TS11	80.574	35.91	349.1	12 TS12	77.474	40.96	11.7
13 TS13	47.264	73.60	30.7	14 TS14	30.697	73.67	57.7
15 TS15	7.216	70.45	84.7	16 TS16	-22.388	64.64	112.1
17 TS17	-54.777	57.50	140.7	18 TS18	-77.686	50.79	171.7
19 TS19	-71.333	46.56	206.0	20 TS20	-31.886	46.46	242.0
21 TS21	13.563	50.55	276.4	22 TS22	43.470	57.20	307.6
23 TS23	56.510	64.35	336.2	24 TS24	56.541	70.25	3.6
25 TS27	-0.740	100.00	90.0	26 TS28	-22.857	93.75	119.6
27 TS29	-43.973	86.54	148.7	28 TS30	-56.727	80.22	178.3
29 TS31	-51.448	76.47	208.7	30 TS32	-28.257	76.39	239.6
31 TS33	0.761	80.00	270.0	32 TS34	23.387	86.25	299.6

SUM OF SQUARED RESIDUALS AFTER 0 ITERATIONS = 90961.7856

SUM OF SQUARED RESIDUALS AFTER 1 ITERATIONS = 304.2244

SUM OF SQUARED RESIDUALS AFTER 2 ITERATIONS = 0.0248

SUM OF SQUARED RESIDUALS AFTER 3 ITERATIONS = 0.0222

SUM OF SQUARED RESIDUALS AFTER 4 ITERATIONS = 0.0222

SUM OF SQUARED RESIDUALS AFTER 5 ITERATIONS = 0.0222

SUM OF SQUARED RESIDUALS AFTER 6 ITERATIONS = 0.0222

SUM OF SQUARED RESIDUALS AFTER 7 ITERATIONS = 0.0222

SUM OF SQUARED RESIDUALS AFTER 8 ITERATIONS = 0.0222

RESULTS AFTER 8 ITERATIONS

23/01/74
11.34.46

	ORIGINAL EPICENTRE	RECALCULATED EPICENTRE	
LATITUDE	0.0 N	10.000 S	+OR- 0.21 KM
LONGITUDE	45.000 W	45.000 W	+OR- 0.20 KM
ORIGIN TIME	1 0 0.0	0 59 60.0	+OR- 0.01 S
DEPTH (KM)	0.0	-0.00	+OR- 0.00*

JB TRAVEL TIMES USED

* RESTRAINED PARAMETERS

ALL CONFIDENCE LIMITS 95 PERCENT

AREA OF 95 PERCENT CONFIDENCE REGION (F TEST) = 0.20 SQ.KM

LATITUDE SHIFTED***** KM LONGITUDE SHIFTED -0.04 KM
TOTAL SHIFT = 1104.69 KM DIRECTION OF SHIFT = 180.0 DEGS

TABLE OF RESIDUALS

23/01/74
11.34.46

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 TS01	-0.010	52.20	28.9	2 TS02	0.034	49.96	47.8
3 TS03	0.028	44.26	66.6	4 TS04	0.036	35.71	85.7
5 TS05	-0.038	25.18	106.8	6 TS06	-0.005	13.99	137.6
7 TS07	-0.025	7.90	218.3	8 TS08	-0.026	16.24	284.5
9 TS09	-0.018	27.47	311.7	10 TS10	-0.010	37.68	332.1
11 TS11	-0.011	45.70	351.1	12 TS12	-0.015	50.72	9.9
13 TS13	-0.030	82.19	29.6	14 TS14	-0.026	79.13	55.7
15 TS15	-0.040	71.66	81.4	16 TS16	-0.019	61.27	107.3
17 TS17	0.015	50.08	135.8	18 TS18	0.051	40.98	170.2
19 TS19	0.001	37.82	211.3	20 TS20	-0.020	42.51	251.3
21 TS21	0.034	52.34	284.2	22 TS22	0.018	63.57	311.9
23 TS23	0.054	73.50	337.7	24 TS24	-0.031	80.17	3.5
25 TS27	0.008	99.85	91.7	26 TS28	-0.005	88.82	119.8
27 TS29	0.005	78.08	148.	28 TS30	-0.020	70.29	178.2
29 TS31	-0.002	67.81	210.	30 TS32	0.006	71.53	242.1
31 TS33	0.012	80.15	271.	32 TS34	0.049	91.18	299.8

STATISTICAL AND OTHER VARIABLES USED

23/01/74
11.34.46

SUM OF SQUARED RESIDUALS = 0.02220

AVERAGE SQUARED RESIDUAL = 0.00077

STANDARD DEVIATION = 0.02767

NUMBER OF DEGREES OF FREEDOM = 29

NUMBER OF UNKNOWN = 3

STUDENTS T = 2.05

VARIANCE RATIO F = 3.33

TIME FOR THIS EVENT (SECONDS) = 0.37

EPICENTRE DETERMINATION

23/01/74
11.34.47

10S 45W

STATION	ARRIVAL TIME
1 TS01	2 9 16.0
2 TS02	2 8 59.9
3 TS03	2 8 15.5
4 TS04	2 7 4.4
5 TS05	2 5 29.8
6 TS06	2 3 21.9
7 TS07	2 1 57.9
8 TS08	2 3 49.6
9 TS09	2 5 48.1
10 TS10	2 7 17.4
11 TS11	2 8 23.7
12 TS12	2 9 3.7
13 TS13	2 12 25.1
14 TS14	2 12 10.2
15 TS15	2 11 28.2
16 TS16	2 10 21.6
17 TS17	2 8 59.8
18 TS18	2 7 46.2
19 TS19	2 7 19.1
20 TS20	2 7 57.4
21 TS21	2 9 14.4
22 TS22	2 10 33.4
23 TS23	2 11 35.3
24 TS24	2 12 13.2
25 TS27	2 13 50.6
26 TS28	2 12 59.4
27 TS29	2 12 3.1
28 TS30	2 11 16.7
29 TS31	2 11 0.8
30 TS32	2 11 23.5
31 TS33	2 12 12.4
32 TS34	2 13 7.0

TABLE OF RESIDUALS

23/01/74
11.34.47

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 TS01	0.983	52.20	28.9	2 TS02	1.727	49.98	47.8
3 TS03	2.021	44.26	66.6	4 TS04	1.729	35.71	85.7
5 TS05	0.954	25.18	106.8	6 TS06	-0.015	13.99	137.6
7 TS07	-1.043	7.90	218.3	8 TS08	-1.740	16.24	284.5
9 TS09	-2.029	27.47	311.7	10 TS10	-1.719	37.68	332.1
11 TS11	-1.019	45.70	351.1	12 TS12	-0.022	50.72	8.9
13 TS13	0.962	82.19	29.6	14 TS14	1.666	79.13	55.7
15 TS15	1.952	71.65	81.4	16 TS16	1.673	61.27	107.3
17 TS17	1.005	50.08	135.8	18 TS18	0.039	40.98	170.2
19 TS19	-1.014	37.82	211.3	20 TS20	-1.735	42.51	251.3
21 TS21	-1.979	52.34	284.2	22 TS22	-1.693	63.57	311.9
23 TS23	-0.956	73.50	337.7	24 TS24	-0.040	80.17	3.5
25 TS27	1.999	99.85	91.7	26 TS28	1.685	88.82	119.8
27 TS29	0.994	78.08	148.0	28 TS30	-0.032	70.29	178.2
29 TS31	-1.016	67.81	210.2	30 TS32	-1.707	71.53	242.1
31 TS33	-2.000	80.15	271.7	32 TS34	-1.662	91.18	299.8

SUM OF SQUARED RESIDUALS AFTER 0 ITERATIONS = 65.7421

SUM OF SQUARED RESIDUALS AFTER 1 ITERATIONS = 13.7159

SUM OF SQUARED RESIDUALS AFTER 2 ITERATIONS = 13.7135

SUM OF SQUARED RESIDUALS AFTER 3 ITERATIONS = 13.7149

SUM OF SQUARED RESIDUALS AFTER 4 ITERATIONS = 13.7170

SUM OF SQUARED RESIDUALS AFTER 5 ITERATIONS = 13.7135

SUM OF SQUARED RESIDUALS AFTER 6 ITERATIONS = 13.7138

RESULTS AFTER 6 ITERATIONS

23/01/74
11.34.47

	ORIGINAL EPICENTRE	RECALCULATED EPICENTRE	
LATITUDE	10.000 S	10.003 S	+DR-
LONGITUDE	45.000 W	45.226 W	+DR-
ORIGIN TIME	2 0 0.0	1 59 59.9	+UR-
DEPTH (KM)	0.0	-0.00	+UR-
			5.24 KM
			4.86 KM
			0.25 S
			0.00*

JB TRAVEL TIMES USED

* RESTRAINED PARAMETERS

ALL CONFIDENCE LIMITS 95 PERCENT

AREA OF 95 PERCENT CONFIDENCE REGION (F TEST) = 126.46 SQ.KM

LATITUDE SHIFTED -0.28 KM LONGITUDE SHIFTED -24.77 KM
TOTAL SHIFT = 24.77 KM DIRECTION OF SHIFT = 269.4 DEGS

TABLE OF RESIDUALS

23/01/74
11.34.47

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 TS01	0.261	52.31	29.0	2 TS02	0.558	50.13	48.0
3 TS03	0.460	44.46	66.7	4 TS04	-0.057	35.93	85.7
5 TS05	-0.941	25.39	106.7	6 TS06	-1.870	14.14	136.9
7 TS07	0.994	7.76	217.0	8 TS08	1.093	16.03	284.7
9 TS09	-0.432	27.31	312.1	10 TS10	-0.764	37.58	332.4
11 TS11	-0.666	45.67	351.3	12 TS12	-0.232	50.76	10.1
13 TS13	0.481	82.30	29.7	14 TS14	0.768	79.32	55.7
15 TS15	0.732	71.88	81.4	16 TS16	0.335	61.49	107.3
17 TS17	-0.059	50.23	135.7	18 TS18	-0.151	41.01	170.0
19 TS19	0.077	37.71	211.1	20 TS20	0.105	42.30	251.3
21 TS21	-0.261	52.12	284.3	22 TS22	-0.500	63.41	312.1
23 TS23	-0.377	73.42	337.8	24 TS24	-0.022	80.18	3.5
25 TS27	1.086	100.07	91.8	26 TS28	0.869	89.02	119.8
27 TS29	0.460	78.19	148.0	28 TS30	0.043	70.29	178.1
29 TS31	-0.192	67.70	210.2	30 TS32	-0.416	71.33	242.1
31 TS33	-0.709	79.93	271.8	32 TS34	-0.675	90.98	299.8

STATISTICAL AND OTHER VARIABLES USED

23/01/74
11.34.47

SUM OF SQUARED RESIDUALS = 13.71376
 AVERAGE SQUARED RESIDUAL = 0.47289
 STANDARD DEVIATION = 0.68767
 NUMBER OF DEGREES OF FREEDOM = 29
 NUMBER OF UNKNOWNNS = 3
 STUDENTS T = 2.05
 VARIANCE RATIO F = 3.33

TIME FOR THIS EVENT (SECONDS) = 0.37

EPICENTRE DETERMINATION

23/01/74
11.34.47

29/10/65

STATION ARRIVAL TIME

1	CUL	21	4	50.3
2	MAT	21	6	32.2
3	KIP	21	6	53.9
4	BMU	21	7	48.5
5	PAS	21	8	36.0
6	UBO	21	8	47.2
7	TRD	21	9	53.9
8	HNR	21	10	27.0
9	OTT	21	10	30.8
10	CPO	21	10	45.6
11	PMG	21	10	51.4
12	UPP	21	10	57.7
13	WES	21	10	59.8
14	KON	21	11	4.2
15	SHL	21	11	4.6
16	VUN	21	11	8.6
17	KOU	21	11	31.2
18	PPT	21	11	37.5
19	DAR	21	11	49.0
20	CTA	21	11	52.6
21	QUE	21	12	7.2
22	TEH	21	12	20.0
23	BRS	21	12	20.7
24	IST	21	12	30.0
25	RIV	21	12	53.7
26	SJG	21	13	1.3
27	TOO	21	13	16.3

TABLE OF RESIDUALS

23/01/74
11.34.47

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 COL	-3.641	21.68	39.0	2 MAT	-2.569	32.55	258.9
3 KIP	-0.827	34.84	140.8	4 BMO	-3.184	41.69	73.2
5 PAS	-3.312	47.60	85.9	6 UBO	-2.592	48.97	73.7
7 TRD	-4.789	58.38	352.0	8 HNR	-3.141	62.86	201.4
9 OTT	-6.234	63.99	49.2	10 CPO	-5.162	66.09	62.6
11 PMG	-3.070	66.61	214.8	12 UPP	-5.009	68.06	350.1
13 WES	-5.045	68.34	48.7	14 KON	-4.000	68.95	354.4
15 SHL	-3.485	68.81	284.6	16 VUN	-1.880	69.48	180.7
17 KOU	-1.471	72.87	194.6	18 PPT	-1.466	73.95	149.0
19 DAR	-2.533	76.13	228.8	20 CTA	-2.880	76.85	211.6
21 QUE	-1.705	79.33	305.4	22 TEH	-2.217	81.87	319.5
23 BRS	-1.676	81.86	203.5	24 IST	-4.546	84.29	337.8
25 RIV	-1.216	88.41	203.0	26 SJG	-3.419	90.43	59.8
27 TOO	-1.819	93.43	206.2				

SUM OF SQUARED RESIDUALS AFTER 0 ITERATIONS = 305.1199

SUM OF SQUARED RESIDUALS AFTER 1 ITERATIONS = 24.4881

SUM OF SQUARED RESIDUALS AFTER 2 ITERATIONS = 24.4907

SUM OF SQUARED RESIDUALS AFTER 3 ITERATIONS = 24.4907

	ORIGINAL	RECALCULATED		
	EPICENTRE	EPICENTRE		
LATITUDE	51.440 N	51.643 N	+OR-	9.84 KM
LONGITUDE	179.180 E	179.210 E	+OR-	10.21 KM
ORIGIN TIME	21 0 0.1	20 59 57.0	+OR-	0.40 S
DEPTH (KM)	0.0	-0.00	+OR-	0.00*

JB TRAVEL TIMES USED
 * RESTRAINED PARAMETERS
 ALL CONFIDENCE LIMITS 95 PERCENT

AREA OF 95 PERCENT CONFIDENCE REGION (F TEST) = 487.23 SQ.KM

LATITUDE SHIFTED 22.65 KM LONGITUDE SHIFTED 2.08 KM
 TOTAL SHIFT = 22.74 KM DIRECTION OF SHIFT = 5.2 DEGS

TABLE OF RESIDUALS

23/01/74
11.34.47

STATION	RESIDUAL	DISTANCE	AZIMUTH	STATION	RESIDUAL	DISTANCE	AZIMUTH
1 COL	1.129	21.51	39.3	2 MAT	-0.018	32.61	258.7
3 KIP	0.972	34.98	141.0	4 BMO	0.499	41.62	73.4
5 PAS	0.003	47.57	86.1	6 UBU	1.041	48.89	73.9
7 TRO	-0.339	58.18	352.0	8 HNR	-1.381	63.06	201.4
9 OTT	-2.205	63.84	49.3	10 CPU	-1.399	65.98	62.7
11 PMG	-1.152	66.79	214.7	12 UPP	-0.714	67.86	350.1
13 WES	-1.068	68.20	48.8	14 KON	0.302	68.74	354.4
15 SHL	-0.222	68.78	284.6	16 VUN	-0.067	69.39	180.8
17 KOU	0.403	73.08	194.6	18 PPT	0.635	74.11	149.1
19 DAR	-0.306	76.28	228.8	20 CTA	-0.845	77.03	211.6
21 QUE	1.906	79.23	305.3	22 TEH	1.583	81.72	319.5
23 BRS	0.371	82.06	203.6	24 IST	-0.580	84.11	337.8
25 RIV	0.907	88.60	203.1	26 SJG	0.185	90.31	59.8
27 TUO	0.360	93.62	206.2				

STATISTICAL AND OTHER VARIABLES USED

23/01/74
11.34.47

SUM OF SQUARED RESIDUALS = 24.49070
 AVERAGE SQUARED RESIDUAL = 1.02045
 STANDARD DEVIATION = 1.01017
 NUMBER OF DEGREES OF FREEDOM = 24
 NUMBER OF UNKNOWNNS = 3
 STUDENTS T = 2.06
 VARIANCE RATIO F = 3.40

TIME FOR THIS EVENT (SECONDS) = 0.25

F4. ADDITIONAL INPUT AND OUTPUT FOR JED

Two examples of the use of JED are shown.

F4.1 Theoretical station study: J-B arrival times adjusted by
2 sin A seconds

This example uses arrival times predicted from the J-B tables (to which a bias has been added) for a set of 36 hypothetical stations and 5 fictitious earthquakes. The true epicentre of these earthquakes are used as names for the earthquakes, their origin times were all set to 02.00. 00 GMT. The bias added to the travel times takes the form of a station correction of $2 \sin A$ seconds where A is the azimuth of the station from the point 10N 35W, the epicentre of the middle earthquake of the group. Using JED this bias can be recovered and the true epicentre determined (cf, results obtained in SPUR and SPEEDY).

F4.2 JED test data - full float

This uses observed data from the explosion LONGSHOT and six earthquakes. Note that the error in the LONGSHOT epicentre is smaller than that obtained in SPUR and SPEEDY but that the confidence limits are larger.

12.70	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26	2.23	2.20	2.18	2.16	2.14	2.13	2.12
2.11	2.10	2.09	2.05	2.08	2.07	2.07	2.06	2.06	2.06	2.05	2.05	2.05	2.04	2.02	2.00
2.00	1.99	1.98	1.98	1.98	1.98	1.98	1.97	1.97	1.97	1.97	1.97	1.97	1.96		
199.519.00	9.55	6.94	5.79	5.14	4.74	4.46	4.26	4.10	3.98	3.89	3.81	3.74	3.68	3.63	
3.59	3.55	3.52	3.49	3.47	3.44	3.42	3.40	3.39	3.37	3.35	3.34	3.33	3.32	3.23	3.15
3.12	3.09	3.07	3.07	3.06	3.05	3.04	3.03	3.02	3.01	3.01	3.00				

**** PUT EXTRA STATIONS BEFORE HERE

5

10N 35W	2 CC CO.	10.	N	35.	W	RESTRAN
30N 24W	2 CC CO.	30.	N	24.	W	RESTRAN
20N 30W	2 CC CO.	20.	N	30.	W	RESTRAN
30N 40W	2 CC CO.	00.	N	40.	W	RESTRAN
10S 45W	2 CC CO.	10.	S	45.	W	RESTRAN
THEORETICAL STATIONS STUDY - JB ARRIVAL TIMES ADJUSTED BY 2*SIN(AZ)						
THEORETICAL STATIONS STUDY - JB ARRIVAL TIMES ADJUSTED BY 2*SIN(AZ)						1
10N 35W	2 CC CO.	10.	N	35.	W	RESTRAN

TS01	2 6 13.7	10N 35W
TS02	2 6 14.6	10N 35W
TS03	2 6 15.0	10N 35W
TS04	2 6 14.7	10N 35W
TS05	2 6 13.9	10N 35W
TS06	2 6 12.9	10N 35W
TS07	2 6 11.9	10N 35W
TS08	2 6 11.3	10N 35W
TS09	2 6 11.0	10N 35W
TS10	2 6 11.2	10N 35W
TS11	2 6 11.7	10N 35W
TS12	2 6 12.7	10N 35W
TS13	2 10 11.6	10N 35W
TS14	2 10 12.8	10N 35W
TS15	2 10 13.4	10N 35W
TS16	2 10 13.0	10N 35W
TS17	2 10 11.9	10N 35W
TS18	2 10 10.8	10N 35W
TS19	2 10 9.9	10N 35W
TS20	2 10 9.6	10N 35W
TS21	2 10 9.4	10N 35W
TS22	2 10 9.4	10N 35W
TS23	2 10 9.6	10N 35W
TS24	2 10 10.4	10N 35W
TS25	2 13 3.6	10N 35W
TS26	2 13 5.0	10N 35W
TS27	2 13 5.6	10N 35W
TS28	2 13 5.0	10N 35W
TS29	2 13 3.6	10N 35W
TS30	2 13 2.2	10N 35W
TS31	2 13 1.6	10N 35W
TS32	2 13 1.6	10N 35W
TS33	2 13 1.6	10N 35W
TS34	2 13 1.6	10N 35W
TS35	2 13 1.6	10N 35W
TS36	2 13 2.2	10N 35W

30N 24W	2 CC CO.	30.	N	24.	W	RESTRAN
TS01	2 1 58.9	30N 24W				
TS02	2 3 57.8	30N 24W				
TS03	2 5 56.2	30N 24W				
TS04	2 7 24.6	30N 24W				
TS05	2 8 28.8	30N 24W				
TS06	2 9 6.0	30N 24W				
TS07	2 9 15.2	30N 24W				
TS08	2 8 56.4	30N 24W				
TS09	2 8 10.1	30N 24W				
TS10	2 6 58.3	30N 24W				
TS11	2 5 23.7	30N 24W				
TS12	2 3 15.6	30N 24W				
TS13	2 7 19.6	30N 24W				
TS14	2 8 2.0	30N 24W				
TS15	2 9 21.1	30N 24W				
TS16	2 10 39.8	30N 24W				
TS17	2 11 39.9	30N 24W				
TS18	2 12 15.1	30N 24W				
TS19	2 12 24.0	30N 24W				
TS20	2 12 6.4	30N 24W				
TS21	2 11 22.4	30N 24W				
TS22	2 10 15.1	30N 24W				
TS23	2 8 53.7	30N 24W				
TS24	2 7 42.5	30N 24W				
TS25	2 11 1.6	30N 24W				
TS26	2 11 27.3	30N 24W				
TS27	2 12 17.8	30N 24W				
TS28	2 13 12.1	30N 24W				
TS29	2 13 44.8	30N 24W				
TS30	2 12 53.6	30N 24W				
TS31	2 11 58.3	30N 24W				
TS32	2 11 14.3	30N 24W				

ZON	30W	2	CC	00.	20.	N	30.	W	RESTRAIN
TS01		2	4	26.7					20N 30W
TS02		2	4	57.0					20N 30W
TS03		2	5	47.8					20N 30W
TS04		2	6	37.7					20N 30W
TS05		2	7	17.0					20N 30W
TS06		2	7	40.5					20N 30W
TS07		2	7	45.9					20N 30W
TS08		2	7	33.1					20N 30W
TS09		2	7	3.1					20N 30W
TS10		2	6	19.3					20N 30W
TS11		2	5	28.2					20N 30W
TS12		2	4	42.4					20N 30W
TS13		2	8	51.1					20N 30W
TS14		2	9	8.8					20N 30W
TS15		2	9	43.9					20N 30W
TS16		2	10	23.1					20N 30W
TS17		2	10	55.7					20N 30W
TS18		2	11	15.9					20N 30W
TS19		2	11	20.8					20N 30W
TS20		2	11	9.7					20N 30W
TS21		2	10	43.8					20N 30W
TS22		2	10	7.3					20N 30W
TS23		2	9	28.2					20N 30W
TS24		2	8	58.8					20N 30W
TS25		2	12	8.0					20N 30W
TS26		2	12	19.8					20N 30W
TS27		2	12	42.8					20N 30W
TS28		2	13	9.0					20N 30W
TS29		2	13	32.2					20N 30W
TS30		2	13	47.7					20N 30W
TS32		2	13	42.9					20N 30W
TS33		2	13	23.1					20N 30W
TS34		2	12	57.2					20N 30W
TS35		2	12	30.9					20N 30W
TS36		2	12	12.2					20N 30W

ZON	40W	2	00	00.	00.	N	40.	W	RESTRAIN
TS01		2	7	48.4					00N 40W
TS02		2	7	38.0					00N 40W
TS03		2	7	9.4					00N 40W
TS04		2	6	25.6					00N 40W
TS05		2	5	33.1					00N 40W
TS06		2	4	44.1					00N 40W
TS07		2	4	23.8					00N 40W
TS08		2	4	51.0					00N 40W
TS09		2	5	41.1					00N 40W
TS10		2	6	32.0					00N 40W
TS11		2	7	13.5					00N 40W
TS12		2	7	39.9					00N 40W
TS13		2	11	23.1					00N 40W
TS14		2	11	14.3					00N 40W
TS15		2	10	49.8					00N 40W
TS16		2	10	13.1					00N 40W
TS17		2	9	32.4					00N 40W
TS18		2	9	0.0					00N 40W
TS19		2	8	48.8					00N 40W
TS20		2	9	3.8					00N 40W
TS21		2	9	37.8					00N 40W
TS22		2	10	17.7					00N 40W
TS23		2	10	52.3					00N 40W
TS24		2	11	15.2					00N 40W
TS26		2	13	47.4					00N 40W
TS27		2	13	28.6					00N 40W
TS28		2	13	2.2					00N 40W
TS29		2	12	34.2					00N 40W
TS30		2	12	12.8					00N 40W
TS31		2	12	5.7					00N 40W
TS32		2	12	15.4					00N 40W
TS33		2	12	37.4					00N 40W
TS34		2	13	4.4					00N 40W
TS35		2	13	29.4					00N 40W
TS36		2	13	47.5					00N 40W

10S 45W	2	CC	CO.	10.	S	45.	W	RFSTRAIN
TS01			2	9	16.0			10S 45W
TS02			2	8	59.9			10S 45W
TS03			2	8	15.5			10S 45W
TS04			2	7	4.4			10S 45W
TS05			2	5	29.8			10S 45W
TS06			2	3	21.9			10S 45W
TS07			2	1	57.9			10S 45W
TS08			2	3	49.6			10S 45W
TS09			2	5	48.1			10S 45W
TS10			2	7	17.4			10S 45W
TS11			2	8	23.7			10S 45W
TS12			2	9	3.7			10S 45W
TS13			2	12	25.1			10S 45W
TS14			2	12	10.2			10S 45W
TS15			2	11	28.2			10S 45W
TS16			2	10	21.6			10S 45W
TS17			2	8	59.8			10S 45W
TS18			2	7	46.2			10S 45W
TS19			2	7	19.1			10S 45W
TS20			2	7	57.4			10S 45W
TS21			2	9	14.4			10S 45W
TS22			2	10	33.4			10S 45W
TS23			2	11	35.3			10S 45W
TS24			2	12	13.2			10S 45W
TS27			2	13	50.6			10S 45W
TS28			2	12	59.4			10S 45W
TS29			2	12	3.1			10S 45W
TS30			2	11	16.7			10S 45W
TS31			2	11	0.8			10S 45W
TS32			2	11	23.5			10S 45W
TS33			2	12	12.4			10S 45W
TS34			2	13	7.0			10S 45W

7
 29/10/65 21 CC 00.1 51.44 N 179.18 E 0.7 RESTRAIN
 02/06/66 3 27 53.3 51.08 N 175.97 E 41. RESTRAIN
 22/C1/66 14 27 07.9 55.97 N 153.69 W 33. RESTRAIN
 11/C8/66 10 45 59.6 52.76 N 169.74 W 61. RESTRAIN
 06/C2/65 16 5C 28.6 53.29 N 161.81 W 33. RFSTRAIN
 19/C7/66 1 4C 53.9 56.20 N 164.90 E 18. RESTRAIN
 19-C7-66 19 2C 33.4 51.73 N 173.30 W 47. RESTRAIN
 JED TEST DATA - FULL FLOAT
 JED TEST DATA - FULL FLOAT

29/10/65 21 CC 00.1 51.44 N 179.18 E 0.7 RESTRAIN
 COL 29/10/65 21 04 50.3 JED TEST DATA
 MAT 29/10/65 21 06 32.2 JED TEST DATA
 KIP 29/10/65 21 06 53.9 JED TEST DATA
 BMO 29/10/65 21 07 48.5 JED TEST DATA
 PAS 29/10/65 21 08 36.0 JED TEST DATA
 UBO 29/10/65 21 08 47.2 JED TEST DATA
 TRO 29/10/65 21 09 53.9 JED TEST DATA
 HNR 29/10/65 21 10 27.0 JED TEST DATA
 DTT 29/10/65 21 10 30.8 JED TEST DATA
 CPD 29/10/65 21 10 45.6 JED TEST DATA
 PMG 29/10/65 21 10 51.4 JED TEST DATA
 UPP 29/10/65 21 10 57.7 JED TEST DATA
 WFS 29/10/65 21 10 59.8 JED TEST DATA
 KDN 29/10/65 21 11 04.2 JED TEST DATA
 SHL 29/10/65 21 11 04.6 JED TEST DATA
 VUN 29/10/65 21 11 08.6 JED TEST DATA
 KOU 29/10/65 21 11 31.2 JED TEST DATA
 PPT 29/10/65 21 11 37.5 JED TEST DATA
 DAR 29/10/65 21 11 49.0 JED TEST DATA
 CTA 29/10/65 21 11 52.6 JED TEST DATA
 QUE 29/10/65 21 12 07.2 JED TEST DATA
 TEH 29/10/65 21 12 20.0 JED TEST DATA
 BRS 29/10/65 21 12 20.7 JED TEST DATA
 IST 29/10/65 21 12 30.0 JED TEST DATA
 RIV 29/10/65 21 12 53.7 JED TEST DATA
 SJG 29/10/65 21 13 01.3 JED TEST DATA
 TOO 29/10/65 21 13 16.3 JED TEST DATA

02/06/66 3 27 53.3 51.08 N 175.97 E 41. RESTRAIN
 COL 02/06/66 3 32 56.4 JED TEST DATA
 MBC 02/06/66 3 34 44.4 JED TEST DATA
 KIP 02/06/66 3 34 51.5 JED TEST DATA
 BMO 02/06/66 3 35 56.1 JED TEST DATA
 PAS 02/06/66 3 36 42.0 JED TEST DATA
 UBO 02/06/66 3 36 53.4 JED TEST DATA
 TRO 02/06/66 3 37 46.3 JED TEST DATA
 PMG 02/06/66 3 38 31.0 JED TFST DATA
 DTT 02/06/66 3 38 33.5 JED TEST DATA
 SHL 02/06/66 3 38 44.0 JED TEST DATA
 UPP 02/06/66 3 38 49.4 JED TEST DATA
 CPD 02/06/66 3 38 49.6 JED TEST DATA
 CTA 02/06/66 3 39 34.1 JED TEST DATA
 QUE 02/06/66 3 39 48.5 JED TEST DATA
 STU 02/06/66 3 39 59.3 JED TEST DATA
 BRS 02/06/66 3 40 03.6 JED TEST DATA
 IST 02/06/66 3 40 20.0 JED TEST DATA
 SJG 02/06/66 3 41 01.8 JED TEST DATA

22/01/66	14	27	07.9	55.97	N	153.69	W	33.	RESTRAIN
MBC	22/01/66	14	32	21.1					JED TEST DATA
BMO	22/01/66	14	32	34.4					JED TEST DATA
PAS	22/01/66	14	33	39.0					JED TEST DATA
UBO	22/01/66	14	33	39.5					JED TEST DATA
KIP	22/01/66	14	33	56.5					JED TEST DATA
MAT	22/01/66	14	35	49.0					JED TEST DATA
CPO	22/01/66	14	35	54.9					JED TEST DATA
TRO	22/01/66	14	36	34.6					JED TEST DATA
KON	22/01/66	14	37	39.3					JED TEST DATA
UPP	22/01/66	14	37	40.8					JED TEST DATA
CLL	22/01/66	14	38	32.7					JED TEST DATA
STU	22/01/66	14	38	45.5					JED TEST DATA
VUN	22/01/66	14	39	05.4					JED TEST DATA
PMG	22/01/66	14	39	21.0					JED TEST DATA
SHL	22/01/66	14	39	22.0					JED TEST DATA
IST	22/01/66	14	39	33.0					JED TEST DATA
TEH	22/01/66	14	39	48.0					JED TEST DATA
CTA	22/01/66	14	40	08.8					JED TEST DATA

11/08/66	10	45	59.6	52.76	N	169.74	W	61.	RESTRAIN
COL	11/08/66	10	49	46.0					JED TEST DATA
MBC	11/08/66	10	52	05.0					JED TEST DATA
BMO	11/08/66	10	52	45.3					JED TEST DATA
MAT	11/08/66	10	53	25.2					JED TEST DATA
PAS	11/08/66	10	53	37.0					JED TEST DATA
UBO	11/08/66	10	53	46.4					JED TEST DATA
TRO	11/08/66	10	55	45.0					JED TEST DATA
OTT	11/08/66	10	55	45.0					JED TEST DATA
CPO	11/08/66	10	55	54.6					JED TEST DATA
UPP	11/08/66	10	56	50.9					JED TEST DATA
PMG	11/08/66	10	57	17.5					JED TEST DATA
SHL	11/08/66	10	57	34.9					JED TEST DATA
CTA	11/08/66	10	58	13.0					JED TEST DATA
SJG	11/08/66	10	58	23.5					JED TEST DATA
QUE	11/08/66	10	58	24.7					JED TEST DATA
TEH	11/08/66	10	58	30.0					JED TEST DATA
BRS	11/08/66	10	58	35.4					JED TEST DATA

06/02/65	16	50	28.6	53.29	N	161.81	W	33.	RESTRAIN
MRC	06/02/65	16	56	18.9					JED TEST DATA
BMO	06/02/65	16	56	35.6					JED TEST DATA
KIP	06/02/65	16	56	54.0					JED TEST DATA
MAT	06/02/65	16	58	35.0					JED TEST DATA
OTT	06/02/65	16	59	44.7					JED TEST DATA
CPO	06/02/65	16	59	52.9					JED TEST DATA
TRO	06/02/65	17	00	16.2					JED TEST DATA
UPP	06/02/65	17	01	21.1					JED TEST DATA
HNR	06/02/65	17	01	40.2					JED TEST DATA
PPT	06/02/65	17	01	47.1					JED TEST DATA
PMG	06/02/65	17	02	12.4					JED TEST DATA
SHL	06/02/65	17	02	28.0					JED TEST DATA
SJG	06/02/65	17	02	30.5					JED TEST DATA
KOU	06/02/65	17	02	31.0					JED TEST DATA
CTA	06/02/65	17	03	04.2					JED TEST DATA
IST	06/02/65	17	03	06.4					JED TEST DATA
DAR	06/02/65	17	03	10.0					JED TEST DATA
TEH	06/02/65	17	03	12.0					JED TEST DATA
BRS	06/02/65	17	03	23.0					JED TEST DATA
RIV	06/02/65	17	03	55.1					JED TEST DATA
TOO	06/02/65	17	04	20.0					JED TEST DATA

19/07/66	1	40	53.9	56.20	N	164.90	E	18.	RESTRAIN
COL	19/07/66	1	46	11.0					JED TEST DATA
MAT	19/07/66	1	46	33.0					JED TEST DATA
MBC	19/07/66	1	47	31.0					JED TEST DATA
KIP	19/07/66	1	49	10.0					JED TEST DATA
BMO	19/07/66	1	49	34.9					JED TEST DATA
PAS	19/07/66	1	50	28.0					JED TEST DATA
UBO	19/07/66	1	50	29.7					JED TEST DATA
SHL	19/07/66	1	50	57.0					JED TEST DATA
UPP	19/07/66	1	51	09.7					JED TEST DATA
HNR	19/07/66	1	51	40.0					JED TEST DATA
PMG	19/07/66	1	51	50.5					JED TEST DATA
QUE	19/07/66	1	52	03.0					JED TEST DATA
CLL	19/07/66	1	52	08.1					JED TEST DATA
CPO	19/07/66	1	52	10.1					JED TEST DATA
TEH	19/07/66	1	52	21.0					JED TEST DATA
STU	19/07/66	1	52	27.5					JED TEST DATA
VUN	19/07/66	1	52	38.1					JED TEST DATA
IST	19/07/66	1	52	43.0					JED TEST DATA
CTA	19/07/66	1	52	51.0					JED TEST DATA
PPT	19/07/66	1	53	24.0					JED TEST DATA

	19-07-66	19	20	33.4	51.73	N	173.30	W	47.	RESTRAIN
COL	19-07-66	19	24	47.9						JED TEST DATA
MBC	19-07-66	19	26	56.0						JED TEST DATA
MAT	19-07-66	19	27	41.0						JED TEST DATA
PAS	19-07-66	19	28	29.0						JED TEST DATA
UBO	19-07-66	19	28	40.9						JED TEST DATA
TRO	19-07-66	19	30	27.2						JED TEST DATA
OTT	19-07-66	19	30	37.0						JED TEST DATA
CPO	19-07-66	19	30	47.3						JED TEST DATA
WES	19-07-66	19	31	07.6						JED TEST DATA
HNR	19-07-66	19	31	15.0						JED TEST DATA
UPP	19-07-66	19	31	30.7						JED TEST DATA
PMG	19-07-66	19	31	40.3						JED TEST DATA
SHL	19-07-66	19	32	00.3						JED TEST DATA
CLL	19-07-66	19	32	24.0						JED TEST DATA
CTA	19-07-66	19	32	36.0						JED TEST DATA
STU	19-07-66	19	32	38.9						JED TEST DATA
QUE	19-07-66	19	32	54.9						JED TEST DATA
TEH	19-07-66	19	33	04.0						JED TEST DATA
IST	19-07-66	19	33	08.0						JED TEST DATA
SGJ	19-07-66	19	33	09.7						JED TEST DATA

5 JB 1 1 1 1 0
(1X,A4,15X,12+1X,I2,1X,F4.1)

USES DIMENSION A(16, 17),B(17, 84),C(5, 84)

1196

272

986

1202

MULTIPLE EPICENTRE DETERMINATION

THEORETICAL STATIONS STUDY - JB ARRIVAL TIMES ADJUSTED BY 2*SIN(AZ)

10N 35W

STATION	ARRIVAL TIME
1 TS01	2 6 13.7
2 TS02	2 6 14.6
3 TS03	2 6 15.0
4 TS04	2 6 14.7
5 TS05	2 6 13.9
6 TS06	2 6 12.9
7 TS07	2 6 11.9
8 TS08	2 6 11.3
9 TS09	2 6 11.0
10 TS10	2 6 11.2
11 TS11	2 6 11.7
12 TS12	2 6 12.7
13 TS13	2 10 11.6
14 TS14	2 10 12.8
15 TS15	2 10 13.4
16 TS16	2 10 13.0
17 TS17	2 10 11.9
18 TS18	2 10 10.8
19 TS19	2 10 9.9
20 TS20	2 10 9.6
21 TS21	2 10 9.4
22 TS22	2 10 9.4
23 TS23	2 10 9.6
24 TS24	2 10 10.4
25 TS25	2 13 3.6
26 TS26	2 13 5.0
27 TS27	2 13 5.6
28 TS28	2 13 5.0
29 TS29	2 13 3.6
30 TS30	2 13 2.2
31 TS31	2 13 1.6
32 TS32	2 13 1.6
33 TS33	2 13 1.6
34 TS34	2 13 1.6
35 TS35	2 13 1.6
36 TS36	2 13 2.2

30N 24W

STATION	ARRIVAL TIME
1 TS01	2 1 58.9
2 TS02	2 3 57.8
3 TS03	2 5 56.2
4 TS04	2 7 24.6
5 TS05	2 8 28.8
6 TS06	2 9 6.0
7 TS07	2 9 15.2
8 TS08	2 8 56.4
9 TS09	2 8 10.1
10 TS10	2 6 58.3
11 TS11	2 5 23.7
12 TS12	2 3 15.6
13 TS13	2 7 19.6
14 TS14	2 8 2.0
15 TS15	2 9 21.1
16 TS16	2 10 39.8
17 TS17	2 11 39.9
18 TS18	2 12 15.1
19 TS19	2 12 24.0
20 TS20	2 12 6.4
21 TS21	2 11 22.4
22 TS22	2 10 15.1
23 TS23	2 8 53.7
24 TS24	2 7 42.5
25 TS25	2 11 1.6
26 TS26	2 11 27.3
27 TS27	2 12 17.8
28 TS28	2 13 12.1
29 TS33	2 13 44.8
30 TS34	2 12 53.6
31 TS35	2 11 58.3
32 TS36	2 11 14.3

20N 30W

STATION	ARRIVAL TIME
1 TS01	2 4 26.7
2 TS02	2 4 57.0
3 TS03	2 5 47.8
4 TS04	2 6 37.7
5 TS05	2 7 17.0
6 TS06	2 7 40.5
7 TS07	2 7 45.9
8 TS08	2 7 33.1
9 TS09	2 7 3.1
10 TS10	2 6 19.3
11 TS11	2 5 28.2
12 TS12	2 4 42.4
13 TS13	2 8 51.1
14 TS14	2 9 8.8
15 TS15	2 9 43.9
16 TS16	2 10 23.1
17 TS17	2 10 55.7
18 TS18	2 11 15.9
19 TS19	2 11 20.8
20 TS20	2 11 9.7
21 TS21	2 10 43.8
22 TS22	2 10 7.3
23 TS23	2 9 28.2
24 TS24	2 8 58.8
25 TS25	2 12 8.0
26 TS26	2 12 19.8
27 TS27	2 12 42.8
28 TS28	2 13 9.0
29 TS29	2 13 32.2
30 TS30	2 13 47.7
31 TS32	2 13 42.9
32 TS33	2 13 23.1
33 TS34	2 12 57.2
34 TS35	2 12 30.9
35 TS36	2 12 12.2

00N 40W

STATION ARRIVAL TIME

1	TS01	2 7 40.4
2	TS02	2 7 38.0
3	TS03	2 7 0.4
4	TS04	2 6 25.6
5	TS05	2 5 33.1
6	TS06	2 4 44.1
7	TS07	2 4 23.8
8	TS08	2 4 51.0
9	TS09	2 5 41.1
10	TS10	2 6 32.0
11	TS11	2 7 13.5
12	TS12	2 7 39.9
13	TS13	2 11 23.1
14	TS14	2 11 14.3
15	TS15	2 10 40.8
16	TS16	2 10 13.1
17	TS17	2 9 32.4
18	TS18	2 9 0.0
19	TS19	2 8 48.8
20	TS20	2 9 3.8
21	TS21	2 9 37.8
22	TS22	2 10 17.7
23	TS23	2 10 52.3
24	TS24	2 11 15.2
25	TS25	2 13 47.4
26	TS26	2 13 28.6
27	TS27	2 13 2.2
28	TS28	2 12 34.2
29	TS29	2 12 12.8
30	TS30	2 12 5.7
31	TS31	2 12 15.4
32	TS32	2 12 37.4
33	TS33	2 13 4.4
34	TS34	2 13 29.4
35	TS35	2 13 47.5

10S 45W

STATION ARRIVAL TIME

1	TS01	2 9 16.0
2	TS02	2 8 59.9
3	TS03	2 8 15.5
4	TS04	2 7 4.4
5	TS05	2 5 29.8
6	TS06	2 3 21.9
7	TS07	2 1 57.9
8	TS08	2 3 49.6
9	TS09	2 5 48.1
10	TS10	2 7 17.4
11	TS11	2 8 23.7
12	TS12	2 9 3.7
13	TS13	2 12 25.1
14	TS14	2 12 10.2
15	TS15	2 11 28.2
16	TS16	2 10 21.6
17	TS17	2 8 59.8
18	TS18	2 7 46.2
19	TS19	2 7 19.1
20	TS20	2 7 57.4
21	TS21	2 9 14.4
22	TS22	2 10 33.4
23	TS23	2 11 35.3
24	TS24	2 12 13.2
25	TS25	2 13 50.6
26	TS26	2 12 59.4
27	TS27	2 12 3.1
28	TS28	2 11 16.7
29	TS29	2 11 0.8
30	TS30	2 11 23.5
31	TS31	2 12 12.4
32	TS32	2 13 7.0

TOTAL NUMBER OF STATIONS USED = 35

TABLE OF RESIDUALS

STATION	10N 35W	30N 24W	20N 30W	00N 40W	10S 45W
1 TS01	0.9717*	0.9586*	1.0137*	0.9959*	0.9827*
2 TS02	1.7406*	1.6693*	1.7278*	1.7014*	1.7269*
3 TS03	2.0427*	2.0105*	1.9648*	1.9789*	2.0212*
4 TS04	1.7295*	1.7501*	1.6617*	1.6998*	1.7291*
5 TS05	0.9811*	0.9592*	1.0386*	0.9967*	0.9540*
6 TS06	0.0121*	0.0098*	0.0332*	-0.0441*	-0.0155*
7 TS07	-1.0189*	-1.0131*	-1.0131*	-0.9783*	-1.0429*
8 TS08	-1.6702*	-1.7350*	-1.6859*	-1.7280*	-1.7396*
9 TS09	-1.9578*	-1.9940*	-1.9662*	-1.9894*	-2.0289*
10 TS10	-1.6591*	-1.6722*	-1.6898*	-1.7478*	-1.7194*
11 TS11	-1.0285*	-1.0378*	-1.0371*	-0.9612*	-1.0190*
12 TS12	0.0315*	0.0049*	-0.0038*	-0.0202*	-0.0224*
13 TS13	0.9506*	1.0189*	0.9987*	1.0485*	0.9616*
14 TS14	1.7031*	1.6865*	1.7438*	1.6804*	1.6661*
15 TS15	2.0316*	2.0453*	1.0896*	2.0126*	1.9522*
16 TS16	1.7432*	1.7407*	1.7321*	1.6669*	1.6727*
17 TS17	0.9713*	1.0494*	0.9517*	1.0145*	1.0048*
18 TS18	0.0480*	0.0197*	0.0460*	0.0374*	0.0389*
19 TS19	-1.0287*	-0.9636*	-0.9698*	-1.0345*	-1.0135*
20 TS20	-1.6568*	-1.7077*	-1.6975*	-1.7403*	-1.7348*
21 TS21	-1.9691*	-2.0387*	-1.9981*	-2.0352*	-1.9789*
22 TS22	-1.6769*	-1.7120*	-1.7461*	-1.6762*	-1.6925*
23 TS23	-1.0494*	-1.0454*	-1.0210*	-0.9910*	-0.9556*
24 TS24	-0.0360*	0.0227*	-0.0013*	-0.0073*	-0.0400*
25 TS25	1.0304*	0.9518*	1.0225*	0.0	0.0
26 TS26	1.7456*	1.7026*	1.7311*	1.6744*	0.0
27 TS27	2.0028*	2.0056*	2.0307*	1.9601*	1.9999*
28 TS28	1.7439*	1.7155*	1.7397*	1.7168*	1.6854*
29 TS29	1.0263*	0.0	0.9683*	0.9993*	0.9998*
30 TS30	-0.0302*	0.0	-0.0087*	-0.0220*	-0.0319*
31 TS31	-0.9737*	0.0	0.0	-1.0007*	-1.0157*
32 TS32	-1.6568*	0.0	-1.6520*	-1.6676*	-1.7070*
33 TS33	-1.9372*	-2.0174*	-2.0033*	-2.0392*	-1.9997*
34 TS34	-1.6551*	-1.6891*	-1.7192*	-1.6522*	-1.6616*
35 TS35	-0.3696*	-0.9815*	-1.0121*	-1.0014*	0.0
36 TS36	-0.0295*	0.0148*	-0.0244*	0.0056*	0.0

SUM OF SQUARED RESIDUALS AFTER 0 ITERATIONS = 342.65929

SUM OF SQUARED RESIDUALS AFTER 1 ITERATIONS = 0.10398

SUM OF SQUARED RESIDUALS AFTER 2 ITERATIONS = 0.10303

SUM OF SQUARED RESIDUALS AFTER 3 ITERATIONS = 0.10394

SUM OF SQUARED RESIDUALS AFTER 4 ITERATIONS = 0.10394

RESULTS AFTER 4 ITERATIONS

	EVENT	ORIGIN TIME	DEPTH (KM)	LATITUDE	LONGITUDE
ORIGINAL EPICENTRE	10N 35W	2 0 0.0	0.0	10.000 N	35.000 W
RECALCULATED EPICENTRE		2 0 0.01	0.0 *	10.000 N	34.999 W
EPICENTRE SHIFTED	0.088 KM	AZIMUTH 277.71 DEGS			
ORIGINAL EPICENTRE	30N 24W	2 0 0.0	0.0	30.000 N	24.000 W
RECALCULATED EPICENTRE		2 0 0.00	0.0 *	30.000 N	24.000 W
EPICENTRE SHIFTED	0.036 KM	AZIMUTH 319.11 DEGS			
ORIGINAL EPICENTRE	20N 30W	2 0 0.0	0.0	20.000 N	30.000 W
RECALCULATED EPICENTRE		2 0 0.00	0.0 *	20.000 N	30.000 W
EPICENTRE SHIFTED	0.015 KM	AZIMUTH 218.85 DEGS			

IHC209I IBCOM - PROGRAM INTERRUPT- DIVIDE CHECK OLD PSM IS FFD5000F820EE4C0 . REGISTER CONTAINED 4110000000000000

TRACEBACK ROUTINE	CALLED FROM ISN	REG. 14	REG. 15	REG. 0	REG. 1
BAZDEL	0324	420E6C0C	000E158	00115888	000E4810
SNORM	0206	420E3D28	000E3D98	001234F8	000E2D4C
JED	7006	420E288C	000E28F8	FF000018	00000000
MAIN		0001386A	010E2810	FF000018	00141FD0

ENTRY POINT= 010E2810

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

ORIGINAL EPICENTRE 00N 40W 2 0 0.0 0.0 0.0 N 40.000 W
 RECALCULATED EPICENTRE 1 59 60.00 0.0 * 0.001 S 39.999 W

EPICENTRE SHIFTED 0.176 KM AZIMUTH 333.62 DEGS

ORIGINAL EPICENTRE 10S 45W 2 0 0.0 0.0 10.000 S 45.000 W
 RECALCULATED EPICENTRE 1 59 59.99 0.0 * 10.001 S 45.000 W

EPICENTRE SHIFTED 0.130 KM AZIMUTH 347.38 DEGS

MEAN EPICENTRE 10.015 N 34.500 W

* RESTRAINED PARAMETERS

JH TRAVEL TIMES USED

STATION CORRECTIONS (SECONDS)

			MEAN DISTANCE	MEAN AZIMUTH	NO. OF READINGS
1	TS01	0.983 +OR- 0.039	52.202	28.86	5.
2	TS02	1.713 +OR- 0.037	49.960	47.79	5.
3	TS03	2.005 +OR- 0.036	44.260	66.60	5.
4	TS04	1.716 +OR- 0.036	35.711	85.69	5.
5	TS05	0.989 +OR- 0.037	25.176	106.78	5.
6	TS06	0.004 +OR- 0.038	13.986	137.56	5.
7	TS07	-1.011 +OR- 0.039	7.895	218.28	5.
8	TS08	-1.716 +OR- 0.037	16.241	284.46	5.
9	TS09	-1.994 +OR- 0.036	27.473	311.73	5.
10	TS10	-1.705 +OR- 0.036	37.680	332.12	5.
11	TS11	-1.023 +OR- 0.037	45.701	351.07	5.
12	TS12	-0.006 +OR- 0.038	50.724	9.90	5.
13	TS13	0.995 +OR- 0.033	82.193	29.61	5.
14	TS14	1.696 +OR- 0.033	79.133	55.69	5.
15	TS15	2.008 +OR- 0.033	71.655	81.35	5.
16	TS16	1.714 +OR- 0.033	61.273	107.33	5.
17	TS17	1.002 +OR- 0.034	50.076	135.82	5.
18	TS18	0.041 +OR- 0.033	40.977	170.21	5.
19	TS19	-1.001 +OR- 0.033	37.824	211.28	5.
20	TS20	-1.709 +OR- 0.033	42.507	251.33	5.
21	TS21	-1.008 +OR- 0.033	52.338	284.23	5.
22	TS22	-1.709 +OR- 0.034	63.571	311.94	5.
23	TS23	-1.017 +OR- 0.034	73.504	337.73	5.
24	TS24	-0.015 +OR- 0.033	80.168	3.47	5.
25	TS25	0.997 +OR- 0.038	78.986	31.38	3.
26	TS26	1.712 +OR- 0.033	99.289	60.06	4.
27	TS27	2.001 +OR- 0.030	99.848	91.74	5.
28	TS28	1.722 +OR- 0.030	88.824	119.77	5.
29	TS29	1.001 +OR- 0.033	78.078	148.01	4.
30	TS30	-0.020 +OR- 0.033	70.287	178.18	4.
31	TS31	-0.993 +OR- 0.038	67.813	210.25	3.
32	TS32	-1.671 +OR- 0.033	71.532	242.05	4.
33	TS33	-2.014 +OR- 0.030	80.152	271.74	5.
34	TS34	-1.679 +OR- 0.030	91.176	299.77	5.
35	TS35	-0.996 +OR- 0.033	96.043	329.07	4.
36	TS36	-0.013 +OR- 0.033	99.898	359.13	4.

5% PERCENT CONFIDENCE LIMITS (KILOMETRES)

	10N 35W	30N 24W	20N 30W	00N 40W
LATITUDE	10.000 N +OR- 0.411	30.000 N +OR- 0.378	20.000 N +OR- 0.394	0.001 S +OR- 0.393
LONGITUDE	34.999 W +OR- 0.413	24.000 W +OR- 0.313	30.000 W +OR- 0.381	39.999 W +OR- 0.405
DEPTH (KM)	0.0 +OR- 0.0	0.0 +OR- 0.0	0.0 +OR- 0.0	0.0 +OR- 0.0
ORIGIN TIME	2 0 0.01 +OR- 0.01 S	2 0 0.00 +OR- 0.01 S	2 0 0.00 +OR- 0.01 S	1 59 60.00 +OR- 0.01 S
AREA OF CONF. REGION SQ.KM.	0.83	0.58	0.74	0.78

10S 45W

LATITUDE	10.001 S +OR- 0.376
LONGITUDE	45.000 W +OR- 0.357
DEPTH (KM)	0.0 +OR- 0.0
ORIGIN TIME	1 59 59.99 +OR- 0.01 S
AREA OF CONF. REGION SQ.KM.	0.66

TABLE OF RESIDUALS

STATION	10N 35W	30N 24W	20N 30W	00N 40W	10S 45W
1 TS01	-0.0189*	-0.0210*	0.0261*	0.0097*	0.0032*
2 TS02	0.0225*	-0.0434*	0.0112*	-0.0097*	0.0197*
3 TS03	0.0331*	0.0040*	-0.0436*	-0.0189*	0.0252*
4 TS04	0.0067*	0.0309*	-0.0584*	-0.0040*	0.0246*
5 TS05	-0.0176*	-0.0335*	0.0456*	0.0253*	-0.0198*
6 TS06	-0.0049*	0.0022*	0.0251*	-0.0276*	0.0046*
7 TS07	-0.0240*	-0.0060*	-0.0063*	0.0473*	-0.0108*
8 TS08	0.0279*	-0.0228*	0.0257*	-0.0107*	-0.0201*
9 TS09	0.0172*	-0.0042*	0.0226*	-0.0018*	-0.0337*
10 TS10	0.0282*	0.0293*	0.0094*	-0.0522*	-0.0140*
11 TS11	-0.0201*	-0.0177*	-0.0198*	0.0528*	0.0048*
12 TS12	0.0270*	0.0107*	-0.0029*	-0.0206*	-0.0145*
13 TS13	-0.0523*	0.0261*	-0.0002*	0.0529*	-0.0269*
14 TS14	0.0003*	-0.0087*	0.0435*	-0.0125*	-0.0221*
15 TS15	0.0170*	0.0370*	-0.0219*	0.0124*	-0.0451*
16 TS16	0.0218*	0.0251*	0.0142*	-0.0340*	-0.0269*
17 TS17	-0.0408*	0.0448*	-0.0540*	0.0282*	0.0208*
18 TS18	-0.0056*	-0.0245*	0.0008*	0.0115*	0.0179*
19 TS19	-0.0430*	0.0340*	0.0267*	-0.0227*	0.0048*
20 TS20	0.0356*	-0.0016*	0.0071*	-0.0269*	-0.0142*
21 TS21	0.0217*	-0.0333*	0.0053*	-0.0288*	0.0358*
22 TS22	-0.0035*	-0.0047*	-0.0418*	0.0277*	0.0212*
23 TS23	-0.0464*	-0.0297*	-0.0093*	0.0198*	0.0649*
24 TS24	-0.0313*	0.0386*	0.0089*	0.0040*	-0.0204*
25 TS25	0.0237*	-0.0447*	0.0207*	0.0	0.0
26 TS26	0.0260*	-0.0083*	0.0155*	-0.0333*	0.0
27 TS27	-0.0064*	0.0044*	0.0258*	-0.0333*	0.0097*
28 TS28	0.0128*	-0.0084*	0.0134*	0.0047*	-0.0228*
29 TS29	0.0154*	0.0	-0.0364*	0.0111*	0.0097*
30 TS30	-0.0228*	0.0	0.0073*	0.0098*	0.0052*
31 TS31	0.0054*	0.0	0.0	0.0016*	-0.0066*
32 TS32	-0.0005*	0.0	0.0149*	0.0087*	-0.0231*
33 TS33	0.0007*	-0.0059*	0.0057*	-0.0245*	0.0229*
34 TS34	0.0080*	-0.0120*	-0.0452*	0.0248*	0.0237*
35 TS35	0.0139*	0.0141*	-0.0205*	-0.0077*	0.0
36 TS36	-0.0277*	0.0281*	-0.0161*	0.0162*	0.0

STATISTICAL AND OTHER VARIABLES USED

SUM OF SQUARED RESIDUALS = 0.10594

AVERAGE SQUARED RESIDUAL = 0.00088

STANDARD DEVIATION = 0.02971

NUMBER OF DEGREES OF FREEDOM = 120

NUMBER OF UNKNOWNS = 50

STUDENTS T = 1.98

VARIANCE RATIO F = 3.07

SUM OF SQUARES DUE TO EPICENTRE SHIFTS = 0.00209

VARIANCE DUE TO EPICENTRE SHIFTS = 0.00021

NUMBER USED = 10

AREA OF CONFIDENCE REGION ON MEAN EVENT = 0.85 * F(10, 120) SQ.KM.

TIME TAKEN FOR JOB = 13.99 SECONDS

7 JB 1 1 1 1 0
(1X,A4,15X,I2,1X,I2,1X,F4.1)

USES DIMENSION A(22, 23), B(23, 46), C(7, 46)

1196 506 1035 1202

MULTIPLE EPICENTRE DETERMINATION

JED TEST DATA - FULL FLOAT

29/10/65

STATION ARRIVAL TIME

1	COL	21	4	50.3
2	MAT	21	6	32.2
3	KIP	21	6	53.9
4	BMO	21	7	48.5
5	PAS	21	8	36.0
6	UBO	21	8	47.2
7	TRO	21	9	53.0
8	HNR	21	10	27.0
9	OTT	21	10	30.8
10	CPO	21	10	45.6
11	PMG	21	10	51.4
12	UPP	21	10	57.7
13	WES	21	10	59.8
14	KUN	21	11	4.2
15	SHL	21	11	4.6
16	VUN	21	11	8.5
17	KOU	21	11	31.2
18	PPT	21	11	37.5
19	DAR	21	11	49.0
20	CTA	21	11	52.6
21	QUE	21	12	7.2
22	TEH	21	12	20.0
23	BRS	21	12	20.7
24	IST	21	12	30.0
25	RIV	21	12	53.7
26	SJG	21	13	1.3
27	TOO	21	13	16.3

02/06/66

STATION ARRIVAL TIME

1	COL	3	32	56.4
2	MRC	3	34	44.4
3	KIP	3	34	51.5
4	BMO	3	35	56.1
5	PAS	3	36	42.0
6	UBO	3	36	53.4
7	TRO	3	37	46.3
8	PMG	3	38	31.0
9	OTT	3	38	33.5
10	SHL	3	38	44.0
11	UPP	3	38	49.4
12	CPO	3	38	49.6
13	CTA	3	39	34.1
14	QUE	3	39	48.5
15	STU	3	39	59.3
16	BRS	3	40	3.6
17	IST	3	40	20.0
18	SJG	3	41	1.8

22/01/66

STATION ARRIVAL TIME

1	MBC	14	32	21.1
2	BMO	14	32	34.4
3	PAS	14	33	39.0
4	UBO	14	33	39.5
5	KIP	14	33	56.5
6	MAT	14	35	49.0
7	CPO	14	35	54.9
8	TRO	14	36	34.6
9	KON	14	37	39.3
10	UPP	14	37	40.8
11	CLL	14	38	32.7
12	STU	14	38	45.5
13	VUN	14	39	5.4
14	PMG	14	39	21.0
15	SHL	14	39	22.0
16	IST	14	39	33.0
17	TEH	14	39	48.0
18	CTA	14	40	8.8

11/08/66

STATION ARRIVAL TIME

1	COL	10 49 46.0
2	MBC	10 52 5.0
3	BMO	10 52 45.3
4	MAT	10 53 25.2
5	PAS	10 53 37.0
6	UBO	10 53 46.4
7	TRO	10 55 45.0
8	OTT	10 55 45.0
9	CPO	10 55 54.6
10	UPP	10 56 50.9
11	PMG	10 57 17.5
12	SHL	10 57 34.9
13	CTA	10 58 13.0
14	SJG	10 58 23.5
15	QUE	10 58 24.7
16	TEH	10 58 30.0
17	BRS	10 58 35.4

06/02/65

STATION ARRIVAL TIME

1	MBC	16 56 18.9
2	BMO	16 56 35.6
3	KIP	16 56 54.0
4	MAT	16 58 35.0
5	OTT	16 59 44.7
6	CPO	16 59 52.9
7	TRO	17 0 16.2
8	UPP	17 1 21.1
9	HNR	17 1 40.2
10	PPT	17 1 47.1
11	PMG	17 2 12.4
12	SHL	17 2 28.0
13	SJG	17 2 30.5
14	KOU	17 2 31.0
15	CTA	17 3 4.2
16	IST	17 3 6.4
17	DAR	17 3 10.0
18	TEH	17 3 12.0
19	BRS	17 3 23.0
20	RIV	17 3 55.1
21	TOO	17 4 20.0

19/07/66

STATION ARRIVAL TIME

1	COL	1 46 11.0
2	MAT	1 46 33.0
3	MBC	1 47 31.0
4	KIP	1 49 10.0
5	BMO	1 49 34.9
6	PAS	1 50 28.0
7	UBO	1 50 29.7
8	SHL	1 50 57.0
9	UPP	1 51 9.7
10	HNR	1 51 40.0
11	PMG	1 51 50.5
12	QUE	1 52 3.0
13	CLL	1 52 8.1
14	CPO	1 52 10.1
15	TEH	1 52 21.0
16	STU	1 52 27.5
17	VUN	1 52 38.1
18	IST	1 52 43.0
19	CTA	1 52 51.0
20	PPT	1 53 24.0

19-07-66

STATION	ARRIVAL TIME
1 COL	19 24 47.9
2 MBC	19 26 56.0
3 MAT	19 27 41.0
4 PAS	19 28 22.0
5 URO	19 28 40.0
6 TRO	19 30 27.2
7 OTT	19 30 37.0
8 CPO	19 30 47.3
9 WES	19 31 7.6
10 HNR	19 31 15.0
11 UPP	19 31 30.7
12 PMG	19 31 40.3
13 SHL	19 32 0.3
14 CLL	19 32 24.0
15 CTA	19 32 36.8
16 STU	19 32 38.9
17 QUE	19 32 54.9
18 TEH	19 33 4.0
19 IST	19 33 8.0
20 SJG	19 33 9.7

TOTAL NUMBER OF STATIONS USED = 30

TABLE OF RESIDUALS

STATION	29/10/65	02/06/66	22/01/66	11/08/66	06/02/65	19/07/66	19-07-66
1 COL	-3.5437*	-0.9211*	0.0	-2.2480*	0.0	0.5190*	-0.8151*
2 MAT	-2.4693*	0.0	-2.1595*	-0.2193*	-1.5253*	-0.3846*	-0.9193*
3 KIP	-0.7249*	0.0421*	0.4423*	0.0	0.5594*	6.2043*	0.0
4 BMO	-3.0824*	0.2797*	0.7363*	-0.1833*	0.3057*	0.2512*	0.0
5 PAS	-3.2084*	-0.5688*	-0.0567*	0.7296*	0.0	-0.9442*	0.1464*
6 URO	-2.4879*	0.6076*	0.5441*	0.2519*	0.0	0.6652*	0.5608*
7 TRO	-4.6829*	-0.1011*	0.2276*	-0.7531*	0.9816*	0.0	0.0791*
8 HNR	-3.0341*	0.0	0.0	0.0	-1.2044*	1.6007*	3.3400*
9 OTT	-6.1255*	-1.9999*	0.0	-1.1835*	-2.0313*	0.0	-1.0523*
10 CPO	-5.0532*	-0.5962*	-1.5991*	-2.4800*	-2.5957*	-1.0043*	-1.5368*
11 PMG	-2.9598*	-1.6974*	-1.6480*	-1.2443*	-1.4683*	2.6166*	-0.2746*
12 UPP	-4.8988*	-0.2833*	-0.6459*	0.0544*	0.4946*	-0.8641*	-0.7569*
13 WFS	-4.9348*	0.0	0.0	0.0	0.0	0.0	0.4803*
14 KON	-3.8900*	0.0	0.1270*	0.0	0.0	0.0	0.0
15 SHL	-3.3748*	0.5259*	-1.9725*	-0.3694*	-2.5184*	-3.1163*	-0.7130*
16 VUN	-1.7698*	0.0	4.3293*	0.0	0.0	3.1578*	0.0
17 KOU	-1.3605*	0.0	0.0	0.0	-0.6620*	0.0	0.0
18 PPT	-1.3554*	0.0	0.0	0.0	0.2048*	5.5429*	0.0
19 DAR	-2.4225*	0.0	0.0	0.0	-0.9498*	0.0	0.0
20 CTA	-2.7717*	-0.9932*	21.3134*	-1.1566*	-1.0435*	0.4250*	-1.2680*
21 QUE	-1.5970*	0.4412*	0.0	1.5314*	0.0	-0.9012*	1.0105*
22 TEH	-2.1088*	0.0	1.5165*	1.4723*	1.8634*	0.0143*	1.7914*
23 BRS	-1.5680*	-0.2359*	0.0	-0.0813*	-0.3964*	0.0	0.0
24 IST	-4.4352*	0.7513*	0.8615*	0.0	2.2378*	0.8310*	0.6254*
25 RIV	-1.1036*	0.0	0.0	0.0	2.5081*	0.0	0.0
26 SJG	-3.3066*	1.2534*	0.0	0.4664*	-0.2079*	0.0	-0.8067*
27 TOO	-1.7077*	0.0	0.0	0.0	2.7826*	0.0	0.0
28 MBC	0.0	0.3571*	2.0652*	-1.1591*	0.5996*	1.1049*	-0.8331*
29 STU	0.0	0.6572*	0.5976*	0.0	0.0	1.1952*	1.0374*
30 CLL	0.0	0.0	0.3085*	0.0	0.0	0.2474*	0.7040*

SUM OF SQUARED RESIDUALS AFTER 0 ITERATIONS = 550.65040

SUM OF SQUARED RESIDUALS AFTER 1 ITERATIONS = 86.84699

SUM OF SQUARED RESIDUALS AFTER 2 ITERATIONS = 86.84105

RESULTS AFTER 2 ITERATIONS

	EVENT	ORIGIN TIME	DEPTH (KM)	LATITUDE	LONGITUDE
ORIGINAL EPICENTRE	29/10/65	21 0 0.10	0.700	51.440 N	179.180 E
RECALCULATED EPICENTRE		20 59 57.13	0.700*	51.476 N	179.106 E
EPICENTRE SHIFTED 6.562 KM AZIMUTH 308.21 DEGS					
ORIGINAL EPICENTRE	02/06/66	3 27 53.30	41.000	51.080 N	175.970 E
RECALCULATED EPICENTRE		3 27 53.40	41.000*	50.949 N	175.888 E
EPICENTRE SHIFTED 16.014 KM AZIMUTH 201.61 DEGS					
ORIGINAL EPICENTRE	22/01/66	14 27 7.90	33.000	55.970 N	153.690 W
RECALCULATED EPICENTRE		14 27 8.03	33.000*	55.915 N	153.994 W
EPICENTRE SHIFTED 20.399 KM AZIMUTH 252.18 DEGS					
ORIGINAL EPICENTRE	11/08/66	10 45 59.60	61.000	52.760 N	169.740 W
RECALCULATED EPICENTRE		10 45 59.90	61.000*	52.782 N	169.844 W
EPICENTRE SHIFTED 7.434 KM AZIMUTH 70.71 DEGS					
ORIGINAL EPICENTRE	06/02/65	16 50 28.60	33.000	53.290 N	161.810 W
RECALCULATED EPICENTRE		16 50 28.48	33.000*	53.124 N	161.944 W
EPICENTRE SHIFTED 20.984 KM AZIMUTH 205.97 DEGS					
ORIGINAL EPICENTRE	19/07/66	1 40 53.90	18.000	56.200 N	164.900 E
RECALCULATED EPICENTRE		1 40 54.81	18.000*	56.338 N	164.478 E
EPICENTRE SHIFTED 30.559 KM AZIMUTH 300.55 DEGS					
ORIGINAL EPICENTRE	19-07-66	19 20 33.40	47.000	51.730 N	173.300 W
RECALCULATED EPICENTRE		19 20 34.12	47.000*	51.796 N	173.450 W
EPICENTRE SHIFTED 13.198 KM AZIMUTH 305.40 DEGS					
MEAN EPICENTRE 53.644 N 177.172 W					

* RESTRAINED PARAMETERS

JB TRAVEL TIMES USED

STATION CORRECTIONS (SECONDS)

			MEAN DISTANCE	MEAN AZIMUTH	NO. OF READINGS		
1	COL	-1.671	+OR-	3.350	18.614	35.35	5.
2	MAT	-0.373	+OR-	2.953	37.150	265.11	6.
3	KIP	1.660	+OR-	2.603	44.503	125.97	5.
4	BMD	-0.855	+OR-	2.604	46.342	68.75	6.
5	PAS	-1.206	+OR-	2.386	43.004	91.95	6.
6	UBO	-0.611	+OR-	2.425	44.421	78.76	6.
7	TKU	-0.645	+OR-	2.006	59.546	354.95	6.
8	HNR	0.579	+OR-	2.548	65.149	209.14	4.
9	OTT	-2.591	+OR-	2.186	60.180	53.59	5.
10	CPD	-2.631	+OR-	2.103	61.777	67.57	7.
11	PMG	-0.445	+OR-	2.394	69.742	221.88	7.
12	UPP	-0.844	+OR-	1.917	68.341	354.01	7.
13	WES	-1.250	+OR-	2.315	64.548	53.34	2.
14	KDN	-0.569	+OR-	2.166	64.044	9.18	2.
15	SHL	-0.987	+OR-	1.966	73.096	289.80	7.
16	VUN	2.366	+OR-	2.323	75.023	166.23	3.
17	KOU	0.556	+OR-	2.518	79.000	212.05	2.
18	PPT	1.521	+OR-	2.066	83.097	136.32	3.
19	DAR	0.239	+OR-	2.443	86.708	244.47	2.
20	CTA	-0.709	+OR-	2.150	79.771	218.15	7.
21	QUE	0.828	+OR-	1.754	82.730	310.63	5.
22	TFH	1.298	+OR-	1.562	84.406	324.81	6.
23	BRS	0.498	+OR-	2.175	89.321	219.19	4.
24	IST	0.449	+OR-	1.529	85.494	343.16	6.
25	RIV	2.613	+OR-	2.273	95.705	217.65	2.
26	SJG	-0.492	+OR-	1.632	86.104	65.51	5.
27	TDO	2.454	+OR-	2.247	101.154	220.02	2.
28	MCC	-0.560	+OR-	2.649	31.985	21.47	6.
29	STU	0.500	+OR-	1.783	79.786	358.22	4.
30	CLL	0.227	+OR-	1.915	77.125	355.85	3.

5% PERCENT CONFIDENCE LIMITS (KILOMETRES)

	20/10/65	02/06/66	22/01/66	11/08/66
LATITUDE	51.476 N +OR-	35.621	50.949 N +OR-	37.619
LONGITUDE	179.106 E +OR-	21.766	175.888 E +OR-	22.486
DEPTH (KM)	0.700 +OR-	0.0	41.000 +OR-	0.0
ORIGIN TIME	20 59 57.13 +OR-	0.46 S	3 27 53.40 +OR-	0.62 S
AREA OF CONF. REGION SQ.KM.	3749.88	4109.47	3199.68	3651.66
	06/02/65	19/07/66	19-07-66	
LATITUDE	53.124 N +OR-	33.887	56.338 N +OR-	37.499
LONGITUDE	161.944 W +OR-	22.509	164.478 E +OR-	18.007
DEPTH (KM)	33.000 +OR-	0.0	18.000 +OR-	0.0
ORIGIN TIME	16 50 28.49 +OR-	0.54 S	1 40 54.81 +OR-	0.52 S
AREA OF CONF. REGION SQ.KM.	3709.15	3266.70	3924.64	

TABLE OF RESIDUALS

STATION	29/10/65	02/06/66	22/01/66	11/08/66	06/02/65	19/07/66	19-07-66
1 COL	1.0894*	-0.5419*	0.0	-1.0901*	0.0	0.4029*	0.1367*
2 MAT	1.2116*	0.0	-0.6527*	0.3726*	-0.4590*	0.0642*	-0.5371*
3 KIP	C.0831*	-1.2280*	-0.6959*	0.0	0.3809*	1.4544*	0.0
4 BMO	C.4655*	0.2946*	-0.0225*	-0.1341*	0.5028*	-1.1049*	0.0
5 PAS	C.7223*	0.1245*	0.0102*	1.1992*	0.0	-2.0078*	-0.0483*
6 UBO	C.8293*	0.4393*	-0.3578*	0.0750*	0.0	-0.8105*	-0.1757*
7 TRO	-0.7676*	-0.3809*	0.2742*	-0.2227*	0.5784*	0.0	0.5179*
8 HNR	-C.7555*	0.0	0.0	0.0	-0.5803*	-0.6267*	1.9622*
9 OTT	-0.6379*	-0.3193*	0.0	0.8276*	-0.4465*	0.0	0.5742*
10 CPO	C.3926*	1.2555*	-0.4399*	-0.5079*	-0.7145*	0.0485*	-0.0345*
11 PMG	0.4341*	-0.4660*	-0.4210*	-0.9228*	0.0321*	1.8147*	-0.4700*
12 UPP	-C.8106*	-0.2684*	-0.3803*	0.7672*	0.4008*	0.4583*	-0.1679*
13 WES	-C.7805*	0.0	0.0	0.0	0.0	0.0	0.7799*
14 KON	-C.0653*	0.0	0.0650*	0.0	0.0	0.0	0.0
15 SHL	C.9209*	1.5540*	-0.5326*	0.7069*	-1.4560*	-1.3864*	0.1926*
16 VUN	-1.3650*	0.0	2.5530*	0.0	0.0	-1.1885*	0.0
17 KOU	C.5148*	0.0	0.0	0.0	-0.5149*	0.0	0.0
18 PPT	-0.6261*	0.0	0.0	0.0	-0.7486*	1.3738*	0.0
19 DAR	C.3705*	0.0	0.0	0.0	-0.3703*	0.0	0.0
20 CTA	C.8706*	0.4093*	0.0663*	-0.6145*	0.6165*	-0.0979*	-1.2493*
21 QUE	0.8659*	-0.6413*	0.0	0.7164*	0.0	-0.9831*	0.0406*
22 TEH	-0.1329*	0.0	0.1283*	0.1416*	0.1255*	-0.5747*	0.3103*
23 BRS	0.8266*	-0.0897*	0.0	-0.8002*	0.0615*	0.0	0.0
24 IST	-1.6544*	-0.2927*	0.0363*	0.0	1.1508*	0.8636*	-0.1033*
25 RIV	-0.3197*	0.0	0.0	0.0	0.8202*	0.0	0.0
26 SJG	0.0562*	1.1201*	0.0	0.4043*	-0.2641*	0.0	-1.3169*
27 TOU	-1.2455*	0.0	0.0	0.0	1.2466*	0.0	0.0
28 MBC	0.0	-0.3759*	1.4393*	-0.9197*	-0.3637*	0.9739*	-0.7554*
29 STU	C.0	-0.5960*	-0.5431*	0.0	0.0	0.9517*	0.1873*
30 CLL	0.0	0.0	-0.5276*	0.0	0.0	0.3723*	0.1543*

STATISTICAL AND OTHER VARIABLES USED

SUM OF SQUARED RESIDUALS = 86.84105
AVERAGE SQUARED RESIDUAL = 0.95430
STANDARD DEVIATION = 0.97688
NUMBER OF DEGREES OF FREEDOM = 91
NUMBER OF UNKNOWN = 50
STUDENTS T = 2.00
VARIANCE RATIO F = 3.12

SUM OF SQUARES DUE TO EPICENTRE SHIFTS = 160.63583
VARIANCE DUE TO EPICENTRE SHIFTS = 11.47399
NUMBER USED = 14

AREA OF CONFIDENCE REGION ON MEAN EVENT = 2509.79 * F (14, 91) SQ.KM.

TIME TAKEN FOR JOB = 7.60 SECONDS

F5. SAMPLE INPUT AND OUTPUT FOR EFA

Two examples of the use of EFA are given.

F5.1 Longshot at the four arrays - computed data

This example uses the computed azimuth of the LONGSHOT epicentre from each of the four arrays: Yellowknife, Canada (YKA), Eskdalemuir, Scotland (EKA), Gauribidanur, India (GBA) and Warramunga, Australia (WRA). The data are error free so the estimated epicentre should be exactly the true epicentre (which it is) within the rounding error of the input.

F5.2 LONGSHOT at the four arrays - real data

This example uses observed data. The input is the azimuth of LONGSHOT as estimated by each of the four arrays: YKA, EKA, GBA and WRA.

EKA ESKDALEMUIR ARRAY SCOTLAND LAT 55.333189 LONG -3.158756
 GBA GAURIBIDANUR ARRAY INDIA LAT 13.604167 LONG 77.436111
 WRA WARRAMUNGA ARRAY AUSTRALIA LAT-19.947778 LONG 134.350833
 YKA YELLOW KNIFE ARRAY CANADA LAT 62.492858 LONG-114.604593

**** END OF STATIONS

TITLE LONGSHOT AT THE FOUR ARRAYS -- COMPUTED DATA

NORTH	51.44
EAST	179.18
YKA	283.6
EKA	358.5
GBA	37.9
WRA	26.5

TITLE LONGSHOT AT THE FOUR ARRAYS -- REAL DATA

NORTH	51.44
EAST	179.18
YKA	285.1
EKA	0.5
GBA	36.4
WRA	31.7

FINDING EPICENTRES FROM AZIMUTHS

LONGSHOT AT THE FOUR ARRAYS -- COMPUTED DATA

INITIAL EPICENTRE	LATITUDE	51.440	NORTH
	LONGITUDE	179.180	EAST

RESULTS AFTER 13 ITERATIONS

COMPUTED EPICENTRE	LATITUDE	51.417	NORTH	+/-	3.8 KM
	LONGITUDE	179.134	EAST	+/-	3.6 KM

SUM SQUARED RESIDUALS = 0.0002
 SHIFT IN EPICENTRE = 4.1 KM
 DIRECTION OF SHIFT = 232.1 DEGS

STATION	AZIMUTH	RESIDUAL	STATION	AZIMUTH	RESIDUAL
1 YKA	283.60	-0.006	2 EKA	358.50	-0.004
3 GBA	37.90	0.002	4 WRA	26.50	-0.014

FINDING EPICENTRES FROM AZIMUTHS

LONGSHOT AT THE FOUR ARRAYS -- REAL DATA

INITIAL EPICENTRE	LATITUDE	51.440	NORTH
	LONGITUDE	179.180	EAST

RESULTS AFTER 6 ITERATIONS

COMPUTED EPICENTRE	LATITUDE	51.434	NORTH	+/-	1432.1 KM
	LONGITUDE	179.382	EAST	+/-	1376.1 KM

SUM SQUARED RESIDUALS = 35.2771
 SHIFT IN EPICENTRE = 14.3 KM
 DIRECTION OF SHIFT = 92.4 DEGS

STATION	AZIMUTH	RESIDUAL	STATION	AZIMUTH	RESIDUAL
1 YKA	285.10	1.676	2 EKA	0.50	2.201
3 GBA	36.40	-1.399	4 WRA	31.70	5.066

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<p>Abstract</p> <p>Four programs for determining the epicentre (and origin time and depth where possible) of a seismic event are described: SPEEDY uses Geiger's classical method of estimating the epicentre, origin time and depth of focus of an event; SPUR is similar to SPEEDY but is more compact and hence suitable for a small machine; JED is an extension of the classical method to estimate the epicentres, origin times and depths of a large number of events and station (time) terms simultaneously; and EFA estimates epicentres given the azimuth of an event from each of a number of stations.</p>			