*** Please read the README file on the HYPO71PC Distribution diskette. ***

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

HYPO71PC: A Personal Computer Version of the HYPO71 Earthquake Location Program

by

W. H. K. Lee
Branch of Seismology
MS 77, U. S. Geological Survey
Menlo Park, CA 94025

and

C. M. Valdes
Dept. of Geology and Geophysics
University of Wisconsin
Madison, WI 53706

Open-file Report 85-749

December, 1985

Menlo Park, California 94025

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

README file for HYPO71PC (3/13/87)

```
*****************************************************************************
*   ALTHOUGH THIS PROGRAM HAS BEEN EXTENSIVELY TESTED, THE U.S. GEOLOGICAL *
*   SURVEY CANNOT GUARANTEE THAT IT WILL GIVE ACCURATE RESULTS FOR ALL     *
*   APPLICATIONS OR THAT IT WILL WORK ON ALL COMPUTER SYSTEMS.             *
*****************************************************************************
```

The present HYPO71PC distribution disk contains the following six files:
(1) README -- a copy of this note.
(2) HYPO71PC.EXE -- executable code for the program HYPO71PC.
(3) INPUTSTA.EXE -- executable code for helping you to enter station data.
(4) INPUTPHA.EXE -- executable code for helping you to enter phase data.
(5) HYPO71.INP -- test data from the original HYPO71 program.
(6) HYPO71.OUT -- output file by HYPO71PC using HYPO71.INP as input data.

This distribution disk is NOT bootable. The reason for making this change is that many users prefer to boot the PC with their own disk. In order to run HYPO71PC, you must have at least 256K bytes of RAM, a math coprocessor (Intel 8087 or 80287), and the operating system must be DOS 2.1 or higher. You must also have enough room (>40K bytes) in your default disk for output.

To check the files on the disk you received, please make a test run using the file HYPO71.INP as input (see attached Manual for details). Answer the prompt for the input data filename by typing HYPO71.INP and press the ENTER key. Please note the default choice (by pressing only the ENTER key) is for a file called HYPO71PC.INP which is NOT on the distribution disk. The word HYPO71 contains 2 parts: (1) the letters H,Y,P,O (not zero), and (2) the numbers 7 and 1.

You may answer the prompts for the output print and punch files by pressing the ENTER key; the output will then be written in files called HYPO71PC.PRT and HYPO71PC.PUN. Actually, there is no punch output for the test input file HYPO71.INP, but a file called HYPO71PC.PUN is created anyway. The program should terminate with the message -- Execution terminated : 0.

Next, compare the file HYPO71PC.PRT with the file HYPO71.OUT on the distribution disk by using the COMP command (read your DOS Manual for the COMP command). These two files should be identical and compared O.K.; if not, you may have a bad distribution disk (possibly caused by mailing).

Abnormal termination of HYPO71PC during execution is usually indicated by an error message on your display screen with an error number. Consult the IBM Professional Fortran Manual for explanations (Appendixes in the Installation and Use binder list the Runtime error messages). The followings are some examples:
(1) Error Number 4001 -- No math coprocessor; you need to install a math coprocessor (Intel 8087 or 80287 chip) in your PC.
(2) Error Number 4002 -- Wrong DOS, i.e., you need DOS 2.1 or later versions.
(3) Error Number 3000's -- Problems in reading or writing from disk. Check for enough space on your default disk to hold the output. The size of the output files depend on your choices and are usually ten times larger than your input file size. If you have enough space, then make sure your disk is good (i.e., you should be able to display your input file on screen), and is NOT write protected.

If you have problems, contact Willie Lee (415-323-8111 ext. 2630), or mail him a copy of your input file on a disk & tell him the problems you have. A copy of the FORTRAN source code for HYPO71PC is also available upon request (with a blank diskette). However, we DO NOT support any modifications of it.

1. INTRODUCTION

For the past 15 years, HYPO71 (Lee and Lahr, 1972; 1975) has been one of the popular computer programs for locating local earthquakes. It was written in FORTRAN IV language and has been successfully executed under a large number of mainframe and mini computers, including those made by IBM**, CDC, and DEC. It is a "stable" program in that no major changes were made since its original release in 1971 and minor revisions in 1973.

In recent years, personal computers (PCs) have become widely within the profession. For example, the computational power of these PCs is considerable. For the IBM PC (with 8087) it is about 10% of that of an IBM 360/65, the mainframe computer original used to run the HYPO71 program in the early 1970's. Because PCs are readily available and portable, they can also be deployed in the field for rapid analysis of earthquake observations.

Mendoza and Morgan (1985) have written BASIC-HYPO, an earthquake location program in the BASIC language for micro-computers. The advantage of their approach is that BASIC-HYPO will run on most microcomputers that have 16 k-bytes of free memory, with little or no modification. Although BASIC is the most popular language used in the micros, its performance in large scientific application programs (such as an earthquake location program with lots of options), particularly in the interpreter mode, is poor in comparison with the FORTRAN language. Their program takes 4 minutes per iteration and thus tens of minutes to locate an earthquake.

** Any use of the trade names is for descriptive purposes only and thus not imply endorsement by the USGS.

Because the HYPO71 earthquake location program has been widely used, we decided to implement it on the IBM PC personal computer in its entirety. We first converted the HYPO71 program into FORTRAN 77 language, to be compatible with the compilers available for the IBM PC. We also made minor changes to improve the clarity of the program. These changes do not affect the use of the HYPO71 program, and they will be discussed in the next section. Using the IBM Professional FORTRAN Compiler for personal computers (IBM, 1984), we sucessfully compiled the HYPO71PC earthquake location program. Typically, it only takes about 10 seconds to locate an earthquake on an IBM PC.

2. CONVERSION OF HYPO71 FOR PERSONAL COMPUTERS

A major difference between FORTRAN IV and FORTRAN 77 is that character variables must be explicitly declared in FORTRAN 77. HYPO71 program also used non-standard techniques to achieve printing blanks for variables whose values do not exist. We made the following programming changes to HYPO71. They do not affect its function in locating earthquakes but do make the code cleaner.

(1) All character variables and constants have been explicitly declared.

(2) Most common statements have been replaced by arguments in subroutine calls. This greatly clarify the relationships between the calling and the called routines. The original use of common statements in HYPO71 was to speed up the execution time of the program. However, this is not judged to be worth the inconvenience.

(3) Because the IBM Professional Compiler allows a maximum of 63 arguments in a subroutine, we had to use a few common statements to bypass this

limit.

(4) The Non-standard output technique in HYPO71 was replaced by internal read and write statments.

(5) The table-lookup calculation of distances in HYPO71 was replaced by direct calculation using formulas given in Lee and Stewart (1981, p. 131). Please note that there is a typographic error in Equation (6.3) of Lee and Stewart, in that the value for A should be given by the right-hand side multiplied by cos(Φ). Values for A and B are given by:

$A = [1.8553654 + 0.0062792 \sin^2(\Phi) + 0.0000319 \sin^4(\Phi)] \cos(\Phi)$, and

$B = 1.8428071 + 0.0187098 \sin^2(\Phi) + 0.0001583 \sin^4(\Phi)$.

In addition, we have added a few options that may be useful under certain conditions. We designed these options such that the previous usage of HYPO71 can still be retained. These options are:

(1) To facilitate the entry of input data, we have written two auxiliary programs to collect the input data and they will be described in Section 4.

(2) To allow printed output on smaller paper, an option called KPAPER is added in column 56 of the CONTROL card. If KPAPER = 0 or blank, we assume traditional computer output, i.e., 132 columns on 14 by 11 inches paper. If KPAPER = 1, then we assume columns on 11 by 8.5 inches paper.

(3) Our colleague, Al Lindh, recommended some changes in the subroutine SINGLE in order to handle earthquakes located outside the network (Lindh, personal communication, 1985). The changes (i) extend the distance weighting so that distant stations will still be used in the location precedure, (ii) postpone Jeffrey's weighting until the fourth iteration, and (iii) change the denominator inside the square root of the RMS calculation to N-4, instead of N. Therefore, we added an

option called KSING in column 1 of the CONTROL card. If KSING = 0 or blank, then the original SINGLE subroutine is used. If KSING = 1, then a modified SINGLE subroutine (as prescribed by Al Lindh) is used. Please note that this option affects the field for trial focal depth. Originally, the trial focal depth occupies columns 1 to 5 of the CONTROL card in F5.0 format. Now, it is changed to occupy columns 2 to 5 of the CONTROL card in F4.0 format. This should not cause any trouble as most users use a trial focal depth of a few kilometers so that column 1 of the CONTROL card is not used. However, please do check your CONTROL card to make sure its proper usage under the current definition.

(4) We added messages to be displayed on the computer monitor to report the progress in execution.

3. HOW TO USE HYPO71PC

We assume that users are familiar with the HYPO71 earthquake location program (Lee and Lahr, 1972; 1975). For your convenience, we reproduced p.1 to p.30 of Lee and Lahr (1975) in Appendix 1. These pages describe the input data and output results of the HYPO71 program. If you have HYPO71 input data available on a mainframe or mini computer, you may download it as an ASCII file to your personal computer. You may also edit the input data with any editor program. We have used KEDIT by Mansfield Software Group to edit our input data and examine the output files.

The equipment you need to run HYPO71PC without further modification is an IBM personal computer or "work-a-like". Your computer must have the mathematic co-processor (8087 or 80287 microprocessor), and at least 256 Kbytes random access memory. We have tested HYPO71PC on IBM PC, IBM PC/XT, IBM PC/AT, and COMPAQ computers. The diskette we provide is self-loadable with DOS 2.1 COMMAND.COM., and contains the following additional files: (1) HYPO71PC.EXE -- an executable program of HYPO71PC compiled and linked by the IBM Professional FORTRAN Compiler (IBM, 1984), (2) INPUTSTA.EXE -- an execuatble program to help users to enter station list, crustal model, and CONTROL card, (3) INPUTPHA.EXE -- an executable program to help users to enter earthquake phase lists and INSTRUCTION cards, (4) HYPO71.INP -- The input data file used orginally to test the HYPO71 program, and (5) HYPO71.OUT -- the output file generated when HYPO71.INP is used as input.

HYPO71PC works best if you have a hard disk. First, create a directory called HYPO71PC in your hard disk. Second, copy all files from the HYPO71PC diskette into this directory of your hard disk. Third, test run HYPO71PC by typing HYPO71PC and press the ENTER key. Please note that you must press the ENTER or RETURN key (abbreviated as CR) after you type in the appropriate words. Answer HYPO71.INP when asked for the FILENAME for the input data, HYPO71.PRT when asked for the FILENAME for the printed output, and HYPO71.PUN when asked for the FILENAME for the punched output. (Actually, there is no punched output for the HYPO71.INP input data). The progress of the execution will be displayed on your computer monitor, and you should compare the HYPO71.PRT file with the HYPO71.OUT file to make sure that HYPO71PC is running properly in your machine.

For a personal computer with floppy disk drives only, we recommend that you set up a RAM drive called C: (This assume that you have the full 640 Kbytes on your personal computer. If not, we highly recommend this upgrade to speed up HYPO71PC). You then copy your input data for HYPO71PC to drive C:, and remember to prefix the drive name C: in answering the prompts for the FILENAME of input and output files. After the execution, you may copy the results from the RAM drive to a diskette for permanent storage. As shown below, the execution time wili be improved by a factor of 3 for the

IBM PC with standard floppy disk drives if you use a RAM drive. Please note that timing for an IBM PC/XT with floppy disk is the same as that for an IBM PC with floppy disk. The approximate execution time for running the HYPO71PC program using HYPO71.INP as the input data to locate 4 quakes are:

	Floppy Disk	RAM Disk	Hard Disk
IBM PC/AT (80287)	25 sec*	22 sec	22 sec
IBM PC/XT (8087)	125 sec**	45 sec	54 sec
(IBM 3081K mainframe)			(CPU time = 0.2 sec Actual time = 9 sec)

* High capacity floppy disk drive. ** Standard floppy disk drive.

4. <u>HOW TO SET UP THE INPUT DATA USING INPUTSTA AND INPUTPHA PROGRAMS</u>

Two programs (INPUTSTA and INPUTPHA) have been designed to interactively create the HYPO71PC input data files.

Program INPUTSTA asks : (1) enter a filename for the file generated by this program, (2) if you want to see a short example of how to run this program, you should enter HELP, otherwise, press the ENTER key to continue, (3) enter a HEADING, that will appear on all the ouput events, (4) if you want to reset TEST VARIABLES , enter yes or no, if yes, (5) enter the TEST number and the NEW VALUE, if you enter no, the program prompts, (6) what type of station format do you want ? (1 or 2), 1 represents the station delay model, 2 the variable first layer model. After entering the selected model, (7) the program displays a long heading containing the required variables that should be entered for each station (i.e. WEIGHT, NAME, LATITUDE, NORTH OR SOUTH, LONGITUDE, EAST OR WEST, ELEVATION, AND DELAY). After the last station you should press the ENTER key again to go on to the crustal model, (8) the program prompts for VELOCITY and DEPTH. After the last VELOCITY and DEPTH specification press the ENTER key again to go on to the CONTROL CARD, (9) the program will display a long heading requesting CONTROL CARD varaibles (i.e. TRIAL DEPTH, minimum distance where WEIGHT is 1, maximum distance where WEIGHT is 0, P to S RATIO, QUALITY CLASS of earthquakes included in the residual summary, MISSING DATA INDICATOR, and MINIMUM FIRST MOTION READINGS to plot a first motion diagram. The next line will ask for more CONTROL CARD VARIABLES (i.e. indicator for PUNCH CARDS, MAGNITUDE SELECTION, SYSTEM CURVE response, PRINTING INDICATOR, CODE, and LATITUDE and LONGITUDE of the trial hypocenter). After this data is entered the program will exit, and the output file will be in the HYPO71PC input format. If you wish to use the KSING (Al Lindh's modification) and KPAPER (Different paper size option), you must use a text editor to modify the CONTROL CARD.

Program INPUTPHA asks: (1) the name of the output file for this program, (2) the program will prompt for the DATE (i.e. YEAR, MONTH, DAY, HOUR, and MINUTE) of the earthquake event, and after pressing the ENTER key, (3) the program displays a heading asking for STATION NAME, P REMARK (i.e. Impulsive or Emergent, P wave, Up or Down, and WEIGHT), the SECOND of P arrival, S REMARK (similar to P REMARK), the SECOND of S arrival, maximum peak to peak AMPLITUDE, and the signal duration or FMP time. You should enter one line for each station that recorded the earthquake. After the last line, press the ENTER key again to go on to the INSTRUCTION CARD, (4) the program prompts if S arrival is to be USED, if you want to FIX the LOCATION, and if you want a TRIAL DEPTH. At this point by pressing the ENTER key again, the program goes back to ask for data for the next earthquake event, and if you press the ENTER key instead of answering the prompts, the program will exit.

An example of using programs INPUTSTA and INPUTPHA is shown in Table 1.

After these files are created, you may use the COPY command of DOS (Disk Operating System for your personal computer) to create an input file for the HYPO71PC program. For example, if you name the file generated by INPUTSTA to be QUAKE.STA and the file generated by INPUTPHA to be QUAKE.PHA, then type COPY QUAKE.STA+QUAKE.PHA QUAKE.INP and press the ENTER key. The file QUAKE.INP is a combination of QUAKE.STA and QUAKE.PHA and is ready as an input file for the HYPO71PC program.

ACKNOWLEDGEMENTS

We thank Randy White for encouraging us to convert the HYPO71 program for use on personal computers. We are also grateful for help from John Lahr, Al Lindh, and Jim Newberry.

REFERENCES

IBM, IBM Personal Computer Professional FORTRAN Compiler (by Ryan-Mcfarland Corp.), International Business Machines Corp., Boca Raton, 2 volumes, 1984.

Lee, W. H. K., and J. C. Lahr, HYPO71: a computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes, Open-file report, U. S. Geological Survey, 100 pp., 1972.

Lee, W. H. K., and J. C. Lahr, HYPO71 (REVISED): a computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes, Open-file report 75-311, U. S. Geological Survey, 114 pp., 1975.

Lee, W. H. K., and S. W. Stewart, Principles and Applications of Microearthquake Networks, Academic Press, New York, 293 pp., 1981.

Mendoza, J., and D. Morgan, BASIC-HYPO: a BASIC language hypocenter location program, Bull. Seism. Soc. Am., 75, 1211-1216, 1985.

Table 1. Example of Using INPUTSTA and INPUTPHA

(Bold face words are entries by users)

INPUTSTA

```
*****  INPUTSTA  (11/22/85)  *****

*** This program creates a station file for HYPO71PC; ***

   Please enter a filename (8 or less characters) --->
```

SHORT.STA

```
This program interactively asks for data.
If you need some help type: HELP; or
Press RETURN to continue.


Enter the HEADING   (no more than 50 characters
----------------------------------------------
```

SHORT DATA SET TO TEST HYPO71PC

```
Do you want to reset TEST VARIABLES? (Yes or no) --->
```

YES

```
TEST  NEW
  #   VALUE
 --   ---.----
```

06 1.0

```
Do you want to reset TEST VARIABLES? (Yes or no) --->
```

NO

```
What type of station format do you want? (1 or 2)
```

1

WEIGHT *=0	STATION NAME	LATITUDE DEGREES	LATITUDE MINUTES	N S	LONGITUDE DEGREES	LONGITUDE MINUTES	E W	ELEV	DELAY
-	----	--	--.--	-	---	--.--	-	----	--.--
	SR07	**38**	**32.20**	**N**	**122**	**42.78**	**W**		**0.0**
	SR10	**38**	**25.00**	**N**	**122**	**38.75**	**W**		**-0.1**
	SR13	**38**	**28.50**	**N**	**122**	**41.10**	**W**		**-0.0**
	SR13	**38**	**29.40**	**N**	**122**	**35.95**	**W**		**0.0**
	SR16	**38**	**32.02**	**N**	**122**	**58.55**	**W**		**0.0**

```
** Remember the DEPTHS are to the top of the LAYER,
  and the FIRST LAYER should be DEPTH = 0.0

VELOCITY  DEPTH

---.---   ---.---
  3.30      0.00
  5.00      1.00
  5.70      4.00
  6.70     15.00
  8.00     25.00


TRIAL  DISTANCE  DISTANCE   P TO S  QUALITY  MISSING    MINIMUM
DEPTH   WEIGHT    WEIGHT    RATIO    CLASS    DATA      F. MOTION
         OF 1     OF 0                      INDICATOR   READING

----.   ----.    ----.      --.--      -        -          --
   5.     50.     100.       1.78      2                   18

PUNCH  MAGNITUDE  SYSTEM  PRINTING               LATITUDE         LONGITUDE
CARDS  SELECTION  CURVE   INDICATOR  C O D E  DEGREE MINUTE   DEGREE MINUTE

  -        -        -        -       - - - -    --   --.--      ---   --.--
           1                 1       1 1 1 1

Execution terminated : 0
```

(This is a system message showing 0 error in execution.)

```
C>INPUTPHA

***** INPUTPHA   (11/22/85) *****

*** This program creates a phase file. ***
 Please enter a filename (8 or less characters)

 SHORT.PHA


D A T E
YR MO DY    HR MN

-- -- --    -- --
69 10 05    11 12


       P remark          S remark

 STA    I U              I U
 NAME   EPDW  SECOND     ESDW  SECOND   AMPL   CODA

 ----   ----  --.--      ----  --.--    ---.   ----.
 SR07   IPD0  54.81
 SR10   IPU0  54.80
 SR13   IPD0  54.89
 SR15   IPU0  55.21
 SR16   IPD0  58.04
```

```
I N S T R U C T I O N   C A R D
USE S   FIX     TRIAL
      LOCATION DEPTH
 -       -      --.--
 0


D A T E
YR MO DY   HR MN
-- -- --   -- --

Execution terminated : 0
```

APPENDIX 1. Pages 1 to 30 of Lee and Lahr (1975) describing the input data and output results of HYPO71 program.

1. INTRODUCTION

HYPO71 is a computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes. The original program was dated December 21, 1971, and a user's manual was released as an open-file report of the U.S. Geological Survey on March 30, 1972 (Lee and Lahr, 1972). In order to generalize HYPO71 for worldwide usage and to correct a few programming "bugs", the program HYPO71 was revised on November 25, 1973, and a note on "Revisions of HYPO71" was released on January 30, 1974. Now that all reprints of the original HYPO71 manual have been exhausted, we take this opportunity to release a revised and updated HYPO71 manual. For simplicity, HYPO71 (Revised) will be referred to as HYPO71.

Because this report is intended as a manual for HYPO71 users, emphasis has been placed upon how to use the program. Our experience indicates that locating local earthquakes accurately requires considerable efforts. One must have accurate station coordinates (better than ± 0.1 km if possible), a reasonable crustal structure model (from controlled explosions), and reliable P and S arrivals. Naturally no computer program will give correct answers if the input data contain errors, so careful checking is essential before HYPO71 is run. One should also remember that small residuals and standard errors are NOT sufficient to guarantee accurate hypocenter solution.

HYPO71 is designed to catch some common mistakes in the input data, but this should not be counted on to find all of the errors. HYPO71 also provides an assessment of the quality of the hypocenter solution (see p. 26) and much other information. Users are urged to study the output carefully. We wish to emphasize that values for "TEST VARIABLES" (see p. 7) must be carefully chosen for a given application because they influence how the program goes about locating the earthquakes. The standard values in the program were developed for the large and closely spaced network of seismic stations in central California (with over 100 stations and station separation usually less than 10 kilometers).

HYPO71 differs from HYPOLAYR (Eaton, 1969) and its revised version HYPOMAG in its scope and design, except that a similar subroutine is used to calculate traveltimes and their derivatives. Although major results of HYPOLAYR (or HYPOMAG) could be reproduced with HYPO71, several additional features are available in HYPO71 to streamline routine data processing. Several schemes of detecting errors in input data are used to prevent erroneous solutions and premature termination. Options to make first-motion plots, calculate duration magnitudes, map residual minima, and compute more realistic traveltimes are now available.

Comments and criticisms of HYPO71 from users are welcome so that further improvements can be made. Users are urged to write or call Willie Lee (415-323-8111, Ext. 2630) should any problem occur in using HYPO71.

2. HOW TO USE HYPO71

The HYPO71 program is available in two versions: one for the IBM 360 or 370 computer in EBCDIC punched code, and the other for the CDC 6600 or 7600 computer in BCD punched code. It is written in FORTRAN IV language and has been successfully executed under the FORTRAN H compiler for IBM computers or under the MNF (University of Minnesota FORTRAN) compiler for CDC computers. The program requires approximately 150,000 bytes (or 37,500 words) of core storage for execution. Section 2.4 will describe how to adapt HYPO71 to your computer, especially when the available core storage is less than what is required. A listing of HYPO71 is given in Appendix 1 (p.45-86).

If HYPO71 is to be used routinely, a load module should be created and stored on disk. Since compilation and link-editing are not needed to execute a load module, considerable savings in computer time is achieved (about 2 minutes per run on an IBM 360/65 computer). In the following two sections, a step-by-step description of how to use the load module of HYPO71 is presented. A listing of a test run for IBM 360 or 370 computers is illustrated in Appendix 2 (p.87-89).

2.1 Input Card Deck Setup.

To execute the load module of HYPO71 the following input card deck setup is required:

(1) Job card

(2) Job control cards

(3) Input data cards

(4) End card

Because "Input Data Cards" are independent of the computer facility, they will be treated in detail in Section 2.2. For NCER users, a load module of HYPO71 (large version) has been stored on (1) USGS Computer Center at Reston, (2) Computing Services at Stanford Linear Accelerator Center, & (3) Computing Facility at Lawrence Berkeley Laboratory. The input card deck setup for the Reston computer is illustrated in Appendix 2 (p.87-89). The deck setup for the SLAC computer is as follows:

```
--SLAC JOB CARD--(YOU MUST SET OUTPUT LINES & PUNCHED CARDS NEXT)
//*MAIN LINES=10,CARDS=10
//*FORMAT PR,DDNAME=,TRAIN=TN  (optional card to print on large paper)
//HELP EXEC LOADGO,GORGN=300K,LKEDPRM='SIZE=500000'
//GO.SYSLIN DD DSN=WYL.W6.MZS.LEE(HYPO71),DISP=SHR
//GO.SYSIN DD *
- - - - - INPUT DATA CARDS FOR HYPO71 - - - - -
/*
```

The deck setup for the LBL computer (BKY) is as follows:

```
- - - - - JOB CARD FOR BKY CDC 7600 COMPUTER - - - - -
LIBCOPY(UPGEO,BIN/BR,RHP71)
LINK,B,F=BIN.
LGOB,LC=20000.      (NOTE: LC=MAXIMUM NUMBER OF OUTPUT LINES)
EXIT.
7/8/9 CARD      (NOTE: MULTIPLE PUNCH OF 7,8,& 9 AT COLUMN 1)
- - - - - INPUT DATA CARDS FOR HYPO71 - - - - -
6/7/8/9 CARD     (NOTE: THIS IS THE BKY END OF JOB CARD)
```

2.1-1. <u>Job Card</u>. This card must be prepared according to the computer facility used. One should normally allow 1 second computer time (IBM 360/65) and 100 lines printout for each earthquake. In addition, 5 seconds and 500 lines should be allowed for overhead. The actual computer time and printout depend, of course, on the options chosen and on the amount of data for each earthquake.

2.1-2. Job Control Cards. These cards depend on the computer facility used and how the load module is stored. Examples for IBM and CDC computers are shown in Section 2.1 above.

2.2. Input Data Cards.

These cards contain the input data for HYPO71, and are set up as described below. A quick reference guide for variable names and formats of the input data is given in Figure 1. To denote a blank punch in the text, we use $_\Delta$.

Item	Maximum Number of cards	Remarks	Page
(1) Heading card	1	optional	5
(2) Reset list	13	optional	7
(3) Selection card	1		9
(4) Station list,	NMAX = 150*		9
(5) Blank card	1	to signal end of (4)	12
(6) Crustal model list,	LMAX = 20*		12
(7) Blank card	1	to signal end of (6)	12
(8) Control card	1		12
(9) Phase list,	MMAX = 100*	repeated for each quake	15
(10) Instruction card	1	repeated for each quake	17
(11) Additional instruction list		optional	17
(12) Recycle card		optional	18

2.2-1 Heading Card. This card is optional and is used to write a heading above each earthquake in the output. Punch HEAD in columns 1 to 4, and the heading in columns 26 to 74.

---

* For IBM large version, NMAX=500, LMAX=50, & MMAX=300.
For CDC large version, NMAX=300, LMAX=20, & MMAX=250.

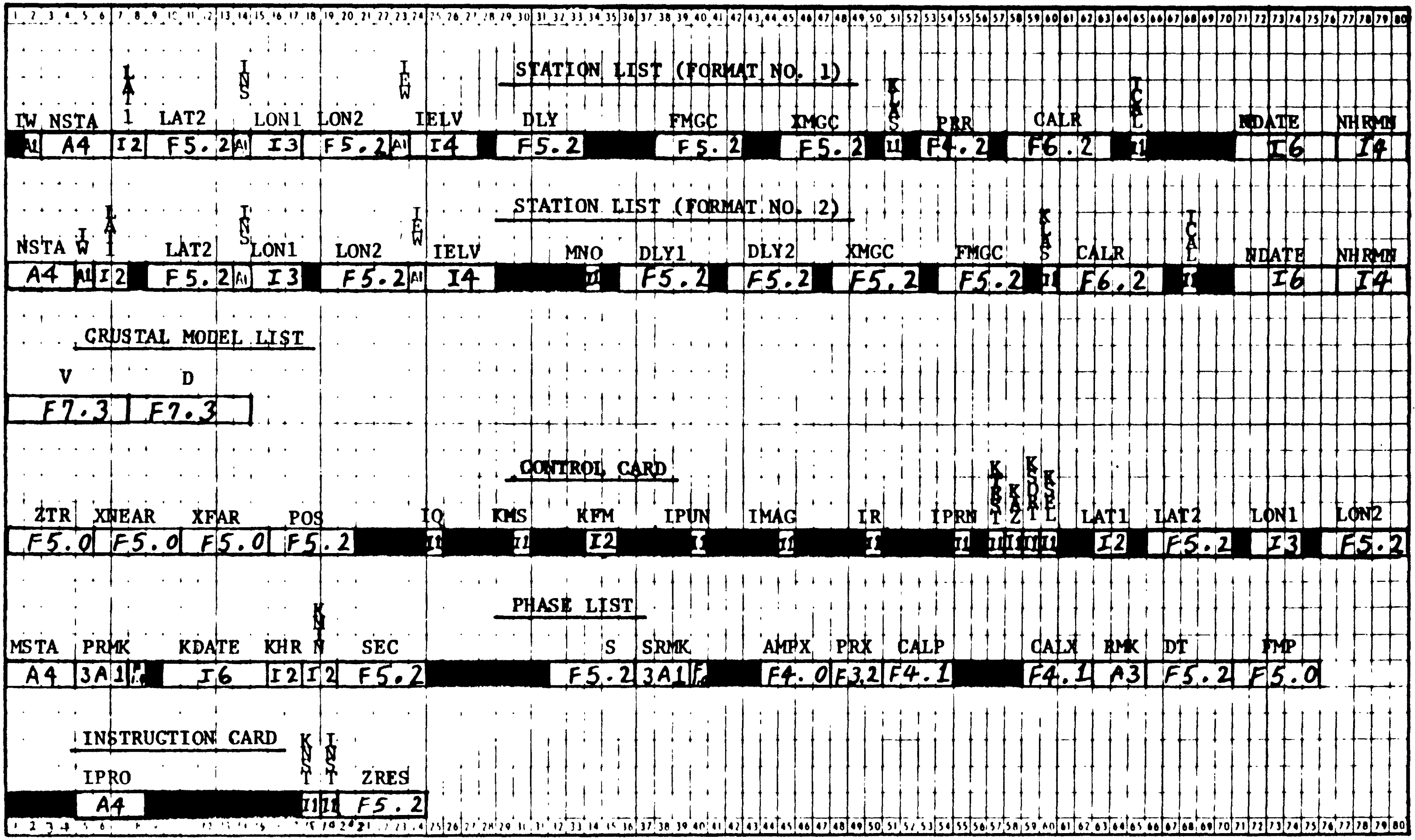

Figure 1. Variable Names and Formats of HYPO71 Input Data.

2.2-2 Reset List. This list is optional and may contain any number of cards up to a maximum of 13. The purpose of this list is to reset values of the test variables used in the program. The standard values (initiated by the program) are appropriate for earthquakes recorded by the USGS California Network of stations. Careful consideration should be given to their definitions and the values appropriate to a given set of data before this program is used.

An example of a reset card is:

RESET$_\Delta$TEST(06)=0.75 starting at column 1. The subscript of the test variable must be punched in columns 12 and 13, and the value of the test variable must be punched in F-format in columns 16 to 25. Definitions for the test variables are given as follows:

Test Variable	Standard Value	Definition
TEST(01)	0.1 sec	TEST(01) is the cutoff value for RMS below which Jeffreys' weighting of residuals is not used. It should be set to a value approximately equal to the overall timing accuracy of P-arrivals in seconds.*
TEST(02)	10 km	For each iteration step, if the epicentral adjustment $\geq$ TEST(02), this step is recalculated without focal-depth adjustment. TEST(02) should be set to a value approximately equal to station spacing in kilometers.
TEST(03)	2.	Critical F-value for the stepwise multiple regression (Draper and Smith, 1966). TEST(03) should be set according to the number and quality of P- and S-arrivals. A value between 0.5 and 2 is recommended. If TEST(03) $\doteq$ 0., a simple multiple regression is performed regardless of whether the matrix is ill-conditioned (p.32-33).

* Jeffreys' weighting is designed to catch large arrival-time errors. Therefore, it is useful to use it on preliminary runs. After arrival-time errors have been corrected, Jeffreys' weighting is not recommended. (i.e. Reset TEST(01) to a large value, such as 0.5, on your final run).

Test Variable	Standard Value	Definition
		This is not desirable because the hypocenter solution may be meaningless. On the other hand, if TEST(03) is set to 2 or greater, then Geiger's iteration may be terminated prematurely, before a good hypocenter is found.
TEST(04)	0.05 km	If the hypocentral adjustment is less than TEST(04), Geiger's iteration is terminated.
TEST(05)	5. km	If the focal-depth adjustment (DZ) is greater than TEST(05), DZ is reset to DZ / (K + 1), where K = DZ / TEST(05). TEST(05) should be set to a value approximately equal to half the range of focal depth expected. For example, most earthquakes have focal depths between 0 and 10 km in central California. Therefore, we use a value of 5 km for trial focal depth (p. 12), and TEST(05) = 5 km.
TEST(06)	4.	If no significant variable is found in the stepwise multiple regression, the critical F-value, TEST(03), is reduced to TEST(03)/TEST(06), and the regression is repeated. If TEST(06) $\leq$1., then the regression is repeated to find one variable, and the adjustment is made only if it is greater than TEST(06)* standard error. If TEST(03) is set to be less than 2, then TEST(06) should be set to 1.
TEST(07)	-0.87	Coefficients for calculating the duration magnitude (FMAG) (Lee, Bennett and Meagher, 1972): FMAG = -0.87 + 2 log(T) + 0.0035 D where T is signal duration in sec, and D is epicentral distance in km.
TEST(08)	2.00	
TEST(09)	0.0035	
TEST(10)	100 km	If the latitude or longitude adjustment (DX or DY) is greater than TEST(10), then DX is reset to DX/(J+1), and DY is reset to DY/(J+1), where J = D/TEST(10), D being the larger of DX or DY.

Test Variable	Standard Value	Definition
TEST(11)	8.	Maximum number of iterations in the hypocentral adjustment.
TEST(12)	0.5	If the focal-depth adjustment (DZ) would place the hypocenter in the air, then DZ is reset to DZ = -Z * TEST(12), where Z is the focal depth.
TEST(13)	1. km	Auxiliary RMS values are optionally calculated at ten points on a sphere of radius $\sqrt{3}$ * TEST(13) centered on the final solution. Eight of the ten points fall on the corners of a cube, with sides equal to 2 * TEST(13). If the solution converged to a minimum of RMS, then all nearby values of RMS will be greater. TEST(13) should be set to a value approximately equal to the standard error of hypocenter in kilometers. (See p. 30 for details).

2.2-3 Selection Card. In HYPO71, travel time from a trial hypocenter to a station is calculated from a given crustal model consisting of multiple horizontal layers. Each layer is specified by a P-velocity and the depth to the top of the layer. Additional complexity in crustal structure may be modeled in two ways:

a) Station Delay Model. The selection card is a blank, and the station delay is simply added to the calculated travel time for each station.

b) Variable First-Layer Model. The selection card has a 1 punched in Column 1. To account for different travel paths, the station delay at a given station is converted to an equivalent first-layer thickness. This then alters the crustal structure under this station. In other words, all stations have slightly different crustal structure: the P-velocities are the same, but the layer thickness of the first and second layers differ from station to station. In addition, two delays may be assigned to a given station corresponding to different earthquake source regions.

2.2-4 Station List. For each seismograph station, a station card must be punched. Use Station Format No. 1 for the Station Delay Model, and Station Format No. 2 for the Variable First-Layer Model. A maximum of 150 station cards is allowed in the program.

Station Format No. 1 (for Station Delay Model)

Column	Name	Format	Explanation	Examples
2	IW	A1	If IW = *, then this station has zero weight assighed to its P and/or S reading(s).	Normally blank
3-6	NSTA	A4	Station name	SBSM or ΔMOB
7-8	LAT1	I2	Degree portion of latitude	37
9-13	LAT2	F5.2	Minute portion of latitude	15.72
14	INS*	A1	Punch N or leave this column blank for stations in northerm hemisphere. Punch S for stations in southern hemisphere.	N or S
15-17	LON1	I3	Degree portion of longitude	121
18-22	LON2	F5.2	Minute portion of longitude	30.45
23	IEW*	A1	Punch E for eastern longitude. Punch W or leave this column blank for western longitude	E or W
24-27	IELV	I4	Elevation in meters. This data is not used in the program	1250 or ΔΔ50
29-33	DLY	F5.2	Station delay in seconds	+0.20 or -0.08
38-42	FMGC	F5.2	Station correction for FMAG	+0.25 or -0.50
45-49	XMGC	F5.2	Station correction for XMAG	+0.25 or -0.50
51	KLAS	I1	System number is assigned for each station so that the frequency response curve of the seismometer and preamp is specified for the amplitude magnitude calculation (XMAG)	0 for Wood-Anderson 1 for NCER Standard 2 for EV-17 & Develco 3 for HS-10 & Teledyne 4 for HS-10 & Develco 5 for L-4C & Develco 6 for L-4C & Teledyne 7 for L-4C replacing HS-10 & Develco 8 for 10-day recorders

* INS and IEW must be the same for all stations.

Column	Name	Format	Explanation	Examples
53-56	PRR	F4.2	Standard period for XMAG	0.15 or blank
58-63	CALR	F6.2	Standard calibration for XMAG	Δ10.50 or blank
65	ICAL	I1	Calibration indicator: punch 1 if one always wants to use the standard calibration; otherwise leave it blank	1 or blank
71-76	NDATE	I6	Year, month, and day	710625 or blank
77-80	NHRMN	I4	Hour and minute	1224 or blank
			Station Format No. 2 (for Variable First-Layer Model)	
1-4	NSTA	A4	Station name	SBSM or ΔMOB
5	IW	A1	If IW=*, then this station has zero weight assigned to its P &/ S readings	normally blank
6-7	LAT1	I2	Degree portion of latitude	37
9-13	LAT2	F5.2	Minute portion of latitude	15.72
14	INS*	A1	Punch N or leave this column blank for stations in northern hemisphere. Punch S for stations in southern hemisphere	N or S
15-17	LON1	I3	Degree portion of longitude	121
19-23	LON2	F5.2	Minute portion of longitude	30.45
24	IEW*	A1	Punch E for eastern longitude. Punch W or leave this column blank for western longitude	E or W
25-28	IELV	I4	Elevation in meters. This data is not used in the program.	1250 or ΔΔ50
34	MNO	I1	Preferred model number. If MNO=1 and this station is nearest to the earthquake, then model 1 is used.	1 or 2
36-40	DLY1	F5.2	Station delay for model 1 in seconds	+0.20 or -0.08
42-46	DLY2	F5.2	Station delay for model 2 in seconds	+0.20 or -0.08
48-52	XMGC	F5.2	Station correction for XMAG	+0.25 or -0.50
54-58	FMGC	F5.2	Station correction for FMAG	+0.25 or -0.50

---

* INS and IEW _must_ be the same for all stations.

Station Format No. 2 (for Variable First-Layer Model)

Column	Name	Format	Explanation	Examples
60	KLAS	I2	System number (see explanation in Station Format No. 1).	
61-66	CALR	F6.2	Standard calibration for XMAG	Δ10.50 or blank
68	ICAL	I1	Calibration indicator: punch 1 if the standard calibration is to be used; otherwise leave it blank.	1 or blank
71-76	NDATE	I6	Year, month and day	710625 or blank
77-80	NHRMN	I4	Hour and minute	1224 or blank

2.2-5 Blank Card. Signals end of station list.

2.2-6 Crustal Model List. For each flat layer, a crustal model list card must be punched as follows:

Column	Name	Format	Explanation	Examples
1-7	V	F7.3	P-velocity in km/sec in a given layer	ΔΔ3.5ΔΔ
8-14	D	F7.3	Depth in km to the top of a given layer	ΔΔ0.00Δ for the first layer

2.2-7 Blank Card. Signals end of crustal model.

2.2-8 Control Card. This card selects some of the options in HYPO71 and must be punched as follows:

Column	Name	Format	Explanation	Examples
1-5	ZTR	F5.0	Trial focal depth in km	ΔΔΔ5.
6-10	XNEAR	F5.0	Distance in km from epicenter where the distance weighting is 1	ΔΔ50.
11-15	XFAR	F5.0	Distance in km from epicenter beyond which the distance weighting is 0	Δ200.

2.2-8 <u>Control Card</u> -- Continued

Column	Name	Format	Explanation	Examples
16-20	POS	F5.2	Ratio of P-velocity to S-velocity	$_\Delta$1.78 is recommended
25	IQ	I1	Quality class of earthquake to be included in the summary of residuals	1 for class A 2 for A and B 3 for A, B, and C 4 for all
30	KMS	I1	Indicator to check missing data	0 for NOT checking 1 for checking
34-35	KFM	I2	Minimum number of first motion readings required before it is plotted. Leave it blank if no first motion plot is needed.	15 or blank
40	IPUN	I1	Indicator for punched cards	0 for no punched cards 1 for punching summary cards 2 for punching summary and station cards 3 for punching summary cards and new station list with revised residuals 4 for punching summary cards and new station list with revised system number and standard calibration.
45	IMAG	I1	Method of selecting earthquake magnitude (MAG)	0 for MAG = XMAG 1 for MAG = FMAG 2 for $MAG = \frac{XMAG + FMAG}{2}$
50	IR	I1	Number of new system response curves to be read in. Normally leave it blank unless one wishes to override the NCER system response curves. See Appendix 6 by Fischer (p. 114)	blank

2.2-8 Control Card -- Continued

Column	Name	Format	Explanation	Examples
55	IPRN	I1	Indicator for printed output. We recommend IPRN = 1	0 for final solution and station residuals 1 for above plus one line each per iteration 2 for above plus station residuals per iteration 3 for above plus details from stepwise multiple regression
57	KTEST (CODE)	I1	If KTEST = 1, then auxiliary RMS values are calculated at ten points on a sphere centered at the hypocenter. (See p.9). This option will help to determine if the solution is at the RMS minimum. (See p.30).	1 or blank
58	KAZ (CODE)	I1	If KAZ = 1, then azimuthal weighting of stations is applied. See page 29.	1 or blank
59	KSORT (CODE)	I1	If KSORT = 1, then the stations are sorted by distance in the output	1 or blank
60	KSEL (CODE)	I1	If KSEL = 1, then printed output for each earthquake will start at a new page.	1 or blank
63-64	LAT1	I2	Degree portion of the trial-hypocenter latitude	
66-70	LAT2	F5.2	Minute portion of the trial-hypocenter latitude	
72-74	LON1	I3	Degree portion of the trial-hypocenter longitude	
76-80	LON2	F5.2	Minute portion of the trial-hypocenter longitude	

Note: If columns 63-80 are blank, then location of the nearest station is used as trial-hypocenter (with addition of 0.1 minute to both latitude and longitude to avoid "ARCTAN (0/0)" in calculating the azimuth between epicenter and station).

2.2-9 Phase list. For each seismographic station recording the earthquakes, a phase list card must be punched as follows. A maximum of 100 cards is allowed in the phase list. Examples of data forms for punching phase cards are shown in Appendix 5 (p. 111-113).

Column	Name	Format	Explanation	Examples
1-4	MSTA	A4	Station name	SBSM or $_\Delta$MOB
5	PRMK	A1	Description of onset of P-arrival	I denotes impulsive or sharp E denotes emergent or gradual
6	PRMK	A1	"P" to denote P-arrival	P or blank
7	PRMK	A1	First motion direction of P-arrival	U = Up = C = Compression D = Down = Dilatation + = poor U or C - = poor D N = Noisy blank = Not readable
8	PRMK	F1.0	Weight assigned to P-arrival	0 or blank = Full weight 1 = 3/4 weight 2 = 1/2 weight 3 = 1/4 weight 4 = No weight
10-15	KDATE	I6	Year, month, and day of P-arrival *	700105 for Jan. 5, 1970
16-17	KHR	I2	Hour of P-arrival*	18
18-19	KMIN	I2	Minute of P-arrival**	32
20-24	SEC	F5.2	Second of P-arrival	15.25
32-36	S	F5.2	Second of S-arrival	20.10

* 'KDATE' and 'KHR' must have the same values for P and S arrivals for a given earthquake. For arrival times where 'KHR' changes, the extra hour MUST be carried into 'KMIN'.

** For arrival times where 'KMIN' changes, 'KMIN' may be punched as it is, or if the same 'KMIN' is punched, carry the extra minute into 'SEC' & 'S'.

2.2-9 Phase list. -- Continued

Column	Name	Format	Explanation	Examples
37	SRMK	A1	Description of onset of S-arrival	I or E or blank
38	SRMK	A1	"S" to denote S-arrival	S or blank
39	SRMK	A1	First motion direction	U, or D, or +, or -, or N, or blank
40	SRMK	F1.0	Weight assigned to S-arrival	Same as that for P-arrival at Column 8
44-47	AMPX	F4.0	Maximum peak-to-peak amplitude in mm	Δ24. or ΔΔ24
48-50	PRX	F3.2	Period of the maximum amplitude in sec. Standard period (PRR) for this station as specified in the station list will be used if this field is blank.	.15
51-54	CALP	F4.1	Normally not used except as noted in next item.	
59-62	CALX	F4.1	Peak-to-peak amplitude of 10 μv calibration signal in mm. If this field is blank, then CALX = CALP. If again CALX is blank, then the standard calibration (CALR) for this station as specified in the station list will be used. If ICAL = 1 (in the station list for this station), then CALX will always be replaced by CALR.	Δ5.4
63-65	RMK	A3	Remark for this phase card. Any three characters (except CAL) may be used.	Q05 or blank
66-70	DT	F5.2	Time correction in sec. Normally not used for telemetered stations, so leave it blank.	blank

2.2-9 Phase list. -- Continued

Column	Name	Format	Explanation	Examples
71-75	FMP	F5.0	F-P time in sec. This is the duration time of earthquake. In NCER practice, one measures the time between the first P-arrival and that where the peak-to-peak amplitude of the seismic trace drops below 1 cm.	ΔΔ15.

2.2-10 Instruction Card. At the end of the phase list for each earthquake, one instruction card must be punched as follows. For routine runs, one usually chooses free solution (i.e. let the program decide what is the best solution), so that the instruction card is simply a blank card.

Column	Name	Format	Explanation	Examples
5-8	IPRO	A4	Normally IPRO = blank. If IPRO = Δ**Δ, additional instruction card will follow	blank or Δ**Δ
18	KNST	I1	KNST = 0 implies do not use S Data KNST = 1 Use S Data Add 5 if First motion plot is desired	0, 1, 5, or 6
19	INST	I1	INST = 0 implies don't fix depth INST = 1 fix depth INST = 9 fix lat, lon, and depth. See 2.3-1 below	0, 1, or 9
20-24	ZRES	F5.2	Trial focal-depth. Normally this field is left blank unless one wishes to replace ZTR (in the control card) by ZRES for this earthquake.	blank

2.2-11 Additional Instruction List. Additional instruction cards may be optionally added to obtain other solutions for the same earthquake data. They are punched as follows:

Column	Name	Format	Explanation
5-8	IPRO	A4	If this is the last card in the instruction list, IPRO = blank. If more instruction cards follow, IPRO = $_\Delta$**$_\Delta$.
18	KNST	I1	Same as that described in section 2.3-10 (p. 17).
19	INST	I1	
20-24	ZRES	F5.2	
28-29	LAT1	I2	Degree portion of trial-hypocenter latitude
31-35	LAT2	F5.2	Minute portion of trial-hypocenter latitude
37-39	LON1	I3	Degree portion of trial-hypocenter longitude
41-45	LON2	F5.2	Minute portion of trial-hypocenter longitude

2.2-12 Recycle Card. Previous items may be repeated by using a recycle card to be punched on columns 2 to 4

Columns (2 to 4)	Remarks
***	Repeat (1) to (12) by returning to (1)
$$$	Repeat (6) to (12) by returning to (6)
¢¢¢	Repeat (8) to (12) by returning to (8)

2.3 Additional Options.

Several additional options are available in HYPO71, as follows:

2.3-1. All Fixed Solution. This option may be used to calculate the travel times to various stations for a known origin time and hypocenter (e.g. nuclear explosions or quarry blasts). This is achieved by specifying INST = 9, and an additional card must then be punched as follows:

Column	Name	Format	Explanation	Examples
1-5	ORG1	F5.0	Minute portion of origin time	ΔΔ15.
6-10	ORG2	F5.2	Second portion of origin time	10.05
11-15	LAT1	I5	Degree portion of latitude of hypocenter	ΔΔΔ37
16-20	LAT2	F5.2	Minute portion of latitude of hypocenter.	15.50
21-25	LON1	I5	Degree portion of longitude of hypocenter	ΔΔ121
26-30	LON2	F5.2	Minute portion of longitude of hypocenter	32.45
31-35	Z	F5.2	Focal depth of hypocenter in km	Δ0.00

2.3-2 Use of S-Arrivals. Whether or not S-arrivals are used in the hypocenter solution, they will appear on the output if they are punched on phase cards. To use S-arrivals in the solution, set KNST = 1 on the instruction card (p. 17 & 18).

2.3-3 Use of S-P Intervals. If the same time base is not available for some stations, it is still possible to include the recorded S-P intervals in the hypocentral solution. This is very useful when there are few available stations. The phase cards of the S-P interval data are punched as usual (see P.15). However, the weight assigned to the P-arrival (column 8) must be 9, and the weight assigned to S-arrival (column 40) is that desired for the S-P interval.

2.3-4 Calibration Changes. The system number (KLAS), and/or standard calibration (CALR) for any station may be changed from time to time by inserting a calibration card like an earthquake event. In this case, the phase list and instruction card are replaced by one card punched as follows:

Column	Name	Format	Explanation	Examples
1-4	MSTA	A4	Station name	SBSM or $_{\Delta}$MOB
10-15	KDATE	I6	Year, month, and day of new calibration	700215
16-17	KHR	I2	Hour of new calibration	21
18-19	KMIN	I2	Minute of new calibration	54
22	KLAS	I1	New system number	1
59-62	CALX	F4.1	New station calibration value (10 μv signal in mm)	13.2
63-65	RMK	A3	Must be "CAL"	CAL only

This option therefore allows an automatic updating of instrumental changes so that correct magnitudes based on amplitude data will be computed.

2.4 Adapting HYPO71 for Your Computer. The EBCDIC punched code of the HYPO71 program is written for an IBM 360 or 370 computer. A listing is given in Appendix 1 (p.45-86), where the number in the right hand side is the FORTRAN card sequence number. If you have an IBM 360 or 370 computer, adapting HYPO71 for your computer will be easy, except perhaps the error handling facility of your FORTRAN compiler and the amount of core storage available. If your FORTRAN compiler does not have ERRSET subroutines, you must delete HYPO71 cards numbered from 22 to 27 (see p.46). If the amount of core storage available to you is less than 150,000 bytes, you may reduce the dimension of the arrays and/or delete some non-critical subroutines.

The length of various HYPO71 components as compiled by FORTH on an IBM 360/65 computer is as follows:

2.4 Adapting HYPO71 for Your Computer. (continued)

HYPO71 Components	Card Sequence Number	Length (bytes)
MAIN	1 - 98	1,588
ANSWER	99 - 133	1,520
AZWTOS	134 - 211	1,836
BLOCK DATA	212 - 248	7,676
FMPLOT	249 - 361	13,568
INPUT1	362 - 562	5,766
INPUT2	563 - 676	2,574
MISING	677 - 737	1,218
OUTPUT	738 - 1021	7,604
SINGLE	1022 - 1499	9,028
SORT	1500 - 1526	560
SUMOUT	1527 - 1652	9,048
SWMREG	1653 - 1857	5,730
TRVDRV	1858 - 2024	4,344
XFMAGS	2025 - 2123	2,502
COMMON BLOCKS		47,318
FORTRAN LIBRARY		24,096
	Total	145,976 bytes

To execute HYPO71, however, one must add several thousand bytes to this total for buffers (this depends on the computer facility). Therefore, we suggest a core storage requirement of 150,000 bytes, although the program length is less than 146,000 bytes.

HYPO71 is dimensioned for a maximum of 150 station cards (NMAX = 151), and 100 phase cards (MMAX = 101). If not needed, the core storage may be reduced by redimensioning arrays that have been dimensioned for NMAX = 151 and MMAX = 101. In addition the statement (card number 245) which defines the values of NMAX and MMAX must be modified to the new values chosen. Savings of up to about 25,000 bytes may be realized.

Another way to reduce the core storage requirement is to remove non-critical subroutines and statements that call them:

Subroutine	Card Sequence Number	Cards Calling the Subroutine
ANSWER	99 - 133	1793, 1821
AZWTOS	134 - 211	1174
FMPLOT	249 - 361	1451
MISING	677 - 737	1450
SUMOUT	1527 - 1652	91

Up to about 30,000 bytes may be saved in this manner.

The BCD punched code for HYPO71 is a modification of the IBM version for CDC computers. It is essentially identical except for the following:

(1) Because CDC allows 131 characters per line (vs 132 characters for IBM), "SDFM" reads "SDF", and only one '*' follows large S-residuals instead of two '*'. This difference has no effect on your result.

(2) Because CDC only recognizes BCD punched codes, please avoid using characters such as "+", "#", "¢", "%".

(3) You <u>can</u> use "+" for your first P-motion, but not elsewhere. This restriction is not damaging, because you do not need to use "+" anywhere else.

(4) "¢" in the IBM version (and HYPO71 manual) has been replaced by "=" in the CDC version.

If you do not have either an IBM or CDC computer, adapting HYPO71 for your computer will depend on how similar your computer is to the IBM 360 or 370 computers. We suggest that you consult your computer center staff before undertaking this work.

Finally, to facilitate your adaption, a deck of test data (see p.87-89) always accompanies a request for the HYPO71 program. You should reproduce the results (within 1 or 2 counts of the last significant figures) shown on p. 90-96.

On page ii of this report, various releases of HYPO71 are listed.

3. OUTPUTS OF HYPO71

Most outputs of HYPO71 are printed by the line-printer. Cards are punched only when the data must be read back into the computer for subsequent running of other computer programs. The printer outputs are generally self-explanatory; the following explanations may be helpful to the users. Results of the test run (listed in Appendix 2) is given in Appendix 3 (p. 90-96).

3.1 Iteration Output (optional).

If IPRN = 1 on the control card, a one-line output appears for each iteration. This information shows what happened in each adjustment from the trial hypocenter to the final hypocenter.

Heading	Explanation
I	Iteration step number. If a particular step is repeated, I is also repeated.
ORIG	Origin time in sec. Date, hour and minute are given in HYPOCENTER OUTPUT (Section 3.2).
LAT LONG Depth	Hypocenter location at Step I. See Section 3.2 for details.
DM	Epicentral distance in km to the nearest station.
RMS	Root mean square error of time residuals in sec. corrected for average P & S residual (AVRPS).
SKD	For S and D explanation, see Section 3.2. K denotes the status of the critical F-value (CF) in the iteration step. See Section 4 for more details. For K = 0, CF = TEST(03). For K = 1, CF = TEST(03)/TEST(06). For K = 2, F-test is skipped in order to calculate error estimates. For K = 3, On this step no variable met the F-test entrance criterion and termination will occur. For K = 4, F-test is skipped, and the most significant variable is found. This step is taken only if the adjustment is greater than TEST(06) times its standard error.

3.1 Iteration Output (optional). -- Continued

Heading	Explanation
CF	Critical F-value. Its value is controlled by K as described above.
ADJUSTMENTS (km)	Under these three columns, adjustments in km for the latitude (DLAT), longitude (DLON), and focal depth (DZ) from the multiple regression analysis are given.
PARTIAL F-VALUES	Under these three columns, the partial F-values for the hypocentral adjustments are given. Values not calculated are set equal to -1.00.
STANDARD ERRORS	Under these three columns, the standard errors for the hypocenter adjustments are given in km.
ADJUSTMENTS TAKEN	Under these three columns, the actual adjustments taken to reach the next trial hypocenter are given in km.

3.2 Hypocenter Output.

Heading	Example	Explanation
DATE	700630	Date of earthquake: Year, month, and day. In this case, it is June 30, 1970.
ORIGIN	1659 24.05	Origin time: hour, minute, and second (Greenwich civil time). In this case, it is 16 hr, 59 mn, and 24.05 sec.
LAT	37-48.64	Latitude of epicenter in degrees and minutes: 37° 48.64'.
LONG	121-57.59	Longitude of epicenter in degrees and minutes: 121° 57.59'
DEPTH	3.62	Focal depth in km: 3.62 km. A '*' may follow the DEPTH to indicate a fixed focal depth solution.
MAG	1.35	Magnitude of the earthquake. User specifies its choice from XMAG and/or FMAG.
NO	15	Number of station readings used in locating the earthquake. P and S arrivals for the same station are regarded as 2 readings. If NO = 3, a fixed depth solution is given. If NO<3, no solution is given.

3.2 Hypocenter Output. -- Continued

Heading	Example	Explanation
DM	2	Epicentral distance in km to the nearest station.
GAP	110	Largest azimuthal separation in degrees between stations.
M	1	Crustal model number. M is used for the Variable First-Layer Model only.
RMS	0.09	Root mean square error of time residuals in sec. $RMS = \sqrt{\Sigma R_i^2/NO}$, where R_i is the time residual for the i^{th} station.
ERH	0.4	Standard error of the epicenter in km.* $ERH = \sqrt{SDX^2 + SDY^2}$, where SDX and SDY are the standard errors in latitude and longitude, respectively, of the epicenter. If ERH = blank, this means that ERH cannot be computed because of insufficient data.
ERZ	1.2	Standard error of the focal depth in km.* If ERZ is blank, this means that ERZ cannot be computed either because focal depth is fixed in the solution or because of insufficient data.
Q	B	Solution quality of the hypocenter. This measure is intended to indicate the general reliability of the solution:

Q	Epicenter	Focal Depth
A	Excellent	good
B	good	fair
C	fair	poor
D	poor	poor

Q is taken as the average of QS and QD (defined below). For example, an A and a C yield a B, and two B's yield a B. When QS and QD are only one level apart, the lower one is used, i.e., an A and a B yield a B.

Heading	Example	Explanation
SQD	A|B	QS and QD rating, In this case, QS = A, and QD = B. QS is rated by the statistical measure of the solution as follows:

* Statistical interpretation of standard errors involves assumptions which may not be met in earthquake locations. Therefore the standard errors may not represent actual error limits.

3.2 Hypocenter Output. -- Continued

QS	RMS (sec)	ERH (km)	ERZ (km)
A	< 0.15	≤ 1.0	≤ 2.0
B	< 0.30	≤ 2.5	≤ 5.0
C	< 0.50	≤ 5.0	
D	Others		

QD is rated according to the station distribution as follows:

QD	NO	GAP	DMIN
A	≥ 6	≤ 90°	≤ DEPTH or 5 km
B	≥ 6	≤ 135°	≤ 2x DEPTH or 10 km
C	≥ 6	≤ 180°	≤ 50 km
D	Others		

Heading	Example	Explanation
ADJ	0.0	Last adjustment of hypocenter in km. Normally this is 0 or less than 0.05.
IN	0	Instruction code (KNST and INST in input)
NR	17	Number of station readings available. This includes readings which are not used in determining hypocenter.
AVR	0.00	Average of time residuals in sec. $AVR \equiv \sum_i R_i/NO$. Normally this is 0.
AAR	0.07	Average of the absolute time residuals in sec. $AAR \equiv \sum_i \lvert R_i \rvert /NO$.
NM	5	Number of station readings available for computing maximum amplitude magnitude (XMAG).
AVXM	1.4	Average of XMAG of available stations.
SDXM	0.1	Standard deviation of XMAG of available stations.
NF	3	Number of station readings available for computing F-P magnitude (FMAG).
AVFM	1.3	Average of FMAG of available stations.
SDFM	0.2	Standard deviation of FMAG of available stations.
I	4	Number of iterations to reach the final hypocenter.

Items from DATE to Q inclusive are repeated at the head of every first-motion plot. If summary cards are punched, these items occupy from column 1 to 80.* However, order for M, GAP, and DMIN are changed. A heading card is punched preceding the summary cards, if IPUN $\geq$ 1 on the control card.

3.3 Station Output.

After each hypocenter output of 2 lines, station output follows for each station.

Heading	Example	Explanation
STN	BOL	Station name.
DIST	1.3	Epicentral distance in km.
AZM	202	Azimuthal angle between epicenter to station measured from north in degrees.
AIN	94	Angle of incidence measured with respect to downward vertical.
PRMK	IPUO	This is PRMK from input data.
HRMN	1659	Hour and minute of arrival time from input data.
P-SEC	25.30	The second's portion of P-arrival time from input data.
TPOBS	1.25	Observed P-travel time in sec. TPOBS ≡ T + DT - ORG where T is the P-arrival time, ORG is the origin time, and DT is the time correction from input data.
TPCAL	1.09	Calculated travel time in sec.
DLY/H1	0.05 or 3.12	If the Station Delay Model is used, then DLY means the station delay in sec from the input station list. If the Variable First-Layer Model is used, then H1 means the thickness of the first-layer in km at this station.
P-RES	0.16	Residual of P-arrival in sec. If the Station Delay Model is used, then P-RES ≡ TPOBS - (TPCAL + DLY). If '**' follows P-RES, it means that in the Jeffreys' weighting, this P-arrival is not reliable. If the Variable First-Layer Model is used, then P-RES ≡ TPOBS - TPCAL.

* The punch format is given on p.61 (773-775) & is used on p.64 (934-935).

3.3 Station Output. -- Continued

Heading	Example	Explanation
P-WT	1.06	Weight used in hypocenter solution for P-arrival. This weight is a combination of quality weight specified in the data and other selected weightings. WT's are always normalized so that the sum is equal to NO. Normalization is necessary so as to avoid distortion in computing standard errors.
AMX	15.0	Maximum amplitude in mm from input data.
PRX	0.10	Period of maximum amplitude in sec. from input data. If PRX is not given on the phase card, then PRR from the corresponding station card is used in the computation of XMAG, but is not printed here.
CALX	2.20	Calibration in mm used in computing XMAG. If CALX is blank in the phase card, then CALR from the corresponding station card is used and is printed here as CALX.
K	5	System number for the station from input data.
XMAG	1.60	Maximum amplitude magnitude computed from AMX, PRX, CALX and K. A * follows XMAG if $\lvert$XMAG - AVXM$\rvert \geq 0.5$.
RMK	Q05	Remark from input data.
FMP	10.0	F-P in sec from input data.
FMAG	1.02	F-P magnitude computed from F-P and DIST. A * follows FMAG if $\lvert$FMAG - AVFM$\rvert \geq 0.5$.
SRMK	$ES_{\Delta}2$	This is SRMK from input data.
S-SEC	26.50	The second's portion of S-arrival time from input data.
TSOBS	2.45	Observed S-travel time in sec. TSOBS ≡ T + DT - ORG, where T is the S-arrival time, ORG is the origin time, and DT is the time correction from input data.
S-RES	-0.22	Residual of S-arrival in sec. If the Station Delay Model is used, then S-RES ≡ TSOBS - POS* (TPCAL + DLY). If the Variable First-Layer Model is used, then S-RES ≡ TSOBS - POS*TPCAL.
S-WT	0.5	Weight used in hypocenter solution for S-arrival. See explanation of P-WT for additional information.
DT	blank	Station time correction in sec. from input data. DT is used to correct all stations to the same time base.

If S-P interval data are used, the meanings of some of the above headings are changed as follows.

Heading	Explanation
P-RES	S-P residual in sec. It is defined by P-RES ≡ TSOBS - TPOBS - (POS - 1) (DLY + TPCAL) for the Station Delay Model. DLY is multiplied by zero for computing P-RES as above for the Variable First-Layer Model.
S-RES	Same as P-RES
P-WT	Weight used in hypocenter solution for S-P interval data.
S-WT	Will always be **** to denote S-P interval data.
TSOBS	Observed S-P interval in sec.

3.4 Map of Auxiliary RMS Values.

This is an optional output for which KTEST is set to 1 on the Control Card (see p. 14). RMS values are computed at 10 points on a sphere centered on the final hypocenter. Each RMS value corresponds to an origin time which has been corrected for the average residual of the P and S arrivals (AVRPS) given at that point. A 3-dimensional view of the auxiliary RMS value minus the final hypocenter RMS value is printed (DRMS). An example is shown below; the view is looking down to the northwest. It is necessary by NOT sufficient for all DRMS values to be positive for a good solution. If any DRMS value is negative, then the solution has not converged to a minimum. It is important to set the radius of the sphere appropriately for a given application (see p.9, TEST(13)).

LAT	LON	Z	AVRPS	RMS
8.17	14.76	0.0	-0.39	0.63
8.17	8.02	0.0	-1.42	0.23
8.17	14.76	9.62	-0.31	0.81
8.17	8.02	9.62	-1.19	0.30
5.47	11.39	0.0	-0.26	0.34
				0.11
5.47	11.39	13.28	-0.56	0.48
2.77	14.76	0.0	0.50	0.27
2.77	8.02	0.0	-0.88	0.60
2.77	14.76	9.62	0.37	0.63
2.77	8.02	9.62	-0.74	0.70

DRMS