U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Routine processing of seismic hypocentral data using personal computers

by

Thomas L. Murray[1]

[1]U.S. Geological Survey
Cascades Volcano Observatory
5400 MacArthur Blvd.
Vancouver, Washington, 98661

U.S. Geological Survey Open-File Report 94-170-A

1994

Table of Contents

Introduction

The release of IASPEI *Toolbox for Seismic Acquisition, Processing and Analysis* (Lee, 1989) provided the basic framework for seismic-event detection, acquisition, and analysis on IBM PC-compatible computers. The analysis software, though useable, did not move data smoothly through the analysis system. Little work available to the general public has been done to integrate the acquisition programs, *XDETECT.EXE* (Tottingham and Lee, 1989; Rogers, 1993) or *MDETECT.EXE* (Tottingham and others, 1989), the picking program *PCEQ.EXE* (Valdes, 1989), and the location program *HYPO71PC.EXE* (Lee and Valdes, 1989) into a seamless data-processing routine. Though such a routine may not be needed in instances where the system is used to collect data for specific experiments with definite beginnings and endings, it is necessary in an observatory environment where data are constantly being collected and analyzed in as near as possible to realtime.

The following programs provide the framework for setting up the processing routine. They allow the user to semi-automatically transfer data from the acquisition computer to the analysis computer, archive the data, pick arrival times, locate events, and prepare the data for plotting. Where appropriate, programs have been written in GWBASIC to allow users to tailor the routine to their specific configuration.

The routine processing consists of six steps (figure 1); (1) data acquisition, (2) deleting false events (optional), (3) transferring data from the acquisition computer to another computer for analysis and archiving, (4) picking and locating events, (5) creating listings of the events suitable for use by plotting programs, and (6) plotting the data. This report will discuss only steps 2-5. The programs used in steps 1 and 6 are described in detail in the referenced reports.

The following are the primary programs used in each step.

1. Data acquisition.

   XDETECT.EXE (Tottingham and Lee, 1989) analyzes seismic signals in realtime, recording the waveforms from detected events for later analysis. Modifications to the original version (Rogers, 1993) include recording data in SUDS format (Ward, 1989) and recording Seismic Spectral Amplitude Measurements (SSAM) (Rogers and Stephens, 1991)

2. Deleting false events.

   XPLAY.EXE (Tottingham, 1989; Lee, 1993) displays the individual traces from the waveform files created by *XDETECT.EXE*. It enables you to examine the traces before moving the data from the acquisition computer into the processing queue. False events can be deleted before starting the analysis and archival process. This is especially important if telemetry problems cause numerous false triggers.

Steps in Routine Seismic Data Processing

Task	Primary Programs
Data Acquisition	XDETECT.EXE (Tottingham and Lee, 1989; Rogers, 1993)
Delete false events (optional)	XPLAY.EXE (Tottingham, 1989; Lee, 1993)
Move data from acquisition computer for processing and archiving	TRANSFER.BAS IRIG.EXE (Banfill, 1993) DEMUX.EXE (Banfill, 1993) SUDSPLOT.EXE (Banfill, 1993)
Pick arrival times and locate events	PICK_EM.BAS BUDSPICK.EXE HYPO71PC.EXE (Lee and Valdes, 1989) RESIDS.EXE RELOCATE.BAS
Develop event listings for use by plotting programs	DO_MASTR.BAT CR_MASTR.EXE SELECT.EXE
Plotting data	QPLOT.EXE (Murray and others, 1993) VOLQUAKE.EXE (R.P. Hoblitt, written commun.) SEISPLOT.EXE (March and Murray, 1992)

Figure 1

3. Transferring and archiving data.

TRANSFER.BAS is a GWBASIC program that builds and executes the batch files that transfer the event or waveform files (*.*WV**), the SSAM files (*.*FFT*), and the log files (*.*LOG*) from the acquisition computer to the analysis and archive computers. The batch files call the program *IRIG.EXE* (Banfill, 1993) to correct the time tag for each event with the IRIG E time code (if present) and the program *DEMUX.EXE* (Banfill, 1993) to demultiplex the individual traces in the waveform files so that they will be ready for the picking program. The demultiplexed files have the suffix *DMX*.

4. Picking and locating events.

PICK_EM.BAS is a GWBASIC program that builds and executes the batch file used to time and locate the events using *BUDSPICK.EXE* and *HYPO71PC.EXE*. The phase data produced by *BUDSPICK.EXE* for each event are stored in a separate file with the suffix *PHA*. The location calculated for each event by *HYPO71PC.EXE* is written to two files (1) **.PUN* - a 1-line summary of location, time, and quality, and (2) **.PRN* - location, quality, time, phase arrivals, phase residuals and other information.

BUDSPICK.EXE is the program for interactively picking the arrival times and coda lengths for the events. It includes an autopicker. I developed *BUDSPICK.EXE* from an early version of *SUDSPICK.EXE* (Banfill, 1993). Later versions of *SUDSPICK.EXE* did not keep the input/output features that allowed it be used in conjunction with the system described here.

HYPO71PC.EXE (Lee and Valdes, 1989) locates the events using the picks made with *BUDSPICK.EXE*.

RELOCATE.BAS is a GWBASIC program that builds and executes a batch file that re-locates events using *HYPO71PC.EXE*. It is used after the velocity model has been changed or a station location corrected.

5. Creating listings of the events suitable for use by plotting programs.

CR_MASTR.EXE collects all the locations in **.PUN* files created by *HYPO71PC.EXE*, and creates a single, master file. Analysis programs such as *QPLOT.EXE* can use the master file. Typically, *CR_MASTR.EXE* will be executed after every picking session.

SELECT.EXE creates a data file containing only events from the master hypocenter file that meet user-specified criteria. Typically, *SELECT.EXE*

will use as its input listing the file created by *CR_MASTR.EXE*.

DO_MASTR.BAT is a batch file that combines calls to *CR_MASTR.EXE* and *SELECT.EXE* during routine processing.

6. Plot the data.

A variety of programs including *QPLOT.EXE* (Murray and others, 1993), *VOLQUAKE* (R.P. Hoblitt, written commun.), *ACROSPIN* (Parker, 1990), and *SEISPLOT.EXE* (March and Murray, 1992) can be used to plot the hypocentral data. These programs are not discussed in this report.

Throughout the process, the prefix originally assigned to the waveform file by *XDETECT.EXE* is retained by the different programs, with only the suffix changing. The system produces the following files for each event (using event 9307250A as the example, the tenth event recorded on 07/25/93).

9307250A.WVC	original waveform file produced by *XDETECT.EXE*
9307250A.DMX	demultiplexed waveform file produced by *DEMUX.EXE*
9307250A.PHA	phase arrivals output by *BUDSPICK.EXE*
9307250A.INP	input file for *HYPO71PC.EXE*
9307250A.PUN	1-line summary of *HYPO71PC.EXE* output
9307250A.PRN	complete *HYPO71PC.EXE* output

INSTALLATION

To run these programs, the analysis computer must be networked (an Artisoft Lantastic 2-mbps network suffices) to the acquisition computer (Lee, 1989) with the acquisition computer functioning as a server (figure 2). Because many of the programs make use of the switches available to the DIR command in DOS 5.0, **the analysis computer MUST be running DOS 5.0 or greater.** *GWBASIC.EXE* must also be available through the PATH statement. The analysis computer requires a math coprocessor, and its hard-disk-drive capacity should be at least 80 Mbytes. Obviously, the more powerful the computer and the larger the hard disk drive, the better. The programs work comfortably on a 25-mHz 386SX-based computer.

To install the programs:

1) Insert the distribution diskette into the floppy drive of the computer to be used for picking and locating the events.

2) Create the directory \QUAKES on the computer by using the DOS command:

MKDIR C:\QUAKES

If the programs are to be put on another drive, substitute that drive for C in the above.

3) Use the XCOPY command to copy the programs and directory tree onto the hard drive. If the distribution diskette is in drive A: and it is to be installed in C:\QUAKES, use the DOS command:

XCOPY A:*.* C:\QUAKES*.* /s

4) The following programs need to be edited to reflect your specific drive designations are used and file locations. The necessary editing is explained at the beginning of the individual programs. The DOS 5.0 text editor can be used.

a) *QUAKES\TRANSFER\TRANSFER.BAS*

b) *QUAKES\BUDSPICK\PICK_EM.BAS*

c) *QUAKES\BUDSPICK\BUDSPICK.INI*

d) *QUAKES\BUDSPICK\HYPO_LOC.INI*

e) *QUAKES\HYPO71\STATIONS.INP.* Lee and Valdes, 1989, describe the format of the this file. It contains the parameter information used by *HYPO71PC.EXE* to determine epicentral locations.

f) *QUAKES\XPLAY.BAT*

g) *QUAKES\PICK_EM.BAT*

h) *QUAKES\TRANSFER.BAT*

i) *QUAKES\DO_MASTR.BAT*

5) Move the batch files *QUAKES\TRANSFER.BAT, QUAKES\XPLAY.BAT, QUAKES\PICK_EM.BAT,* and *QUAKES\DO_MASTER.BAT* from the \QUAKES subdirectory to a directory accessible by your path statement, C:\ for instance.

6) The programs *HYPO71PC.EXE, SUDSPLOT.EXE, IRIG.EXE, XPLAYx.EXE* (there are versions for different graphics adapters), and *DEMUX.EXE* are available through IASPEI, P.O. Box "I", Menlo Park, CA, 94025, USA. Requests should be for IASPEI Software library volume #1 and the December 1993 supplement. Then:

HYPO71PC.EXE should be copied to \QUAKES\HYPO71

IRIG.EXE should be copied to \QUAKES\UTILS

DEMUX.EXE should be copied to \QUAKES\UTILS

XPLAYx.EXE should be copied to \QUAKES\UTILS

SUDSPLOT.EXE and its attendent files (Banfill, 1993, describes its installation and use) should be copied to \QUAKES\UTILS

Typical Hardware Configuration for Seismic Data Acquisition and Processing

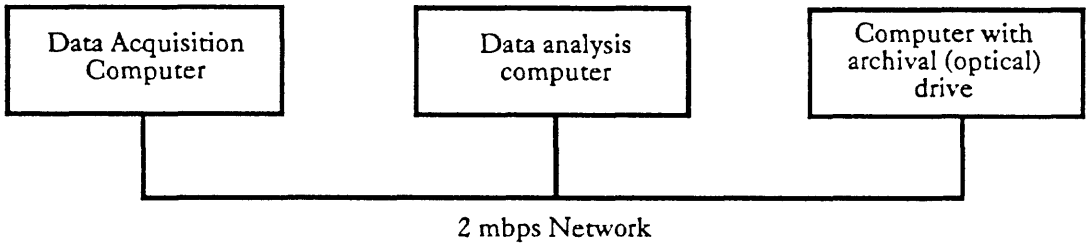


Figure 2

DESCRIPTION OF THE DIRECTORY STRUCTURE

The install program will create the directory structure shown in figure 3. This structure determines the flow of data through the system (figure 4). Certain directories can be considered holding areas for data awaiting further processing. Data can accumulate in these areas without affecting the processing procedure. As time or disk space permits, the data in the holding areas can be moved onwards.

The data holding areas are:

1) The data directory on the acquisition computer. Data files accumulate here until transferred to the analysis computer by the program *TRANSFER.BAS*.

2) The \TEMP directory under \TRANSFER. *TRANSFER.BAS* first moves the data files from the acquisition computer to this directory. Then *TRANSFER.BAS* processes and archives all data contained in the \TEMP directory, minimizing the time spent accessing the acquisition computer. Data can remain here if there are problems with the archive disk or lack of space in the \DMX directory. When the problem is fixed, the next time you run *TRANSFER.BAS*, new data will be moved into \TEMP from the acquisition computer and they, along with the data remaining from the last attempt, will be processed and archived. Note that if the problem was only with the archive disk AND in the meanwhile you successfully picked the event, *TRANSFER.BAS* will write the event again to the \DMX directory. The *WV** files will be removed from the \TEMP directory only after they have been moved to the archive directory. If it seems you are re-picking the same events, this is what probably happened. You can either re-pick them or manually delete them from \DMX (don't delete the new events that you haven't picked; check in the \DONE directory to see what was picked and what wasn't).

3) The archive disk. Raw waveform data (WV*), *FFT*, and *LOG* files are stored on the archive disk. *FFT* files are stored in daily directories for later compressing. *WV** and *LOG* files are stored in monthly directories.

   IF YOU DO NOT HAVE AN OPTICAL DRIVE but must instead must use tape backup, create a subdirectory somewhere (under \BUDSPICK for instance) to simulate the archive disk. Data in this directory and its attendant subdirectories can be manually stored on tape when desired. This relieves you from seriously modifying *TRANSFER.BAS* and keeps the data flow consistent with this report.

4) The \DMX directory under \BUDSPICK. Event files accumulate here to be picked by the program *PICK_EM.BAS*. If the backlog becomes too great, manually move the files to the directory \OVERFLOW. This allows

Figure 3

Directory Structure for Processing Seismic Events

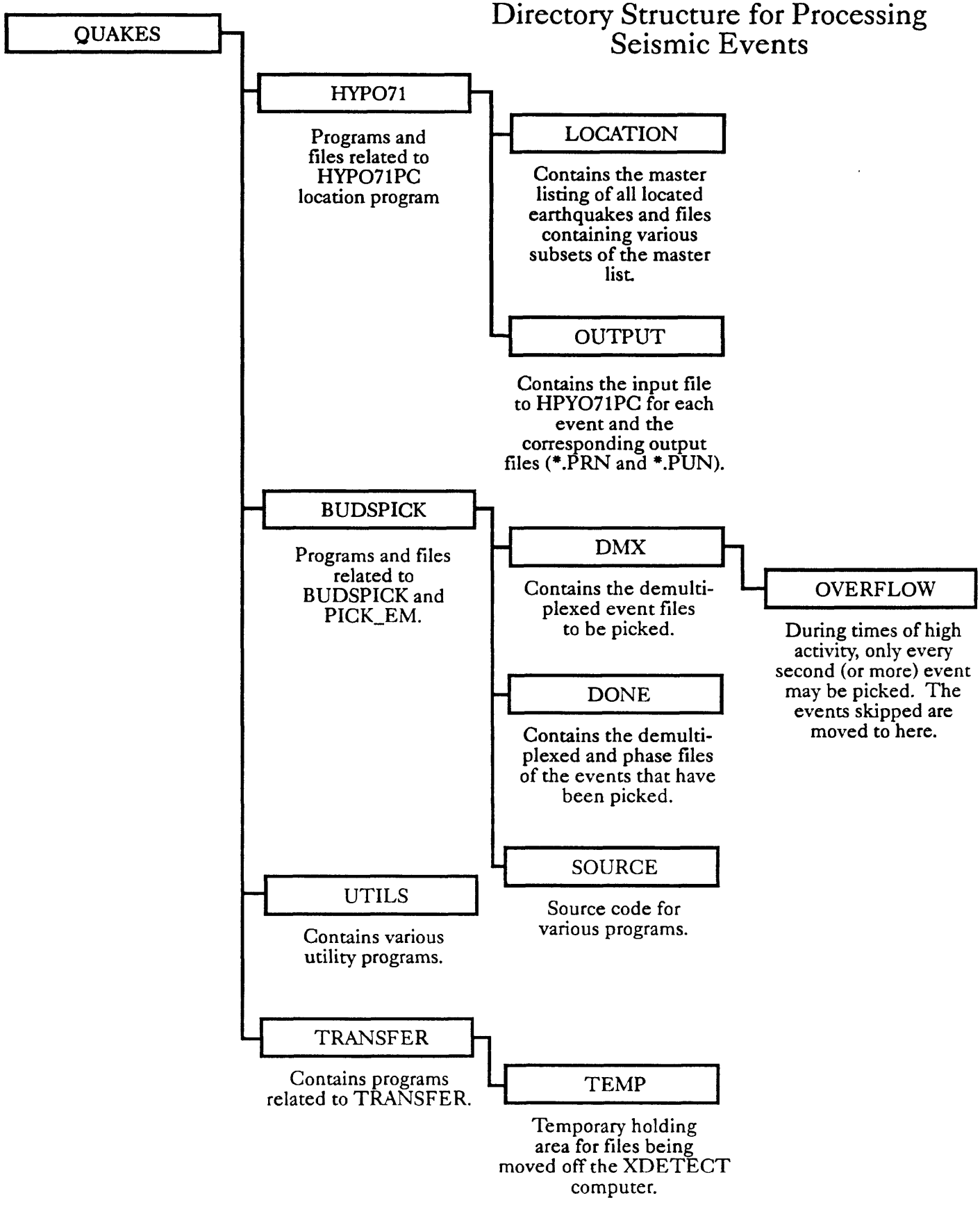
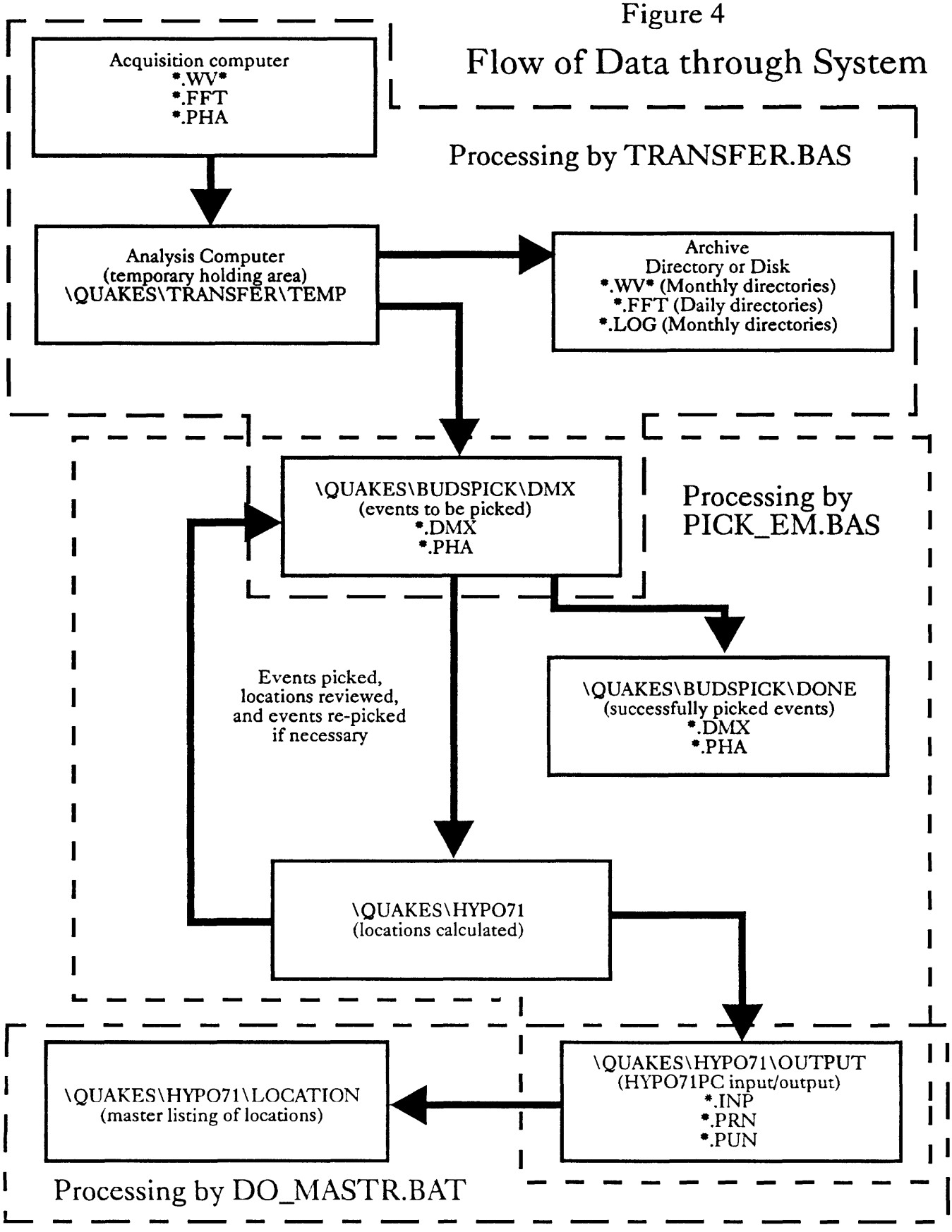


Figure 4

Flow of Data through System



you to continue to process the most recent data. As time allows, manually move data back from \OVERFLOW to \DMX and gradually reduce the backlog. If \OVERFLOW becomes too large, back its contents off to tape or another machine before moving them back for processing.

5) The \DONE directory under \HYPO71 holds the trace data (*DMX*) and phase files (*PHA*) of those events that have been successfully picked. These files can be periodically backed off to archive media.

6) The \OUTPUT directory under \HYPO71. The *HYPO71PC.EXE* input files (**.INP*) and output (**.PRT* and **.PUN)* files are stored here. The location information from all the event files can be combined into master listings used by the various plotting packages. These master listings should NOT reside in \OUTPUT but either in \LOCATION or elsewhere.

Uses of the directories:

\QUAKES conveniently keeps the seismic-event processing programs and data together, and initially contains the batch files *TRANSFER.BAT, XPLAY.BAT, DO_MASTR.BAT,* and *PICK_EM.BAT.* These batch files should be moved to a directory accessible through your PATH statement such as C:\.

\HYPO71 contains the earthquake-location program *HYPO71PC.EXE. PICK_EM.BAS* moves files in and out of this directory as they are processed.

\OUTPUT The *HYPO71PC.EXE* input files (**.INP*) and output files *(*.PUN* and **.PRT)* are moved here by *PICK_EM.BAS* after an event is successfully picked.

\LOCATION The master earthquake-location files are stored here. They are built by combining the *PUN* files stored in the \OUTPUT directory. Different "master" files (such as all events in 1992) can be constructed and stored here also.

\BUDSPICK contains the picking program *BUDSPICK.EXE* and the GWBASIC program *PICK_EM.BAS* that builds the batch file used to do the routine picking of the events.

\DMX After the waveform data (*.*WV**) are transferred from the acquisition computer to the analysis computer, the data are time-corrected (*IRIG.EXE*), demultiplexed (*DEMUX.EXE*), and finally transferred to this directory to await picking. Preliminary phase files from events that have not been successfully picked reside in this directory.

\OVERFLOW If the pace of activity prevents all of the events to be picked in a timely manner, unpicked events can be moved here so that the more recent events can be picked. Later, the overflow events can be moved back into \DMX and processed normally.

\DONE After a **.DMX* file is successfully picked and located, it and its **.PHA* file are moved into this directory.

\SOURCE contains the source code for *BUDSPICK.EXE*.

\TRANSFER contains the GWBASIC program *TRANSFER.BAS* which is used to move the data from the acquisition computer to the analysis computer and then to either an optical disk or archive directory. The transfer program time-corrects the files, demultiplexes them, and moves them into the \DMX directory.

\TEMP When transferring the *WV**, *LOG*, and *FFT* data, this directory is used as a temporary holding area.

\UTILS contains various utility programs used in manipulating the seismic data.

STEPS IN THE ROUTINE PROCESSING

The routine data processing consists of the tasks shown in figure 1. The main programs, *PICK_EM.BAS* and *TRANSFER.BAS*, **require** GWBASIC or a BASIC compiler. QBASIC, which comes bundled with DOS 5.0 requires so much memory that you cannot SHELL out of it to run programs such as *BUDSPICK.EXE*. Alternatively, a BASIC compiler permits the programs to be compiled into executables and eliminates the need for GWBASIC.

Note: If the message "network connection to drive X broken" appears, it means that the network connection to the specified computer has been broken (usually because the computer has been re-booted). Choose R for retry. If that doesn't work, re-boot your computer.

The routine processing is done on the analysis computer. The steps are:

1) Use **XPLAY.BAT** to view the events and delete ones that have no scientific value (mainly ones caused by telemetry problems).

2) If your system uses an optical drive, insert the disk used for the data archival into the optical drive.

3) Execute **TRANSFER.BAT**. This will start *TRANSFER.BAS* (figure 5). After answering the prompts, the program will build batch files to transfer the waveform data from the acquisition computer to the \TEMP directory on the analysis computer. The raw waveform files (*WV**) will be archived in either the archive directory or on the optical diskette and a picking worksheet will printed. Optionally, the waveforms will be sent to the printer. The transfer can take 30 minutes or more depending on network traffic and the amount of data.

4) Grab the picking worksheet printed by *TRANSFER.BAS* above.

5) Begin picking events by typing **PICK_EM.BAT** This will begin execution of *PICK_EM.BAS* (figure 6).

6) Interactively pick the phase arrivals for each event. Use the picking worksheet to "catalog" event types and write notes concerning each event.

7) Execute **DO_MASTR.BAT**. This updates the master listing of events and any subsets by running *CR_MASTR.EXE* and *SELECT.EXE*.

The new data should now be available for plotting.

In summary, the following commands execute the entire processing.

XPLAY.BAT
TRANSFER.BAT
PICK_EM.BAT
DO_MASTR.BAT

Figure 5

Processing performed by TRANSFER.BAS

Data Files collected by XDETECT to be processed by TRANSFER.BAS

9307240A.WVC
9307240B.WVC
93072412.FFT

1) Move files from Acquisition System to \QUAKES\TRANSFER\TEMP

9307240A.WVC
9307240B.WVC
93072412.FFT

2) Prepare event files for picking

a) Correct time from IRIG code (IRIG.EXE)

9307240A.WVC
9307240B.WVC

b) Demultiplex event file (DEMUX.EXE)

9307240A.WVC
9307240A.DMX
9307240B.WVC
9307240B.DMX

c) Move DMX file into picking queue \QUAKES\BUDSPICK\DMX

9307240A.DMX
9307240B.DMX

d) Print "picking" worksheet for transfered events

9307240B.PRT

e) Print waveforms using SUDSPLOT.EXE

WAVEPRT.BAT

3) Move event and FFT files to optical or archive area

9307240A.WVC
9307240B.WVC
93072412.FFT

Note: The last letter in the event filename created by XDETECT is the first letter of the network name defined by the XDETECT input file.

The above example uses WVC (for Cascades Volcano Observatory). For the Alaska Volcano Observatory the files might use WVA for the suffix.

Figure 6
Event Processing using PICK_EM.BAS

1) Determine which events you want picked

(A) Pick all events (.DMX) in \QUAKES\BUDSPICK\DMX

(S) Pick only a specific event (.DMX) in \QUAKES\BUDSPICK\DMX

(P) Pick only a portion of the events (.DMX) in \QUAKES\BUDSPICK\DMX

2) Build and execute batch file BATCH_PK.BAT

a) Run event through BUDSPICK.

Read in old picks (.PHA) if present, otherwise run traces through autopicker.

Display residual information (if present) from HYPO71PC output (.PRT)

Pick arrival times and coda lengths

Upon exiting BUDSPICK, update *.PHA file.

b) Locate event using HYPO71PC

Prepare HYPO71PC input file by appending *.PHA file to station listing.

Run HYPO71PC. Its output files have the suffixes PRN and PUN.

c) Check solution. Run RESIDS.EXE to display the residual information.

(R) Repick the event. Rerun the event through BUDSPICK.

(S) Save the solution. The solution is satisfactory

1) Move *.DMX and *.PHA from \QUAKES\BUDSPICK\DMX to \QUAKES\BUDSPICK\DONE

2) Move *.INP, *.PRN and *.PUN from \QUAKES\HYPO71 to \QUAKES\HYPO71\OUTPUT

3) Move on to the next event.

(D) Delete the event. The event is of no interest (perhaps a telemetry problem).

1) Delete the .DMX and .PHA files in \QUAKES\BUDSPICK\DMX

2) Move on to the next event.

(K) Keep the event in picking directory, but move on to the next event. The event should not be deleted, but neither is the solution satisfactory. Move on to the next event.

(Q) Quit. Exit BATCH_PK.BAT.

Note: All files associated with a specific event will have the same file name, but with different suffixes.

For instance, the files:

9307250A.DMX
9307250A.PHA
9307250A.INP
9307250A.PUN
9307250A.PRN

are all associated with the original file 9307250A.WVC

DETAILED DESCRIPTIONS OF CRITICAL PROGRAMS

The following describes the critical programs in detail. The programs *XDETECT.EXE* (Tottingham and others, 1989; Rogers, 1993) and *HYPO71PC.EXE* (Lee and Valdes, 1989), are not described here.

XPLAY.EXE

XPLAY.EXE (Tottingham, 1989; Lee, 1993) provides a quick method to display the traces for each event. If the event is of no interest (telemetry noise for instance), it can be erased. This prevents events triggered falsely from occupying space on the archive disk or slowing down the picking process.

XPLAY.EXE is started by typing **XPLAY [data directory]** where data directory is the location of the *WV** files. If *QUAKES\XPLAY.BAT* was properly modified, you will only need type **XPLAY**. The contents of the directory will be displayed. Move the cursor to the first *WV** and press <enter>. The traces for the event will be displayed. Press <F1> for information on how to view the data. Press <Q> to return to the directory display where you can either delete the event or move on to the next event. Press <Q> when the directory is displayed to exit the program.

SUDSPLOT.EXE

SUDSPLOT.EXE plots the waveforms for a specified event. Up to 16 traces can be plotted on a single page. If there are more than 16 stations, multiple pages (or screens) will be used. These plots provide you with a convenient hard copy of each event for future reference.

Banfill (1993) describes the use of *SUDSPLOT.EXE*. I recommend calling it with the following switches.

SUDSPLOT /DSCREEN.DRV$ /PCON: /B /L30 /J10 /X [file name]

TRANSFER.BAS

TRANSFER.BAS moves data from the acquisition computer for processing. The raw data are also written to an archive area. Ideally this will be an optical drive, but if one is not present, you can set aside a portion of your hard-disk drive to store the data until it can be backed off to tape or other media.

TRANSFER.BAS uses the DOS DIR command to get the filenames of the waveform (*WV**), SSAM (*FFT*) (Rogers and Stephens, 1991), and *LOG* files to be moved. Then *TRANSFER.BAS* builds batch files to move the these files and, using the SHELL command, executes the batch files. The locations of the various destinations and supplementary programs can be changed by editing lines 132-151 of the program. All transfers of the raw data are done with the DOS XCOPY command. The error code returned by XCOPY determines whether or not the copy was successful. Only if it was successful is the original file erased.

TRANSFER.BAS assumes that a network printer is used to print the worksheets. If a local printer is used, line 2590 should be commented out (an apostrophe needs to be placed after the line number) and line 2591 needs to have the apostrophe removed. The DOS editor can be used.

If you do not wish to have *SUDSPLOT.EXE* plot the waveforms, comment out line 2640.

TRANSFER.BAS does the following (figure 4):

1) Creates the file *DATA.TRA* which lists the files to be transferred. These include event data (*.*WV**), SSAM data (*.*FFT*), and log data (*.*LOG*). The most recent *FFT* and *LOG* files are NOT copied because *XDETECT.EXE* may append more data to them later. Note that the last letter of the suffix for the event data is the first letter of the network name defined in the input file used by *XDETECT.EXE*. At the *C*ascades Volcano Observatory the event files have the suffix *WVC*. At the *A*laska Volcano Observatory the suffix is *WVA*.

2) Builds and executes the batch file *MOVE_EM.BAT* that copies the files to the temporary directory \QUAKES\TRANSFER\TEMP. Files are moved to a temporary directory instead of to their final destinations so as to minimize the impact on the acquisition computer. If the files were successfully copied, *MOVE_EM.BAT* erases the files on the acquisition computer.

3) Makes the file *WV_FILES.DAT* listing all the event (*.*WV**) files in the temporary directory. From this list the batch file *TIME_EM.BAT* is constructed and executed. *TIME_EM.BAT* runs *WV** files first through the program *IRIG.EXE* to correct the time and sample rate using the IRIG E code recorded on channel 00. Then the program *DMUX.EXE* demultiplexes the data in the waveform files and puts the *DMX* files in the \DMUX directory for picking.

4) Builds a "picking" worksheet which is used by the person picking the events to note comments about the specific events. The sheet is in a file named after the last event plus the suffix *PRT*. The sheet is sent to the printer in step 6 below.

5) Creates the file *ERASEME.TRA* listing all the files in the \TEMP directory. From the list, the batch file *ARCHIVE.BAT* is built and executed. *ARCHIVE.BAT* copies the files to the archive disk. The *WV** and *LOG* files are stored in monthly directories (*ARCHIVE.BAT* creates the directories). The *FFT* files are stored in daily directories (*ARCHIVE.BAT* also creates these). If the files were successfully copied, *ARCHIVE.BAT* erases them from the temporary directory.

6) Prints the picking worksheet.

7) Constructs *WAVEPRT.BAT* which plots the waveforms for each *WV** file. This batch file runs the *WV** files through the program *SUDSPLOT.EXE* to produce a plot of the waveforms for all the stations for individual events. If you do not want the waveforms printed, comment out line calling *WAVEPRT.BAT* in *TRANSFER.BAT.*

The above sequence may not be appropriate for all (or even most) circumstances. Because the program is written in GWBASIC, it can be easily modified for specific configurations.

PICK_EM.BAS

PICK_EM.BAS is a GWBASIC program that builds the batch file used to pick phase arrivals and locate events. The batch file allows you to pick phase arrivals, review the location calculated from those picks, and adjust the picks until you are satisfied with the results.

PICK_EM.BAS first builds a list of all the events in the directory \QUAKES\BUDSPICK\DMX where *TRANSFER.BAS* has placed them. *PICK_EM.BAS* informs you of the total number of events and asks you whether you wish to pick all of them, a portion of them, or a specific event. You would use the portion option if the number of events being recorded is so great that you cannot possibly pick all of them in a timely manner. This could happen during an earthquake swarm or an eruption. By choosing the portion command, the batch file will be set up to skip over a certain number of events before choosing one to pick. *PICK_EM.BAS* prompts you for the number of events to skip. This way you can pick a representative number of events without getting hopelessly behind. If you use the portion option, you should move the unpicked events to the \QUAKES\BUDSPICK\DMX\OVERFLOW directory after you have finished picking. This way, when the next group of events comes in, you can pick a representative number of the new events, again moving the unpicked events to the overflow directory. As time allows, events in the \OVERFLOW directory can be moved back into the \DMX directory and picked. If the \OVERFLOW directory grows too large, its contents can be backed off to tape or other medium until time permits them to be picked.

Because *PICK_EM.BAS* is a GWBASIC program, it can be modified if your directory tree is different from the default tree. Edit lines 501-520 to indicate where the various directories are located on your system.

The batch file built by *PICK_EM.BAS* does the following (figure 5):

1) Runs the first event through the program *BUDSPICK.EXE*, which allows you to pick the phase arrivals interactively.

2) Builds the input file for *HYPO71PC.EXE* by appending the phase information produced by *BUDSPICK.EXE* (*.*PHA* located in the \DMX directory) to the station information/velocity model file, *STATIONS.INP*. The *HYPO71PC.EXE* input file will be located in \HYPO71.

3) Runs *HYPO_IN.EXE* to build the three-line text file *HYPO_IN.TXT* that *HYPO71PC.EXE* uses to determine the input and output files. All files keep the 8-character event tag.

4) Runs *HYPO71PC.EXE*.

5) Runs *RESIDS.EXE*. *RESIDS.EXE* displays the output from *HYPO71PC.EXE* and prompts you for the next course of action. You have five choices:

(S) If you are satisfied with the location you can save the location and continue on to the next event. The *HYPO71PC.EXE* output files are transferred to the \OUTPUT directory and the *DMX* and *PHA* files are moved from the \DMX directory to the \DONE directory.

(D) If you found the event had nothing of interest in it (telemetry noise for instance), you can delete the *DMX* and *PHA* files and the *HYPO71PC.EXE* output files, moving on to the next event.

(R) If you are not satisfied with the location, you can re-pick the event. You will be cycled back into *BUDSPICK.EXE* with your picks and residual information shown.

(K) If are not satisfied with the location, but do not wish to re-pick the event immediately or delete it, you can keep the event but move on to the next event. Because the event file remains in the \DMX directory, it will show up in the queue the next time you run *PICK_EM.BAS*.

(Q) You can quit picking altogether.

RESIDS.EXE returns an error code corresponding to your choice. The batch file uses the error code to determine where to GOTO next.

BUDSPICK.EXE

BUDSPICK.EXE is the interactive, mouse-driven picking program. When it first starts, it looks for a phase file (*PHA*) for the event and reads in the old picks. If it doesn't find an old phase file, it runs the traces through the autopicker.

The first trace then appears on the screen. At the top of the screen will be a plot of the entire trace, with any previous picks. The lower portion of the screen will have an expanded view of the trace. In the middle of the screen will be the main menu. At the bottom of the screen, the P and S residuals (if found) will be shown. These will only be found only when re-picking in interactive mode. It will not look through the *HYPO71PC.EXE* output files of completed events.

Main Menu Options

ZOOMING	The bottom trace is the portion of the upper trace bounded by the brackets shown on the upper trace. To change the bottom trace move the mouse to the upper trace area. Click the left button to reposition the left bracket (beginning time). Click the right button to reposition the right bracket (end time).
FRST	Jump to the first trace.
PREV	Jump to previous trace.
NEXT	Jump to the next trace.
LAST	Jump to the last trace.
JUMP	Displays all the station names. Click on the station you want to jump to.
P	Pick the P-arrival time.
S	Pick the S-arrival time.
CODA	Pick the coda.
EXIT	Exit the program. The phase file is automatically created or updated.

Picking the P and S arrival times.

There are two ways to do this. With the main menu displayed:

1) Choose either P or S on the main menu, move the cursor to the arrival time and click on it.

2) Alternatively, you can bypass clicking on P or S in the main menu. Using the lower trace, position the cursor at the arrival time and push the left mouse button for the P arrival, the right button for the S arrival.

Next the weight menu will appear. If you got here by accident click on QUIT. If you

want to erase the current pick, click on ERAS.

Otherwise, choose the correct weight, motion, and onset. The screen will be updated with the new information and a return to the main menu. The width of the lines associated with the weight numbers indicate the time uncertainty of the pick.

Note that for *HYPO71PC.EXE* to process an S arrival, it requires a P arrival from that trace. If the P arrival is uncertain, as may be the case for a horizontal geophone, pick a P arrival, but give it a weight of 4. This will cause *HYPO71PC.EXE* to virtually ignore the P arrival in its calculations, but still allow the S arrival to be used.

Picking the Coda

After clicking on CODA, position the cursor at the end of the coda and click the mouse. This can be done on either the top or bottom trace. To erase the coda, pick it in front of the P-arrival time. Also note that you cannot have a coda length until the P-arrival has been picked.

RELOCATE.BAS

RELOCATE.BAS is a GWBASIC program that builds and executes a batch file that reruns phase files (*.*PHA*) from already picked and located events through *HYPO71PC.EXE*. This may be necessary if it is discovered that the location for a station is incorrect or if you wish to try different velocity models.

To re-locate events:

1) Put all the *.*PHA* files for the events you want recalculated into a single directory. *RELOCATE.BAS* will recalculate all *.*PHA* files in its local directory.

2) Edit the *HYPO71PC.EXE* input file *QUAKES\HYPO71\STATIONS.INP* to reflect the new parameters. Make a copy of the old input file before making the changes.

3) Copy *RELOCATE.BAS* into the directory that contains the *.*PHA* files. Check line 512 to see if it contains the correct path to the \HYPO71 directory. Edit line 516 to reflect the name of the \HYPO71 input file you want to use.

4) Run *RELOCATE.BAS* by entering **GWBASIC RELOCATE.BAS**
RELOCATE.BAS will then build the batch file *HYPO_EM.BAT* and execute it. For each event in the directory, *HYPO_EM.BAT* will:
   a) Append the *.*PHA* file to the input file *QUAKES\HYPO71\STATIONS.INP* (or file you specified in line 516) and place the resulting file in the \HYPO71 directory.
   b) Run *HYPOIN.EXE* with the event name as an argument to provide *HYPO71PC.EXE* with the correct input file names.
   c) Run *HYPO71PC.EXE*
   d) Strip the header line out of the resulting *.*PUN* file with *NO_HDR.EXE*.
   e) Move the input file (*.*INP*) and *HYPO71PC.EXE* output files, *.*PUN* and *.*PRT* back to the directory containing the *.*PHA* files.

5) If you are satisfied with the results, move the *.*PRT*, *.*INP*, and *.*PUN* files back into the \HYPO71\OUTPUT directory. This will overwrite the old solutions.

6) Put all the *.*PHA* files back into the \BUDSPICK\DONE directory if they were moved instead of copied to the directory.

CR_MASTR.EXE

CR_MASTR.EXE is used to append all the **.PUN* files together in chronological order. The resulting master or summary file can be used by plotting programs (*QPLOT.EXE*, *BOB.EXE*, etc.) for plotting the data. The format for running *CR_MASTR.EXE* is:

CR_MASTR.EXE PUN=PunFileDirectory OUT=MasterFile

where PunFileDirectory is the directory containing all the **.PUN* files that are to be appended together and MasterFile is the name of the master event file to be created. Two things to note:

1) If the PUN= argument is not used, *CR_MASTR.EXE* will use the local directory.

2) If a MasterFile already exists, it will be renamed with the suffix **.BAK* and a new one created.

Example:

CR_MASTR.EXE PUN=QUAKES\HYPO71\OUTPUT OUT=QUAKES\LOCATION\SUMMARY.DAT

All the **.PUN* files in the directory \QUAKES\HYPO71\OUTPUT will be appended together in the file *\QUAKES\LOCATION\SUMMARY.DAT*. If *SUMMARY.DAT* already existed, the old file will be renamed *SUMMARY.BAK*.

In normal operation you would run *CR_MASTR.EXE* after you have run through *PICK_EM.BAS* and have new events located. To make this easier, an example batch file, *DO_MASTR.BAT* is provided in \QUAKES. It calls *CR_MASTR.EXE* to produce a new master event listing. After running *PICK_EM.BAS*, you would run *DO_MASTR.BAT*.

In typical operation, *CR_MASTR.EXE* will process over 20 events/second. If there are so many events that the it takes too much time for *CR_MASTR.EXE* to build a new summary file, I suggest archiving older portions of the data into monthly or yearly master files. This way, *CR_MASTR.EXE* will have to work only on the current events. If you want to continue creating a master file with all the events (including archived) each time, add a line to *DO_MASTR.BAT* that appends the current master file to the older master files each time *DO_MASTR.BAT* is run.

SELECT.EXE

In many instances, you will not want to plot all the events in the master summary file, but only a subset. This subset may contain only events that occurred in a specific time interval or geographic area, or of only a certain quality. Use *SELECT.EXE* to create a file containing only those events in the summary file that meets the specified criteria.

SELECT.EXE is located in the directory \HYPO71\LOCATION. It is run with the command line format:

SELECT.EXE IN=SummaryFile OUT=OutputFile FILTER=FilterFile

SummaryFile is the file containing all the events. OutputFile is the file you wish to create containing only specific events. If OutputFile already exists, it is renamed with the suffix **.BAK*. FilterFile is a file containing the criteria to see which events are written to OutputFile. An example FilterFile is provided, *FILTER.DAT*. *FILTER.DAT* describes how it is used.

If your network gets data from two volcanoes, you might wish to separate out events for each volcano from the summary file. To do this create two filter files, one for each volcano. Each time your summary file is updated, run *SELECT.EXE* twice, once with FilterFile defining volcano #1's geographic area, and then again with another FilterFile defining volcano #2's geographic area. For example:

SELECT.EXE IN=SUMMARY.DAT OUT=VOLC1.DAT FILTER=VOL1.FIL
SELECT.EXE IN=SUMMARY.DAT OUT=VOLC2.DAT FILTER=VOL2.FIL

You may wish to execute *SELECT.EXE* from *DO_MASTR.BAT*. This would insure that files containing the hypocenters for different volcanoes would be updated whenever the master list was updated (see *CR_MASTR.EXE* above).

ACKNOWLEDGEMENTS

I thank Elliot Endo, Andrew Lockhart, and Gloria Smith for identifying which features were required for smooth processing of the data, which features were little-used luxuries, and where bottlenecks occurred. Most of all, I thank John Power for identifying the limitations of the original PC-based seismic-processing software and for continually providing me (who had never picked an earthquake in his life) with insights about how seismic data are processed on other systems.

REFERENCES CITED

Banfill, R., 1993, PC-SUDS utilities: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, supplement to v. 1, 91 p.

Lee, W.H.K., ed., 1989, Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, 284 p.

Lee, W.H.K., ed., 1993, Preliminary updates for IASPEI software volumes 1 and 3: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, 90 p.

Lee, W.H.K. and Valdes, C.M., 1989, User manual for HYPO71PC, *in* Lee, W.H.K., ed., Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, p. 203-236.

March, G.D., and Murray, T.L., 1992, VOLPLOT; A PC-based program for viewing Cook Inlet Volcano-seismic data: U.S. Geological Survey Open-File Report 92-560-A, 6 p.

Murray, T.L., Power, J.A., and Klein, F.W., 1993, PC_QPLOT, an IBM-PC compatible version of the earthquake plotting program QPLOT: U.S. Geological Survey Open-File Report 93-22, 17 p.

Parker, D.B., 1990, User manual for AcroSpin, *in* Lee, W.H.K., ed., Toolkit for plotting and displaying seismic and other data: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 2, p. 119-164.

Rogers, J.A., 1993, XDETECT version 3.18 user's reference guide: U.S. Geological Survey Open-File Report 93-261, 26 p.

Rogers, J.A., and Stephens, C.D., 1991, SSAM: a PC-based seismic spectral amplitude measurement system for volcano monitoring: Seismological Research Letters, v. 62, p. 22.

Tottingham, D.M., 1989, User manual for XPLAY, *in* Lee, W.H.K., ed., Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, p. 119-134.

Tottingham, D.M., and Lee, W.H.K., 1989, User manual for XDETECT, *in* Lee, W.H.K., ed., Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, p. 89-118.

Tottingham, D.M., Lee, W.H.K., and Rogers, J.A., 1989, User manual for MDETECT, *in* Lee, W.H.K., ed., Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, p. 49-88.

Valdes, C.M., 1989, User manual for PCEQ, *in* Lee, W.H.K., ed., Toolkit for seismic data acquisition, processing and analysis: El Cerrito, Calif., Seismological Society of America, International Association of Seismology and Physics of the Earth's Interior Software Library, v. 1, p. 175-201.

Ward, P.L., 1989, SUDS: Seismic Unified Data System: U.S. Geological Survey Open-File Report 89-188, 123 p.