UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

Seismic Cassette Recorder (SCR) Playback and Digitizing System for IBM AT Compatible Computers

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OPEN-FILE REPORT 90-99

1990

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INTRODUCTION AND OVERVIEW

The U.S. Geological Survey in Menlo Park, CA currently maintains and operates a set of 120 portable analog seismic cassette recorders (SCR's) (Healy and others, 1982; Murphy, 1988). These instruments were designed and built in 1976-1977 to record a 1000 km long seismic refraction profile in Saudi Arabia. Since that time, they have been used for many seismic refraction experiments throughout the continental United States, including Alaska.

From 1978 to 1988, Digital Equipment Corporation (DEC) PDP 11/03 and PDP 11/23 computer systems were used for data entry, digitizing, and record section plotting. For their time, these systems were innovative since they allowed playback operations to be accomplished quickly (within a few days), and since they were transportable, data quality and preliminary analyses could be accomplished in the field. When International Business Machines (IBM) model AT microcomputer systems became available, several advantages over PDP 11 systems became apparent:

1. Since IBM AT systems are produced in much greater quantities than PDP 11 systems, the IBM system costs much less. Parts, accessories, supplies, and repairs are also less expensive. Since IBM AT compatible dealers are located throughout the United States and, indeed, throughout most of the world, it is much easier to maintain IBM AT systems in the field than it is to maintain PDP 11 systems.

2. IBM AT systems are generally smaller and lighter in weight than PDP 11 systems. Also, they use less electrical power and produce less heat during operation. This is important when operating in motels and field offices.

3. IBM AT computers can directly access 640 KB of memory. PDP 11 computers can directly access only 128 kb of memory.

4. There is a great deal of off-the-self software available for IBM AT computers compared to PDP 11 computers.

In 1986-1988, the U.S. Geological Survey purchased an Everex 80386 desktop computer system, a Compaq Portable II system, and two Data Translation DT2821 I/O modules. We then interfaced the new computer equipment (Tables 1 and 2) with existing analog playback equipment and developed new software for data entry and digitizing (Figure 1). In October, 1988, we tested the new system in a major refraction experiment in New England, which traversed the northern Appalachian Mtns, the Adirondack Mtns, and extended into southern Ontario.

The new playback system is capable of digitizing three data channels plus time code at a speed of four times real time at 200 samples per second. Digitized data records may be of any length,

TABLE 1
Everex Computer System Components

Component	Port Address	Interrupt	DMA Channel
Everex System 1800; 16 Mhz; 1 meg RAM; 80287 coprocessor			
Teac 1.2 megabyte diskette (drive A)	3F0-3F7	6	2
Micropolis 72 megabyte disk (drive C) Seagate 40 megabyte disk (drive D)	1F0-1FF	14	3
Printer Port 1 (LPT1) (on Everex Magic I/O module)	3BC-3BF	7	
Serial Port 1 (COM1) (on Everex Magic I/O module; connected to Houston Instruments DMP51 pen plotter)	3F8-3FF	4	
Serial Port 2 (COM2) (on Everex Magic I/O module; connected to ROLM phone system)	2F8-2FF	3	
Everex Excel 40 megabyte digital cassette tape backup	280	5	2
3-Com Etherlink Ethernet module	300-30F	3	1
Data Translation DT2821 Analog to Digital Module	240	15	5,6

although it becomes impractical to digitize more than about 60 seconds per trace due to limitations of available disk storage. Each analog tape contains data for several shots detonated during one deployment. During digitizing, all shots on an analog field tape are digitized in one pass through the tape and are later sorted by shot so that plots of each shot can be made.

The data is stored in two formats, "raw" and SEGY. Raw files contain data for one instrumental recording of one shot, with all three gain channels plus digitized time code. The SEGY data files (Barry and others, 1975) each contain data for all instruments for one shot (a shot gather). The SEGY format is used because it is standard in seismic reflection data processing systems, although

TABLE 2
Compaq Portable II System Components

Component	Port Address	Interrupt	DMA Channel
Compaq Portable II computer; 1.6 megabyte RAM; 80287 coprocessor chip;			
EDA Fastlink module for high speed communication with PRS4 seismograph			
Printer Port 1 (LPT1)	3BC-3BF	7	
Serial Port 1 (COM1) (connected to Summagraphics digitizing tablet)	3F8-3FF	4	
Serial Port 2 (COM2)	2F8-2FF	3	

we have redefined some header values for use with seismic refraction data (see Appendix). The SEGY header definitions we use are compatible with the Canadian Geological Survey SEGY format version 2.0. The digitizing program (DTS) writes data in raw format. At a later stage of processing, data from raw files is combined into one SEGY file per shot.

Data entry, digitizing, and plotting record sections can be done in a field office (often set up in a motel room), using the Everex and Compaq computers. When the field experiment has been completed, the system is brought back to the home office in Menlo Park, CA. There, the data are uploaded to a VAX VMS system for further processing, and they are written to 9-track magnetic tapes for distribution to other institutions.

Data processing is accomplished in three stages. First, before the SCR's are deployed, recording stations and shot points are located on maps or using satellite receiving equipment (Global Positioning System). Location coordinates are determined from maps using a digitizing tablet. After locations are entered, the computer is used to plot overlay maps to recheck data entry. If coordinates are determined in some other way, they are simply typed into the computer or imported from IBM diskette files. After the SCR's are deployed, the data is recorded on cassette tapes, and the SCR's are retrieved, the second stage of data entry begins. Shot times are obtained from the shooting crew, and are typed into the computer. A location number is assigned to each SCR, and this number, along with the recorder attenuation settings and clock drifts, are entered into the computer. The user must enter the number of seconds of data to be digitized and the digitizing start time. Then, the analog tapes are digitized, and the data is stored as raw

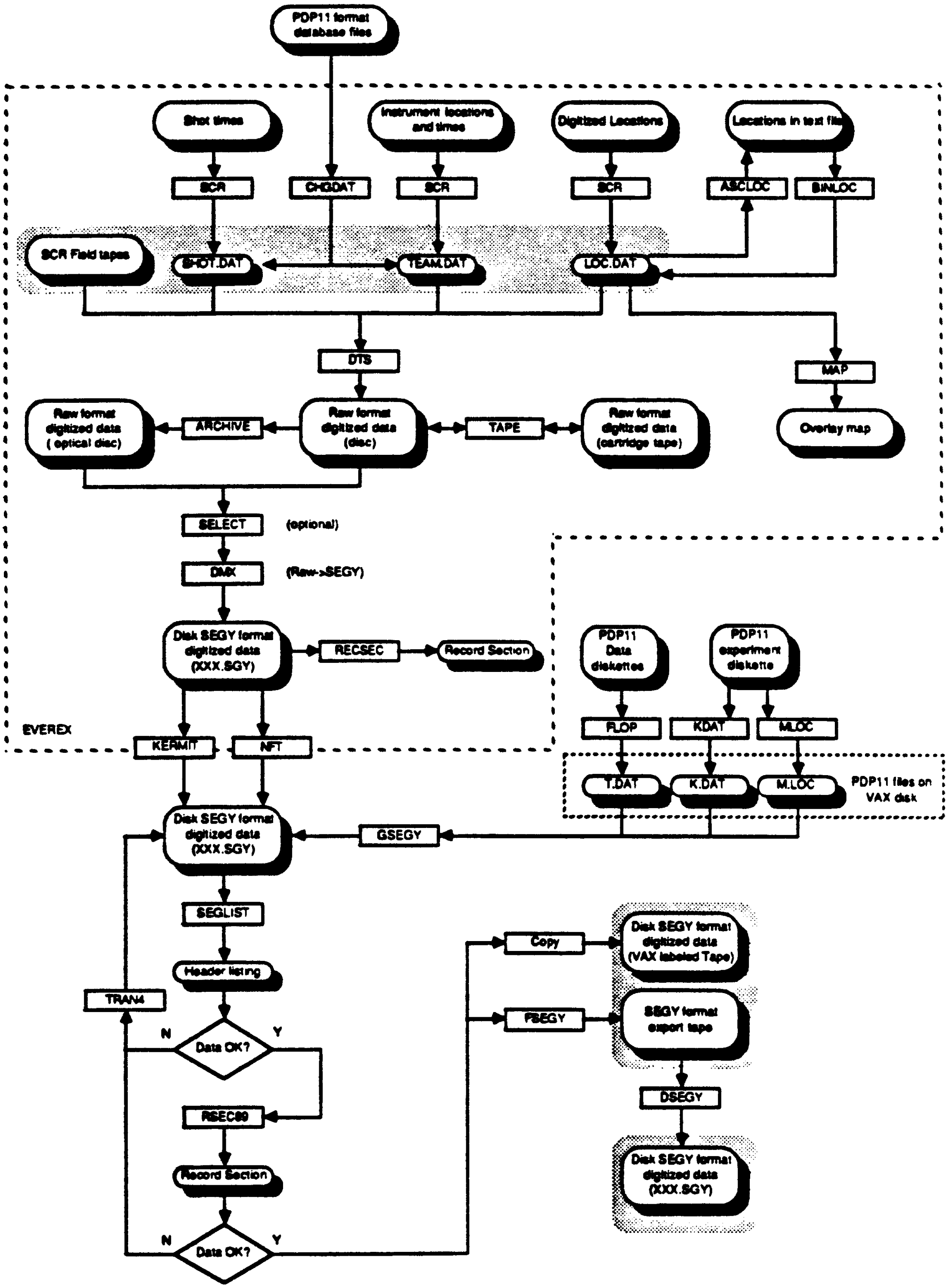

Figure 1. Software and data file flow chart. All components within the large box are contained in the Everex digitizing system. Components below the box are implemented on a VAX 11/785 minicomputer at the USGS in Menlo Park, CA.

files on the computer hard disk. Raw files are archived either to digital cassette tapes or to the write-once optical disk. Next, SEGY files are generated from the raw files, and record section plots are made from the SEGY files. The third stage of processing is the clean-up stage, which usually occurs in the central office after the experiment has been completed. In this stage, instrument gains are manually selected. Any errors in locations or times are corrected, and new record sections are plotted. Stage one takes place over a period of several months before the experiment. Stage two is accomplished in the field and is completed within a few days after shooting the shots. Stage three takes place over a period of about six months after the field work is completed. In this report, it is assumed that the reader is familiar with field procedures for using the cassette recorders (Murphy, 1988).

GETTING STARTED

Each experiment has its own set of data files which reside in a subdirectory on the hard disk and, as a backup, on a floppy diskette. To prevent accidental erasure, the data files, named SHOT.DAT, TEAM.DAT, and LOC.DAT (Figure 1), are read-only files. This prevents them from being modified or erased, except using the programs described in this report. During the digitizing process, raw files are written to the experiment directory on the hard disk. Typically, one deployment for 20 instruments is digitized at a time, and the raw files are then archived to either digital cassette tapes or to optical disk cartridges. Similarly, SEGY files are written to the experiment directory, and are archived to disk or tape, or they may be uploaded to the VAX VMS computer and archived to 9-track tape.

To prepare for data entry or digitizing, first boot the system and create an appropriate subdirectory using the Disk Operating System (DOS) MKDIR (MD) command[1], e.g., for the New England experiment:

C:\>md \neweng (This command is entered only once. Type whatever is in lowercase.)

Then, make the neweng directory the current directory:

```
C:\>cd \neweng
C:\NEWENG>_     (Underscore is the cursor.)
```

To create new data files for an experiment, simply type SCR<Enter>. The SCR program will see if data files already exist in the current directory. If they do not, the program asks whether you wish to create data files, and also prompts for an experiment name to be stored in the SHOT.DAT file. This name will be displayed when you are running the programs so that you know which data files are being edited.

<u>IMPORTANT:</u> After the data files have been modified, they should be backed up to the appropriate diskette using the DOS COPY command, i.e. put the experiment diskette in drive A and type:

```
copy *.dat a:
```

---

[1] The system prompts for user commands by displaying the current working directory, followed by the > character. After entering each command, press the Enter key on the keyboard. For an introduction to DOS commands, many sources of information are available, including books, video tapes, diskettes, and seminars.

PRE-EXPERIMENT ACTIVITIES: ENTERING AND PRINTING SHOT POINT AND RECORDER LOCATIONS (SCR AND SQLOC PROGRAMS)

In the weeks or months preceding an experiment, surveying crews locate all shot points and recording stations in the field. The stations are marked with a wooden stake, which is identified with a location number. The surveying crew marks each station on a map (usually, a 7.5' topographic map or orthophoto sheet), and they may determine the location coordinates using a GPS satellite receiver. The maps are returned to the data center, so that latitude-longitude coordinates can be determined, and these coordinates are correlated to the location number written on the stake. Location numbers may be any whole number from 1 to 9999, and there is no distinction between shot point location numbers and recording station numbers (numbers such as 3a or 245c are not permitted). By convention, numbers from 1 to 99 are reserved for shot points, but this is not a requirement of the data processing programs. Locations on maps are digitized using a Summagraphics ID series digitizing tablet. If coordinates are known, they may be either typed directly into the SCR program or typed into an ASCII text file and loaded into the data using the BINLOC program (Figure 1). After coordinates have been entered, they may be converted to ASCII representation using the ASCLOC program.

```
                    Program SCR Main Menu

New England, 1988
Format Version number 1.000


        S :  Edit shot list and digitizing parameters

        T :  Edit team-shot list

        L :  Edit location list

        C :  Enter clock drifts

        E :  Exit program
```

Figure 2. SCR program main menu.

Location Editing Menu

New England, 1988

L : Enter locations from keyboard

V : Enter elevations from keyboard

D : Delete locations

T : Enter locations with digitizing tablet

P : Print location list

E : Exit to main menu

Figure 3. SCR program location editing menu.

To digitize coordinates from a map, tape the map to the digitizing tablet. Change to the appropriate experiment directory, and type "SCR" to run the SCR program. From the SCR main menu (Figure 2), enter L to edit location list. Then, from the location editing menu (Figure 3), enter T to enter locations with digitizing tablet. The program will prompt for map scale; enter the appropriate map scale or "Other" if the map scale is not listed by the program. The program prompts for the coordinates of the lower-left corner of the map in degrees, minutes, and seconds[2]. The user digitizes by aligning the crosshairs of the cursor with the map corner and pressing the yellow button on the cursor. Then, the program will prompt the user to digitize latitude-longitude tick marks across the bottom of the map, and across the top of the map. When this is finished, the program will prompt for location numbers and elevations in meters. Enter the numbers of all stations on the map sheet and the elevations of the stations. If elevations are unknown, enter only the station numbers. When this is completed, the program will ask the user to digitize each station. If an error is made, go on to the remaining stations on the same sheet. The program will prompt whether you wish to digitize more stations on this map. If errors have been made, reenter the station numbers

---

[2] Whenever the programs prompt for more than one number at a time, the numbers must be separated by spaces.

with errors and redigitize them. When all stations on a map sheet have been digitized (i.e., you request no more stations), the program will return to the location editing menu. To digitize another map sheet, enter the T command, tape the next map sheet to the digitizing tablet, and start again.

In the location editing menu, the L command allows the user to enter locations in degrees and decimal minutes. The V command is used to enter elevations in either meters or feet. The D command is used to delete locations from the data. The P command is used to print locations in degrees and minutes on the computer screen.

The SQLOC program is used on rare occasions when location are deleted from the bottom of the location list, i.e. the locations with the highest location numbers are deleted. When these locations are deleted using the SCR program, the space they occupied in the LOC.DAT file does not automatically become free for other uses. The SQLOC program will free this data space, resulting in a smaller LOC.DAT file. To run the program, change to the subdirectory containing the LOC.DAT file, and type SQLOC<Enter>.

PRE-EXPERIMENT ACTIVITIES: CONVERTING LOCATIONS TO ASCII FORMAT (ASCLOC PROGRAM)

The SCR program stores location coordinates in a binary data file named LOC.DAT on the hard disk. Occasionally, it is necessary to convert the location data file to ASCII format so that it can be printed on a line printer or transferred to another computer system (Figure 1). To accomplish this conversion, enter the ASCLOC command from the DOS prompt. The syntax is:

```
ASCLOC f >outfile
```

where f = D or M or S,
D = Output in decimal degrees
M = Output in degrees and decimal minutes
S = Output in degrees, minutes, and decimal seconds.
outfile = Name of new file to contain ASCII locations.

A location data file must be in the default directory. If >outfile is not specified, output will go to the computer screen instead of a disk file.

If f = D (degrees), the output line format is:

```
sn    alatd       alond      elev     <-- Variables
122  35.123456  -121.234567  1200     <-- Sample line
```

where,
sn is the station location number,
alatd is the latitude in decimal degrees,
alond is the longitude in decimal degrees,
elev is the elevation in whole meters.

Positive latitudes are north of the equator. Positive longitudes are east of zero longitude.

If f = M (minutes), the output line format is:

```
sn  latd  alatm  ns  lond  alonm  ew  elev     <-- Variables
122  35   45.823  N   121  12.167  W   1200     <-- Sample line
```

where,
latd is the latitude in whole degrees,
alatm is the latitude in decimal minutes,
ns is the letter N (north) or S (south),
lond is the longitude in whole degrees,
alonm is the longitude in decimal minutes,
ew is the letter E (east) or W (west).

If f = S (seconds), the output line format is:

```
sn  latd latm alats ns  lond lonm alons ew  elev    <-- Variables
122   35  45  47.11 N    121  12  10.62 W   1200   <-- Sample line
```

where,

latm is the latitude in whole minutes,
alats is the latitude in decimal seconds,
lonm is the longitude in whole minutes,
alons is the longitude in decimal seconds.

PRE-EXPERIMENT ACTIVITIES: READING LOCATIONS FROM ASCII FILES (BINLOC PROGRAM)

A conversion program named BINLOC is available to import an ASCII location file into a LOC.DAT data file (Figure 1). The BINLOC program updates an existing data file which has been created using the SCR program. If SCR does not find a file named LOC.DAT in the current directory, it will create a new LOC.DAT file. If a location data file already exists, and it contains some locations, BINLOC can be used to import additional locations.

To run BINLOC, first change to the subdirectory containing data files, and use the SCR program to create a location data file named LOC.DAT, if none exists. Then, type:

```
BINLOC f <infile
```

where,

f = D or M or S,
D = Output in decimal degrees,
M = Output in degrees and decimal minutes,
S = Output in degrees, minutes, and decimal seconds,
infile = Name of an existing ASCII file containing location coordinates.

The program will print each line as it is read from the input file. Any line which begins with an asterisk (*) is interpreted as a comment line, which will be ignored. If a line cannot be interpreted, the program will print an error message and stop.

Lines other than comment lines each specify one location in free format with fields separated by spaces. The format of each line depends on the value of f.

If f = D (degrees), the input line format is:

```
sn    alatd      alond       elev    <-- Variables
122   35.123456  -121.234567 1200    <-- Sample line
```

where,

sn is the station location number,
alatd is the latitude in decimal degrees,
alond is the longitude in decimal degrees,
elev is the elevation in whole meters.

Station numbers must be in the range 1 to 9999, and they must contain digits only (no letters or other characters). Positive latitudes are north of the equator. Positive longitudes are east of zero longitude. Elevations may be omitted.

If f = M (minutes), the input line format is:

```
sn  latd  alatm  ns  lond  alonm  ew  elev     <-- Variables
122  35  45.823  N   121  12.167  W   1200     <-- Sample line
```

where,
latd is the latitude in whole degrees,
alatm is the latitude in decimal minutes,
ns is the letter N (north) or S (south),
lond is the longitude in whole degrees,
alonm is the longitude in decimal minutes,
ew is the letter E (east) or W (west).

The values of latd, alatm, lond, and alonm must be greater than or equal to zero.

If f = S (seconds), the input line format is:

```
sn  latd latm alats ns  lond lonm alons ew  elev    <-- Variables
122   35  45  47.11 N    121  12  10.62 W   1200   <-- Sample line
```

where,
latm is the latitude in whole minutes,
alats is the latitude in decimal seconds,
lonm is the longitude in whole minutes,
alons is the longitude in decimal seconds.

The values of latd, latm, alats, lond, lonm, and alons must be greater than or equal to zero.

PRE-EXPERIMENT ACTIVITIES: PLOTTING OVERLAY MAPS (MAP PROGRAM)

To check the quality of location coordinates, it is desirable to make map plots of locations using the Houston Instruments pen plotter. If the plots are made on vellum type paper, they can be overlaid on the original field maps showing the station locations. If there is a discrepancy, the field maps need to be redigitized. The level of accuracy of station locations depends on the map scale, the presence of nearby landmarks, and the accuracy of distance measurements by the surveying crew. For stations located on roads and plotted on 7.5' maps, locations are accurate to about 30 meters or better.

The MAP program is used to plot overlay maps, but it can also be used to plot maps of any scale (Figure 1). The map projection is Lambert Conformal Conic with two standard parallels. The default standard parallels are 33 and 45 degrees north, which is suitable for work anywhere in the continental United States. For maps in Alaska, the standard parallels can be set to 60 and 70 degrees north for better results.

Map plotting is a two step procedure. First, the MAP program is used to make a batch plot file in the default directory named BATCH.PLT. Then, a second program named VIEW reads the batch file and makes the actual plot. See the next section of this report for a description of the VIEW program.

To run the MAP program, first change to the directory containing the location data file (LOC.DAT) and type MAP<Enter>. The program will print a menu (Figure 4). Then, enter macro 11 to open the location file.

Menu options 1, 6, 7, 9, and 16 are optional commands used to set up the plot, and, if used, these options should be entered before option 2. These options are not needed for plotting overlay maps but are useful for other applications.

Enter option 2 to plot the map frame. The program will prompt for the minimum and maximum latitudes to plot in degrees and minutes. Enter these values on one line, with numbers separated with commas, e.g. "44,0,44,7.5". Similarly, the program will prompt for the minimum and maximum longitudes to plot in degrees and minutes. For the purposes of this program positive latitudes are north and positive longitudes are west. Next, the program will prompt for map scale. Enter a scaling factor number e.g. for a 1 to 250,000 scale map, enter 250000<Enter>. Finally, the program will prompt for the grid interval in minutes. The program will plot tick marks on the map at this grid interval. Recommended grid interval values for selected map scales are shown below.

```
USGS Computer Program MAP; Version 1.10; June 7, 1989
         Compiler: Microsoft FORTRAN V4.000

H = Print description of macros
1 = Specify plot type
2 = Initialize plot and plot frame
3 = Terminate plot
4 = Plot locations
5 = Plot locations at any position
6 = Set symbol type and size
7 = Enter min,max locations to plot
9 = Enter label size/symbol size
10 = Find min,max coordinates in location file
11 = Open location file
14 = Plot boundaries from digitizing tablet
15 = Plot boundaries from DOD data base
16 = Enter istep of locations to plot
99 = Stop program

> _
```

Figure 4. MAP program main menu.

Map scale	Recommended Grid Interval
1:24,000	2.5'
1:62,500	5.0'
1:125,000	7.5'
1:250,000	15.0'
1:500,000	30.0'

Next, enter option 4 to plot locations, option 3 to terminate the plot, and option 99 to stop the MAP program and return to DOS. The VIEW program can now be used to convert the file BATCH.PLT to an actual plot.

Instead of typing commands into the MAP program (interactive mode), it is also possible to run the program in batch mode. To run in batch mode, create a file using a text editor program which contains all the necessary plotting commands (Figure 5). Then, enter the command:

```
MAP <infile
```

where infile is the name of the file containing the plot commands. As before, the program will produce a plot file named BATCH.PLT.

```
11              (Open LOC.DAT file)

2               (Start plotting map frame)
44,0,45,0       (Min,max latitude)
69,0,70,0       (Min,max longitude)
750000          (Map scale; no commas)
30              (Grid interval in minutes)

4               (Plot locations)

3               (Stop plotting)

99              (Stop program)
```

Figure 5. Sample input file for use of MAP program in batch mode. A batch file can be entered using any text editor program.

PRE-EXPERIMENT ACTIVITIES: PLOTTING BATCH FILES (VIEW PROGRAM)

The MAP and RECSEC programs are capable of generating disk files containing plot commands which can be used to drive many different kinds of output devices. A second program named VIEW is used to read these disk files (plot files) and actually create the plot. The VIEW program is mainly useful for making map plots. For large record section plots, the program is very slow, and it is usually better to make these plots directly from the RECSEC program.

```
IOMO ioport, model.
 Current:    99     99
 99,99 = IBM Color Monitor   9600,20 = HP7470A Plotter (COM1)
 0,3 = IBM Graphics Printer  9600,51 = Houston Plotter (COM1)
 0,62  = Laserjet Printer 150 dpi.
FACT f.
 Current :   0.750
 f      = Scaling factor
ORIG xorg,yorg.
 Current :   0.000   0.000
 xorg,yorg = x,y coords of origin (in)
NEWP inp.    Set line width.
 Current:    1
 inp = Line width (1 to 27 dots, pen strokes)
PLOT filename.  Begin plotting.
 Blank filename = batch.plt
EXIT or QUIT.   Stop program.

Enter four letter command followed by one space,
followed by arguments separated by commas.
```

Figure 6. VIEW program main menu.

To run the VIEW program, type VIEW<Enter>. The program will print a menu (Figure 6). The current value of each option is printed next to each option in the menu. Change the values of the options until they are correct, and then enter the PLOT command to begin plotting. When more than one number is entered on the same line, they must be separated by commas.

The IOMO command sets the plotter type. For plots to the computer screen, it is usually necessary to set the scaling factor, FACT, to 0.75. For plots to other devices, set FACT to 1.00 for a 1:1 scale plot.

The ORIG command resets the plot origin, allowing plots to be made at different positions on the printed page.

The NEWP command sets the width of all plotted lines. For a bold appearance, set NEWP to 2 or 3.

The EXIT or QUIT commands terminate the program and return to DOS.

ACTIVITIES DURING EXPERIMENT: ENTERING SHOT TIMES AND INSTRUMENT DATA (SCR PROGRAM)

After the shots have been fired and the instruments have been retrieved from the field, shot times and instrument data are entered into the computer with the SCR program (Figure 1). Shots are assigned shot sequence numbers which normally count upwards from one, so that shot one is the first shot fired, shot two is the second shot fired, etc. Although it is not recommended, shot number gaps may be left in the shot list.

```
                         Shot Editing Menu

New England, 1988


        S :  Enter info for one shot into shot list

        P :  Print shot list

        D :  Enter digitizing parameters

        T :  Print digitizing parameters

        E :  Exit to main menu
```

Figure 7. SCR program shot editing menu.

To enter shot times, run the SCR program and enter the S command from the main menu (Figure 2). The program then displays the shot editing menu (Figure 7). Enter S to enter one shot into the shot list. The program prompts for shot number (=shot sequence number) and shot point number. Shot point number is the location number of the shot point being entered. By this time the shot point location will already have been entered into the computer. Then, the program prompts for the shot date, which is usually entered in local time. The shot date is not used in further processing, but it appears in printouts of shot lists. Next, enter the shot time in day of year, hours, minutes, and decimal seconds. The shot time is UCT (GMT) time and should be corrected for any delays in the shooting system. The shot time is usually determined using a strip chart playback comparing the shooting clock time with the blasting cap detonation pulse. Next, the program prompts for shot size, which may be entered either in units of kilograms or pounds. The program then returns to the shot editing menu, and another shot may be entered with the S command.

The P command prints the shot list. Any errors can be corrected by reentering the S command. The D and T commands are used for entering digitizing parameters. They will be discussed in a later section of this report.

```
                         Team Editing Menu

 New England, 1988


          S :  Enter new data for one team-deployment

          T :  Delete data for one team-deployment

          P :  Print team-shot list

          D :  Edit distance signs

          E :  Exit to main menu
```

Figure 8. SCR program team editing menu.

When observer teams return from the field, they fill out "blue sheets" which specify which instrument was deployed at which station, and how the attenuation controls of each instrument were set. This information must be typed into the computer using the T command from the SCR main menu (Figure 2). The program displays the team editing menu (Figure 8). To enter new blue sheet data use the S command from the team editing menu. The program prompts for the minimum and maximum shot numbers for the data to be entered. These are the smallest and largest shot numbers for which the instruments were not physically moved (one deployment of the instruments). Then, enter the team number, a number from 1 to 6. Then, enter the location number at which each instrument was deployed or press Enter if an instrument was not deployed. When all location numbers have been entered, enter attenuation numbers for each instrument (usually, 30 12 48). Press Enter to repeat the attenuation numbers for the next instrument.

From the team editing menu (Figure 8), enter T to delete blue sheet data. Enter P to print blue sheet data on the computer screen. Enter D to enter distance signs. Traces with positive distance signs are plotted to the right on a record section. Traces with negative distance signs are plotted to the left on a record section.

Clock Correction Editing Menu

New England, 1988

W : Enter drifts from white sheet.

M : Manually enter drifts at shot time

S : Shift traces (usually by one second)

E : Exit to main menu

Figure 9. SCR program clock correction editing menu.

The observers enter clock drift values onto the "white sheets", and these values are entered into the computer using the C option in the SCR main menu. Before entering clock drifts, shot times and blue sheet data must be entered for the deployment, as described above. From the clock correction editing menu (Figure 9), enter W to enter clock drift values from the white sheet. Responses to program prompts come directly from the white sheet:

Enter HHT set time (day, hour, minute):
Enter HHT check time (day, hour, minute):
Enter predeployment HHT drift (msec):
Enter HHT reset time (day, hour, minute):
Enter HHT recheck time (day, hour, minute):
Enter postdeployment HHT drift (msec):
Enter team number:

Enter set time for each instrument (day, hour, minute):
Enter check time for each instrument (day, hour, minute):
Enter drift for each instrument (milliseconds):

The program prints a table showing the instrument clock drift rate in milliseconds per hour. This table is not stored in the data files, but it is worthwhile to examine the table for instruments with clock drifts greater than 1.00 milliseconds per hour. These instruments have clocks which need to be adjusted.

After the user enters the minimum and maximum shots in the deployment, the program calculates instrument clock drifts at each shot time and writes these values to the team data. The calculated clock drifts are accurate as long as the HHT and instrument clocks drift linearly. If they do not drift linearly, some error will be introduced, and the amount of error depends on the drift characteristics of each clock. In order to minimize uncertainties in instrument clock drifts, the clocks are set immediately before the instruments are deployed, the instruments are left in the field for the shortest possible time, and the clocks are checked immediately after the instruments are picked up. We estimate that most clock drifts are accurate to about 10 milliseconds, but a few have larger drifts, due to inaccurate clocks and clerical errors.

The M option in the clock correction editing menu (Figure 9) is used to enter clock drift values directly into the data files without using an interpolation scheme. The program prompts for the minimum and maximum shot numbers to enter drifts, and then prompts for team number. Enter a team number between 1 and 6. The program then prompts for the clock drift value in msec for each instrument in the specified team. The program writes these same drift values to the disk for all specified shots.

Occasionally, SCR clocks are set to a time which is incorrect by an even multiple of one second. This error will be noticeable when record sections are plotted. If arrivals for one instrument appear to be late, they can be corrected by adding one second to the clock drift values for the instrument. The S option in the clock correction editing menu (Figure 9) is used to add or subtract time from the clock correction values for a particular instrument. The program prompts for the instrument number for traces to shift, the time in milliseconds to be added to the clock drift values, and the min, max shot numbers to shift. The specified amount of time is then added to the drift values of the specified instrument for all specified shots.

ACTIVITIES DURING EXPERIMENT:
DIGITIZING CASSETTE RECORDER TAPES
(DTS PROGRAM)

After locations, shot times, blue sheets, and white sheets have all been entered, digitizing cassette tapes can proceed. The DTS program (Figure 1) calculates the digitizing start time according to the formula:

$$td = tshot + ts + abs(dist) / vreduc + cor \qquad (2)$$

where,

td = digitizing start time,
tshot = shot time,
ts = reduced start time,
dist = shot point to recorder distance,
vreduc = digitizing reduction velocity, and
cor = instrument clock drift at shot time.

If any of the above parameters are incorrect at digitizing time, the digitizing start time will be off, but unless the time is off by many seconds, it won't matter too much since the program that converts from raw files to SEGY files uses the current values of dist, vreduc, and cor. If the start time is far off, the digitized data may not include the desired seismic arrivals. In this case, the cassette tape will need to be redigitized.

In general, it is not necessary to enter clock drifts before digitizing, since clock drift values are usually small (less than one second). Shot point and station locations can be approximate (within about 5 km). Shot times should be correct to within about one second.

The digitized data is stored in "raw files" with one file per data trace. At the beginning of each raw file is a header block 28 bytes long:

Byte number	Variable	Type	Description
1	errlt	int	Error light code
3	day	int	Start time (day)
5	hour	int	Start time (hour)
7	min	int	Start time (minute)
9	sec	double	Start time (seconds)
17	sint	double	Sampling interval (msec)
25	nsave	long	Number of samples

The digitized data, in multiplexed form, follows the header block. The samples are stored as 16 bit integers (int variables). All raw file names begin with R, followed by a three digit shot number and a three digit instrument number, e.g. file R012.038 contains data for shot number 12, instrument number 38.

Before digitizing, it is necessary to enter digitizing parameters in the data. To do this, enter S from the SCR program main menu (Figure 2). Then, enter D from the shot editing menu. The program will prompt for minimum and maximum shot numbers and the number of samples per trace. In the current implementation the sampling interval is fixed at 5 milliseconds, so the number of samples is:

$$nsave = (tl / sint) + 1$$

where tl is the trace length in seconds and sint in the sampling interval. In order for the time to decode properly, each digitized trace must be at least 16 seconds long. The maximum trace length is limited only by the SEGY file format. In SEGY files, the maximum trace length is 32767 samples (about 164 seconds at 200 samples per second). The program then prompts for the digitizing reduction velocity (vreduc) and the reduced start time (ts). Recommended values for digitizing parameters are:

```
nsave  = 8001 samples                (40 seconds of data)
vreduc = 8 kilometers per second
ts     = -1 second
```

```
        Warning: Program will crash if tape stop button
                 is pressed while program is digitizing

  Digitizing unit 11.  Press Enter to interrupt acquisition...

                       MOST RECENT TAPE BUFFER
           Released  step    SCR
            Buffer   (sec)   unit   ires   Buffer start
              1      0.0050   11      6   274:06:06:41.220

                       NEXT SHOT TIME WINDOW
              Next      Window                 Seconds
             Window   start time     nsave      to go
                7  274:06:06:10.900  8001         2

        Next     Samples   Samples written   File written
       buffer     to go       to disk          to disk
          1        7196         7748            R035.011

                       Error light is OFF

  Digitize another tape (y or n)?
```

Figure 10. DTS program digitizing status screen.

To start the digitizing, change to the experiment working directory and type DTS<enter>. The program prompts for the minimum and maximum shot numbers to digitize. Enter the shot numbers for all shots recorded on one side of an analog cassette tape. Then, enter the instrument number of the first tape to be digitized. The program then calculates the time windows to be digitized for this tape. The next screen display (Figure 10) shows the progress of digitizing, including the most recent tape buffer digitized, the next shot time window to be saved to disk, and how many samples have been written to disk for the current shot. At the bottom of the screen is an error light indicator, which displays the status of the error light on the front panel of the time code translator. When the error light is on, no data will be saved to disk.

The program waits for the error light to go off. When the light is off, the program continuously digitizes 16 second long buffers of data from the tape and decodes the time using a software time code translator. The system is double buffered so that while one buffer is filling with data, the other one is being decoded. When the time code agrees with the computed digitize time, the appropriate data samples are written to the disk. After the desired number of samples have been written to the disk, the program keeps reading the time code until the next shot window. If it is necessary to stop digitizing, press <enter> on the keyboard before pressing the tape stop button. After all tapes for one team have been digitized, the raw data files should be archived to digital cassette tapes or to the optical disk.

ACTIVITIES DURING EXPERIMENT: ARCHIVING FILES TO DIGITAL CASSETTE TAPE (TAPE PROGRAM)

Digitized raw files can be permanently archived to digital cassette tape using the Everex tape backup unit built into the digitizing computer system. After each team digitizes all analog tapes for one deployment they are backed up to digital tape. Each digital tape has a capacity of 40 megabytes. Backup and restore functions are accomplished with a tape utility program (TAPE) supplied by the manufacturer of the tape drive. To run the TAPE program, simply type "TAPE". The TAPE program main menu will be displayed.

To backup raw files "by file", press F5 from the TAPE program main menu. Then type in the name of the files to be backed up, e.g. "D:\NEWENG\R0*.*". Then insert the cartridge in the tape drive and press F8. After all have been backed up, press F10 <Enter> to return to the main menu. Then, press F10 <Enter> again to leave the TAPE program. Finally, delete the raw files from the hard disk by typing "DEL R0*.*".

To restore files from tape to the hard disk, press F7 from the TAPE program main menu. Press F3 to display the contents of the tape. To restore the entire tape to disk, enter the dataset number as 0. Then, press F8 to begin restoring data. When the program asks whether to pause before each dataset, press N. After all data has been restored and the tape has rewound, press Enter to continue. Then, press F10 <Enter> F10 <Enter> to leave the TAPE program.

The TAPE program is capable of doing many other functions. For further information, see the user's manuals for the Everex EXCEL streaming tape.

ACTIVITIES DURING EXPERIMENT: ARCHIVING FILES TO OPTICAL DISK (ARCHIVE AND RESTOR PROGRAMS)

Archiving raw files can be done using the IBM 3363 optical disk, which is a write-once, read-many-times (WORM) device with a capacity of 200 megabytes. Each time a file is written to an optical disk cartridge, it permanently uses space on the cartridge. Therefore, it is important to carefully plan which data to write to each cartridge. To make it easier to later convert data from raw files to SEGY files, all raw files for each shot should be written to the same optical disk cartridge. More than one deployment can be written to the same disk cartridge if there is enough unused space on the cartridge.

To archive raw files, run the ARCHIVE program. The program will prompt for the minimum and maximum shot numbers to archive, and then it will copy raw files from the default hard disk directory to the optical disk. All raw files for the same shot are written to a subdirectory on the optical disk with the same name as the raw files. For example, file R012.038 is written to subdirectory \R012 on the optical disk. After the ARCHIVE program copies all files for each shot, it erases the files from the hard disk.

The RESTOR program is used to restore raw files from the optical disk to the hard disk. First, change directories to the appropriate directory on the hard disk. Then, type RESTOR. The program prompts for the minimum and maximum shot numbers to restore. The raw files are then restored and the program stops.

SEGY files or any other files may also be written to optical disk cartridges. If a directory named e:\segy does not exist on the optical disk, create a new directory using the DOS MD command:

```
C:\NEWENG>md h:\segy
```

Then, use the DOS COPY command to copy SEGY files to the optical disk:

```
C:\NEWENG>copy *.sgy h:\segy
```

ACTIVITIES DURING EXPERIMENT: CONVERTING RAW FILES TO SEGY FORMAT (DMX PROGRAM)

Before plotting or other processing can be performed on the data, the raw files must be converted to SEGY files (Barry and others, 1975). SEGY files produced by the DMX program have data samples represented by short (16 bit) integers. The reel and trace header blocks have been modified somewhat for seismic refraction use (Appendix B). All SEGY header modifications are compatible with the Geological Survey of Canada (GSC) format version 2.0. Since DOS data files have no inherent record structure, the headers and traces are simply combined in a continuous byte stream on the disk, with one file per shot. The data words are in the natural format for IBM AT compatible computers (i.e., the bytes are swapped with respect to a true SEGY tape).

Before running the DMX program, all shot point and station parameters should be corrected to the final desired accuracy. In particular, clock drifts should be entered, all locations should be correct, and shot times should be accurate before using the DMX program.

To start the DMX program, type DMX<Enter> (Figure 1). The program will prompt for the minimum and maximum shot numbers to convert. Next, the program will prompt whether the raw files are on the hard disk or the optical disk. The program creates a new SEGY file in the default directory for each shot, and copies raw files either from the optical disk or the default directory on the hard disk.

Only one of the three data channels in the raw files is written to the SEGY files. If channel numbers have been selected using the SELECT program (see section on SELECT program), the program will copy the selected channel for each trace to the SEGY file. If the SELECT program has not been used, the DMX program automatically selects the channel to store in the SEGY file. The program usually selects the highest gain channel which is not clipped. In cases where the medium gain channel is clipped and the low gain channel is dead, the medium gain channel is selected.

In addition to copying data from the raw files, the DMX program copies data from the data files (SHOT.DAT, TEAM.DAT, and LOC.DAT) and this data is stored in the SEGY headers. The SEGY files are named SHxxx.SGY, where xxx is a three digit shot number.

ACTIVITIES DURING EXPERIMENT: PLOTTING RECORD SECTIONS (RECSEC PROGRAM)

The RECSEC program is used to plot record sections from SEGY files (Figure 1). The plot may go either to the monitor screen, to a Houston Instruments DMPL protocol plotter, or to a batch file. The batch file can then be plotted on one of a number of devices using the VIEW program. The VIEW program offers more output devices and several more plotting options than the RECSEC program, but the VIEW program is more cumbersome and slower to use.

```
                        RECSEC Main Menu

segy_open = 0
cor applied

              O :  Open SEGY format file

              D :  Print trace directory

              S :  Edit plot parameters

              P :  Plot record section

              E :  Exit program
```

Figure 11. RECSEC program main menu.

To run the RECSEC program, type RECSEC<Enter>. The RECSEC main menu is then displayed (Figure 11). In the upper left corner of the main menu are two informational lines. The first line displays the value of the variable segy_open. If segy_open is zero, a data file has not been opened by the program. If segy_open is one, a data file is open. The second line tells whether instrument clock drifts will be applied to the data when it is plotted (usually desirable).

The first command to enter is the "O" command, which opens a SEGY format file. Type the name of the SEGY file to open, optionally preceded by the full path name. The program will print several of the SEGY file header values, e.g.:

notif: 10	Number of traces in file,
icode: 3	Format code; 3 = two-byte integer,
sint: 5000	Sampling interval in microseconds,
nsam: 12001	Number of samples per trace,
vred: 8000	Digitizing reduction velocity in m/s.

After a file has been opened, a table of trace header values may be printed by entering the "D" command. The table contains the following values for each trace:

tsnt: 1	Trace sequence number within file,
rstnam: 0101	Station number stored as a text string,
scrs: 0001	Instrument id number stored as a text string,
idist: 119041	Shot to recorder distance in meters,
length: 12001	Number of samples in trace,
isi: 5000	Sampling interval in microseconds,
ictime: -1999	Reduced start time in milliseconds,
errlt: -1	Time code error code, -1 = No error,
gc: 6	Gain constant; Multiply digital counts by gc/10 to obtain ground velocity in millimicrons per second,
gidb: 92	Instrument gain in db = 104 - instrument attenuation setting.

```
  dmin:    0.000    dmax:   90.000      dscale:  0.100

  tmin:    0.000    tmax:    7.000      tscale:  1.000

  ddtic:  10.000    dttic:   1.000

  width:   0.400    wreduc:  8.000
---------------------------------------------------------
 dmin:  Distance in km at left side of distance axis
---------------------------------------------------------
 Press Tab to select next parameter  | Input file:
 Press Esc to return to main menu    |
 Press R to read parameter file      | Output file:
 Press W to write parameter file     |
 Press S to scale plot to screen     |
                                     |
 Enter new value:                    |
```

Figure 12. RECSEC program plot parameter editing menu.

Next, enter the "S" command to display the plot parameter editing menu (Figure 12). Press the Tab key to move from one plot parameter to the next. As each plot parameter is highlighted, the definition of the parameter is displayed. For example, to edit TMIN, press the TAB key until the TMIN variable is highlighted. Then type in the new value and press the ENTER key. Continue in this way until all parameters have been set. The S command will set the dscale and tscale parameters so that the plot will fill the computer screen. The "W" command will write the current plot parameters to the disk as a text file. The "R" command will read a plot parameter file from the disk. Press the escape key (ESC) to return to the RECSEC main menu from the plot parameter editing menu.

From the RECSEC main menu, begin the plot by entering the P command. The program will ask which plot device to use:

1 = Monitor screen
2 = Batch file named BATCH.PLT
3 = Monitor screen and batch file
4 = Plot to file only. Prompt for file name.
5 = Plot to Houston plotter (COM1)
6 = Plot to Houston plotter (COM2)

Currently, Color Graphics Adapter (CGA) and Enhanced Graphics Adapter (EGA) monitors are supported by the program. The Houston Instruments brand plotter must support DMPL protocol. Since, in the current implementation, the plotter is connected to COM1, select option 5 to plot directly to the Houston plotter.

Use the VIEW program to plot a batch file (see section of this report on VIEW program).

ACTIVITIES DURING EXPERIMENT: DUMPING RAW AND SEGY FILES ON THE EVEREX SYSTEM (PRRAW, PRSAMP, PRBRIDH, AND PRTRIDH PROGRAMS)

Four utility programs are available on the Everex digitizing system for dumping raw and SEGY files.

PRRAW prints the header values and data sample values from a raw file.

PRSAMP prints the data sample values from a SEGY file.

PRBRIDH prints binary reel identification header values from a SEGY file.

PRTRIDH prints trace identification header values from a SEGY file.

All of these programs take command line options. To print a description of the command line arguments, type the program name followed by <Enter>. For example, typing PRRAW<Enter> prints a description of the PRRAW program and a list of command line options.

To write the program output to a disk file, redirect the program output. For example, to dump file R001.001 to a text file named R001.DMP, type:

```
PRRAW R001.001 >R001.DMP
```

POST-EXPERIMENT ACTIVITIES: DATA CLEAN UP

At some time after all processing has been completed for an experiment, it may be necessary to change the values of some variables stored in the data files. Data clean up may be accomplished on the Everex system by reentering values, or editing may be done on VAX SEGY disk files using the TRAN4 program (Figure 1).

In general, if data variables on the Everex system are changed, the corresponding SEGY files will need to be rebuilt using the DMX program. Because the raw files do not contain locations, clock drift values, distances, etc, the analog cassette tapes will not, in general, need to be redigitized. If locations, shot times, or instrument clock drifts are changed, the beginnings of traces will appear shifted, but the arrivals will line up correctly on record sections. If the shifts are very large, the seismic arrivals will not appear at all on the traces, and, in these cases, redigitizing will be necessary. The following factors can cause traces to appear shifted on record sections:

1. Incorrect shot times
2. Incorrect instrument clock drifts
3. Instrument clocks set a multiple of 1 second off
4. Shot point or instrument site mislocated
5. Wrong shot or instrument assigned to a location number

If wrong instrument attenuation numbers have been entered into the data files, the amplitudes will be incorrect on true amplitude plots.

Sometimes, the automatic channel selection algorithm (see section on DMX program) will not choose the appropriate or desired data channel. In these cases, the SELECT program is used to manually select data channels (see SELECT program description).

Sometimes, a particular instrument will record something, but no ground motion is observed on record sections. It is probably best to simply delete the raw files for this instrument.

POST-EXPERIMENT ACTIVITIES:
MANUAL SELECTION OF RECORDING CHANNELS
(SELECT PROGRAM)

When data tapes are digitized, three data channels are stored in the raw files, along with the digitized time-code channel. The DMX program reads the raw files and writes one of the three data channels for each instrument-shot to a SEGY format file. The DMX program searches the TEAM.DAT data for the channel number of data to be saved for each trace. If a channel number has not been entered into the TEAM.DAT file using the SELECT program, the DMX program selects a channel on its own.

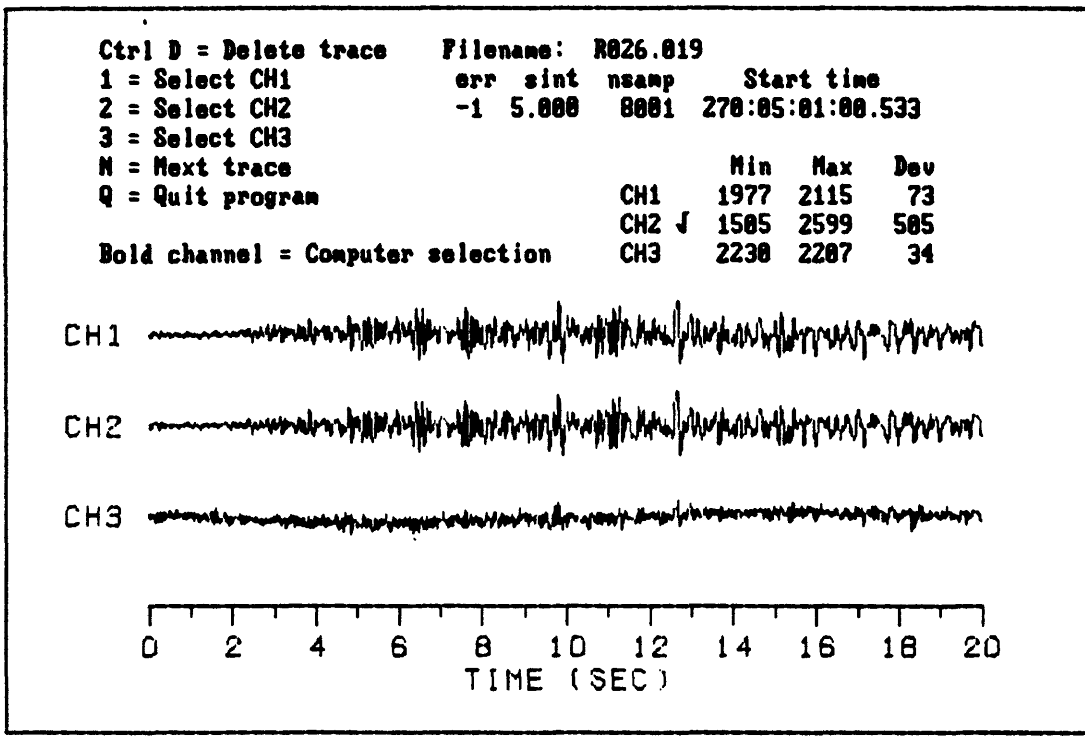

Figure 13. SELECT program interactive display.

A separate program, the SELECT program (Figure 1), is used to interactively select data channels to be written to the SEGY files. Before running this program, the raw files must be available on the hard disk or on an optical disk cartridge. Run the SELECT program by typing SELECT [filename]<Enter> where [filename] is the name of the raw file to be "selected". Wildcard characters (* and ?) are permitted in the file name. If a file name is not specified, the program will select all raw files in the default directory. The program will read raw files, one at a time and plot the first twenty seconds of each data channel on the computer screen (Figure 13).

The following numbers are shown in the top right-hand corner of the display:

Filename:	Name of the raw file currently being displayed
sint:	Sampling interval in milliseconds
nsamp:	Number of samples per channel in the raw file
Start time:	Time of the first sample in the data file as measured by the SCR clock. Times displayed on the time axis are relative to the start time.

The SELECT program will display the computer-selected channel in bold. The user-selected channel will be indicated by a check mark next to a channel number. The user may choose a new channel by pressing a channel number (1, 2, or 3), or if no new channel is chosen, the computer-selected channel will be saved.

Sometimes the displayed data will be completely unusable, if, for example, the geophone is disconnected. In these cases, the raw file may be deleted by entering <Ctrl>D (hold down the Ctrl key and press "D"). To select a channel for the next trace, press, the "N" key. To stop the program, press the "Q" key.

POST-EXPERIMENT ACTIVITIES: UPLOADING DATA TO THE VAX 11/785 (KERMIT AND NFT PROGRAMS)

Data may be uploaded from the digitizing system to the OEVE VAX 11/785 using one of several commercial programs (Figure 1). To upload using a serial port, perhaps the best program to use is KERMIT. An alternative is to transfer data on the Ethernet using the NFT program, which is part of the Decnet DOS data communication package. Both programs can be used to upload either ASCII text files or binary files. Data transfer on Ethernet is much faster than data transfer on a serial port, but an extra interface card is required (3Com IE Etherlink PC Ethernet Network Interface). Uploading one shot using KERMIT takes about 75 minutes, compared to two minutes using NFT.

The KERMIT program is a low-cost commercial communication program which performs error checking to ensure that the files being transferred are not corrupted during the transfer process. Either ASCII text or binary files may be transferred. To upload SEGY files (which are binary) from the Everex system to the VAX, the SEGY files must be stored in disk files on the Everex system. Use the CD command to change directories to the directory containing the data files. Then, type:

```
KERMIT          <Run KERMIT program>
C               <Connect to ROLM system>
<Return>        <Let the ROLM know you're there>
```

The ROLM system will print the prompt:

```
CALL, DISPLAY, OR MODIFY?
```

Type:

```
C GSVAX0
```

After the ROLM system prints "CALL COMPLETE", press <Enter> and log in to the VAX 785 system. Change directories on the VAX to the directory which will contain the data files, e.g.:

```
SET DEFAULT SYS3:[SCRATCH]
```

Now, run KERMIT on the VAX by typing:

```
KERMIT
```

KERMIT will prompt whether you wish to dial out. Press <Enter> to indicate that you don't wish to dial out. Now, <u>for SEGY files only</u>, type:

```
SET FILE TYPE FIXED
```

This will inform KERMIT that you are uploading binary files which are to be stored on the VAX disk with fixed length 512 byte blocks. You can print the file type by typing:

```
SHOW FILE
```

Now, type:

```
RECEIVE         <Get ready to receive file>
Ctrl ] C        <Hold down the Ctrl key and press the ] key.
                Then, release both keys and press the "C" key.>
```

You will be returned to the KERMIT program on the Everex system. Now, begin sending data by typing:

```
SEND <filename>
```

where filename can be any file name. Wild card characters (* and ?) may be used. The files will then be uploaded to the VAX. When uploading is complete, press C<Enter> to return to the VAX KERMIT program, and type exit to stop the VAX KERMIT program. After logging out of the VAX computer, type:

```
Ctrl ] C        <Return to Everex>
HANGUP          <Hang up ROLM phone line>
EXIT            <Exit Everex KERMIT program>
```

In order to upload files using NFT, several memory resident programs must be loaded into the Everex system. To do this, simply type "DECNET". Since the DECNET programs use a lot of computer memory, it is necessary to reboot the computer after using DECNET (press the Ctrl,Alt,Del keys simultaneously).

To transfer SEGY files using the NFT program, change directories to the Everex subdirectory containing the files to be transferred. Then, type:

```
NFT
NFT> SET GSVAX0"username password::SYS3:[SCRATCH.subdir]
NFT> COPY/BLOCK filename GSVAX0::
NFT> DIR GSVAX0::
NFT> EXIT
```

where,

filename = any valid file name on the Everex system. Use of wildcard (* and ?) is ok,

"username password" = VAX login account name and password.

To upload text files using NFT, leave out the /BLOCK switch in the above COPY command.

When files are uploaded using the NFT program, the file modification dates are set to the file creation dates on the digitizing computer system. If the modification date of a file on the scratch directory VAX 785 system is more than about four days old, the system will erase the file on the following night. To reset the file modification dates to the current date, log onto the VAX and change directories to the appropriate scratch subdirectory. Then, type:

```
RENAME *.* *.*
```

POST-EXPERIMENT ACTIVITIES: DUMPING SEGY FILE HEADERS ON THE VAX 11/785 (SGHEAD PROGRAM)

Contents of SEGY format disk file headers on the VAX 11/785 can be printed using the SGHEAD program. To run the program, type SGHEAD<Enter>. The program will prompt for the name of the SEGY file and the name of the output device. For output to the terminal screen, send the output to SYS$OUTPUT. The program will then dump the binary file header variables and the trace header variables for one trace. See the appendix of this report for a description of SEGY header variables.

Header values can also be printed using the SEGLIST, TRAN4, and RSEC89 programs, which are documented elsewhere.

For a low level dump of file contents, use the VAX/VMS DUMP utility.

POST-EXPERIMENT ACTIVITIES: WRITING AND READING SEGY TAPES (FSEGY AND DSEGY PROGRAMS)

The FSEGY program on the OEVE VAX 785 is used to read disk SEGY format files and write true SEGY 9-track tapes suitable for export to other institutions (Figure 1). The DSEGY program reads SEGY tapes and writes disk SEGY files. If you want to create a tape backup of disk SEGY files, it is better to use the VAX VMS BACKUP utility (see VAX VMS documentation).

The header values have been modified to conform with the Canadian Geological Survey (CGS) SEGY format version 2.0. In strict SEGY tape format, each tape reel contains only one file, but the FSEGY and DSEGY programs write or read one file per shot gather.

The FSEGY program writes the text reel header in EBCDIC format, but all text fields in the trace headers are written in ASCII (the variable ccode in the binary reel header is set to 2; see appendix).

All data samples and numeric header values on the tape have "swapped bytes" relative to numbers on the VAX computer. Both the FSEGY and DSEGY programs support either floating point, long integer, or short integer data, but they do not convert from one format to another. Floating point data on disk are in VAX VMS format, while floating point data on tape are in IBM 370 format. See the appendix of this report for a description of SEGY reel and trace header values.

Before running either the FSEGY or DSEGY program, allocate a tape drive with the VAX VMS command:

```
$ ALLOCATE drive
```

where drive = Name of tape drive (MT:, MTA0:, or MTA1:). Then, mount a tape reel on the drive, and set the recording density on the tape drive to either 1600 bpi or 6250 bpi. Now, enter the following commands:

```
$ MOUNT/FOREIGN/BLOCKSIZE=32767 drive
$ ASSIGN drive OUTAPE
```

To write a SEGY tape from disk files, type FSEGY<Enter>. The program will prompt for the name of a SEGY disk file to be written to tape. The program will write data from the disk file to tape and prompt for the name of the next file to write. If another disk file name is entered, the data from the file will be written to another file on tape. If STOP is entered, the program will terminate.

To read a SEGY tape, type DSEGY<Enter>. In the usual mode of operation, the program will create a disk file for each tape file. The first tape file will be written to disk file FILE001.SGY; the second tape file will be written to disk file FILE002.SGY, etc. The program can optionally prompt for disk file names or handle multiple end-of-file marks between files.

To rewind the tape, use the VMS command:

```
$ SET MAGTAPE/REWIND drive
```

POST-EXPERIMENT ACTIVITIES: CONVERTING PDP 11 FORMAT DATA FILES FOR USE IN THE IBM AT/EVEREX DIGITIZING SYSTEM (CHGDAT PROGRAM)

Sometimes, it is necessary to digitize data on the Everex system which has already been digitized on the older PDP 11 system. In order to digitize on the Everex system, all data from the field data sheets must be entered into the data files. Although this information could be typed in using the SCR program, it is usually easier to convert from the old PDP 11 format data files to Everex format data files using the CHGDAT program (Figure 1).

The CHGDAT program converts shot list and team list files from the old PDP 11 system into SHOT.DAT and TEAM.DAT files. Since the CHGDAT program creates new data files named SHOT.DAT and TEAM.DAT, any existing files named SHOT.DAT and TEAM.DAT will be erased. The input files must be in the format written by the DKDAT program on the old PDP 11 digitizing system. Run the DKDAT program on the old system, and enter macros 4 and 14. When prompted by the program for output device, specify that the output should go to ASCII files. The ASCII files can be transferred to the Everex digitizing system in either of two ways.

The first method is to copy the files to an eight-inch floppy diskette, carry the diskette up to the VAX system, and read it using the VAX diskette drives[3]. Install the diskette in drive DYA0:, and enter the following commands:

```
ALLOCATE DYA0:
EXCHANGE COPY DYA0:filename *
```

where filename is the name of a file to be read from the diskette (could include wildcard characters). The files can then be downloaded to the Everex system using the KERMIT program.

The second method is to connect the terminal cable of the PDP 11 system into serial port 2 (COM2) on the Everex system. Then, use a terminal emulator program such as PCPLOT to capture the ASCII shot and team data files. To use the PCPLOT program, first run the program by typing PCP<Enter>. Then, boot the PDP 11 system, using the Everex computer as the system console of the PDP 11 system. Type the following command which will be executed by the PDP 11 system (do not press the return key yet!) :

```
TYPE filename
```

where filename is the name of the ASCII file created by the DKDAT

[3] The VAX diskette drives are sometimes disconnected. See the VAX system manager for assistance.

program on the PDP 11 system. Type <Alt F> to create a new file on the Everex system, and then type <Alt I> to begin accepting data into the new file. Now, press <Enter> to execute the TYPE command which was previously entered. The file will now be transferred. After transfer is complete, type <Alt Q> to close the new file on the Everex system. Repeat the above procedure for the other data file to be transferred. When you are finished transferring data files, type <Alt X> to terminate the PCPLOT program.

Once the shot and team data files have been transferred, run the CHGDAT program on the Everex system to convert them to the correct binary format. The program prompts for the names of the input files, does the conversion, and terminates.

POST-EXPERIMENT ACTIVITIES: CONVERTING PDP 11 FORMAT FILES TO SEGY FORMAT ON THE VAX COMPUTER (FLOP, KDAT, MLOC, AND GSEGY PROGRAMS)

At the USGS, data from experiments between 1977 and 1988 were digitized with an older system, based on the PDP 11/23 microcomputer. To maintain compatibility with the current system, programs are available to convert from the old system to the new system.

PDP 11 format data is stored on eight-inch floppy diskettes encoded in RT11 operating system format. One diskette, known as the "experiment diskette", contains data files named M.LOC and K.DAT. Trace waveform data is stored in files named T.DAT with one file per diskette (the "data diskette"). Generally, there are two data diskettes per shot.

The MLOC program copies the M.LOC file from the experiment diskette to the VAX disk. The KDAT disk copies the K.DAT file from the experiment diskette to the VAX disk. The FLOP program copies trace waveform data from the data diskettes to the VAX disk and, optionally, merges T.DAT files for each shot into one file on the VAX (Figure 1).

All of these programs will prompt for the floppy disk drive to use, DYA0: or DYA1:. Either drive may be used, but if errors occur on one drive, it may be necessary to use the other. When the name of the drive is typed into the computer, the colon (:) at the end of the drive name is required.

To run the MLOC program, change to the directory on the VAX where you would like to copy the files, and type MLOC<Enter>. Mount the experiment diskette in the drive, and press <Enter>. The file named M.LOC will be copied to the VAX. The program then prompts whether you wish to rename the file and prompts for the new file name. The program then renames the file and stops.

The KDAT program works like the MLOC program, except that the K.DAT file is copied to the VAX instead of the M.LOC file.

To run the FLOP program, type FLOP<Enter>. The program prompts for which floppy disk drive to use and then asks the user to mount the first diskette. The program copies the file named T.DAT from a data diskette to the VAX disk and then asks whether to copy another diskette for the same shot. Answer yes to continue copying diskettes for the same shot or answer no to merge T.DAT files into a single new file on the VAX disk. After the T.DAT files have been merged, the program will delete the T.DAT files from the disk. Finally, the program will prompt whether to copy diskettes for another shot. If the answer is yes, the program will restart; if no, the program will stop.

The GSEGY program reads the T.DAT, K.DAT, and M.LOC files from the VAX disk and converts them to SEGY format disk files. To run the program, type GSEGY<Enter>. The program will prompt for the names of the location file, the dkdat file, the new SEGY disk file, and the PDP 11 format data file to convert. Then, the program prints a title line from the PDP 11 format data file and prompts for the shot number. Usually, the shot number can be determined from the title line. The shot number will always be a whole number in the range 1 to 30. The program will then copy and reformat all traces from the PDP 11 format file to the new SEGY disk file. Next, the program will prompt whether to convert another data file using the same experiment disk. If the user types Y<Enter>, the program restarts; otherwise, it terminates.

ACKNOWLEDGEMENTS

I wish to thank the following people for helping create this report. C. McKissick wrote the CHGDAT program for converting PDP 11 format files to SEGY format. R. Catchings reviewed the manuscript. J. Luetgert provided figure 1 and informally reviewed the manuscript.

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APPENDIX
C LANGUAGE INCLUDE FILE FOR SEGY FORMAT HEADER DEFINITION

This appendix consists of the contents of an include file, written in the C language, which specifies header variables for SEGY files. As outlined below, some changes and additions have been made to the SEGY standard.

The time of the first sample of each trace is given by variables in the trace headers, tyear, tday, thour, tmin, tsec, and mst. The time in these variables is relative to the clock time of each recording instrument. To obtain the UCT (Universal Coordinated Time) trace start time, it is necessary to add the time correction value, cor (bytes 185-186 in trace header), to the time of first sample.

Trace waveforms have been "demeaned", so that a value of zero digital counts corresponds to zero ground motion.

Seismic cassette recorder attenuation values are set by rotary switches on three voice-controlled oscillator (VCO) channels. The system gain is 104 db minus the VCO attenuation (Berge and others, 1986), and this number is entered into the SEGY trace header variable gidb (bytes 123-124).

The gain constant, gc (bytes 121-122 in trace header), is a number which when multiplied by the trace amplitude in digital counts gives the velocity of ground motion. For SEGY data stored on tape, the gain constant is in units of millimicrons per second (1 millimicron = 10^{-7} cm). To preserve precision, SEGY files stored on disk have gain constant values which are ten times greater than for SEGY tapes.

```
/*
        INCLUDE FILE FOR C PROGRAMS TO READ AND WRITE SEGY DATA FILES

This file is an implicit definition of SEGY format with additions
for refraction work.  It is the SEGY standard of Barry et al,
Geophysics (1975) with extensions labelled LDS USE and USGS USE for
refraction work.  When used as an include file for a C program, all
variables will be set after reading arrays SEGY1A, SEGY1B, and SEGYDB.

FORTRAN version written by Carl Spencer and Isa Asudeh at the
Canadian Geological Survey.
This version is compatible with version 2.00
*/

#define MAXSEGY 12000             /* Maximum number of short integer samples
                                     in a data record */
  typedef union {
    short s[MAXSEGY];             /* Short data samples */
    long  l[MAXSEGY/2];           /* Long data samples */
    float f[MAXSEGY/2];           /* Float data samples */
  } SEGYSAMPLE;
```

```
/*   ---------------------------------------------------------------
      Binary area of file (or reel) Identification Header starts here.
     Bytes 93-398 of the binary File Identification Header are not used.
     ----------------------------------------------------------------*/

  typedef struct {

/* Job Identification number                                 1 SEGY STANDARD */
    long jobid;

/* Line number                                               5 SEGY STANDARD */
     long lineno;

/* Reel number                                               9 SEGY STANDARD */
     long reelno;

/* Number of data traces per record                         13 SEGY STANDARD */
     short ntrace;

/* Number of auxilliary traces per record                   15 SEGY STANDARD */
     short nauxt;

/* Sample interval in microseconds - this data              17 SEGY STANDARD */
     short sint;

/* Sample interval in microseconds (in field)               19 SEGY STANDARD */
     short sint2;

/* No of samples per trace - this data                      21 SEGY STANDARD */
     short nsam;

/* No of samples per trace (in field)                       23 SEGY STANDARD */
     short nsamf;

/* Data sample format code                                  25 SEGY STANDARD
   icode=0100 (1)    IBM 370 FLOATING POINT                    SEGY STANDARD
   icode=0200 (2)    FIXED POINT (4 bytes)                     SEGY STANDARD
   icode=0300 (3)    FIXED POINT (2 bytes)                     SEGY STANDARD
   icode=0400 (4)    FIXED POINT WITH GAIN                     SEGY STANDARD
   icode=0500 (5)    Institution use                           SEGYLDS
   icode=0600 (6)    Byte and word swapped VAX R*4             SEGYLDS
   icode=0100 (256)  FLOATING POINT - IEEE (eg. MICROSOFT)     SEGYLDS
   icode=0200 (512)  FIXED POINT (4 bytes) - LSB               SEGYLDS
   icode=0300 (768)  FIXED POINT (2 bytes) - LSB               SEGYLDS
   icode=0400 (1024) undefined                                 SEGYLDS
   icode=0500 (1280) institution use                           SEGYLDS
   icode=0600 (1536) VAX R*4                                   SEGYLDS
   icode=0A00 (2560) FIXED POINT 1 BYTE (2'S COMPLEMENT)       SEGYLDS
   icode=0B00 (2816) FIXED POINT 1 BYTE (UNSIGNED)             SEGYLDS      */
     short icode;

/* Number of traces in CDP ensemble                         27 SEGY STANDARD */
     short ncdp;

/* Trace sorting code                                       29 SEGY STANDARD
   itsort=1  as recorded                                       SEGY STANDARD
   itsort=2  CDP ensemble                                      SEGY STANDARD
   itsort=3  Single fold continuous                            SEGY STANDARD
   itsort=4  Horizontal stack                                  SEGY STANDARD
   No LDS or USGS use.                                                      */
     short itsort;

/* Vertical sum code                                        31 SEGY STANDARD
```

```
   vcode=n sum on n traces                                        */
     short vcode;

/* Start sweep frequency (hz)                      33 SEGY STANDARD */
     short ssweep;

/* End sweep frequency (hz)                        35 SEGY STANDARD */
     short esweep;

/* Sweep length in milliseconds                    37 SEGY STANDARD */
     short sleng;

/* Sweep type                                      39 SEGY STANDARD
   stype=1  Linear                                    SEGY STANDARD
   stype=2  Parabolic                                 SEGY STANDARD
   stype=3  Exponential                               SEGY STANDARD
   stype=4  Other                                     SEGY STANDARD
   stype=5  Borehole source                           LDS USE
   stype=6  Water explosive source                    LDS USE
   stype=7  Airgun source                             LDS USE       */
     short stype;

/* Trace number of sweep channel                   41 SEGY STANDARD */
     short nts;

/* Sweep trace taper in milliseconds at start      43 SEGY STANDARD */
     short stts;

/* Sweep trace taper in milliseconds at end        45 SEGY STANDARD */
     short stte;

/* Taper type                                      47 SEGY STANDARD
   ttype=1  Linear                                    SEGY STANDARD
   ttype=2  cos**2                                    SEGY STANDARD
   ttype=3  Other                                     SEGY STANDARD */
     short ttype;

/* Correlated data traces                          49 SEGY STANDARD
   cort=1 no  2 yes                                                 */
     short cort;

/* Binary gain recovered                           51 SEGY STANDARD
   bgr=1  Yes. For USGS data, the data has also been demeaned.
   bgr=2  No                                                        */
     short bgr;

/* Amplitude recovery methods                      53 SEGY STANDARD
   arm=1 none  2 spherical  3 AGC  4 other                          */
     short arm;

/* Measurement system                              55 SEGY STANDARD
   isys=1 meters  2 feet                                            */
     short isys;

/* Polarity                                        57 SEGY STANDARD
   ipol=1 Upward case movement gives negative number  SEGY STANDARD
   ipol=2 Upward case movement gives positive number  SEGY STANDARD */
     short ipol;

/* Vibrator polarity code                          59 SEGY STANDARD */
     short vpc;

/* Number of traces in the file                    61 LDS USE       */
     short notif;
```

```
/* Attribute information                              63 CPSNOV87
   attri=0 velocity/displacement data
   attri=1 instantaneous amplitude
   attri=2 instantaneous frequency
   attri=3 instantaneous phase                                        */
     short attri;

/* Mean amplitude of all samples in all traces in file.  65 CPSNOV87   */
     float meanas;

/* Domain information                                 69 LDS USE
   domain=0 Time - distance
   domain=1 Frequency - wavenumber
   domain=2 Intercept time - slowness */
     short domain;

/* Exponent for sample rate
   SEGY sample is usually in microseconds.  Use this to indicate that units
   for the sample rate are microseconds*(10**msexp) */
     short msexp;

/* Reduction velocity in meters/second if data is reduced 73 CPSNOV87 */
     long vred;

/* Minimum of all samples in the file                 77 CPSNOV87 */
     float minass;

/* Maximum of all samples in the file                 81 CPSNOV87 */
     float maxass;

/* Recording instrument type                          85 USGS USE
   iinstr=1  EDA lunchbox recorder
   iinstr=2  USGS seismic cassette recorder
   iinstr=3  GEOS
   iinstr=4  Springnether
   iinstr=5  Teledyne
   iinstr=6  Kinemetrics
   iinstr=99 Mixed */
     short iinstr;

/* File creation date - Year                          87 USGS USE */
     short cryear;

/* File creation date - Month of year                 89 USGS USE */
     short crmnth;

/* File creation date - Day of month                  91 USGS USE */
     short crday;

/* Disk file format                                   93 SEGYLDS
     = 1  Reel header is 3600 bytes, data is padded to nnb bytes
     = 2  Reel header and data are padded to nnb bytes  */
     short padtyp;

/* Character code                                     95 SEGYLDS
     = 1 EBCDIC
     = 2 ASCII  */
     short ccode;

/* File record length in bytes.                       97 SEGYLDS
   Data are padded to nnb bytes.
   If padtype = 1, then nnb should be >= 240+data length in bytes
   If padtype = 2, then nnb should be >= max(3600, 240+data length in bytes. */
     long nnb;
```

```
/* Byte order within integers                                  101 SEGYLDS
     = '00 01'x  Most significant byte first (eg IBM 370)
     = '01 00'x  Most significant byte last (eg IBM AT or VAX)  */
     short bord;

     char dummy[296];

/* Format version number times 100                             399 USGS USE
     =  99  Version 0.99  October 16, 1986  "Discussion version"
     = 100  Version 1.00  December 5, 1987  "Final version"
     = 200  Version 2.00  January 16, 1989 */
     short fvn;

  } BRIDH;

/*--------------------------------------------------------------------
   Trace Identification Header (total of 240 bytes) starts here
  --------------------------------------------------------------------*/

  typedef struct {

/* Trace sequence number within line -- numbers continue    1 SEGY STANDARD
   to increase if additional reels are required on same
   line. */
     long tsnl;

/* Trace sequence number within reel -- each reel starts    5 SEGY STANDARD
   with trace number one. */
     long tsnt;

/* Original field record number.                            9 SEGY STANDARD
   (Sequential shot number)                                   LDS AND USGS USE */
     long ofrn;

/* Trace number within original field record.              13 SEGY STANDARD
   (Station location number)                                  USGS USE */
     long tnofr;

/* Energy source point number.                             17 SEGY STANDARD
   (Shot point number)                                        USGS USE */
     long espn;

/* CDP ensemble number                                     21 SEGY STANDARD */
     long cdp;

/* Trace number within the CDP ensemble -- each            25 SEGY STANDARD
   ensemble starts with trace number one. */
     long tncdp;

/* Trace identification code                               29 SEGY STANDARD
     1 = Seismic data, 2 = Dead, 3 = Dummy                    SEGY STANDARD
     4 = Time break, 5 = Uphole, 6 = Sweep                    SEGY STANDARD
     7 = Timing, 8 = Water break                              SEGY STANDARD
     9 = Deleted trace                                        USGS USE */
     short tic;

/* Number of vertically summed traces yielding trace       31 SEGY STANDARD */
     short nvs;

/* Number of horizontally stacked traces yielding trace    33 SEGY STANDARD */
     short nhs;

/* Data use (1=production 2=test)                          35 SEGY STANDARD */
     short duse;
```

```
/* Distance from source to receiver                    37 SEGY STANDARD */
    long idist;

/* Receiver group elevation                            41 SEGY STANDARD */
    long irel;

/* Surface elevation of source                         45 SEGY STANDARD */
    long ishe;

/* Shot depth                                          49 SEGY STANDARD */
    long ishd;

/* Datum elevation at receiver                         53 SEGY STANDARD */
    long delr;

/* Datum elevation at source                           57 SEGY STANDARD */
    long dels;

/* Water depth at source                               61 SEGY STANDARD */
    long wds;

/* Water depth at receiver                             65 SEGY STANDARD */
    long wdr;

/* Scalar multiplier/divisor for bytes 41-68           69 SEGY STANDARD */
    short smul1;

/* Scalar multiplier/divisor for bytes 73-88           71 SEGY STANDARD */
    short smul2;

/* Source coordinate X or longitude (East positive)    73 SEGY STANDARD */
    long ishlo;

/* Source coordinate Y or latitude (North positive)    77 SEGY STANDARD */
    long ishla;

/* Group coordinate X or longitude (East positive)     81 SEGY STANDARD */
    long irlo;

/* Group coordinate Y or latitude (North positive)     85 SEGY STANDARD */
    long irla;

/* Coordinate units                                    89 SEGY STANDARD
    1: meters/feet
    2: seconds of arc (smul2 holds multiplier)
    N: mod 100 = TX zone
       div 100 = RX zone */
    short cunits;

/* Weathering velocity (m/s?)                          91 SEGY STANDARD */
    short wvel;

/* Subweathering velocity                              93 SEGY STANDARD */
    short swvel;

/* Uphole time at source                               95 SEGY STANDARD */
    short utimes;

/* Uphole time at group                                97 SEGY STANDARD */
    short utimeg;

/* Source static correction (ms?)                      99 SEGY STANDARD */
    short sstati;

/* Group static                                       101 SEGY STANDARD */
```

```
        short gstati;

/* Total static                                          103 SEGY STANDARD */
        short tstati;

/* Lag time A                                            105 SEGY STANDARD */
        short istime;

/* Lag time B                                            107 SEGY STANDARD */
        short ibtime;

/* Delay recording time (reduced start time) (msec)      109 SEGY STANDARD */
        short ictime;

/* Mute start time                                       111 SEGY STANDARD */
        short mtimes;

/* Mute end time                                         113 SEGY STANDARD */
        short mtimee;

/* No of samples in this trace                           115 SEGY STANDARD */
        short length;

/* Sampling interval in microseconds                     117 SEGY STANDARD */
        short isi;

/* Gain type (1=fixed 2=binary 3=floating)               119 SEGY STANDARD */
        short gaint;

/* Gain constant                                         121 SEGY STANDARD */
        short gc;

/* Instrument or initial gain in DB                      123 SEGY STANDARD */
        short gidb;

/* Correlated 1=no 2=yes                                 125 SEGY STANDARD */
        short tcorr;

/* Start sweep frequency (hz)                            127 SEGY STANDARD */
        short tsswee;

/* End sweep frequency (hz)                              129 SEGY STANDARD */
        short teswee;

/* Sweep length in milliseconds                          131 SEGY STANDARD */
        short tsleng;

/* Sweep type                                            133 SEGY STANDARD
        stype=1 Linear                                       SEGY STANDARD
        stype=2 Parabolic                                    SEGY STANDARD
        stype=3 Exponential                                  SEGY STANDARD
        stype=4 Other                                        SEGY STANDARD
        stype=5 Borehole source                              LDS USE
        stype=6 Water explosive source                       LDS USE
        stype=7 Airgun source                                LDS USE */
        short tstype;

/* Sweep trace taper in milliseconds at start            135 SEGY STANDARD */
        short tstts;

/* Sweep trace taper in milliseconds at end              137 SEGY STANDARD */
        short tstte;

/* Taper type                                            139 SEGY STANDARD
        ttype=1 Linear                                       SEGY STANDARD
```

```
     ttype=2 Cos**2                                   SEGY STANDARD
     ttype=3 Other                                    SEGY STANDARD */
     short tttype;

/* Antialias filter frequency                     141 SEGY STANDARD */
     short aif;

/* Alias filter slope                             143 SEGY STANDARD */
     short ais;

/* Notch filter frequency                         145 SEGY STANDARD */
     short nif;

/* Notch filter slope                             147 SEGY STANDARD */
     short nis;

/* Low cut frequency                              149 SEGY STANDARD */
     short flc;

/* High cut frequency                             151 SEGY STANDARD */
     short fhc;

/* Low cut slope                                  153 SEGY STANDARD */
     short slc;

/* High cut slope                                 155 SEGY STANDARD */
     short shc;

/* Year of start of trace                         157 SEGY STANDARD */
     short tyear;

/* Day of start of trace                          159 SEGY STANDARD */
     short tday;

/* Hour of start of trace                         161 SEGY STANDARD */
     short thour;

/* Minute of start of trace                       163 SEGY STANDARD */
     short tmin;

/* Second of start of trace                       165 SEGY STANDARD */
     short tsec;

/* Time basis code  1=local 2=GMT                 167 SEGY STANDARD */
     short tbcode;

/* Trace weighting factor                         169 SEGY STANDARD */
     short twf;

/* Geophone group number on roll switch first position   171 SEGY STANDARD */
     short ggrp1;

/* Geophone group no. trace position 1 on field record   173 SEGY STANDARD */
     short ggtp;

/* Time code translator error light               175 USGS USE
     Code numbers as generated by the IRIGE translator
     routine:
          0 = Total failure to decode
          1 = 1 Second synch.
          2 = 10 Second synch.
          3 = Minute synch.
          5 = Full time code synch
          6 = Time code + unit number decoded  */
     short errlt;
```

```
/* Distance-azimuth calculation algorithm                177 USGS USE
     1 = Sodano algorithm.  The program utilizes the Sodano and Robinson
         (1963) direct solution of geodesics (Army Map Service, Tech Rep
         #7, Section IV).  */
     short daca;

/* Earth dimension code                                  179 USGS USE
     1 = Fischer spheroid (1960), OMEGA and NASA datums   6378166.   298.30
     2 = Clark ellipsoid (1866), N. American datum 1927   6378206.4  294.98
     3 = Ref ellipsoid (1967), S. American datum          6378160.   298.25
     4 = Hayford International Ellipsoid (1910)           6378388.   297.00
     5 = World Geodetic Survey Ellipsoid (1972)           6378135.   298.26
     6 = Bessel (1841), Tokyo datum                       6377397.   299.15
     7 = Everest (1830), India datum                      6377276.   300.80
     8 = Airy (1936), Ordnance survey of Great Britain    6377563.   299.32
     9 = Hough (1960), Wake-Eniwetok                      6378270.   297.00
    10 = Fischer (1968), Modified Mercury                 6378150.   298.30
    11 = Clarke (1880)                                   6378249.   293.47 */
     short edc;

/* Microseconds of trace start time                      181 LDS USE */
     long mst;

/* Millisecond of timing correction to be added to       185 LDS USE
   reported times to get local or GMT times */
     short cor;

/* Charge size in kg                                     187 LDS USE */
     short charge;

/* Shot time - Year                                      189 LDS USE */
     short syear;

/* Shot time - Day                                       191 LDS USE */
     short sday;

/* Shot time - Hour                                      193 LDS USE */
     short shour;

/* Shot time - Minute                                    195 LDS USE */
     short smin;

/* Shot time - Second                                    197 LDS USE */
     short sseco;

/* Shot time - Microsecond                               199 LDS USE */
     long ssmic;

/* Azimuth of receiver from shot in minutes of arc       203 LDS USE */
     short azimut;

/* Azimuth of geophone orientation axis with respect to  205 CPSNOV87
   true north in minutes of arc */
     short geoazi;

/* Angle between geophone orientation axis and vertical  207 CPSNOV87
   in minutes of arc */
     short geover;

/* Time to be added to recorded trace time to get        209 CPSNOV87
   actual trace start time.  To be used when data has
   been reduced but trace start time is not updated so
   that the actual time can be recovered even if distance
   and shot time have changed (microseconds). */
```

```
     long ttrace;

/* Recording instrument number                             213 LDS USE */
     char scrs[4];

/* Deployment name                                         217 LDS USE */
     char deploy[4];

/* Shotpoint name (shotpoint number)                       221 LDS USE */
     char spname[4];

/* Receiver site name (station number)                     225 LDS USE */
     char rstnam[4];

/* Shot name (shot number)                                 229 LDS USE */
     char shotid[4];

/* Line name                                               233 LDS USE */
     char lineid[4];

/* Geophone orientation eg R40,Z                           237 LDS USE */
     char geoor[4];
  } TRIDH;

/*   End of Trace Identification Header  */
```