

**INSTALLING AND RUNNING THE
TIME-PICKING PROGRAM**

TOMTIME

This is a demo version of TomTime.
It does not write any output files.

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Installing and Running TomTime

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Quick Start

TomTime allows the user to pick traveltimes and amplitudes, and save those data with source and receiver 3-D coordinates in the format used as input by the tomography program GeoTomCG. The most common format is:

Ray Identifier (integer)	Source X, Y, Z	Receiver X, Y, Z	Time	Amplitude (optional)
e.g. 17	10. 0. 155.	120. 0. 145.	35.30	1560

A user who wants to pick traveltimes in the most common seismograph files without reading much of the manual can begin by following the instructions in this section. Only the most commonly used options are described.

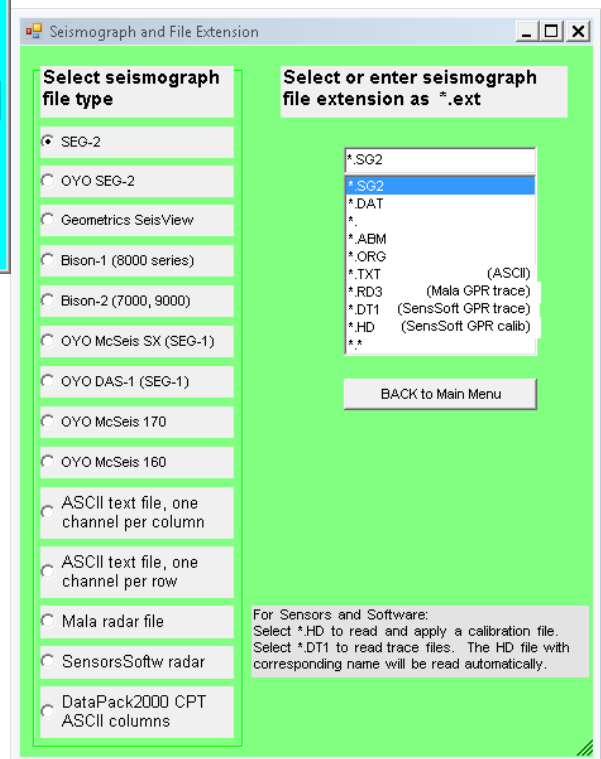
If TomTime is on a CD, run SetupTomTime.exe in the TomTime subdirectory to start the installation. Follow the on-screen instructions. The installation program will install the TomTime

program and sample data files in the chosen subdirectory, and will add TomTime to the Windows list of programs. If installation fails, send an e-mail to sales@geotom.net. If sent by e-mail, the files are in a password-protected compressed file, called TomTime(version).zip. The password is "geotom". Unzip TomTime(version).zip to a subdirectory on your hard disk, then run SetupTomTime.exe and follow the on-screen instructions.



To start TomTime, click on the name in the Windows program list. The program will start and display the program title and company name. Click **Continue** or press the **Enter** key to display the main program menu, shown above.

Click **Select Seismograph and File Extension** to go to the next form, shown to the right. The most common file type from modern exploration seismographs is SEG-2, so select SEG-2 in the left column unless you know it is something else. In the right column, select the extension for your seismograph files, usually SG2 or DAT. Then click **BACK to Main Menu**.



Next click **Display Waveforms and Pick Times**. Select the drive, subdirectory, and seismograph file you want to read. TomTime checks the seismograph files in the selected subdirectory for conformance with the specified file type. If they do not match, the file name will not be displayed. After selecting the file you want, click **READ FILE** to display the next form and click **CONTINUE** on it to display the form shown here. It comes from reading the example file GeomSEG2.SG2. It has source and receiver coordinates in header lines in the seismograph file, used as Z coordinates by TomTime. You can revise the source and receiver coordinates by clicking **NO** and entering new values. The receiver X coordinates were revised to 20.0 for this form. Click **YES** to display the waveforms from the seismograph to pick traveltimes.

Source X 0.000
Source Y 0.000
Source Z 98.000

Source and Rec Locs OK?

Revise Display Trace

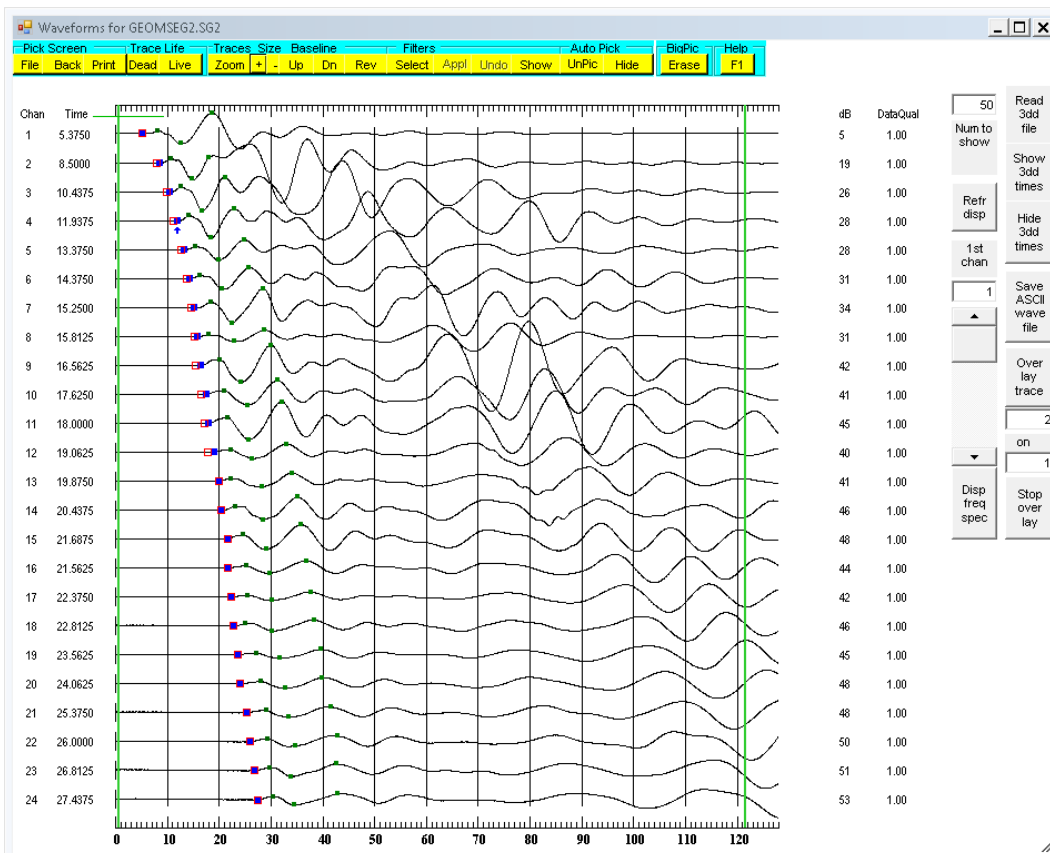
Trace Display
 Clipped
 Shaded

Whole trace
 First half only
Maximum time 128
traces to display 72

Auto pick
 First break Peak
Skip initial time 0

Channel	RecX	RecY	RecZ	Stacks
1	20.000	0.000	100.000	3
2	20.000	0.000	102.000	3
3	20.000	0.000	104.000	3
4	20.000	0.000	106.000	3
5	20.000	0.000	108.000	3
6	20.000	0.000	110.000	3
7	20.000	0.000	112.000	3
8	20.000	0.000	114.000	3
9	20.000	0.000	116.000	3
10	20.000	0.000	118.000	3
11	20.000	0.000	120.000	3
12	20.000	0.000	122.000	3
13	20.000	0.000	124.000	3
14	20.000	0.000	126.000	3
15	20.000	0.000	128.000	3
16	20.000	0.000	130.000	3
17	20.000	0.000	132.000	3
18	20.000	0.000	134.000	3
19	20.000	0.000	136.000	3
20	20.000	0.000	138.000	3
21	20.000	0.000	140.000	3
22	20.000	0.000	142.000	3
23	20.000	0.000	144.000	3
24	20.000	0.000	146.000	3

While displaying waveforms, click **Pick** under **Auto Pick** to make TomTime pick traveltimes. As needed, manually adjust first-arrival times shown as red outlines with blue interiors by clicking the left mouse button first to select the channel and then to pick the times. The waveform display after manual adjustment in several channels is shown below.



The red outlines are the auto picks, and the blue squares are the manual picks. The small green squares are amplitudes, not covered in this Quick Start.

When you are satisfied with the first-arrival times, click **File** to display the form shown to the right. If you are satisfied with the coordinates and file name for saving, click **WRITE 3PK FILE TO DISK** to save a file containing the information shown in the list box. You may get an error message if you try to write in the same subdirectory as the TomTime program because of your computer's security settings.

Channel	SorX	SorY	SorZ	RecX	RecY	RecZ	Time+correction	DataQual
1	0.00	0.00	98.00	20.00	0.00	100.000	5.2500	32317
2	0.00	0.00	98.00	20.00	0.00	102.000	7.8750	103455
3	0.00	0.00	98.00	20.00	0.00	104.000	9.8750	49785
4	0.00	0.00	98.00	20.00	0.00	106.000	11.1250	41265
5	0.00	0.00	98.00	20.00	0.00	108.000	12.6875	25068
6	0.00	0.00	98.00	20.00	0.00	110.000	13.8125	19434
7	0.00	0.00	98.00	20.00	0.00	112.000	14.6250	20355
8	0.00	0.00	98.00	20.00	0.00	114.000	15.3125	9537
9	0.00	0.00	98.00	20.00	0.00	116.000	16.8125	8029
10	0.00	0.00	98.00	20.00	0.00	118.000	17.5000	6435
11	0.00	0.00	98.00	20.00	0.00	120.000	18.2500	6020
12	0.00	0.00	98.00	20.00	0.00	122.000	18.7500	4628
13	0.00	0.00	98.00	20.00	0.00	124.000	19.8750	3989
14	0.00	0.00	98.00	20.00	0.00	126.000	20.4375	3302
15	0.00	0.00	98.00	20.00	0.00	128.000	21.6875	3156
16	0.00	0.00	98.00	20.00	0.00	130.000	21.5625	2327
17	0.00	0.00	98.00	20.00	0.00	132.000	22.3750	1918
18	0.00	0.00	98.00	20.00	0.00	134.000	22.8125	1643
19	0.00	0.00	98.00	20.00	0.00	136.000	23.5625	1575
20	0.00	0.00	98.00	20.00	0.00	138.000	24.0625	1561
21	0.00	0.00	98.00	20.00	0.00	140.000	25.3750	1488
22	0.00	0.00	98.00	20.00	0.00	142.000	26.0000	1443
23	0.00	0.00	98.00	20.00	0.00	144.000	26.8125	1393
24	0.00	0.00	98.00	20.00	0.00	146.000	27.4375	1145

Then write the file in some other subdirectory. After you click **WRITE 3PK FILE TO DISK**, the form for selecting additional seismograph files will be displayed so you can pick more traveltimes. After you have picked all the files you want to, click **BACK** to return to the main menu.

The final step is to combine the separate 3PK files into one data file for GeoTomCG. On the main menu, click **Select 3PK Files for Time and Amplitude Data File** to display the form on the right. Highlight all the files you want and click one of the **Save As** buttons. The selected 3PK files will be combined into one file with sequential raypath numbers.

Keep or omit rays with times ≤ 0 when making files?

Omit
 Keep

Save As *.3dd File, time without data quality

Save As *.3dw File, time and data quality

Save As *.tam File, time and first amplitude

Save As *.13a File, time and three amplitudes

BACK to Main Menu

Comienzo Rápido (Quick Start in Spanish)

Translation to Spanish courtesy of José R. Arce A.
Technical Manager, José Arce Geofísicos S.R.L., Lima, Perú

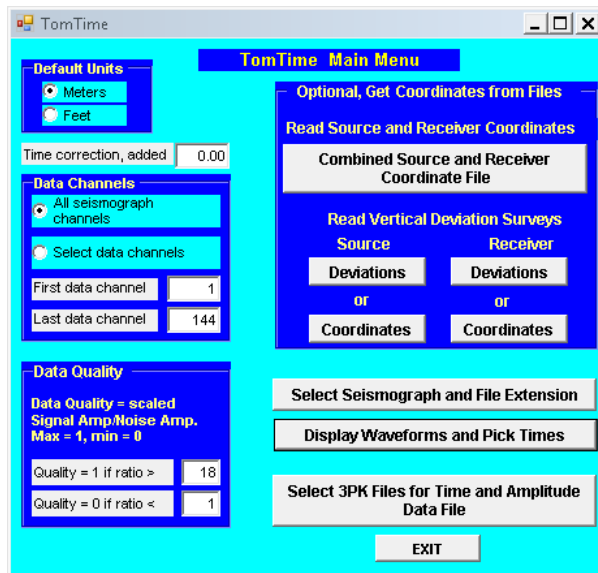
TomTime permite que el usuario escoja tiempos y amplitudes, así como incluir las posiciones en el espacio de la fuente de señal y de los receptores en coordenadas 3-D. El formato de entrada utilizado por el programa de tomografía GeoTomCG es:

	Traza	Fuente X, Y, Z	Receptor X, Y, Z	Tiempo	Amplitud (opcional)
e.g.	17	10. 0. 155.	120. 0. 145.	35.30	1560

Un usuario que quisiera escoger tiempos de los archivos del sismógrafo sin leer el manual, puede comenzar siguiendo las instrucciones que se encuentran en esta sección. Solamente se describen las opciones más comunes de uso.

Si TomTime está en un CD, active SetupTomTime.exe en el subdirectorio de TomTime para comenzar la instalación. Siga las instrucciones en pantalla. El programa de instalación instalará los archivos y directorios del programa de TomTime, así como los datos de ejemplos en el subdirectorio elegido, y agregará TomTime a la lista de programas de Windows. Si la instalación falla, envíe un email a sales@geotom.net. Si son enviados por email, los archivos estarán en un archivo comprimido

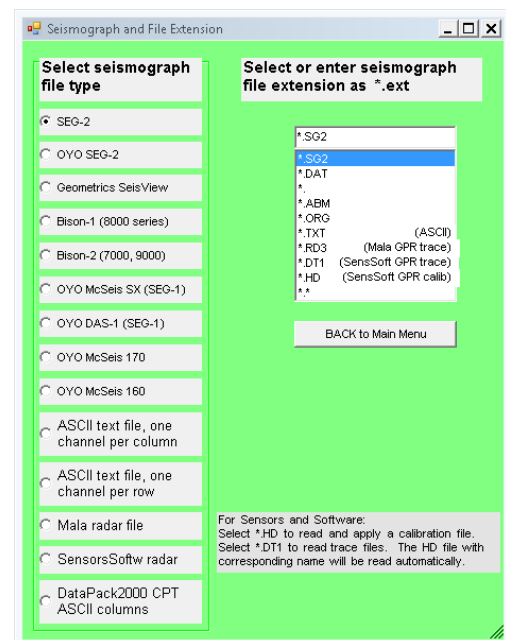
y protegido con contraseña, llamado TomTime(versión).zip. La contraseña será "geotom". Descomprima TomTime(versión).zip a un subdirectorio en su disco duro, después active SetupTomTime.exe y siga las instrucciones de la pantalla.



Para comenzar TomTime, haga clic en el nombre, en la lista de programas de Windows. El programa comenzará y exhibirá el título del programa y el nombre de compañía. Haga clic en **Continue** o pulse la tecla **Enter** para mostrar el menú principal del programa, mostrado a la sobra.

Haga clic en **Select Seismograph and File Extension**

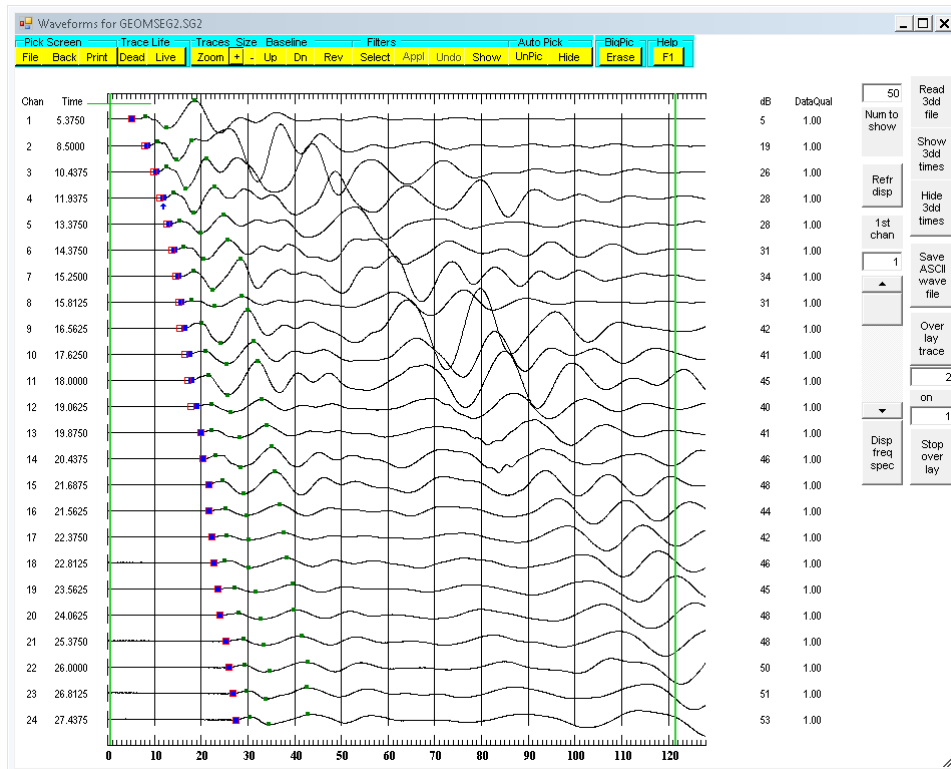
para ir al siguiente recuadro, mostrado a la izquierda. El formato de archivo sísmico de uso más común en los sismógrafos modernos de exploración es SEG-2, así que seleccione SEG-2 en la columna izquierda, a menos que usted esté seguro que sus datos están en otro formato. En la columna derecha, seleccione la extensión de sus archivos de datos, siendo los más comunes SG2 o DAT. Después haga clic en **BACK to Main Menu**.



Ahora seleccione **Display Waveforms and Pick Times**. Seleccione el disco de datos, subdirectorio, y el archivo del sismógrafo que usted quiere leer. TomTime comprobará los archivos de sismógrafo en el subdirectorio seleccionado para saber si son compatibles con el tipo de archivo previamente especificado. En caso no fueran compatibles, no se mostrará el nombre del archivo leído. Después de seleccionar el archivo que usted quiere, haga clic en **READ FILE** para continuar al siguiente formulario seleccione **CONTINUE**, para mostrar la ventana que se ve acá, la cual resulta de leer el archivo de ejemplo GeomSEG2.SG2. Este archivo tiene las coordenadas de la fuente y receptores en el encabezado, las cuales se usarán como coordenadas Z por TomTime. Usted puede corregir las posiciones de la fuente y el receptor seleccionando **NO** y añadiendo nuevos valores. Las coordenadas del receptor X fueron cambiadas a 20.0 en este ejemplo. Pique **YES** para exhibir las trazas del sismógrafo para determinar y seleccionar tiempos de llegada.

Channel	RecX	RecY	RecZ	Stacks
1	20.000	0.000	100.000	3
2	20.000	0.000	102.000	3
3	20.000	0.000	104.000	3
4	20.000	0.000	106.000	3
5	20.000	0.000	108.000	3
6	20.000	0.000	110.000	3
7	20.000	0.000	112.000	3
8	20.000	0.000	114.000	3
9	20.000	0.000	116.000	3
10	20.000	0.000	118.000	3
11	20.000	0.000	120.000	3
12	20.000	0.000	122.000	3
13	20.000	0.000	124.000	3
14	20.000	0.000	126.000	3
15	20.000	0.000	128.000	3
16	20.000	0.000	130.000	3
17	20.000	0.000	132.000	3
18	20.000	0.000	134.000	3
19	20.000	0.000	136.000	3
20	20.000	0.000	138.000	3
21	20.000	0.000	140.000	3
22	20.000	0.000	142.000	3
23	20.000	0.000	144.000	3
24	20.000	0.000	146.000	3

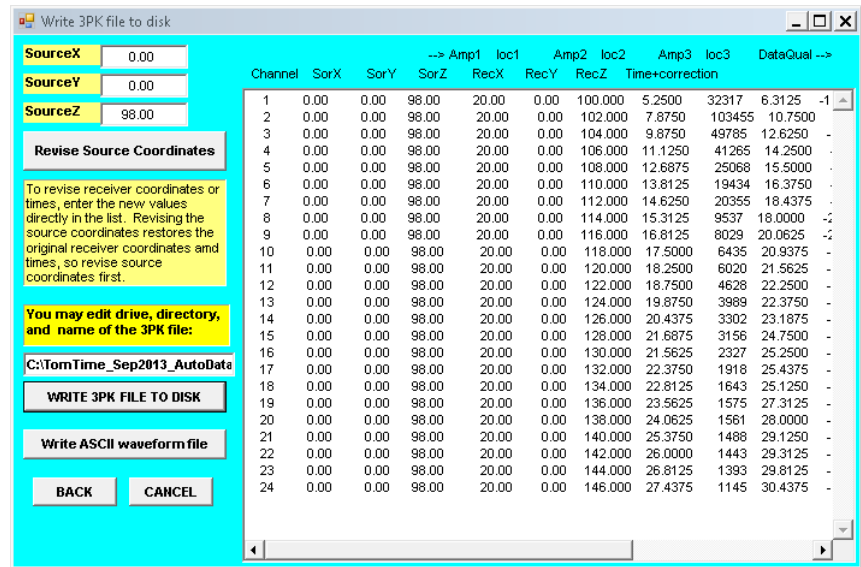
Mientras se exhiben las trazas, haga clic en **Pick** debajo de **Auto Pick**, para que TomTime escoja tiempos de manera automática. De acuerdo a lo necesitado, ajuste manualmente los tiempos de la primera llegada, mostrados con cuadrados rojos con relleno azul, marcando con el botón izquierdo del ratón, primero para seleccionar el canal y después para escoger los tiempos. La pantalla de trazas,



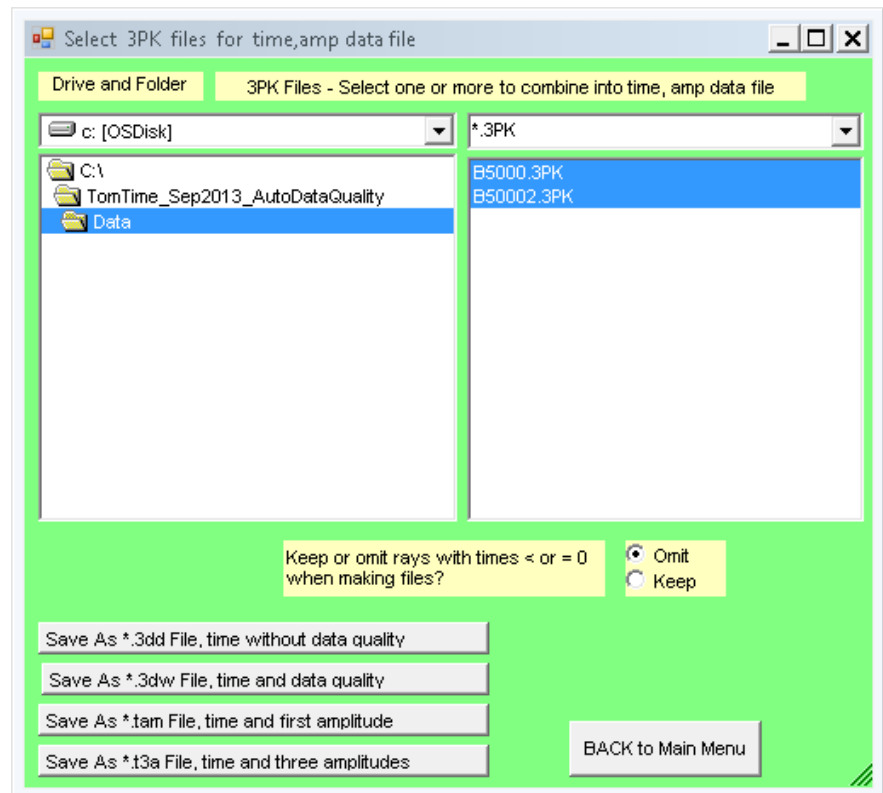
luego de ajustar varios canales, se muestra a continuación.

Las marcas rojas son las selecciones automáticas, y los cuadrados azules son las selecciones manuales. Los pequeños cuadrados verdes son amplitudes, las cuales no se comentan en esta Guía de Inicio Rápido.

Cuando esté satisfecho con los tiempos de las primeras llegadas, haga clic en **File** para exhibir la ventana mostrada a la derecha. Si le satisfacen las coordenadas y nombre de archivo a utilizar, seleccione **WRITE 3PK FILE TO DISK** para grabar el archivo que contiene la información listada. Si intenta escribir el archivo en el mismo directorio donde está instalado TomTime, dependiendo de la configuración de seguridad de su PC. Si este es el caso, grabe el archivo en otro directorio. Una vez haya seleccionado **WRITE 3PK FILE TO DISK**, la ventana para escoger archivos digitales del sismógrafo será exhibida nuevamente para que pueda escoger más tiempos de llegada. Una vez haya escogido todos las primeras llegadas de sus archivos, puede regresar al menú principal haciendo clic en **BACK**.



El último consiste en combinar los archivos individuales 3PK en un archivo de datos para ser usado por GeoTomCG. En el menú principal, seleccione **Select 3PK Files for Time and Amplitude Data File** para mostrar la ventana de la derecha. Seleccione todos los archivos que usted quiere y haga clic en uno de los botones de **Save As**. Los archivos 3PK seleccionadas serán combinados en un archivo con números secuenciales en sus trazas.



Introduction

TomTime allows the user to pick traveltimes and amplitudes, and save those data with source and receiver 3-D coordinates in the format used as input by the tomography program GeoTomCG. The most common format is:

Ray Identifier (integer)	Source X, Y, Z	Receiver X, Y, Z	Time	Amplitude (optional)
(e.g. 17	10. 0. 155.	120. 0. 145.	35.30	1560

TomTime has several features to facilitate data entry and examination. TomTime reads the coordinates in SG2 seismograph files as Z coordinates. If each receiver borehole has constant X and Y coordinates (negligible deviation) and the receiver spacing is uniform, then the coordinates can be entered easily in TomTime. Two other features reduce the manual entry of source and receiver coordinates in deviated boreholes. First, a source-coordinate file allows the user to assign to each source and receiver position an identifying integer, for example 155 for one source position and 145 for one receiver position. A coordinate file lists each source and receiver position once, giving the identifier and the corresponding coordinates. The source and first receiver in each seismograph waveform file can be designated by identifiers, separated by underscores, added to the waveform file name (e.g. WEST0001_155_145.dat). TomTime can read the coordinate file before reading waveform files, and assign coordinates corresponding to the identifiers. Second, TomTime can read deviation surveys and calculate the X, Y, and Z coordinates from the distance along the borehole.

ASCII files of the waveforms can be written and read, which allows processing with a spreadsheet or other programs that can read ASCII files. It also allows regrouping of the channels. For example, suppose triaxial geophones are used, and each seismograph file contains the waveform from the vertical and horizontal hydrophones. One could form sets of data containing waveforms from only the vertical geophone by writing ASCII files of the data, then combining the desired channels with a spreadsheet.

Times from a 3dd data file from GeoTomCG can be displayed on the waveforms. This feature allows the user to compare the time-picks used for a prior tomographic inversion with the traces. Because GeoTomCG can provide a 3dd file of calculated times, this option also allows the user to display on the waveforms the forward-modeling times calculated by GeoTomCG or by other programs that use a similar data format

Much of TomTime is based on the seismic refraction program SIPWin, produced by Rimrock Geophysics, Inc. It has been revised by GeoTom, LLC for tomography under an agreement with Rimrock Geophysics.

Data files from TomTime have the extension 3PK to distinguish them from SIPWin PIK files, which have a different format. One 3PK file is generated from each waveform file. The user can select which 3PK files to combine and save in a data file for GeoTomCG. Options are:

- a) *.3dd file, contains time but not data quality or amplitude;
- b) *.3dw file, contains time and data quality but not amplitude;
- c) *.tam file, contains time and first amplitude peak but not data quality;
- d) *.t3d file, contains time and all three amplitude peaks but not data quality.

Suggestions for improving TomTime and the documentation are welcome. Suggestions, questions, and problems related to TomTime should be directed to:

Daryl Tweeton

GeoTom, LLC

13785 Diamond Path, Apple Valley, MN 55124

Phone or fax (952) 423-3838

E-mail geotom@frontiernet.net

This version was compiled with MS Visual Studio Basic instead of the older MS Visual Basic 5. Some changes have been made to accommodate changes in the Basic compiler. Use the **BACK** button to close a form, rather than clicking on the **X** in the upper right corner of the form if you will want to return to the form during the same operating session. The **BACK** button resets control parameters needed for going back and forth between forms. Additional changes have been made to reduce clutter in the display, to facilitate handling a larger number of channels. Additional options have been added at the request of users or to facilitate the author's processing of data for clients..

The following changes have been made:

1. The accuracy of automatic picking of traveltimes and amplitudes has been improved.
2. The ability to read Sensors & Software crosshole GPR data was added at the request of Sensors & Software. Detailed instructions are in "**Special options for Sensors & Software radar files,**" starting on page 36.
3. The ability to read data from a DataPack 2000 recorder was added at the request of the Minnesota Department of Transportation. Detailed instructions are in "**Special options for DataPack 2000 seismic data files,**" starting on page 40.
4. The ability to calculate, display, and save data quality based on the amplitude signal-to-noise ratio was added as a result of discussions with Geotomographie.
5. The ability to read and apply borehole deviation surveys was added at the request of Geotomographie
6. Long coordinates from GPS systems can be used for source and receiver positions. The long coordinates must be in the form 1234567.123. GPS readings in degrees, minutes, and seconds of latitude and longitude must be converted to the purely numeric form to be read by TomTime.
7. The keys for moving the amplitude dots have been changed to allow one-click key shortcuts for the most commonly used menu selections. See page 49 for a summary.

Suggestions for improving the software or the manual are always welcome. Suggestions from users are an important source of ideas for improvements.

TomTime is copyrighted. It is distributed without copy protection for the convenience of customers and to reduce the cost. Your cooperation in not copying it illegally will allow GeoTom to continue to offer it without copy protection.

Installing TomTime

TomTime is written in MS Visual Studio Basic. The installation uses the msi method for MS Windows 2000 and later. If delivered on a CD, the CD contains a folder TomTime. If sent by e-mail, the files are in a compressed zip file TomTime(version).zip. Uncompress TomTime(version).zip on your hard disk. If a password is required to uncompress it, the password is geotom . Some virus protection programs block e-mail attachments containing an executable file unless protected by a password. To install TomTime, run SetupTomTime.exe in the folder TomTime on the CD or in the uncompressed files from TomTime(version).zip.

With XP and previous operating systems, you may get a message that Microsoft Net Framework 2 must be installed before installing TomTime. If that happens and TomTime is on a CD, run dotnetfx.exe from the MSNetFramework2 folder. The size of dotnetfx.exe is about 22 MB and the installed Net Framework 2 is about 88 MB. If TomTime was sent by e-mail, download Net Framework 3.5 from <http://www.microsoft.com/en-us/download/details.aspx?id=21>. The 32-bit Net Framework 2.0 is no longer offered on the Microsoft download site. You may get a transfer to the Microsoft Download site for Net Framework 4.0. Net Framework 4.0 has more computer requirements than 2.0 or 3.5 and may not work correctly on an older computer, so go to <http://www.microsoft.com/en-us/download/details.aspx?id=21> and download 3.5.

In addition to the TomTime program, there are example waveform files, example source/receiver coordinate files, example vertical deviation survey files, and these instructions. These files require about 4 MB. The installation will add TomTime to the Windows program menu and add an icon. Security settings on your computer may prevent writing practice 3PK files in the Program Files folder. Copying the example data to a folder outside Program Files or installing TomTime in a folder outside of Program Files will allow you to practice with the example files and write 3PK files.

TomTimeDemo_Jan2016.exe is the executable Visual Basic program. Jan2016 is the current version.

The example waveform files are:

Name	Seismograph file type
B5000.SG2	Bison 5000, SEG-2
B5000_1_1.SG2	Bison 5000, with source and receiver identifiers for B5000SR.xyz source and receiver coordinate file.
B9000.	Bison 9000
GeomSeg2.SG2	Geometrics seismographs using SEG-2 format, has source and receiver Z coordinates in header lines
DMT0092.SG2	DMT seismograph SEG-2 file, has source and receiver Z coordinate in header lines. Example for applying vertical deviation surveys.
OYOseg2.SG2	An OYO modified SEG-2 format, has source and receiver Z coordinates in header lines
DAS1.dat	OYO DAS-1, OYO modified SEG-1 format
Db16.dat	Geometrics SeisView
Mc160.dat	OYO McSeis 160

McSeisSX.dat OYO McSeis SX48, OYO modified SEG-1 format
 Smart.dat SmartSeis
 Strata.dat Geometrics StrataView
 Sview.dat Geometrics SeisView
 146ChSEG2_1_1.dat SEG2 file, 144 data channels plus two auxiliary channels, with source and receiver identifiers
 ASCIICol12Chan.txt ASCII file of waveforms with one channel per column, from B5000.SG2
 ASCIIRow2Chan.txt ASCII file of waveforms with one channel per row
 MalaRadarBinData.RD3 Mala radar binary waveform file, 10 channels
 MalaRadarProjInf.RAD Mala radar text file with project information for file above
 SensSoftwRadar.DT1 Sensors & Software radar binary waveform file, 33 channels
 SensSoftwRadar.HD Sensors & Software radar text file, information for file above
 DataPack.017 DataPack 2000 ASCII data file, receiver depth 17 ft., by foundation
 DataPack.024 DataPack 2000 ASCII data file, receiver depth 24 ft., below foundation

The example source-receiver coordinate files are:

B5000SR.xyz Synthetic coordinates for B5000_1_1.SG2
 146ChSEG2SR.xyz Synthetic coordinates for 146ChSEG2_1_1.dat, two auxiliary channels
 144ChSEG2SR.xyz Synthetic coordinates for 146ChSEG2_1_1.dat, no auxiliary channels
 The last two files contain long coordinates, such as those from GPS.

Examples of vertical deviation surveys for correcting source and receiver coordinates are:

B5000SourceDeviations.dev For source borehole with B5000.SG2 or B5000_1_1.SG2.
 B5000ReceiverDeviations.dev For receiver borehole with B5000.SG2 or B5000_1_1.SG2.

The example files of coordinates corrected with vertical deviation surveys are:

DMT92SourceDevCoor.dev For source borehole with DMT0092.SG2
 DMT92ReceiverDevCoor.dev For receiver borehole with REC0092.SG2

The files GeomSeg2.SG2 and OYOseg2.SG2 were downloaded from the Geometrics website <ftp://geom.geometrics.com/pub/seismic>, Sample_Data and are included with permission of Geometrics. GeomSeg2.SG2 is 1000.dat in Sample_Data, Nantes.zip. OYOseg2.SG2 is 1000.dat in Sample_Data, example_data.zip. The names were changed here to make the file types more apparent. The Geometrics website contains an excellent explanation of the SEG-2 format used in Geometrics seismographs at <ftp://geom.geometrics.com/pub/seismic/Geode-NZ/Geode-NZ-File-Formats.pdf>. Sensors & Software provided their GPR crosshole data and many helpful suggestions for implementing the option for reading GPR data collected on their instruments. The Minnesota Department of Transportation provided the DataPack 2000 data.

Preparing Input Files

If the boreholes have negligible deviation from vertical and the receiver spacing is uniform, then the coordinates can be entered easily in TomTime, and no data file needs to be prepared before running TomTime. For example, if the source and receiver boreholes are separated by 20 meters and both are straight and vertical, then X, Y for all sources positions could be 0, 0 and X, Y for all receiver positions could be 20, 0.

For large data sets with deviated boreholes, TomTime provides an option to reduce the manual entry of source and receiver coordinates by reading a source-receiver coordinate file. Manual entry of all coordinates separately is tedious with deviated boreholes, where all three coordinates vary with depth. To prepare input files for this option, do the following two tasks before running TomTime

1. Create a source-receiver coordinate file giving a unique identifier integer to every source and receiver, and listing the X Y Z coordinates. The format is as follows.

One header line for information

For each source:

```
Source identifier      Source X   Y   Z       "label"
(e.g.      155          100.5  10.5  30.0     "S-1")
```

A row following the last source, with -9999 for all fields,
-9999 -9999. -9999. -9999. "-9999"

For each receiver:

```
Receiver identifier   Receiver X  Y   Z       "label"
(e.g.      145          200.5  10.5  32.0     "R-3")
```

The identifiers can be meaningful rather than sequential, such as depth. Long identifiers that combine the hole number and depth can also be used, such as 48155 for a depth of 155 in hole 48. The receivers must be in the order they appear in the seismograph waveform file (see item 2, below). The labels can be any characters, but must be in quotation marks. The -9999 serves as a separator between the sources and receivers so the user does not have to determine how many of each there are. The end-of-file must be in the first line after the last receiver or the program will not count and run correctly.

Example lines from part of the source and receiver positions in B5000SR.xyz look like:
Source and Receiver Coordinates

```
1 -200.0 -2.400 120.000 "S-1"
2 -200.0 -2.400 130.000 "S-2"
-9999 -9999. -9999. -9999. "-9999"
1 0.000 0.000 10.000 "R-1"
2 0.000 0.000 20.000 "R-2"
3 0.000 0.000 30.000 "R-3"
```

2. Modify the names of the seismograph files so each name indicates the source identifier and the receiver identifier for channel 1. The receiver coordinates for the other channels are set equal to those of the receivers that follow the channel 1 receiver sequentially in the source-

receiver coordinate file. Therefore, the receivers in the coordinates file must be listed in the same order that they appear in the seismograph files.

Add the source and receiver identifiers at the end of the base file name, before the dot, separated by underscores_. The source identifier precedes the receiver identifier. For example, the original seismograph file name B5000.SG2 for source identifier 2 and receiver identifier 3 would be changed to B5000_2_3.SG2.

If source and receiver locations have been entered in SEG-2 seismograph files during data collection, those coordinates can be read by TomTime and used as Z coordinates for the source and receiver positions in vertical holes. If the hole is slanted, they can be the distance along the hole from the top or other reference point to the source or each receiver and used when applying deviation surveys. If a source-receiver coordinate file is read first, then the coordinates from that file are used, and source and receiver locations in the seismograph files are ignored. If no source-receiver coordinate file has been read, then source and receiver locations in the seismograph files are used if they are present. If no source-receiver coordinate file has been read and no source or receiver locations are in the seismograph files, then all coordinates are initially set to 0, and the correct coordinates must be entered manually. A source-receiver coordinate file can save considerable time for field data with borehole deviation surveys if coordinates are not in seismograph header lines.

Borehole deviation surveys can be read and applied to the distance from the top of the borehole (or some other reference point) to the source and each receiver. This distance is the depth in vertical boreholes, but deviation surveys can be applied to slanted boreholes if the distances along the boreholes from the tops to the source and to each receiver are provided. The first line of the deviation survey must correspond to distance 0 in the borehole. Applying the deviation survey calculates the X, Y, and Z coordinates consistent with the deviation survey. The deviation survey can use long coordinates such as those from GPS in the format 1234567.123. GPS coordinates in other formats must be converted to that format before being read by TomTime. The file extension must be dev.

Two files of source and receiver coordinates corrected with deviation surveys are provided as examples to be used with the DMT seismograph file DMT0092.SG2. DMT92SourceDevCoor.dev and DMT92ReceiverDevCoor.dev are for the source and receiver boreholes, respectively. The first few lines of DMT92SourceDevCoor.dev are shown below. Two lines of comments are followed by the East (X), North (Y), and Elevation (Z) coordinates. The coordinates in this file are long coordinates from GPS, but the coordinates can be relative to any system.

DMT92 Source coordinates corrected with deviation survey. GPS Coordinates		
East[m]	North [m]	Elevation [m]
586977.261	201998.743	465.886
586977.259	201998.754	464.886
586977.252	201998.759	463.886

DMT0092.SG2 provides the source and receiver distances from the top of the boreholes needed for applying the deviation surveys. The distance from the top of the borehole to the source is shown as 1.0 m before the source deviation survey is applied. The X and Y coordinates are shown as 0. After the source deviation survey is applied, the source Z coordinate is 464.886 m. The borehole is close to vertical, so the correction to Z for slant from vertical is very small. The corresponding X and Y = 586977.259 and 201998.753 m.

To apply deviation surveys if the seismograph file does not provide the distances from the top of the borehole to the source and receivers, a source-receiver coordinate file can be prepared with those distances as Z coordinates and the X, Y coordinates left at 0, 0. Applying the deviation survey will calculate the X, Y, and Z coordinates consistent with the deviation survey and use them in the subsequent steps in TomTime. The B5000 files illustrate this procedure. The deviations in the B5000 deviation files are not coordinates corrected for deviations like the DMT files, but are just the deviations, so they must be added to the nominal uncorrected source and receiver coordinates.

Running TomTime

Running the program involves using controls on nine forms, accessed from the Main menu. Figure 1 shows a pictorial summary of the forms, and Figure 2 shows the Main Menu.

Form 1 just gives the program title and company name. Click **Continue** or press the **Enter** key.

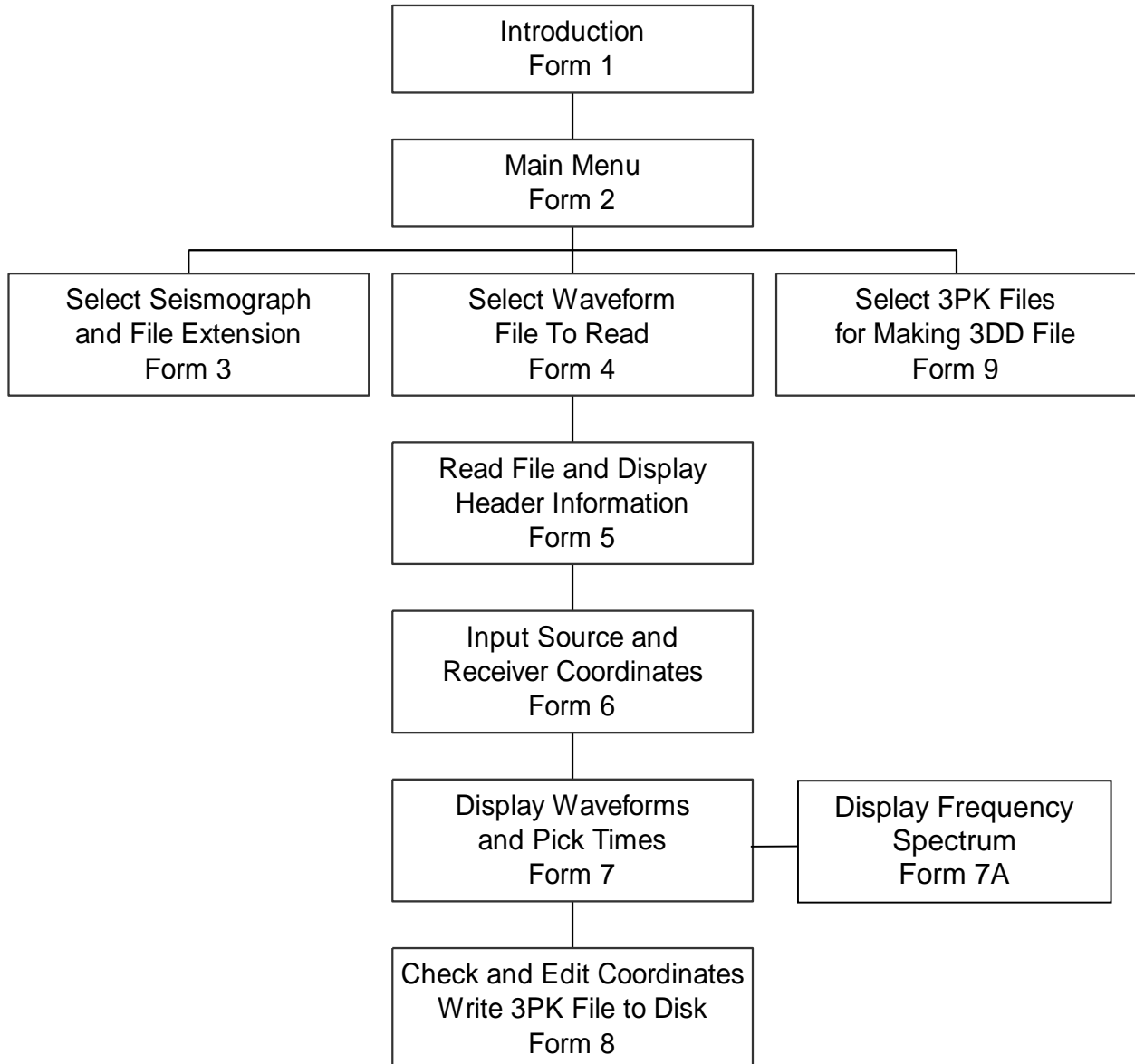


Fig. 1. TomTime Forms

Form 2 is the TomTime **Main Menu**, shown in Figure 2.

Fig. 2. TomTime Main Menu

Select **Default Units** as Feet or Meters. If desired, enter a **Time correction**. The time correction is added to all picked times, so enter a negative number if the correction should be subtracted. The time correction can be used to add the pre-trigger delay time or to correct any zero-time error in the recording system.

Under **Data Channels**, select **All seismograph channels** or **Select data channels**. Some channels may be used for triggering or monitoring some parameter other than traveltimes. For example, the 146ChSEG2_1_1.dat seismograph file has 146 total channels, but only channels 1 – 144 are data channels. When some of the channels are not data channels, you can either specify the correct number of data channels or supply dummy coordinates for the nondata channels and make those traces dead, as explained under Form 7, step 9, below. The files 144ChSEG2SR.txt and 146ChSEG2SR.txt illustrate these two methods. The file 144ChSEG2SR.txt contains coordinates for only the 144 data channels, so you must specify 144 data channels if you use this file as the source-receiver coordinate file. The file 146ChSEG2SR.txt contains dummy coordinates for the two auxiliary channels (145 and 146) so you can select **All seismograph channels** if you use this file.

Under **Data Quality**, there are options for calculating a data quality value for each travelttime. These options can be ignored if you do not plan to include data quality in the data file saved for GeoTomCG. The default options work well for most data sets. Data quality is calculated from the ratio signal amplitude/noise amplitude, abbreviated SNR below. The signal is the absolute value of the amplitude of the first peak, corrected for any baseline shifts made by the user. The signal amplitude is not meaningful if it is not on the first peak after the first-break. Apply manual editing if it is not on the first peak and you want to use the data quality.

The noise amplitude is the difference between the maximum and minimum amplitudes in the range of 25 to 10 samples before the first-break. The data quality can range from 1 (good) to 0 (poor). The data quality is calculated by a 2nd order polynomial scaling of the SNR. If SNR = upper limit, then data quality = 1 and slope = 0. If SNR = lower limit, then data quality = 0. The default upper value of 18 is based on investigations by Geotomographie using a variety of data sets. The default lower value of 1 was chosen because picking first-breaks is not reliable if the noise is as great as the signal. Polynomial rather than linear scaling is used because, for example, an improvement in SNR from 4 to 8 is more significant than an improvement from 14 to 18. Limits are used because the reliability of picking first-breaks does not continue to increase significantly above a threshold SNR and cannot be worse than unreliable below the lower limit.

If the lower limit is SNL and the upper limit is SNU, then the scaled data quality is

$$\frac{-\text{SNR}^2 + 2*\text{SNU}*\text{SNR} - (2*\text{SNU}*\text{SNL} - \text{SNL}^2)}{(\text{SNU}-\text{SNL})^2}$$

SNU must be greater than SNL.

If you have prepared a source-receiver coordinate file, under **Read Source and Receiver Coordinates** click **Combined Source and Receiver Coordinate File**. A standard Open File dialog box appears. Select the file described in step 1 of “Preparing input files” (above). TomTime reads the file and stores all the identifiers and coordinates in memory.

If you have vertical deviation survey files, under **Read Vertical Deviation Surveys** click **Deviations** under **Source** to read the file for the source borehole and **Deviations** under **Receiver** to read the file for the receiver borehole. **Deviations** can be applied to nominal coordinates from the **Combined Source and Receiver Coordinate File**. If you have files of source and receiver coordinates that have been corrected using deviations or other trusted information, under **Read Vertical Deviation Surveys** click **Coordinates** under **Source** to read the file for the source borehole and **Coordinates** under **Receiver** to read the file for the receiver borehole. **Deviations** are corrections that can be applied to nominal coordinates and **Coordinates** are the coordinates after the corrections have been applied. In either case, a standard Open File dialog box appears. After you select the appropriate file, TomTime displays the file in a list box to allow you to verify it is the desired file. Click **OK** to use the information in that file.

Click **Select Seismograph and File Extension** in the Main Menu to open Form 3.

Form 3 is titled **Seismograph and File Extension** and is shown in Figure 3, below.

It allows you to select the seismograph file type from a list and select or enter the file extension. Many modern seismographs use the SEG2 file type, so try that type if another choice does not correctly identify your files.

Two ASCII text file formats are listed. The first ASCII format option requires the amplitudes from each channel to be in a column. The sample data file ASCIICol12Chan.txt is an example using this format for the data in B5000.SG2. The header lines and the first several lines of data are listed below. There are 12 columns of data, each column corresponding to one of the 12 data channels. TomTime can write ASCII files in this same format.

ASCII waveform file, one channel per column

File name = ASCIICol12Chan.TXT

Line number = NOTE

Date = 06/25/1991

Time = 13:02

Instrument = Unknown

Serial number = None

Number of channels = 12

Samples per channel = 2000

Sample interval = 0.2 ms

Delay = 0.0 ms

Seismograph high cut filter = 25024 Hz

Seismograph low cut filter = 20 Hz

Seismograph notch filter = OUT

Source Z = 0

First receiver Z = 0.00

Units = Feet

Default units = Feet

```
187 -167 -127 -53.1 -171 119 -219 46.9 -44.3 -21.4 81.6 -87.9
152 -181 -125 -41.1 -173 108 -211 56.9 -36.3 -18.4 77.6 -92.9
117 -190 -126 -17.1 -175 99.8 -199 67.9 -25.3 -11.4 67.6 -92.9
78.7 -198 -119 9.86 -166 89.8 -187 77.9 -17.3 -1.45 60.6 -86.9
40.7 -204 -115 40.9 -151 80.8 -175 89.9 -10.3 11.6 53.6 -77.9
1.66 -207 -105 74.9 -136 72.8 -163 97.9 -3.34 22.6 44.6 -69.9
```

Fig. 3. Form for selecting file type and extension.

A second type of ASCII data format for input was added at the request of a customer. This format requires the amplitudes from each channel to be in a row. Each amplitude within the row corresponds to a different time. If the number of time samples is so great that one row cannot contain all of them, the data can be continued in the next row. TomTime uses the number of time samples per channel to determine how many to read for each channel. An example file with two channels is shown below and included in the program set as file ASCIIRow2Chan.TXT. The first entry in each row is the source Z, and the next entry is the receiver Z. In this example, the channel 1 has source Z = 20 and receiver Z = 10.0. Channel 2 has both source and receiver Z = 20.0. Each row of the file requires 15 lines of text shown below. The customer stated that source and receiver X and Y were constant for his data, and wanted those coordinates included in the header file. Those coordinates can be edited later if their values change with Z in other applications. TomTime cannot write files in this format.

ASCII waveform file, one channel per row

File name = ASCIIRow2Chan.TXT

Associated image file = Example.jpg

Line number = 12

Date = 07/28/2009

Time = 13:02

Instrument = Unknown

Serial number = None

Number of channels = 2

Samples per channel = 186

Sample interval = 4 ms

Delay = 0.0 ms

Seismograph high cut filter = OUT

Seismograph low cut filter = OUT

Seismograph notch filter = OUT

Source X = 0.0

Source Y = 0.0

Receiver X = 20.0

Receiver Y = 0.0

Units = Meters

SrcZ (m) RecZ(m) Amplitudes

20.0	10.0	-1.125	1	0.625	0.75	0.5	0.375	0.5	0.625	0.625	0.75	0.625	
0.75	0.625	0.75	0.875	0.5	0.375	0.375	0.625	0.5	0.625	0.875	0.75	0.625	
0.625	0.625	0.625	0.625	0.625	0.625	0.5	0.5	0.75	0.875	1	1.25	1.375	
1	0.625	0.625	0.5	0.5	0.625	1	1	1.375	1.375	1.625	1.5	1.5	
1.5	1.125	0.875	0.875	1.125	1.375	1.625	2	2	1.875	1.375	1.375	1.125	
1.375	1.625	1.875	1.75	1.5	1.375	1.375	1.125	1.375	1.625	1.375	1.125	1	
0.875	0.875	1	1.125	1.5	1.625	1.875	1.5	0.875	0.375	0.5	0.375	0.25	
0.25	0.875	1.125	1	0.625	0.25	0.125	0.5	0.5	0.5	0.5	0.125	0	0
	0.125	0.75	0.875	0.875	0.25	-0.625	-1.5	-1	0.125	1.875	2.875	2.625	
2	0.625	-0.625	-1.25	-0.75	0.375	2	2.5	1.625	0.375	0.25	1	1.125	
0	-1.5	-2.625	-1.875	0	2.75	3	1.125	-1.375	-1.75	0.625	4.625	7.625	
5.5	0.25	-3.75	-3	1.75	5.25	3.75	-1.5	-5.625	-5	0.5	5.5	6.25	2
	-2.125	-3.125	0.375	5.625	8.625	7.25	2.375	-0.125	-0.25	0.25	-1	-3.5	

-5	-2.125	3.875	8.5	7.5	2.875	-2.125	-4	-1.25	2.125	2.875	1.125	-0.125	
	0.875	4.25	5.75	4.375	0.875	-2.25							
20.0	20.0	-0.75	0.875	1.25	0.875	0.875	0.5	0.5	0.625	0.625	0.75	0.875	
1.125	1	1.125	1.375	1.5	1.5	1.375	1.625	1.625	1.625	1.625	1.625	1.375	
1.5	1.5	1.375	1.125	0.875	0.75	0.5	0.375	0.125	0.25	0.25	0.125	0.5	
0.625	0.625	0.625	0.625	0.5	0.25	0.5	0.75	1	1.375	1.375	0.875	0.75	
0.625	1	0.875	0.5	-0.125	-0.625	-0.375	0.375	1.5	1.25	0.25	-0.875	-1.375	
	-0.5	1.25	2.75	2.25	0.75	-1.25	-1.875	-1.625	-0.25	1.375	2.125	1.75	
0.25	-1.25	-2.625	-2.625	-1.5	0.75	3	3.5	3.25	1.625	0.25	-0.75	-1	
-0.75	0.125	1	0.75	-0.875	-3.75	-5	-4.25	-0.875	1.5	0.875	-1	-1.87	
1.75	5.875	8	3.375	-5	-12.25	-11	-1.375	8.625	9.125	1.5	-5.5	-5.75	
0.625	7.75	10.5	6.375	-0.25	-4.5	-5.75	-5.125	-3.75	-2.25	-0.75	1.375	3.75	
5.625	4.5	2.25	-0.5	-0.375	2.375	5.25	3.875	-0.375	-2.25	1.625	7.5	8.25 -	
1	-13.125	-16.125	-7.375	6	13.625	11.5	2.375	-5.75	-7.375	0.875	11.875	15	
	7.625	-4.625	-12.875	-12.375	-6.25	0.875	5.125	5.875	5.5	4	-0.125	-5.875	-8.75
	-7.375	-4.25	-1.875	-1.625	-1.625	2.625	11.375	19.5	18.25	7	-6.5	-11.875	-9.625
	-5.625	-3.75	-3.125	-2	-0.625	-0.625	-0.5						

TomTime can read, display, and process Mala Ramac and Sensors & Software crosshole radar files. Radar files usually have evenly spaced source and receiver locations in vertical boreholes, so a source-receiver coordinate file is usually not needed. It may be useful if borehole deviations are significant. Mala and Sensors & Software radar files have the header information and data in separate files.

To read a Mala Ramac radar file, select **Mala radar file** for the type and *.RD3 for the extension. As explained under Form 4 below, the *.RD3 file contains waveform traces. You will also be asked to select the *.RAD file containing project information in header lines.

To read a Sensors & Software crosshole radar file, select **SensorsSoftw radar** for the type and *.DT1 for the extension. As explained under Form 4 below, the *.DT1 file contains waveform traces. TomTime automatically reads the *.HD text file with the same name, except for extension, containing project information. The *.DT1 and the *.HD files must be in the same subdirectory. More detailed instructions are given starting on page 36.

After the seismograph type and file extension are correct, click **Back to Main Menu**. Use the **Back to Main Menu**, **BACK** or a similar button to close a form, not the **X** in the upper right corner. Those buttons reset control parameters needed for going between forms.

In the Main Menu, click **Display Waveforms and Pick Times** to start Form 4.

Form 4 is titled **Select Waveform File to Read**.

Select drive, folder, and extension, then double-click on the folder to display a list of files. You may need to double-click on the parent directory and then on the folder to see all the files. If the selected drive and folder contains files with the extension and for the seismograph selected in form 3, they will be shown on the list. Files are tested to see if they are for the selected seismograph, so a file with the selected extension is not necessarily shown in the list. Files for which there is already a .3pk file containing picked times and amplitudes are marked with a * at the left end of the file name. Select and highlight a file in the list. Click **READ FILE** to continue.

The user will be returned to this form after processing each waveform file. The waveform file that was processed will be moved downward in the list. Files without a * at the left end of the file name are shown above files with a * at the left end to facilitate selecting the next unprocessed file.

To display more than one seismograph file at once, use the **APPEND FILE** option. To load the first seismograph file, highlight the file and click on **READ FILE** as usual in the form for selecting seismograph files. Examine the data as desired in the subsequent forms, then click on **BACK** as many times as needed to return to the form for selecting the seismograph file. To load the second seismograph file, highlight the file and click on **APPEND FILE**. The subsequent forms will display both files. Additional seismograph files can be appended. Whenever **READ FILE** is clicked, the selected file is loaded and the current files are unloaded

If a source-receiver coordinate file is read first, it must provide coordinates for the first seismograph file plus any appended file. The automatic time-picker may give poor results for the last few channels of the first file and the first few channels of the appended file if the time changes a great deal from one channel to the next. The time-picker uses various rules to help select times, and those rules assume smooth changes in position and times.

TomTime can read, display, and process Mala Ramac and Sensors & Software crosshole radar files. Radar files usually have evenly spaced source and receiver locations in vertical boreholes, so making a source-receiver coordinate file outside of TomTime is usually not efficient. It may be useful if borehole deviations are significant. Mala and Sensors & Software radar files have the header information and data in separate files.

For Mala data, the project information is in a text file with extension *.RAD and the radar data are in a binary file with extension *.RD3. If the selected drive and folder contains files with the *.RD3 extension, they will be shown on the list. Select and highlight a file on the list. Click **READ FILE** to continue. TomTime opens a standard file dialog box where the user can select or enter the name of the *.RAD text file. TomTime uses this information to determine the number of samples in each channel, the number of channels, and the receiver positions, so the *.RAD text file must be correct for the selected *.RD3 data file. TomTime reads the *.RAD file and then the *.RD3 file. The reading can be slow if there are many channels. The number of channels read can be reduced by decreasing the value of "LAST TRACE" in the *.RAD file. This reduction is desirable if the lower channels do not contain useful signals. It

may be necessary if there are too many channels for the program to handle. The limit is typically about 400 channels, depending on the number of samples per channel.

For Sensors & Software data, TomTime provides special options that are described in detail, with examples, in “**Special options for Sensors & Software radar files**” starting on page 36.

Clicking **READ FILE** or **APPEND FILE** starts **Form 5**, titled **Reading Waveform File**.

It displays the header information for the waveform file, which shows if you have the correct file. The information cannot be edited in this form. If you do not have the correct file, click **BACK**. If you have the correct file, click **CONTINUE**, which will read the data and then start Form 6. The number of samples per channel is limited to 16380. If there are more than 16380, the number is listed as 16380, and only the first 16380 samples will be read in each channel.

Form 6 is titled **Source and Receiver Information**. It is shown below in Figures 4a and b.

Source X: 0.000
 Source Y: 0.000
 Source Z: 1.000

Source and Rec Locs OK?

 Revise Display Trace

Trace Display
 Clipped
 Shaded
 Whole trace
 First half only
 Maximum time: 127.795
 # traces to display: 72

Auto pick
 First break Peak
 Skip initial time: 0

Channel	RecX	RecY	RecZ	Stacks
1	0.000	0.000	1.000	5
2	0.000	0.000	2.000	5
3	0.000	0.000	3.000	5
4	0.000	0.000	4.000	5
5	0.000	0.000	5.000	5
6	0.000	0.000	6.000	5
7	0.000	0.000	7.000	5
8	0.000	0.000	8.000	5
9	0.000	0.000	9.000	5
10	0.000	0.000	10.000	5
11	0.000	0.000	11.000	5
12	0.000	0.000	12.000	5
13	0.000	0.000	13.000	5
14	0.000	0.000	14.000	5
15	0.000	0.000	15.000	5
16	0.000	0.000	16.000	5
17	0.000	0.000	17.000	5
18	0.000	0.000	18.000	5
19	0.000	0.000	19.000	5
20	0.000	0.000	20.000	5
21	0.000	0.000	21.000	5
22	0.000	0.000	22.000	5
23	0.000	0.000	23.000	5
24	0.000	0.000	24.000	5

Fig. 4 a. Form for showing and revising source and receiver coordinates and display.

It allows selecting **Trace Display** for the waveform as clipped or shaded, and full or first half of trace or the maximum time displayed. The default maximum time is the total time. The time displayed is the smallest of the maximum time or the selected full or half trace time. The

maximum time is retained between records. It also allows you to enter source and receiver X and Y coordinates and to edit the source and receiver Z coordinates along the borehole. The form in Figure 4 comes from reading the example file DMT0092.SG2. That file has source and receiver coordinates in header lines in the seismograph file, used as Z coordinates by TomTime. To revise coordinates, click **No** to answer **Source and Rec Locs OK?** Text boxes for entering new coordinates will appear. Click **Update Sor Loc** to update the source locations, or click **Update Rec Loc** to update receiver locations. Enter any two of Rec1 Z, Rec N Z (last receiver), and spacing, and the remaining parameter will be calculated. In this form, updated receiver X and Z coordinates must be constant and receiver Z coordinates must have a uniform spacing. If the receiver X and Y coordinates are not constant or the receiver Z spacing is not uniform, do not update the receiver coordinates in this form. Instead, do all the receiver coordinate editing later in Form 8.

Coordinates corrected with vertical deviation surveys were available for this data file, DMT0092.SG2, and were applied. To apply the corrections, click **Apply Source Deviations** and **Apply Receiver Deviations**, respectively. The transformed coordinates for these files are shown below. DMT92SourceDevCoor.dev and DMT92ReceiverDevCoor.dev were the source and receiver files of coordinates corrected with borehole deviation surveys.

The screenshot shows a software window with a cyan background. On the left, there are input fields for Source X (586977.259), Source Y (201998.753), and Source Z (464.886). Below these is a 'Source and Rec Locs OK?' dialog with 'NO' and 'YES' buttons, and 'Revise' and 'Display Trace' options. Further down are 'Trace Display' settings: 'Clipped' and 'Shaded' checkboxes, radio buttons for 'Whole trace' (selected) and 'First half only', a 'Maximum time' field (127.795), and a '# traces to display' field (72). At the bottom left are 'Auto pick' radio buttons for 'First break' (selected) and 'Peak', and a 'Skip initial time' field (0). A 'BACK' button is at the bottom left. On the right, a table displays channel data:

Channel	RecX	RecY	RecZ	Stacks
1	586969.488	202005.993	464.815	5
2	586969.490	202005.992	463.815	5
3	586969.493	202005.991	462.815	5
4	586969.496	202005.993	461.815	5
5	586969.495	202005.999	460.815	5
6	586969.490	202006.003	459.815	5
7	586969.484	202006.003	458.815	5
8	586969.483	202006.000	457.815	5
9	586969.484	202005.999	456.815	5
10	586969.488	202006.000	455.815	5
11	586969.492	202006.001	454.815	5
12	586969.496	202006.004	453.815	5
13	586969.497	202006.011	452.815	5
14	586969.495	202006.020	451.815	5
15	586969.486	202006.024	450.815	5
16	586969.484	202006.035	449.815	5
17	586969.488	202006.040	448.815	5
18	586969.493	202006.042	447.815	5
19	586969.497	202006.047	446.815	5
20	586969.496	202006.051	445.815	5
21	586969.493	202006.055	444.815	5
22	586969.493	202006.058	443.815	5
23	586969.493	202006.059	442.815	5
24	586969.496	202006.062	441.815	5

At the bottom right, there are buttons for 'Apply Source Deviations' and 'Apply Receiver Deviations'.

Fig. 4 b. After applying source and receiver corrected coordinates based on deviations surveys.

When source and receiver locations are correct, click **Yes** to answer **Source and Rec Locs OK?** Form 7 for displaying wavetraces and picking traveltimes will then be loaded.

The autopick feature works best if the program has the correct coordinates before autopicking in form 7. The autopick feature uses the coordinates in determining reasonable changes in arrival times between traces, and uses traces with the smallest source-receiver distance (usually highest signal-to-noise ratio) as a guide in picking times for receivers farther from the source.

An option requested by a customer allows the user to make the autopicks be the top of the peak (or bottom of a trough if that precedes a peak) instead of the first-break. The form contains two buttons for making this selection.

An additional option in the same Auto pick group allows the user to select a time to skip at the start of all traces. This option was added to improve the autopicking when there is a large initial noise pulse. The default value is 0. Without any time skip, the noise statistics are measured over a range that may include the initial pulse, so many of the autopicks may be invalid if there is an initial noise pulse. The autopicks may be in the initial pulse or at times greater than the correct first break or peak. The author found that skipping 3.0 ms when processing sparker source data moved the ranges for determining noise statistics and time picks beyond the initial noise pulse, which improved the automatic time picking. (The zoom option described under Form 7 affects the range of autopicking, but does not affect the range where the noise statistics are calculated.) The time to skip must be in the same units as the time displayed. For example, if you want to skip 2.5 ms and the displayed time is in seconds, then enter 0.0025. The skipped time applies to the time shown in the waveform display, and is not affected by the optional time correction that can be entered in the **Main** form.

Form 7 is titled **Display Waveforms and Pick Times**.

Form 7 displays waveforms for the selected seismograph file, as shown in Figures 5 - 7. It is the window for doing the actual picking, and has many options in a menu across the top and at the right side. This display contains several symbols, and uses several different controls for them. The user may find it convenient to refer to the summary at the end of these instructions until becoming familiar with this display.

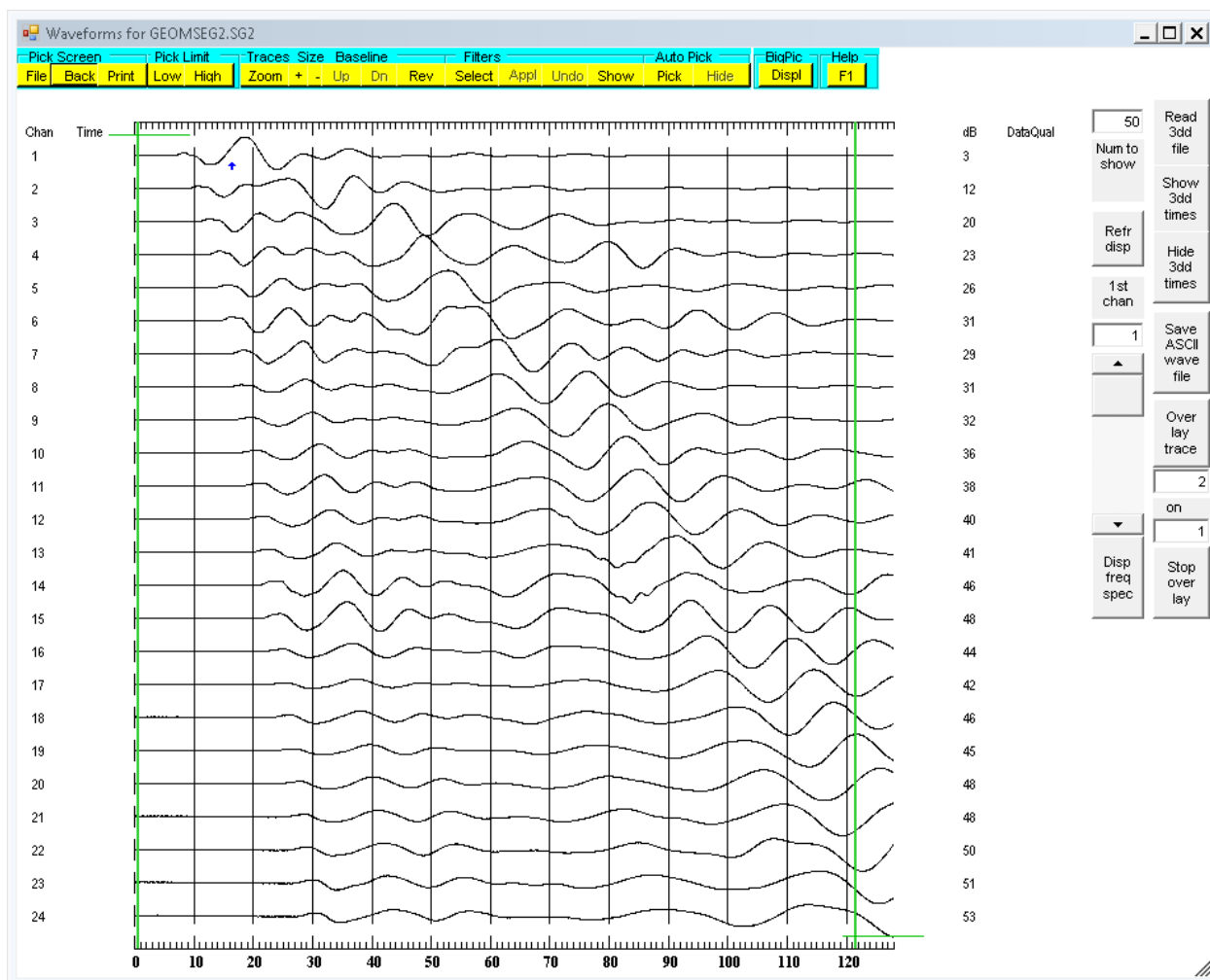


Fig. 5. Waveform display from sample data GeomSEG2.SG2.

Figure 5 shows a typical display, the 24-channel data in the example file GeomSEG2.SG2. The display is capable of displaying many channels. However, the labels at the left and right sides of the display become illegible for more than about 80 channels. Values for Time picks and DataQual (data quality) are not shown until times are picked.

Two different methods can be used for selecting which channels to display. The “zoom” described below in step 8 allows viewing any number of channels, and also allows the time range to be selected. The text box and slide bar described below in step 2 allow the user to

select the number of channels to display and the starting channel. They are more convenient than the zoom, but do not allow the time range to be selected.

To pick times and amplitudes, do the following steps:

1. If desired, traces can be overlaid. As shown below, this option is helpful when examining shear waves that have been collected with the source movement in two different directions. Controls for overlaying traces are on the right edge of the display, near the bottom. The channel number of the first trace to display as an overlay can be set in the text box under **Overlay trace**. The trace on which it is to be overlain can be set in the text box under **on**. Subsequent traces are overlain in the same pattern. To turn on the overlay option, click **Overlay trace**. The overlaid traces are in red. To stop the overlay display, click **Stop overlay**.

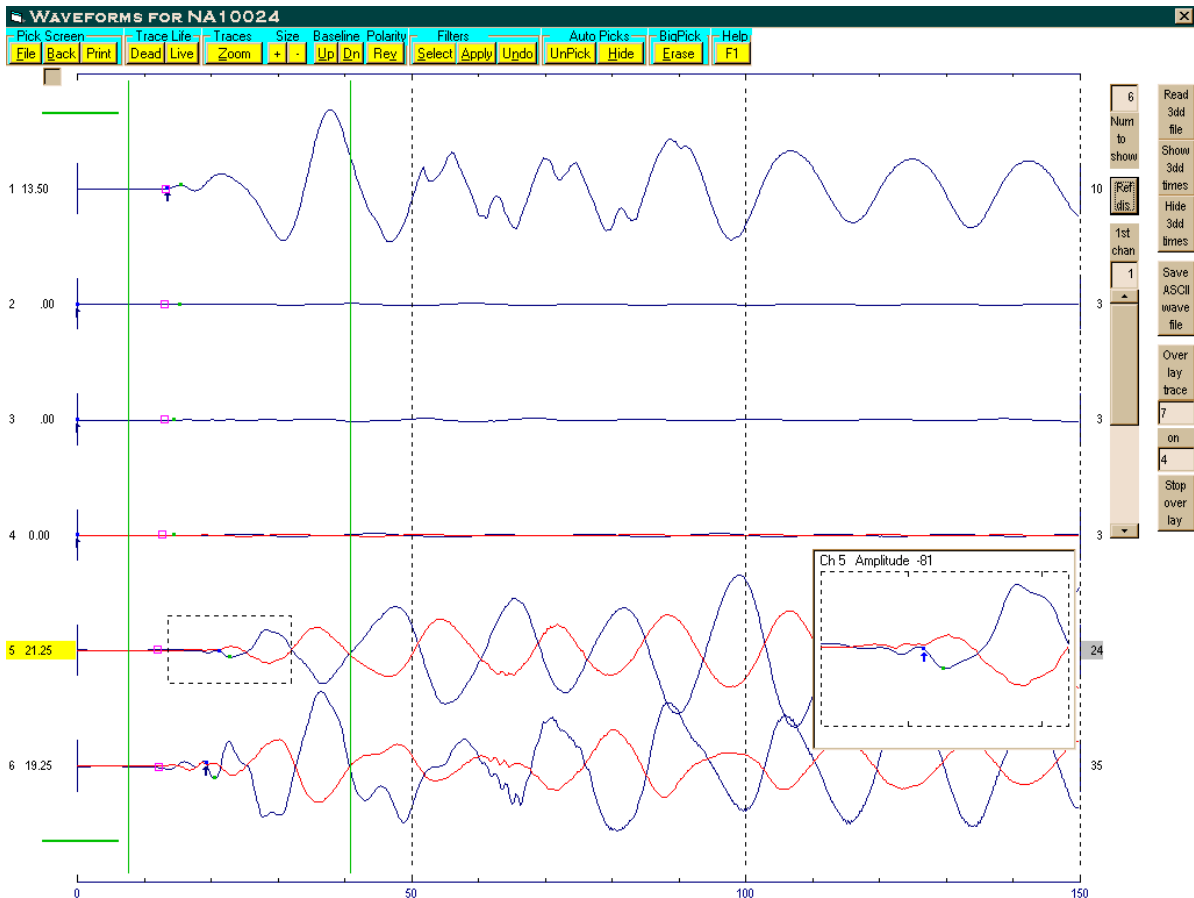


Fig. 6. Display of waveforms with overlay.

Figure 6 contains three files of VSP data collected with a 3-D geophone set. The first three channels were collected with a P-wave source. The next three channels were collected with an S-wave source moving in one direction. The last three channels, shown overlain in red on channels 4-6, were collected with the S-wave source moving in the opposite direction. Channels that were not of interest were marked dead and their amplitudes were reduced.

2. The number of channels to be displayed can be set by entering the number in the text box near the right of the display labeled **Num to show**. The first channel to be displayed can be set with the slider bar below it, labeled **1st chan**. After setting these two numbers, click the button between them labeled **Ref dis** (Refresh display), and the display will reset to the specified number of channels and first channel. If the number of channels displayed is smaller than the total number of channels, pressing the **Page Down** or **Page Up** key will move the displayed traces down or up by the number of channels displayed.

3. There are two controls for saving an ASCII file of the waveform traces. The first control is visible on the traces display. A button along the right edge of the traces display is labeled **Save ASCII wave file**. Click it to call a standard **SAVE AS** dialog box to select a name for the file. The file contains header information, including the sample size. If files have been appended, the header information is for the last file appended. Beneath the header information are columns containing the unscaled amplitudes of each of the waveform points. The traces display is scaled to make the graphs fit in the available space. The differences in unscaled amplitudes will be larger than the differences of heights of the scaled displays, so the plots obtained from graphing the unscaled amplitudes will show greater variation in trace heights than observed in the TomTime display. The same filtering is applied to the saved ASCII file of traces as is applied to the displayed traces (see topic 9 below). The second control is on the form that follows the traces display, after picking times and clicking **File**. (Clicking **File** before picking times will return you to the Main form.)

4. To display times from a 3dd data file of measured or calculated times from a prior tomographic inversion, click on **Read 3dd file** near the right of the display. A standard dialog box for opening a file will appear and allow you to select the file for reading. To show the times, click on **Show 3dd times** below it. These times are represented by red and orange narrow rectangles. Red indicates the first time in the 3dd file with coordinates matching those for a trace, and orange indicates a second match. To hide these times, click on **Hide 3dd times**. The coordinates for the sources and receivers in TomTime must match the corresponding coordinates in the 3dd file. No 3dd times will be shown if coordinates consistent with those in the 3dd file have not been read or entered in TomTime before reading the 3dd file.

5. If desired, set Low Pick Limit and Low Trace Limit. Under **Pick Limit**, left-click **Low**. The Low Pick Limit is the lower limit for autopicking of times and the lower time limit for a zoomed display. The Low Trace Limit is the lowest-number trace that will be in a zoomed display. The Low Pick Limit is shown by a vertical green line near the left edge of the display. The Low Trace Limit is indicated by a horizontal green line initially near the top near the left edge. After setting, it is above the lowest-number trace that will be in a zoomed display. They are both controlled by clicking the left or right mouse button after **Pick Limit, Low** is selected. This is similar to placing the upper left corner of a rectangle in a drawing program.

6. If desired, set High Pick Limit and High Trace Limit. Under **Pick Limit**, left-click **High**. Then the High Pick Limit and High Trace Limit are set in the same manner as the Low Limits. The High Trace Limit line is immediately below the highest-number trace that will be in the zoomed display. Just as for the Low Limits, clicking the left or right mouse button moves the

High Trace Limit and the High Pick Limit. The High Pick Limit should be set high enough to allow room for the amplitude dots. If suitable amplitude peaks cannot be located to the left of the High Pick Limit, their positions are set to zero time.

7. The size of all waveforms can be changed by clicking **+** or **-** under **Size**. The waveform size multiplier shown on the right of each trace will change by 6 decibel (dB) for each click. Doubling the amplitude is an increase of 6 dB. Autopicking of time works best if waveform sizes are reasonable.

8. **Zoom** will display the time between the Low and High Pick Limits and the traces between the Low and High Trace Zoom Limits. Click **Unzoom** to undo.

9. Filtering can be applied. Under **Filters**, Click **Select** and select the desired filters, then click **Apply**. High-frequency noise can be reduced with either a high-cut filter or with smoothing. A high-cut filter gives more control over the filtering limits and is generally preferred. Filtering to reduce high-frequency noise can spread the wave slightly and so decrease the apparent time of the first-break. Although the effect is small, applying the same filter to all waveforms is good practice to obtain the smallest errors when comparing traveltimes. The filter that was applied can be shown in red text at the top of the display by clicking **Show** under **Filters**. After showing it, click **Hide** to hide it.

10. To autopick times or to read previous picks, click **Pick** under **Auto Pick**. If previous picks exist in the same subdirectory, a dialog box will ask if you want to read them or pick new times. If you read previous picks and have appended a file, the number of channels in the previous picks must match the total number of channels or the program will crash. Some manual revision of the autopicked times may be necessary, especially if the signal-to-noise ratio is low. The time picks are blue dots. The small red unfilled squares show the times picked by autopicking. Select a trace by clicking once on it. Pressing the **k** or **i** key will move the selection down or up one trace, and pressing the **K** or **I** keys will move it 5 traces. If a file of former time picks is found, you have the option of displaying the times on the traces and displaying the coordinates from that file on the next form.

After a trace is selected, clicking the left mouse button will move the pick rapidly to the cursor. Pressing the left or right mouse button while holding **Ctrl** will make the time pick move slowly to the left or right. The time pick can also be moved with keyboard keys. Pressing the **j** or **l** keys will move it one sample left or right. Pressing the **J** or **L** keys will move it 5 samples.

The amplitude picks are indicated by smaller dark green and green dots to the right of the blue time dots. The automatic amplitude pick is selected in the following manner. If the wavetrace slopes upward at the autopick time, then the first amplitude pick is the top of the first peak to the right. If the wavetrace slopes downward at the autopick time, then the first amplitude pick is the bottom of the first negative peak (or trough) to the right of the autopick time. The second and third amplitude picks are the next points where the slope reverses.

Clicking the right mouse button will move the first amplitude pick rapidly to the cursor. To move the first amplitude pick slowly left or right, hold the **Alt** key down while pressing the left

or right mouse button. All the amplitude picks can be adjusted with keys on the keyboard. Pressing **e** or **t** moves the first amplitude peak left or right by one sample, and pressing **E** or **T** moves it left or right by five samples. The second and third amplitude picks are controlled in a similar manner by the keys **d** or **g** and **x** or **v**, respectively. The second and third amplitude picks can be moved quickly to the cursor by holding **Shift** while pressing the left or right mouse button, respectively. You do not need to edit amplitude picks that you will not use.

The values of the amplitudes are displayed in the magnified box for each trace. They are sized directly from the seismograph record, so they are not affected by the dB setting for each trace or by filtering. If, as usual, **Auto pick** is **First break**, then Amplitude = (amplitude at amplitude pick) – (amplitude at first break). This difference is used because low-frequency noise can make the trace move up or down unrelated to the signal from the project seismic source. This revision was necessitated by amplitude inversion of a large data set with low-frequency noise. The amplitude at a peak could be zero if low-frequency noise moves the base of the peak. The first-break pick is close to the first peak, so the effect of low-frequency noise is reduced. If **Auto pick** is **Peak**, the amplitude at the peak is displayed.

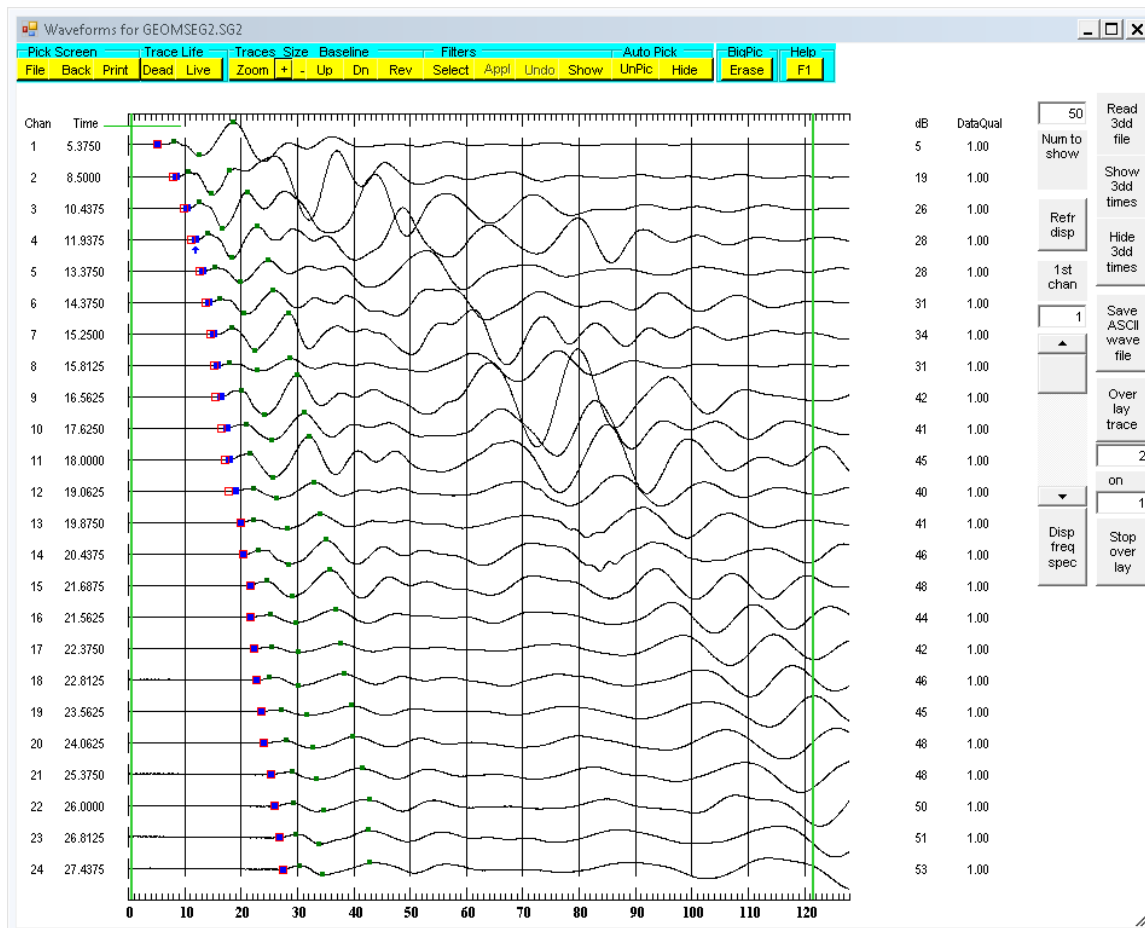


Fig. 7. Waveform display from figure 5 after manual editing of time picks.

11. After autopicking times, individual selected traces can be altered to facilitate manual picking. For example, filtering can be performed on one trace at a time. The amplitude of one

trace can be adjusted by clicking **+** or **-** to increase or decrease the amplitude by 1 dB. The waveform display from Figure 5 after manual adjustment in several channels is shown above in Figure 7. Edited blue time picks are not coincident with the red square auto picks.

Other options in this form include:

Trace Life replaces **Pick Limit** after autopicking times. A selected trace can be killed (time set to 0) by clicking **Dead**. To use zoom after autopicking, the Pick Limit buttons must be restored by unpicking. These old picks can be restored by the autopick Old command.

Baseline, Up and Dn. Shifting the baseline is enabled after times have been picked, so it affects only the active trace. Baseline shifts can be seen best with shaded traces.

Polarity, Rev. Polarity reversal affects all traces before picking times and the selected trace after picking times.

BigPic is the magnified box for time picking. It is enabled after autopicking. It can be hidden by clicking **Erase**. It is not shown when the display is Zoomed.

A Help file for this form can be viewed by clicking the F1 button on the menu (not on the keyboard). It contains the same information as in these printed directions. Use the up and down arrow keys for scrolling the help file.

12. If desired, print the waveform and picks by clicking **Print**.

13. If desired, examine the frequency spectrum by clicking the **Disp Freq Spec** button on the lower right of the display, below the slide control for number of channels. The frequency spectrum in Form 7A will be displayed overlain on Form 7. Instructions follow item 14, below.

14. After the time picks are correct, click **File** to go to Form 8 and select a name for the 3PK file.

Form 7A is titled **Display Frequency Spectrum** and is shown below in Figure 8.

Clicking **Disp Freq Spec** in the **Display Waveforms** form displays a frequency spectrum such as shown in Figure 8 for a selected channel or for the average of selected contiguous channels. The spectrum is calculated using the Fast Fourier Transform (FFT) (See e.g., Numerical Recipes, Cambridge Univ. Press, 1986, pp. 390-395).

The vertical axis is the relative amplitude from the FFT, and should not be confused with the amplitude of the seismograph traces. The maximum FFT amplitude is kept less than 20000 by normalizing all FFT amplitudes, if necessary. The average for multiple channels is calculated by determining the FFT amplitudes for each channel and taking the average, not by taking the average of the trace amplitudes first. Thus the average of traces that have the same frequency but different first breaks will show the correct average of the FFT amplitudes. The frequency is in cycles per second if the times are in milliseconds.

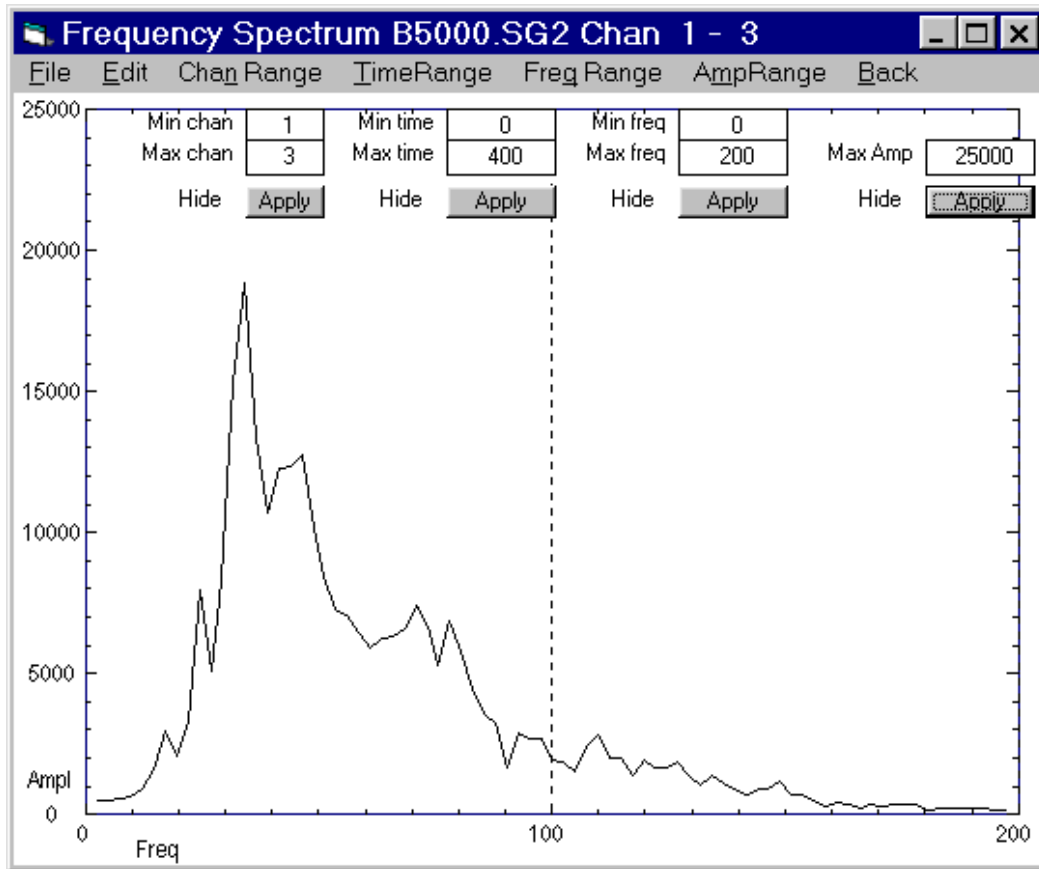


Fig. 8. Display of frequency spectrum.

The controls for setting the ranges for channels, time, frequency, and the maximum amplitude are initially hidden. To show any one of them, click on the corresponding menu item. To hide it, click on the corresponding **Hide**. Max Amp is limited to 25000. To save a file with the frequency and relative FFT amplitudes, click **File, Save**.

Clicking **Edit, Copy** tells how to copy the image of the frequency spectrum. In Windows XP and earlier versions, click Alt+PrintScreen to copy the image to the Windows clipboard. In Windows 7 and later versions, use a word processor such as Word to insert a screen clipping of the image into a document. Click on the explanation to hide it. If part of the spectrum is then missing, select and apply any control to redraw it.

When you have finished examining the frequency spectrum, click **Back** to hide the frequency spectrum form and restore the traces display to its appearance before you clicked **Disp Freq Spec**. After you return to the display of the waveforms and are satisfied with the time and/or amplitude picks, click on **File** in the upper left of the form to start Form 8.

Form 8 is titled **Write 3PK File to disk** and is shown below in Figure 9.

The screenshot shows a window titled "Write 3PK file to disk". On the left side, there are three input fields: "SourceX" with value "586977.259", "SourceY" with value "201998.753", and "SourceZ" with value "464.886". Below these is a button labeled "Revise Source Coordinates". A yellow text box explains: "To revise receiver coordinates or times, enter the new values directly in the list. Revising the source coordinates restores the original receiver coordinates and times, so revise source coordinates first." Another yellow text box says: "You may edit drive, directory, and name of the 3PK file:". Below that is a text field containing "C:\TomTime_Sep2013_AutoData" and a button labeled "WRITE 3PK FILE TO DISK". At the bottom left, there is a button labeled "Write ASCII waveform file" and two buttons labeled "BACK" and "CANCEL".

Channel	SorX	SorY	SorZ	RecX	RecY	RecZ	Time+correction	DataQual
1	586977.259	201998.753	464.886	586969.488	202005.993	464.815	3.2188	.0863
2	586977.259	201998.753	464.886	586969.490	202005.992	463.815	3.0625	.231
3	586977.259	201998.753	464.886	586969.493	202005.991	462.815	3.1250	.243
4	586977.259	201998.753	464.886	586969.496	202005.993	461.815	3.4688	.181
5	586977.259	201998.753	464.886	586969.495	202005.999	460.815	3.4063	.070
6	586977.259	201998.753	464.886	586969.490	202006.003	459.815	3.5000	.115
7	586977.259	201998.753	464.886	586969.484	202006.003	458.815	3.5938	.122
8	586977.259	201998.753	464.886	586969.483	202006.000	457.815	3.6250	.130
9	586977.259	201998.753	464.886	586969.484	202005.999	456.815	4.1563	.098
10	586977.259	201998.753	464.886	586969.488	202006.000	455.815	4.3750	.032
11	586977.259	201998.753	464.886	586969.492	202006.001	454.815	4.6250	.053
12	586977.259	201998.753	464.886	586969.496	202006.004	453.815	4.8750	.044
13	586977.259	201998.753	464.886	586969.497	202006.011	452.815	5.1250	.03E
14	586977.259	201998.753	464.886	586969.495	202006.020	451.815	5.4375	.027
15	586977.259	201998.753	464.886	586969.486	202006.024	450.815	5.8125	.022
16	586977.259	201998.753	464.886	586969.484	202006.035	449.815	6.2188	.01E
17	586977.259	201998.753	464.886	586969.488	202006.040	448.815	6.4375	.01C
18	586977.259	201998.753	464.886	586969.493	202006.042	447.815	6.6875	.01E
19	586977.259	201998.753	464.886	586969.497	202006.047	446.815	6.9063	.017
20	586977.259	201998.753	464.886	586969.496	202006.051	445.815	7.5313	.01E
21	586977.259	201998.753	464.886	586969.493	202006.055	444.815	7.8438	.01E
22	586977.259	201998.753	464.886	586969.493	202006.058	443.815	8.4062	.027
23	586977.259	201998.753	464.886	586969.493	202006.059	442.815	8.8750	.02C
24	586977.259	201998.753	464.886	586969.496	202006.062	441.815	9.1250	.00E

Fig. 9. Form for saving 3PK files with coordinates and picked times. With long GPS coordinates, scroll to right to see amplitudes and data quality.

This form gives you another chance to edit the source and receiver positions and times displayed in a textbox. You can revise the source X Y Z coordinates by entering new values in text boxes, then clicking **Revise Source Coordinates**. You can revise any values directly in the table, including receiver coordinates and times. The revisions in the table should be last, because the table values will be restored to the original values if you press **Revise Source Coordinates**. When all the values are correct, accept or edit the file name shown and click **WRITE 3PK FILE TO DISK**. A 3PK file is written for that file, in the format:

```
Channel Source X,Y,Z Receiver X,Y,Z Time Amp1 loc1 Amp2 loc2 Amp3 loc3
```

Time is the sum of the time picked in the waveform display plus the optional time correction from form **Main**. Amp1 is the amplitude of the first amplitude pick, and loc 1 is the corresponding time in the waveform display. The time corresponding to each amplitude is saved to allow the amplitude dots to be positioned correctly if old picks are read.

A second control for writing an ASCII file of the waveform is on this form. Press the rectangular command button near the bottom left labeled **Write ASCII waveform file**.

After the file is written, you will be returned to **Form 4** for picking a waveform file to read. Options for file reading labeled **Automate** and **Manual** (default) will now be visible. They were invisible during the first file selection because the automate mode makes the program use previous settings for time picking limits and filters. These settings are established during the processing of the first waveform file. Thus, the Automate mode can reduce the number of repetitive button clicks.

TomTime allows the user to examine the time and amplitude picks on the waveform traces and to change them before clicking **File** to save those picks in a 3PK file. Comments from users are invited as to whether the program should be more automated.

After processing all the waveform files you want, click **BACK** rather than **READ FILE**. You are then returned to the TOMTIME Main Menu (**Form 2** described above). The next step is to combine the selected 3PK files into a time and amplitude tomographic data file. In the Main Menu, click **Select 3PK Files for Time and Amplitude Data File** to start form 9.

Form 9 is titled **Select 3PK Files for Time and Amplitude Data File**. It is shown below in Figure 10.

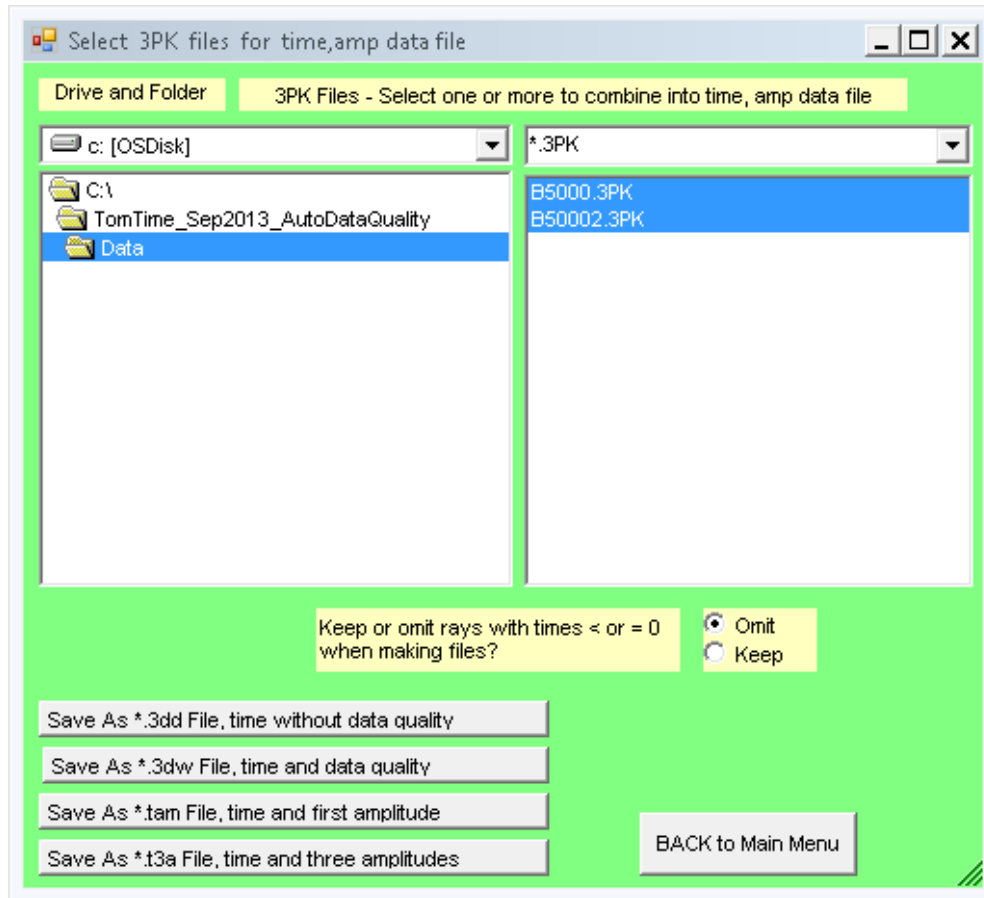


Fig. 10. The form for selecting 3PK files for combining into one file for GeoTomCG.

Data files from TomTime have the extension 3PK to distinguish them from SIPWin PIK files, which have a different format. One 3PK file is generated from each waveform file. This step combines the 3PK files into a data file for the tomographic program GeoTomCG. You can choose whether to write the amplitudes in the data file. **THESE AMPLITUDES MUST BE PREPROCESSED BEFORE TOMOGRAPHIC ATTENUATION INVERSION, AS EXPLAINED IN THE GEOTOMCG INSTRUCTIONS.** Writing amplitudes in a data file provides a convenient method of keeping the traveltimes and amplitudes together, but these amplitudes must be converted to a logarithmic representation and corrected for geometric spreading and angular source and receiver effects before being inverted by GeoTomCG.

The form displays a list of 3PK files. First select the drive and folder containing the 3PK files, then select the 3PK files you want to combine into a data file. All of the standard Windows selection techniques work, such as using Shift to pick sequential files and Ctrl to pick non-adjacent files in the list. You can choose whether to omit raypaths with traveltimes of 0.0 or less, to get rid of data from dead traces. Traveltimes read by GeoTomCG must not be 0, so omit them if you are preparing data files for GeoTomCG.

The user can select the format in which 3PK files are combined and saved in a data file for GeoTomCG. Options are:

a) *.3dd file, contains time but not data quality or amplitude;

Ray Identifier Source X, Y, and Z Receiver X, Y, and Z Time

To read with GeoTomCG, click **Data, Open data file (*.3dd)**

b) *.3dw file, contains time and data quality but not amplitude;

Ray Identifier Source X, Y, and Z Receiver X, Y, and Z Time Data quality

To read with GeoTomCG, click **Data, Open data file with quality weight factors (*.3dw)**

c) *.tam file, contains time and first amplitude peak but not data quality;

Ray Identifier Source X, Y, and Z Receiver X, Y, and Z Time Amplitude

To read with GeoTomCG, click **Data, Combination, read time (*.tam),**

or **Combination, read amplitude (*.tam).**

d) *.t3a file, contains time and all three amplitude peaks but not data quality.

Ray Identifier Source X, Y, and Z Receiver X, Y, and Z Time Amp1 Amp2 Amp3

GeoTomCG cannot read this file with all three amplitudes. The user must process the three amplitudes to determine the appropriate amplitude value for GeoTomCG to read, and prepare a *.tam file.

After you click the appropriate **Save As** button, a dialog box will allow you to select a name for the file to be saved. Ray Identifiers are assigned as sequential integers. Two header lines of information are added at the top of the saved file, as required by GeoTomCG.

To exit TomTime, click on **Back to Main Menu**, and then click **EXIT** in the Main Menu.

Special options for Sensors & Software radar files

TomTime provides special options for working with Sensors & Software radar files. The following explanation of the files and calibration diagram were provided by Sensors & Software. The project information is in a text file with extension *.HD and the radar data are in a binary file with extension *.DT1. If you select a radar file *.DT1 and click **READ FILE**, TomTime automatically reads the *.HD file with the same path and name, except for extension, as the DT1 file. The antenna separation in the *.HD file is used as the receiver X. The receiver Y is 0 unless the user changes it. The receiver Z is calculated from information in the HD file. The user must enter the source Z in either Form 6 or 8 described below. The source X and Y are 0 unless the user changes them in Form 6 or 8.

The *.HD text files contain information about the measurement and recorded trace such as the antenna separation, the length of the total time window in ns, the number of sample points per trace, the number of channels, the start, final, and step length depths of the receiver positions, project information, and the correction that must be applied to the first-break arrival.

An example HD file is shown below and one is included in the example files.

Optional lines of comments, like project description

Time and/or date

NUMBER OF TRACES = 21

NUMBER OF PTS/TRC = 500

TIMEZERO AT POINT = 79.466670

TOTAL TIME WINDOW = 200.0000

STARTING POSITION = 1.000000

FINAL POSITION = 6.000000

STEP SIZE USED = 0.250000

POSITION UNITS = metres

NOMINAL FREQUENCY = 200.000000

ANTENNA SEPARATION = 2.070000

PULSER VOLTAGE (V) = 1000

NUMBER OF STACKS = 64

SURVEY MODE = Trans. - MOG

Comments on recording system

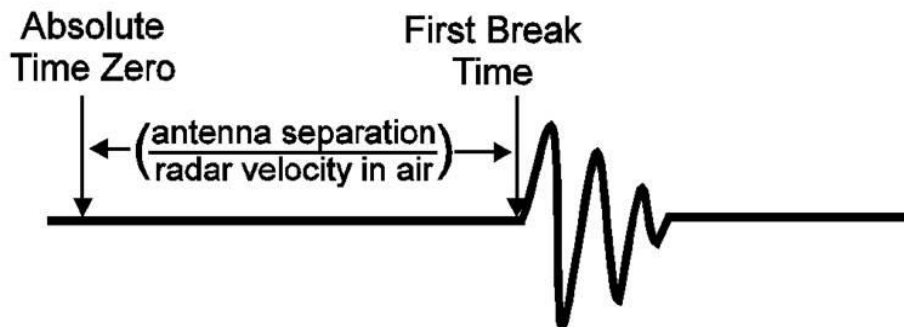
TIMEZERO BASED ON CALIBRATION FILE C:\Apr2013\CAL5.HD

TIMEZERO AT POINT is a correction that is applied to the position of the first-break arrival. The correction is needed because the trace recorder is started slightly before the crosshole radar signal is sent. We need to determine accurately the actual time the signal was sent to set the correct time zero on the traces.

The zero time is determined with a calibration file created by holding the borehole antennas at a known separation in air. The radar velocity in air is 0.3 m/ns, so the time zero in a trace

can be calculated by determining the first-break arrival time as recorded and subtracting the traveltime between the antennas. This subtraction is illustrated in the diagram below.

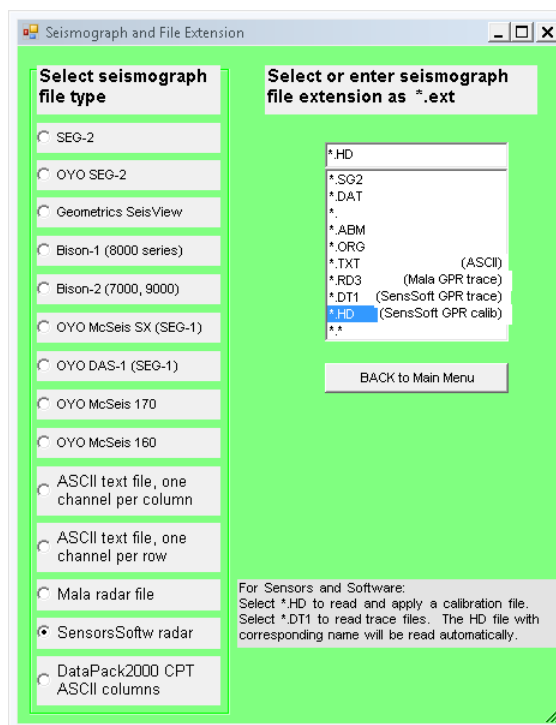
Absolute timezero = first break time - (antenna separation/ velocity of light)



The calibration file is prepared by the user and contains the sample point on the trace corresponding to the first break arrival time before the subtraction. For the example calibration file, the first-break arrival occurred at a time corresponding to 112.8 points on the trace, so the example calibration file contains `TIMEZERO AT POINT = 112.8`. This is the sample point on the trace, not the time, so we need the corresponding time to make the subtraction to find the correct time zero. The HD file contains the total time window and the number of points per trace. The time corresponding to each point = total time window/number of points per trace. In the example file, this time is 200 ns/500 points = 0.4 ns/point.

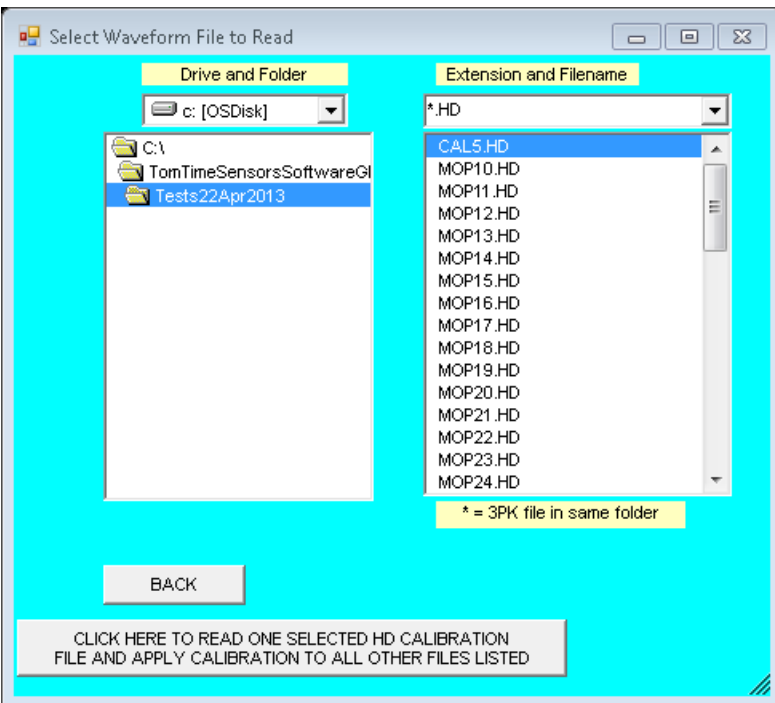
The absolute time zero = $(\text{TIMEZERO AT POINT} * \text{time/point}) - (\text{antenna separation}/0.3)$. For the example calibration file, the antenna separation = 4 meters, so absolute timezero time = $(112.8 * 0.4) - (4/0.3) = 31.7867$ ns. This time corresponds to a point at $31.79 \text{ ns}/0.4 \text{ ns/pt} = 79.4667$, which is shown as the `TIMEZERO AT POINT` in the example HD file above.

TomTime can apply the calibration file correction to a list of HD files automatically. To do so, start TomTime in the usual way and click **Select Seismograph and File Extension** on the main menu to start Form 3. In Form 3 select seismograph type SensorsSoftw radar and file extension *.HD as shown to the right, not *.DT1.



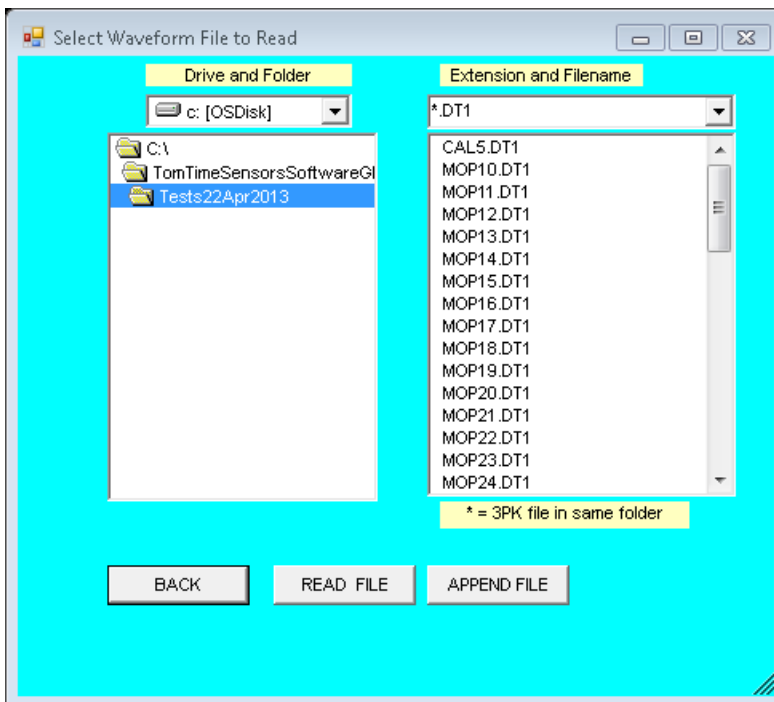
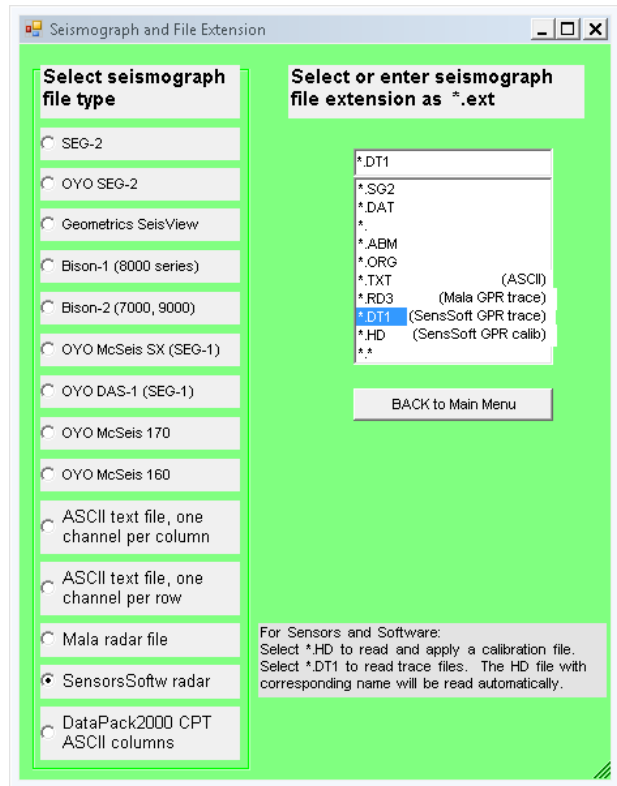
Click **BACK to Main Menu**. In the Main Menu, click **Display Waveforms and Pick Times** to start Form 4. Select the drive and folder containing the calibration HD file and the HD files in which the TIMEZERO AT POINT based on the calibration file should be written. The calibration file must be in the same folder as the HD files you want to correct. Form 4 is shown below with a list containing a calibration file and other HD files. Select the calibration file, then click the wide button near the bottom labeled **CLICK HERE TO READ ONE SELECTED HD CALIBRATION FILE AND APPLY CALIBRATION TO ALL OTHER FILES LISTED**. This button is visible only when the HD file extension is selected. A TIMEZERO AT POINT based on the calibration file will be written in each of the other HD files with no additional user input. The name of the calibration file will be written at the end of each of the other HD files.

A message box will indicate when writing the TIMEZERO AT POINT in the other HD files has been completed.



After the correct TIMEZERO AT POINT has been written in the HD files, you can read the DT1 files to view the traces and pick traveltimes and/or amplitudes. Go back to the Main menu and click **Select Seismograph and File Extension** to open Form 3 again. Select seismograph type SensorsSoftw radar again, but this time select file extension *.DT1, as shown to the right.

Click **BACK to Main Menu**. In the Main Menu, click **Display Waveforms and Pick Times** to start Form 4. Select the drive and folder containing the DT1 files and the corrected HD files. The DT1 and HD files must be in the same folder and the file names must match except for the extension. Form 4 is shown below with a list containing DT1 files. Select a DT1 file as shown. Then click **READ FILE** and proceed with the other forms as described in the general instructions to view



traces and pick traveltimes and/or amplitudes. The HD file corresponding to the DT1 file will be read automatically with no additional user input.

As explained previously, the antenna separation in the *.HD file is used as the receiver X. The receiver Y is 0 unless the user changes it. The receiver Z is calculated from information in the HD file. The user must enter the source Z in either Form 6 or 8 described below. The source X and Y are 0 unless the user changes them in Form 6 or 8.

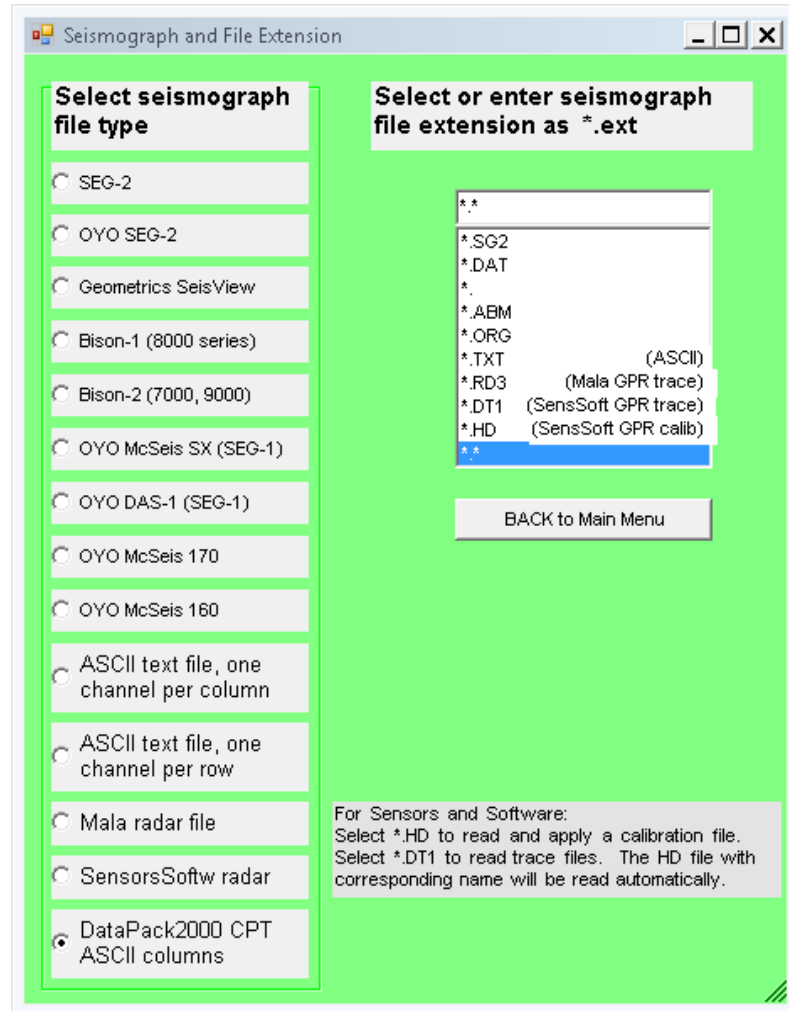
Special options for DataPack 2000 seismic data files

These instructions are for reading and processing DataPack2000 cone penetration (CPT) data. Some of these instructions are for the same forms described in the general instructions, but use examples specific to data from the DataPack 2000 and CPT applications.

This option was first developed for determining the depth of the bottom of foundations of traffic-light towers. A seismic receiver was mounted in the cone of a CPT machine. The top of the foundation was struck with a large hammer, causing the entire foundation to serve as a seismic source. The first-arrival signal came from the point on the foundation nearest the receiver in the CPT. Data were recorded in a DataPack 2000 every foot from near the top of the foundation to a depth known to be below the bottom. Example data consist of two of those files, DataPack.017 and DataPack.024 at receiver depths of approximately 17 and 24 ft, respectively. Users are encouraged to suggest revisions for improving the usefulness of this new option.

TomTime reads the depth from header lines in the file and reads the P-wave data. TomTime automatically reads all the data files the user has selected and displays the P-wave traces in one display for automatic time-picking with an option for manual editing. Applying a 1000-Hz high cutoff filter improved the reliability of the time picking for the example files.

Install and start TomTime as described in the general instructions. After the initial form, you will see the TomTime Main Menu. Click **Select Seismograph and File Extension** to display Form 3 shown to the right.



Select seismograph file type

- SEG-2
- OYO SEG-2
- Geometrics SeisView
- Bison-1 (8000 series)
- Bison-2 (7000, 9000)
- OYO McSeis SX (SEG-1)
- OYO DAS-1 (SEG-1)
- OYO McSeis 170
- OYO McSeis 160
- ASCII text file, one channel per column
- ASCII text file, one channel per row
- Mala radar file
- SensorsSoftw radar
- DataPack2000 CPT ASCII columns

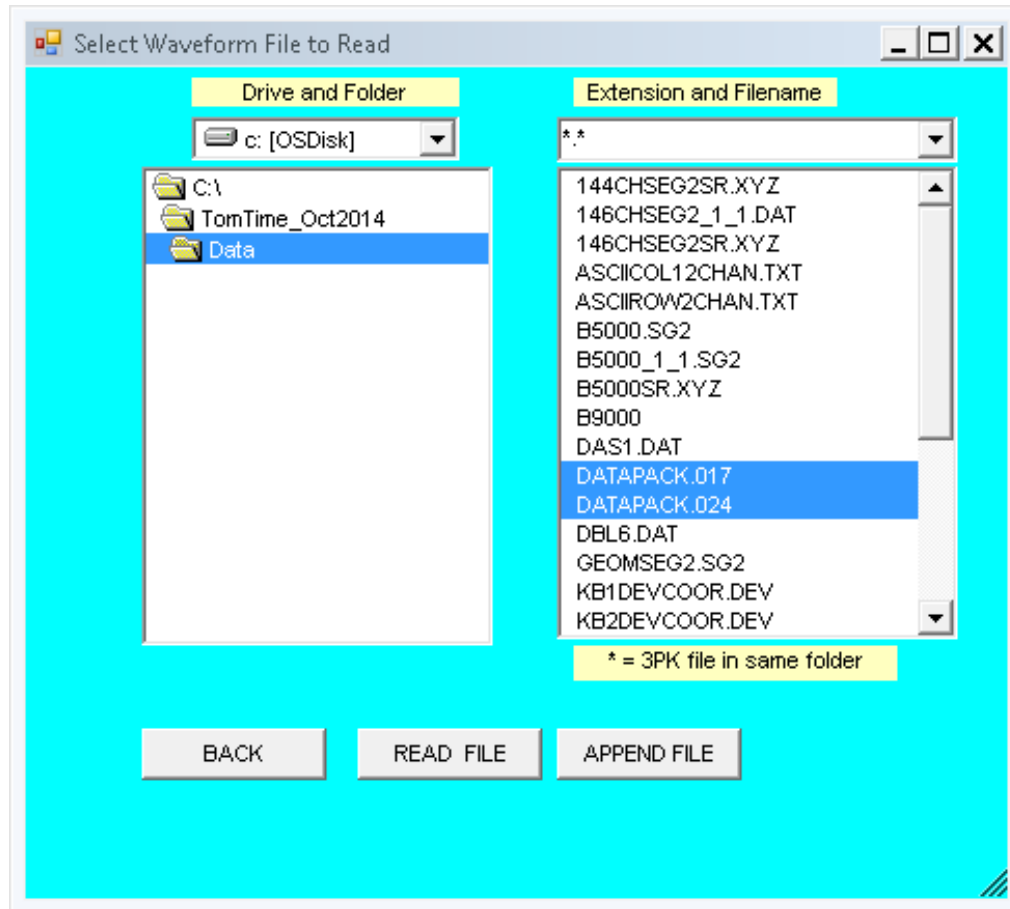
Select or enter seismograph file extension as *.ext

- *.*
- *.SG2
- *.DAT
- *.*
- *.ABM
- *.ORG
- *.TXT (ASCII)
- *.RD3 (Mala GPR trace)
- *.DT1 (SensSoft GPR trace)
- *.HD (SensSoft GPR calib)
- *.*

BACK to Main Menu

For Sensors and Software:
Select *.HD to read and apply a calibration file.
Select *.DT1 to read trace files. The HD file with corresponding name will be read automatically.

Under **Select seismograph file type**, select **DataPack2000 CPT ASCII columns**. Under **Select or enter seismograph file extension**, select ***.*** because the file extension for the DataPack2000 CPT data varies with depth. Click **BACK to Main Menu**. In the TomTime Main Menu, click **Display Waveforms and Pick Times** to display Form 4, shown below.



Keep or select the proper drive, usually C:, in the upper left box. Select the folder containing the DataPack2000 CPT data files in the large list box on the left. The extension the upper right box should be ***.***. The large right list box will contain the file names in the selected folder that have the specified extension and that meet other criteria to confirm it is a data file of that type. There are other criteria for SEG-2 files and some other types, but not for DataPack2000 CPT data, so all files in the folder are shown.

Highlight the files in the large right list box that should be read. You can use the usual Windows highlighting keys such as Shift and Control for highlighting multiple files. Be careful not to highlight files that should not be read. This version of TomTime is quite automated, and will stop with an error if any one of the highlighted files is not a properly formatted DataPack 2000 data file.

After highlighting the desired files, click **READ FILE**, and Form 5 shown to the right will appear.

TomTime will automatically read all the highlighted files in the previous form. The Source Loc and Rec-1 Loc on this form are both the depth of the receiver. The source depth is displayed as the receiver depth because the source is the entire length of the

foundation so the source point for first-arrival times will be the nearest point on the foundation. You can see the depths change as TomTime reads through all the highlighted files and then stops with the last depth displayed.

Click **CONTINUE** to show Form 6, to the right. This form shows the coordinates of all the receivers and of the last source position. This form is a convenient place to enter a value for the receiver X or Y coordinate, to show the horizontal distance from the source to the receiver. For this example, we will enter 6 for the receiver X coordinate. You could choose instead to enter a new Y coordinate for the receiver or new X or Y coordinates for the source.

Reading Waveform File DATAPACK.024

SEG-2 WAVEFORM FILE HEADER

File Name: DATAPACK.024 Line Number: [] Date: []
 Format: [] Time: []

INSTRUMENT

Model: [] Samples/Ch: [] High Cut: OUT
 Serial No: None Sample Rate: [] Low Cut: OUT
 Channels: 1 Delay Time: [] Notch: OUT

SPREAD

Source Loc: 24.238852564 Rec-1 Loc: 24.238852564 File Units: None
 Default Units (Used): Meters

BACK [] CONTINUE []

Source X: 0.000
 Source Y: 0.000
 Source Z: 24.238852564

Source and Rec Locs OK?

 Revise Display Trace

Trace Display
 Clipped
 Shaded

Whole trace
 First half only
 Maximum time: 200.08
 # traces to display: 72

Auto pick
 First break Peak
 Skip initial time: 0

Channel	RecX	RecY	RecZ	Stacks
1	0.00	0.00	17.062	0
2	0.00	0.00	24.238	0

BACK []

To change any of the coordinates, click **NO** under **Source and Rec Locs OK?** The form shown on the right will appear.

To change the receiver X to 6, enter 6 for the **New Receiver X** as shown. Then click **Update Rec Loc** to show the form with the new receiver X as shown below. The receiver Z coordinates cannot be changed with the option on this form for the DataPack 2000 CPT data because this

option assumes even spacing, as is the case for hydrophones and nearly all crosshole seismic tomography data sets. However, the Z spacing is not uniform for DataPack 2000 CPT data, so the option to reset the Z coordinates is disabled here. An option in a subsequent form allows any individual coordinate to be changed.

The screenshot shows a software window with a cyan background. At the top left, there are three input fields for Source X (0.000), Source Y (0.000), and Source Z (24.238852564). To the right is a table with columns: Channel, RecX, RecY, RecZ, and Stacks. The table contains two rows of data:

Channel	RecX	RecY	RecZ	Stacks
1	0.00	0.00	17.062	0
2	0.00	0.00	24.238	0

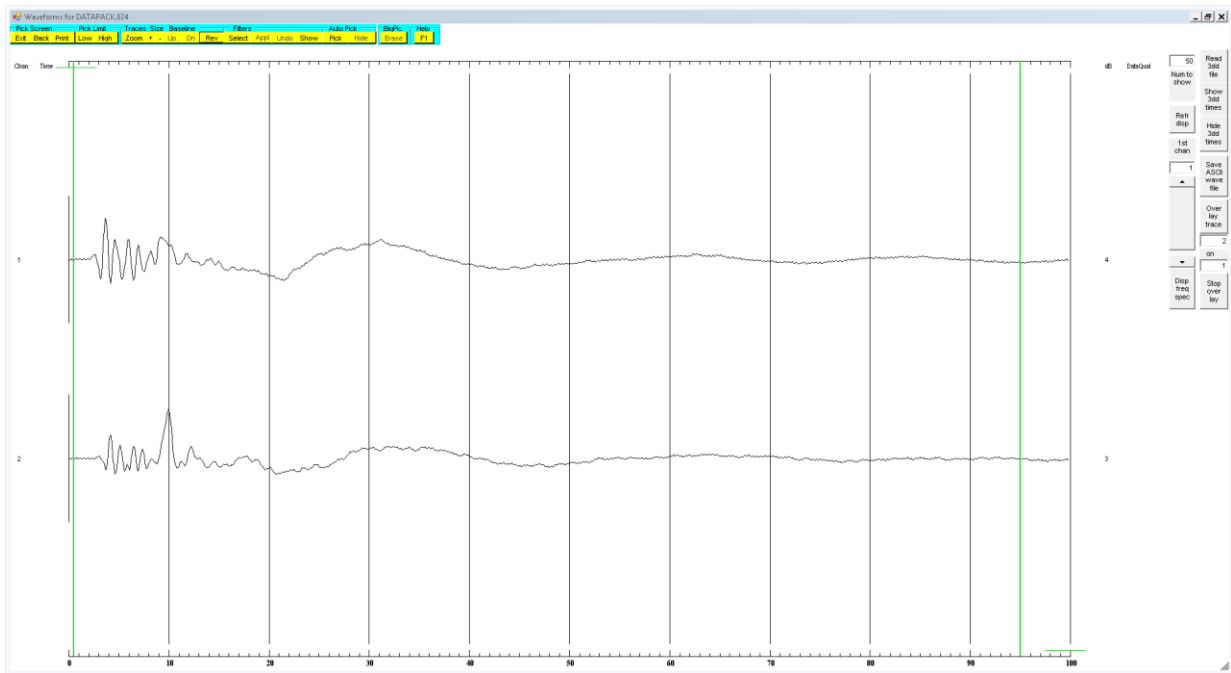
Below the table is a blue button labeled "Enter New Values Below". Underneath are two groups of input fields. The first group, highlighted in yellow, contains "New Source X" (0.000), "New Source Y" (0.000), and "New Source Z" (24.238852564). The second group, also highlighted in yellow, contains "New Receiver X" (6|00), "New Receiver Y" (0.00), "New Rec 1 Z" (17.06), "Rec Z Spacing" (7.1759), and "New Rec 2 Z" (24.23). At the bottom are two buttons: "Update Sor Loc" and "Update Rec Loc", and a "BACK" button at the very bottom.

The screenshot shows a software window with a cyan background. At the top left, there are three input fields for Source X (0.000), Source Y (0.000), and Source Z (24.238852564). To the right is a table with columns: Channel, RecX, RecY, RecZ, and Stacks. The table contains two rows of data:

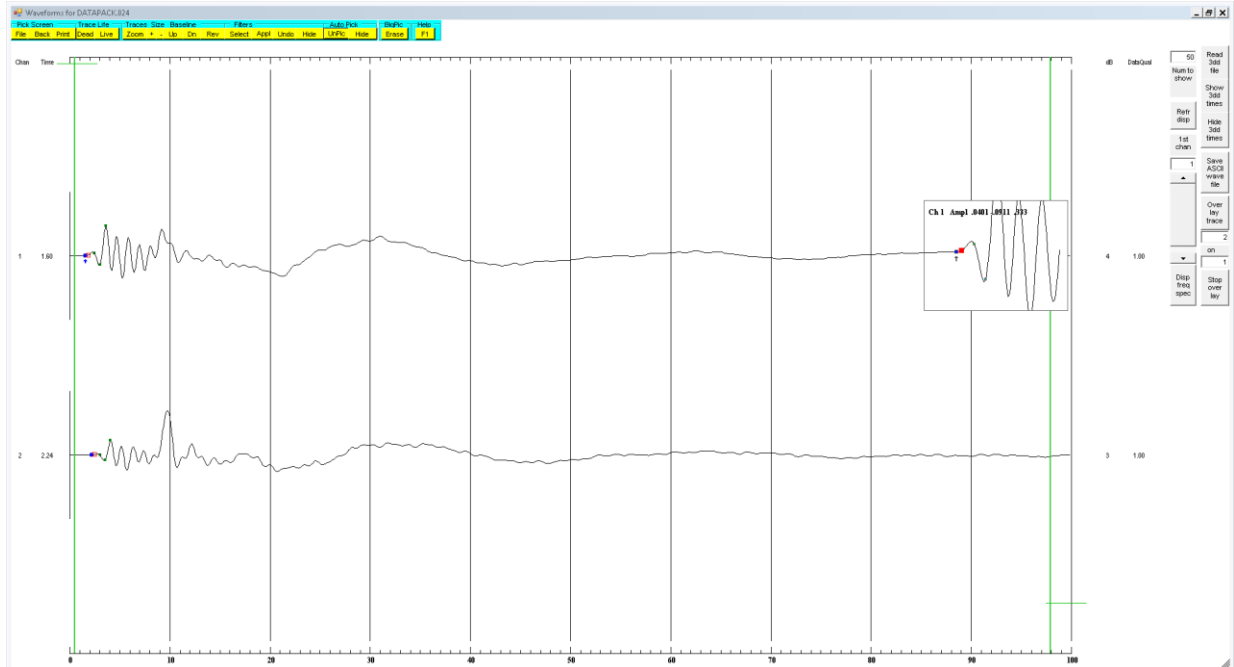
Channel	RecX	RecY	RecZ	Stacks
1	6.000	0.000	17.062	0
2	6.000	0.000	24.238	0

Below the table is a yellow box with the text "Source and Rec Locs OK?" and two buttons: "NO" and "YES". Below this are two buttons: "Revise" and "Display Trace". Underneath is a section titled "Trace Display" with checkboxes for "Clipped" and "Shaded". Below that are radio buttons for "Whole trace" and "First half only" (which is selected). There is an input field for "Maximum time" (200.08) and another for "# traces to display" (72). Below that is a section titled "Auto pick" with radio buttons for "First break" (selected) and "Peak". There is an input field for "Skip initial time" (0). At the bottom is a "BACK" button.

This is the form with the receiver X = 6. Showing only the first half of traces is often adequate to observe the first-arrival time. Click **YES** under **Source and Rec Locs OK?** to display the wave traces shown on the next page, which is Form 7.

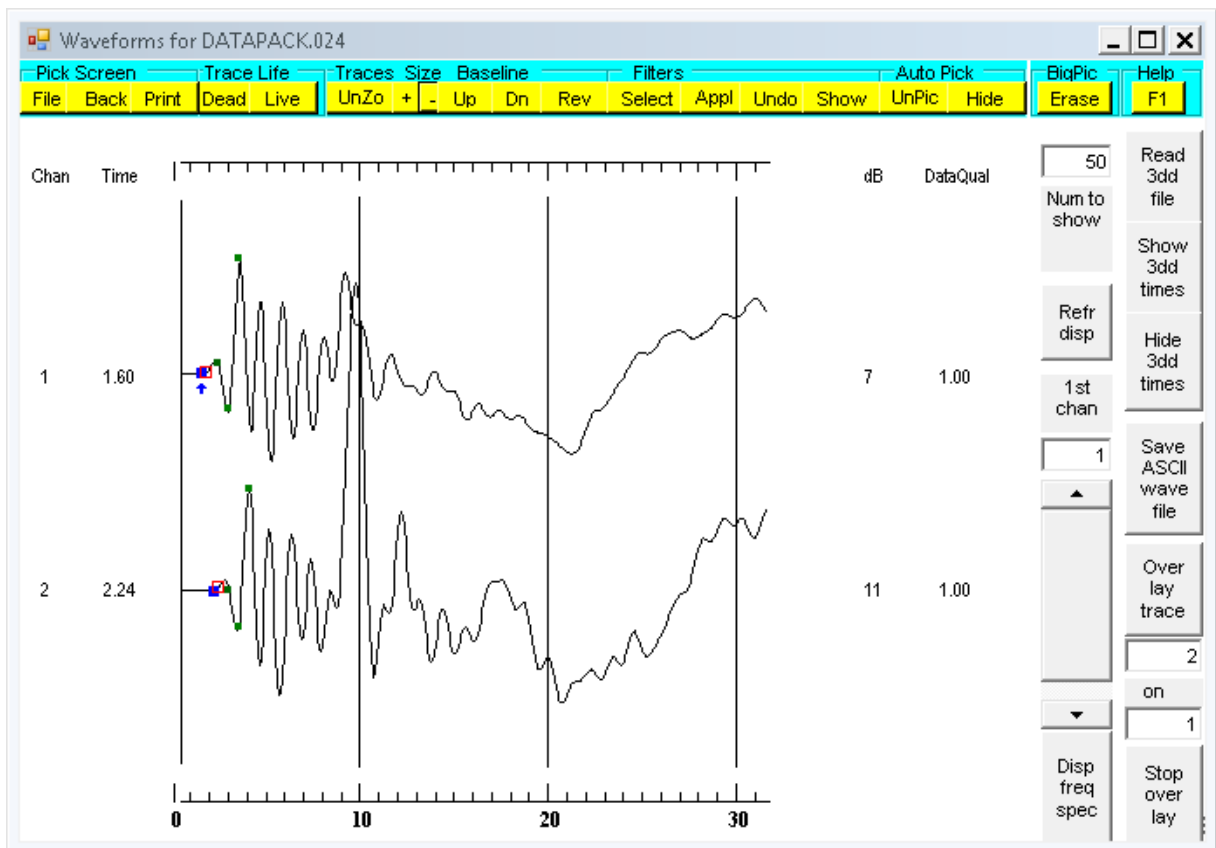


The figure above displays the wave traces before applying any filter and before picking first-arrival traveltimes. Applying a high-cut filter of 1000 Hz reduced high-frequency noise. Under **Filter** at the top, click **Select**, then under **High cut** highlight **1000 Hz**, then click **Appl**. To auto pick first-arrival times, click **Pick** under **Auto Pick** at the top of the form. A display similar to the figure below will appear.



This display shows the wave traces after applying a 1000-Hz high-cut filter, auto-picking, and slightly decreasing the picked times using manual editing. Manual editing is described in the general instructions and the description will not be repeated here.

The Zoom option can be used to limit the display time range to the time of interest. In the display below, the **Pick Limit High** was set to 30 ms and the dialog box was reset from full screen to windowed to show the two wave traces more clearly for this manual.



To write a file with the first-arrival picks in it, click **File** at the top left. Form 8 below will appear.

Write 3PK file to disk

SourceX 0.000 --> Amp1 loc1 Amp2 loc2 Amp3 loc3 DataQual -->

SourceY 0.000

SourceZ 24.238852564

Channel	SorX	SorY	SorZ	RecX	RecY	RecZ	Time+correction				
1	0.000	0.000	17.062952991	6.000	0.000	17.062	1.60	0	2.48	0	3.03
2	0.000	0.000	24.238852564	6.000	0.000	24.238	2.24	0	3.03	0	3.5

Revise Source Coordinates

To revise receiver coordinates or times, enter the new values directly in the list. Revising the source coordinates restores the original receiver coordinates and times, so revise source coordinates first.

You may edit drive, directory, and name of the 3PK file:

C:\TomTime_Oct2014\Data\DATA

WRITE 3PK FILE TO DISK

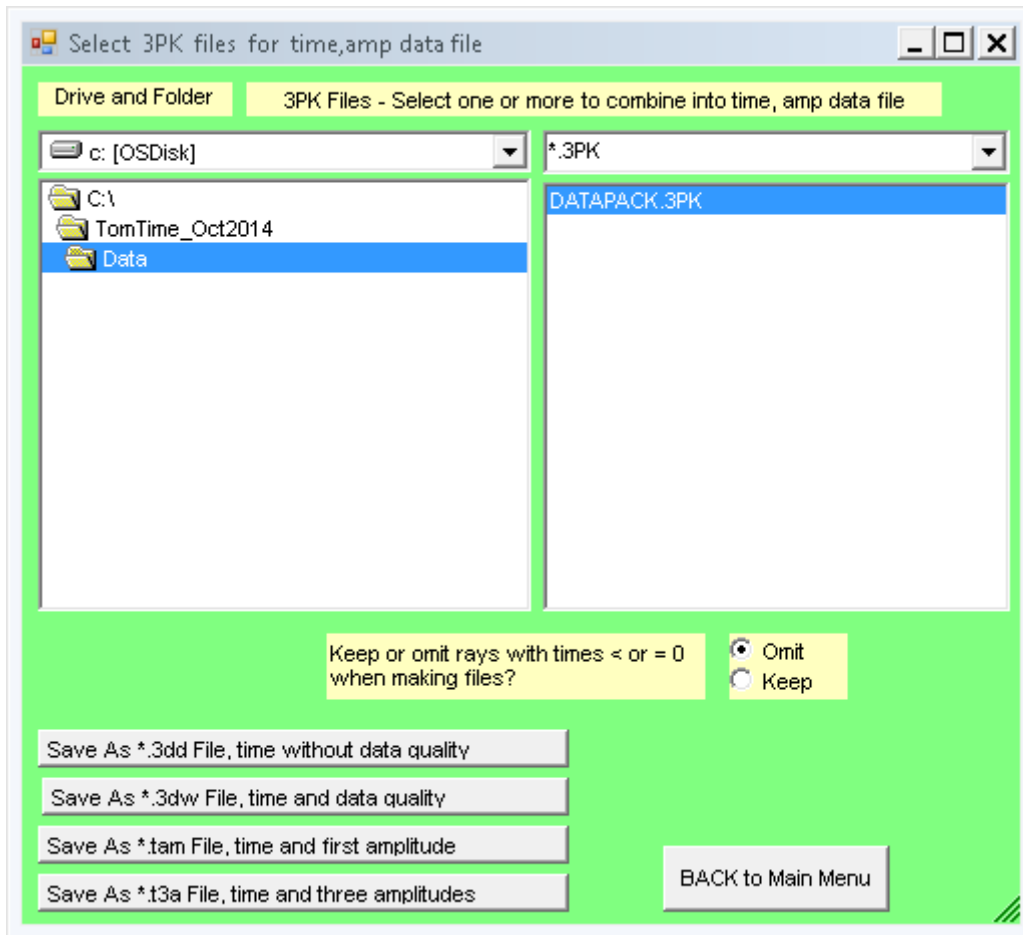
Write ASCII waveform file

BACK CANCEL

This form allows any individual coordinate to be revised by directly entering the changes in the list box. Probably all the coordinates will be correct at this point in the processing. The format for each row is Channel number, Source X Y Z, Receiver X Y Z, Time, amplitude values and positions on the wave-trace display, and data quality. The amplitudes are not used in processing the DataPack 2000 CPT data, and can be ignored.

Accept the default file name or rename it, and click **WRITE 3PK FILE TO DISK** to save a file with the rows shown in the list box. You can look at more data files, or you can generate a 3dw or 3dd file with the data you want that can serve as input for GeoTomCG or a spreadsheet.

To make a data file for GeoTomCG, use **BACK** to return to the TomTime Main Menu and click **Select 3PK files for Time and Amplitude Data File**. Form 9 shown on the next page will be displayed. .



Select the drive, folder, and files you want to read to generate the GeoTomCG data file. Here there is just one file to be read. For processing DataPack 2000 CPT data, you will often have one 3PK file made from a set of data files for a range of depths. The *.3dw file saves data quality with the first-arrival times, and is recommended. After clicking **Save As *.3dw File time and data quality**, click **Back to Main Menu**.

Verify that the data file was written correctly. A 3dw file from the two example data files should resemble the following:

Data file with traveltimes and data quality for GeoTomCG

Data file with traveltimes for GeoTomCG

RayId	SorX	SorY	SorZ	RecX	RecY	RecZ	Time	DataQual
1	0.000	0.000	17.062	6.000	0.000	17.062	1.600	1.00
2	0.000	0.000	24.238	6.000	0.000	24.238	2.240	1.00

A GeoTomCG 3dd data file made with a complete set of field data is shown below. Coordinates are in ft, times are in ms.

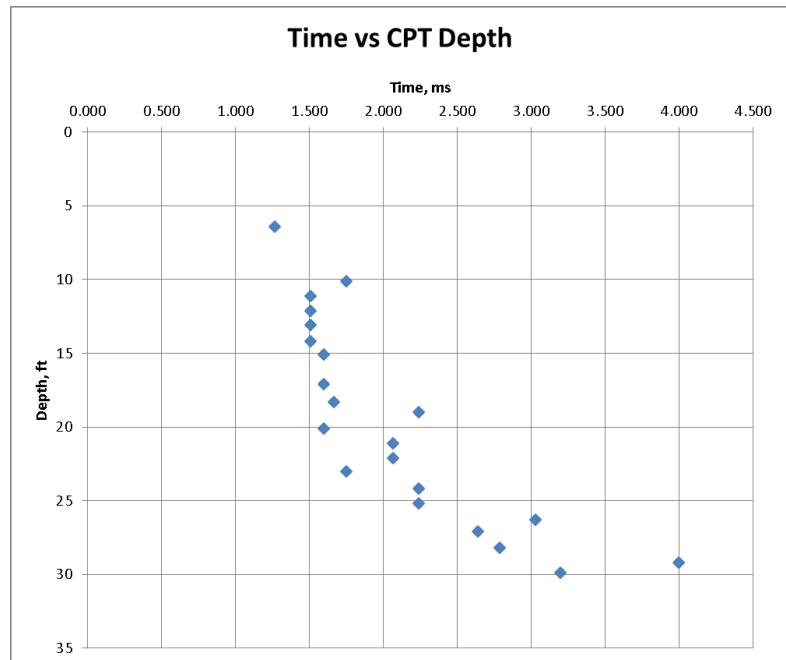
Data file with traveltimes for GeoTomCG

RayId	SorX	SorY	SorZ	RecX	RecY	RecZ	Time
1	0	0	6.4	6	0	6.4	1.269
2	0	0	10.1	6	0	10.1	1.750
3	0	0	11.1	6	0	11.1	1.509
4	0	0	12.1	6	0	12.1	1.509
5	0	0	13.1	6	0	13.1	1.509
6	0	0	14.2	6	0	14.2	1.509
7	0	0	15.1	6	0	15.1	1.600
8	0	0	17.1	6	0	17.1	1.600
9	0	0	18.3	6	0	18.3	1.669
10	0	0	19.0	6	0	19.0	2.240
11	0	0	20.1	6	0	20.1	1.600
12	0	0	21.1	6	0	21.1	2.069
13	0	0	22.1	6	0	22.1	2.069
14	0	0	23.0	6	0	23.0	1.750
15	0	0	24.2	6	0	24.2	2.240
16	0	0	25.2	6	0	25.2	2.240
17	0	0	26.3	6	0	26.3	3.029
18	0	0	27.1	6	0	27.1	2.640
19	0	0	28.2	6	0	28.2	2.789
20	0	0	29.2	6	0	29.2	4.000
21	0	0	29.9	6	0	29.9	3.200

An increase in time can indicate that the source is getting farther from the receiver as the depth of the receiver exceeds the bottom of a foundation serving as a seismic source. A gradual change in time with depth can indicate that the foundation is slanted. A more sudden increase in time with depth can indicate the bottom of the foundation has been passed. Geologic logs should be used to identify changes caused by layers having contrasting seismic velocity.

In the data file above, the bottom of the foundation was at 20 ft. Plotting the time versus CPT

depth as shown to the right can make the significant changes in time easier to distinguish from smaller changes. .



Summary Instructions for Waveform Display (Form 7)

The waveforms display contains several symbols, and uses several different controls for them. The user may find it convenient to refer to this summary until becoming familiar with this display.

Before autopicking times:

Adjust amplitudes of traces – click **Size +** and **-** buttons.

Set low, high time pick limits – click **Pick limits Low** or **High** buttons, then mouse click.

Set number of traces to display – enter number in box **Num to show** at right of display.

Set first channel to display - use slider bar labeled **1st chan** at right of display.

Refresh display to show specified channels – click button **Ref dis** at right of display.

Move display down or up by the number of displayed channels – press **Page Down** or **Page Up**

After autopicking, the symbols represent the following parameters:

Blue dot (larger than amplitude dots) – time.

Dark Green dot – first amplitude pick.

Green dots – second and third amplitude picks.

Small red unfilled square – time picked by autopicking.

Blue arrow pointing up – points to blue dot in the selected trace.

Narrow red rectangle – time read from 3dd file (not shown in Figure 3).

Controls for moving the time and amplitude dots

Select trace - left-click once.

Move trace selection down or up by one – **k** or **i** keys.

Move trace selection down or up by five – **K** or **I** keys.

Coarse movement of blue time dot – left mouse button click, or **J** and **L** keys

Coarse movement of green amp1 dot – right mouse click, or **E** and **T** keys.

Coarse movement of blue-green amp2 dot – **Shift** + left mouse button click, or **D** and **G** keys

Coarse movement of blue-green amp3 dot – **Shift** + right mouse button click, or **X** and **V** keys

Fine movement of blue time dot – **Ctrl** + left or right mouse button, or **j** and **l** keys.

Fine movement of green amp1 dot – **Alt** + left or right mouse button, or **e** and **t** keys.

Fine movement of blue-green amp2 dot – **d** and **g** keys.

Fine movement of blue-green amp3 dot – **x** and **v** keys.