WinSeis 1.8 Tutorial

August 2020

SEISMIC-REFLECTION PROCESSING TUTORIAL USING WINSEIS 1.8

(originally Eavesdropper Tutorial)

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Using WinSeis 1.8

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INTRODUCTION

WinSeis© is a software product developed at the Kansas Geological Survey to process seismic data for imaging seismic reflections. The first version of the software (known as Eavesdropper) was built in 1991 and has been improved over the years, turning it into a robust, reliable, and inexpensive software. The purpose of this WinSeis 1.8 tutorial is to bring the original Eavesdropper tutorial up to date to account for the various improvements over the years and the way data are currently processed at the KGS.

The tutorial update was applied in a fashion trying to preserve the original structure and content of the Eavesdropper Tutorial.

Styles used in this document

1. Folder paths are in a blue font,
2. File names are highlighted in yellow,
3. **Menu and button clicks** are shown in bold.

INSTALLATION INSTRUCTIONS

Programs and data contained on the demo CD will operate in a fashion nearly identical to the full WinSeis 1.8 package. The demonstration software and manual have been compiled to instruct the novice as well as the seasoned processor. It is an opportunity to see and feel the flow of this seismic processing package. Only a small sampling of the operations available with the WinSeis package are included in this demo.

Four types of data are contained in the installation folder and subfolders:

1) seismic data (extension = *.raw or *.dat),
2) sample batch files (extension = *.dek),
3) executable files (extension = *.exe. *.bat), and
4) assistance files (extension = *.ini, *.hlp, *.cfg, *.rd, *.ord, and*.clr).

To minimize confusion, while processing the sample data it is advised to make a sub-folder containing the sample batch files, assistance file, and data files. This folder should be named something similar to "Tutorial."

Run the installation (e.g., "setup.exe" from the installation CD) and follow the instructions.

If you obtained a 30-day free copy, a "RUS" window will appear after the installation with an "**Apply Update**" button. Click on it to apply the 30-day license.

Double clicking on a *.dek file will automatically launch the WinSeis 1.8 processing engine, which will follow the command(s)/parameters and create a corresponding *.lst output file with processing information summary.

CDP PROCESSING WITH WINSEIS 1.8 FOR THE NOVICE

This document is designed to demonstrate the operation of *WinSeis 1.8* by providing step-by-step detailed instructions and explanations of seismic data processing from raw data to brute stack.

The format of the text in this document was specifically designed to aid in identifying 1) *responses and information supplied to the user by the program upon request*, 2) <u>**information or commands supplied to the program by the user**</u>, and 3) **key points (highlights) to remember**. The information supplied by the program will be in *italics* and includes error messages, file contents displayed on screen using the MS-DOS TYPE command, messages concerning information being processed, notes to the user concerning default parameters, etc. All *italicized* text in this manual indicates information generated by the program. Information the user must supply to the program is always <u>**underlined**</u> and in <u>**bold type**</u> and includes execution commands, parameters to input, spaces necessary, etc.

Key information to remember is always in **bold type**. After processing the sample data set completely through using this manual, future data sets could be processed by referring only to the **bold-type** information. The user should become quite comfortable with the material in this manual after processing the sample reflection data set.

The ***WinSeis 1.8* seismic data-processing package** is divided into three main categories:
1) Viewing and Plotting,
2) Graphical user interphase (GUI) routines for preparation of processing parameters modules
3) Seismic data processing (WSeis.exe) engine and additional modules.

The viewing **and plotting** operations are **interactive**, requiring the user to execute the program and enter the requested information. The majority of the data processing procedures are contained within the sub-program file called "WSeis.exe". The program **WSeis** was designed to operate in a **batch processing** mode, requiring an input job file and an output list file.

The input job file **(.dek)** contains all the operation commands/identifiers (***AUTS**, ***EDKL**, ***SORT**, etc.) along with the appropriate user-assigned parameters. The output list file **(.lst)** contains all the significant steps and processes completed during the executed batch job. The list file also contains bits of information concerning processing time, any abnormalities in the flow, any error messages, etc.

A "**.dek**" file can be prepared by 1) using a simple text editor, such as Notepad.exe, which comes with the Windows operating system and 2) by using GUI routines available in the *WinSeis 1.8* installation folder, such as "WinEdit.exe", Winsort.exe, Winstat.exe, etc., which can help visually select the user-assigned parameters for each of the processes/commands. The latter are simultaneously written into a text file utility, "Command Editor", ("Cmdedit.exe") also available in the *WinSeis 1.8* installation folder.

There are three ways way to run/launch a "**.dek**" file:
1. By using File Explorer (available with Windows 10, aka "Windows Explorer" in previous Windows versions) to find the necessary .dek file and just double click on it, which will be assumed by default hear after.
2. Launch "WSeis.exe" from the "WSeis18" folder OR double click on the "WSeis.exe" desktop icon. Then select from the menu:
   File > Open > select ".dek" file > Open > Run
3. The third (original) way to run a ".dek" file is by first launching the Command Prompt (i.e., "cmd.exe", aka DOS Prompt). A shortcut to the Command Prompt can be found in the "Accessories" subfolder of Windows' Start button. After navigating, then the user needs to type on the following:
   >WSEIS "name.dek" "name.lst" <return>

Operation of *WinSeis 1.8* with the assistance of this manual requires a general knowledge of what seismic reflection is, as well as a working knowledge of a computer and the MS-DOS operating system (especially, if the third way of launching a .dek file is to be used).

GENERAL CDP SEISMIC DATA PROCESSING FLOW

The goal of digitally manipulating seismic data is to allow the maximum amount of geologic information to be extracted from a minimal amount of data and effort. The processing of seismic data involves a series of steps. Each seismic processing step generally has a prerequisite step or operation. This means a basic processing flow must be used to effectively process seismic data. The exact processing flow that should be used for a data set depends mainly on two things: 1) the overall quality of the data and 2) the particular information that will be extracted from the final processed section.

The processing flow we use is structured to maximize shallow high frequency CDP seismic reflection data. The general outline of our processing flow is contained in Table 2, which contains all the operations that are routinely used to go from raw field data to finished processed sections. This manual will discuss in some detail all the operations through brute stacking of seismic reflection data. **The intention of this novice user's manual is to get**

a data processor started and somewhat familiar with the organization of the *WinSeis* software as well as some of the rationale for key parameter selections. Each processor should establish a processing flow that is somewhat tailored to both the needs of the particular survey and to existing equipment. Some operations can be reordered/ removed/included/used several times and will either enhance, deteriorate, or not change the final section; however, some of the core operations (stacking, surface consistent statics, and normal moveout) do require prerequisite operations. And all processing operations require proper formatting of the input data.

Processing seismic data requires a basic understanding of acoustic-wave propagation through the earth (layered media). Attempting to process data without the necessary physics and math background will eventually result in frustration or non-results. To assist the novice/or out-of-practice seismic data processor, a sample data set is included with this manual. The data were collected May 1989 along the Thames River in England. Several good quality reflectors can be interpreted directly off the raw field files. The dataset will not present a significant challenge for the seasoned seismic data processor, but it will require a variety of standard processing steps properly applied to obtain a stacked section allowing the most realistic geologic interpretation.

Introduction to Sample Data

The raw data includes 20 field files chopped to a record length of 250 ms at a sample interval of 1/2 ms. The data were acquired with an EG&G 2401 seismograph (processing 24 channels), single 100-Hz geophones, a 12-gauge buffalo gun (both the source and receiver intervals were 2.5 m), and 200 Hz analog low-cut filters. The field notes are included within this manual. Each step in the general PROCESSING flow followed in this manual will use the England data set (DENGLAND.DAT) as the example. Following in Table 1 are the KGS's formatted data as well as 10 text *.dek files used to apply various types of processing. These files can be found in the "SampleData" sub-folder of the application installation folder, e.g., "C:\WSeis18\SampleData".

PROCESS_J.DEK file applies nine processing steps in batch mode, providing single final-results output file. The rest of the .dek files apply only one type of processing. The .dek file name contains a number to indicate its sequence order/location in the all-inclusive PROCESS_J.DEK file. The output data file from each single-step processing is input data for the next step, i.e., the number in the .dek file name will increase by one.

Table 1. Sample-data files

DENGLAND.DAT
EDKL_1J.DEK
EDFM_2.DEK
EDMT_3.DEK
SORT_4.DEK
SURF_5.DEK
NMOT_6J.DEK
FILT_7J.DEK
SCAL_8.DEK
STAK_9.DEK
PROCESS_J.DEK

Table 2. Seismic reflection-data processing

SEISMIC DATA PROCESSING FLOW CHART

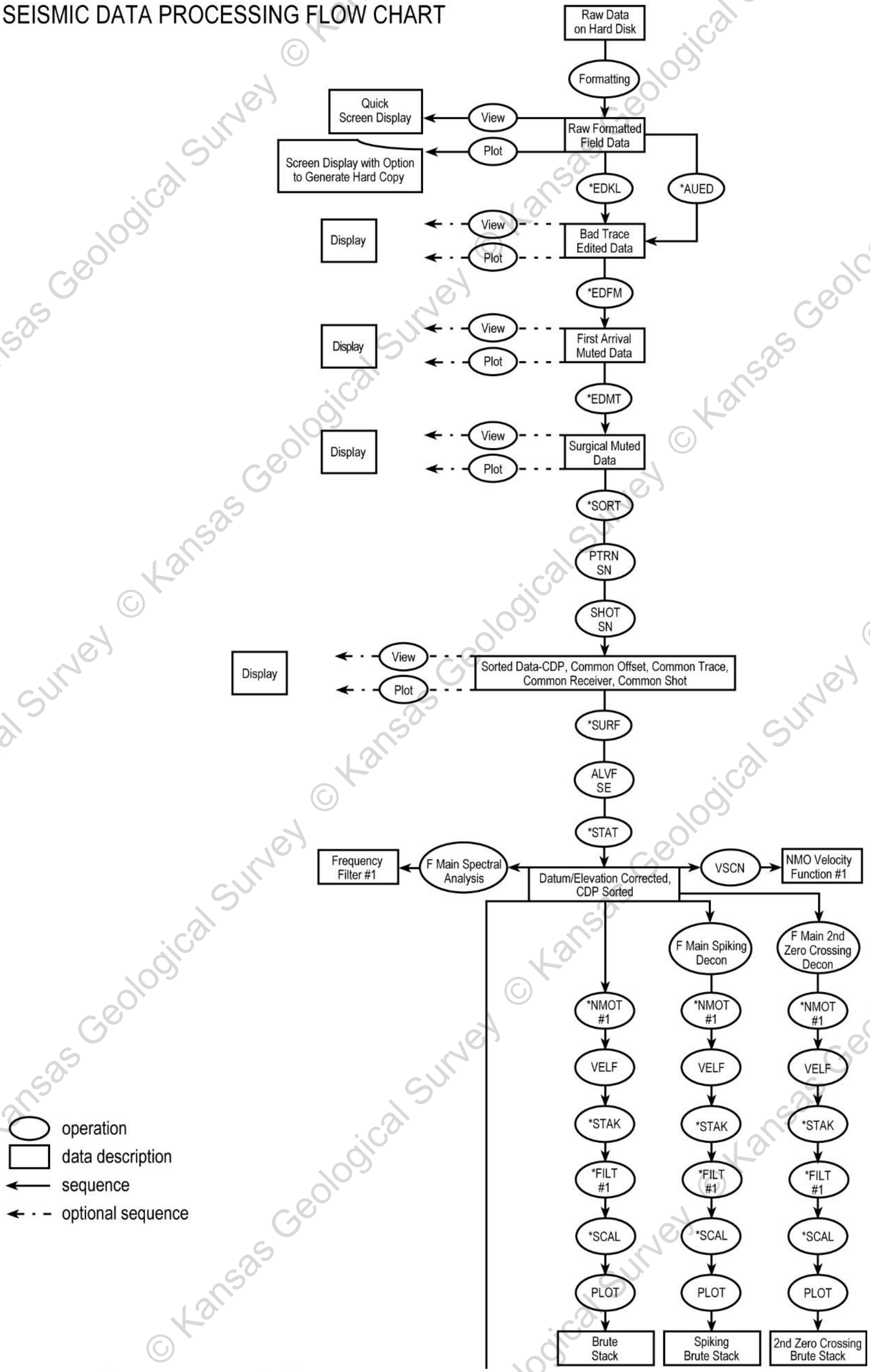
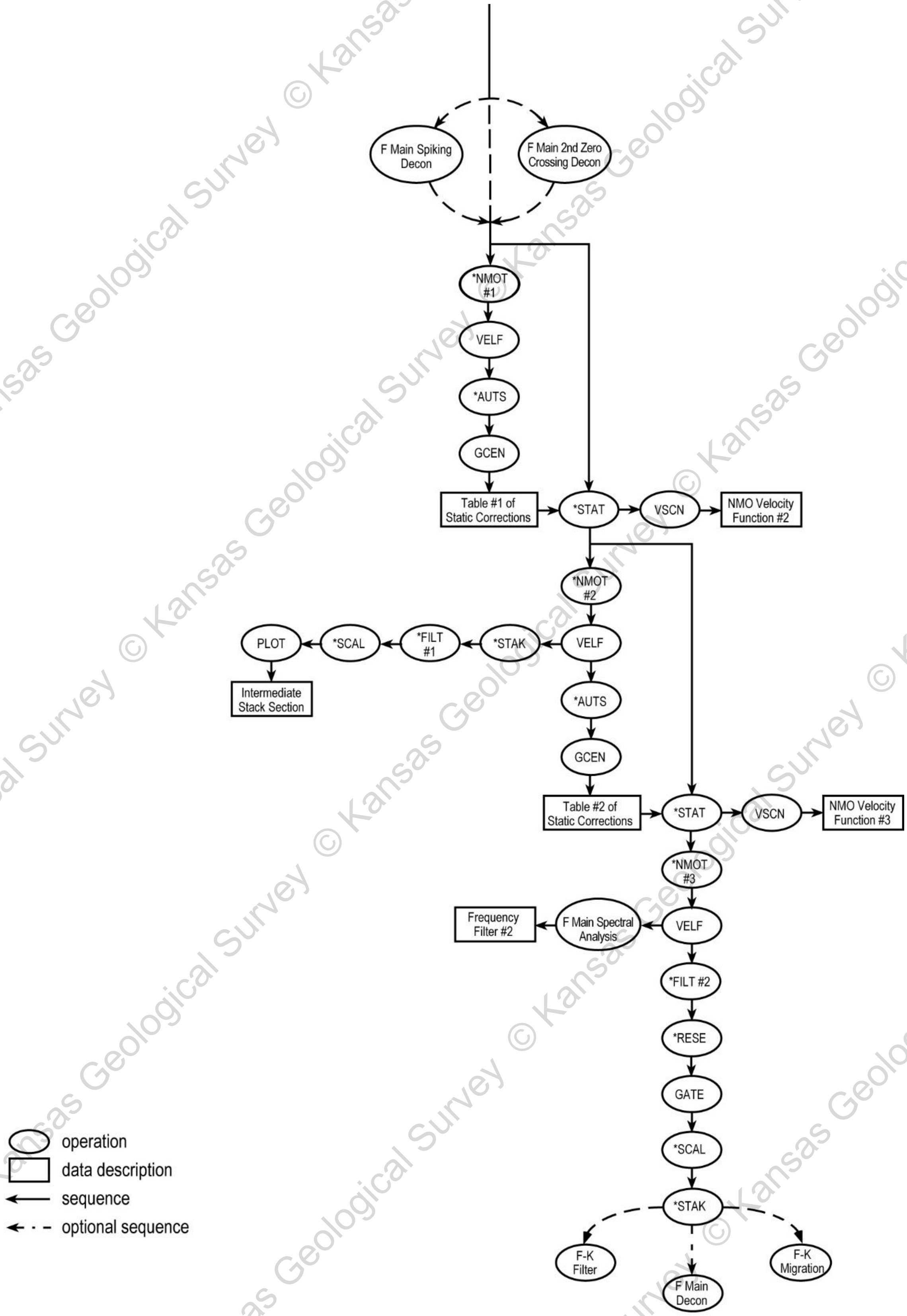


Table 2 concludes next page


F Main Spiking Decon
F Main 2nd Zero Crossing Decon
*NMOT #1
VELF
*AUTS
GCEN
Table #1 of Static Corrections
*STAT
VSCN
NMO Velocity Function #2
*NMOT #2
PLOT
*SCAL
*FILT #1
*STAK
VELF
Intermediate Stack Section
*AUTS
GCEN
Table #2 of Static Corrections
*STAT
VSCN
NMO Velocity Function #3
*NMOT #3
Frequency Filter #2
F Main Spectral Analysis
VELF
*FILT #2
*RESE
GATE
*SCAL
*STAK
F-K Filter
F Main Decon
F-K Migration
operation
data description
sequence
optional sequence

Quick Processing Summary

We recommend, for your convenience, you make a separate folder for experiencing the tutorial (e.g., a "WinSeis Tutorial" folder on one of your drives) and copy the contents of the "C:\WSeis18\SampleData" subfolder (i.e., the files listed in Table 1) into it.

The digit in the above-mentioned file name indicates the processing order sequence in this tutorial. For example, the processing specified in EDKL_1J.DEK is applied first, in EDFM_2.DEK, second, etc. for all nine steps, the output of each being used as input to the next step (see Table 3). The file PROCESS_J.DEK applies all nine steps providing only one final output file, stakAll.dat. Separate GUI applications can facilitate the preparation of the *.**dek** files (last column of Table 3).

Table 3. Processing steps with corresponding input/output data

Processing Sequence	Processing-command *.**dek** file	Input data file	Output data file	*.**dek**-file maker GUI
1	EDKL_1J.DEK	DENGLAND.DAT	EDKL.dat	WinEdit.exe
2	EDFM_2.DEK	EDKL.dat	EDFM.dat	WinEdit.exe
3	EDMT_3.DEK	EDFM.dat	EDMT.dat	WinEdit.exe
4	SORT_4.DEK	EDMT.dat	SORT.dat	Winsort.exe
5	SURF_5.DEK	SORT.dat	SURF.dat	Winstat.exe
6	NMOT_6J.DEK	SURF.dat	NMOT.dat	Winvscn.exe
7	FILT_7J.DEK	NMOT.dat	FILT.dat	Winfilt.exe
8	SCAL_8.DEK	FILT.dat	SCAL.dat	
9	STAK_9.DEK	SCAL.dat	STAK.dat	
1-9	PROCESS_J.DEK	DENGLAND.DAT	stakAll.dat	

Double click on each of the *.DEK files in Table 3 following the processing sequence folder so that the output file from each is available as an input file for the next. Finally, double click on the PROCESS_J.DEK file to run all processing steps in one flow, providing a single output file, stakAll.dat, identical to the STAK.dat from last step 9.

TRACE HEADERS

For a more in-depth discussion on header/format for WinSeis please refer to the Winseis Turbo User's Manual, Section 1.1 (KGS Format, Trace Headers, Trace Header Change, and Check Data).

IMPORTANT: All acquisition information essential to future seismic data processing as well as update information derived from intermediate processing operations is organized and stored within each trace header. The organization of trace headers is dependent on the programmer of the software and manufacturer of the seismograph. **The size and organization of the trace header, its location, as well as the organization and size of each sample of data within the trace itself is commonly referred to as seismic data format**. The format of seismic data is critical to the effective operation of seismic data processing programs. Each format is different, requiring a different approach.

Most, but not all, operations use the header to obtain key information about the data contained within each trace. Some operations will update the header with information; others will simply use the information to physically change the data set according to the prescribed operation and designated parameters. The trace header locations will always remain the same. The actual values within each word in the header can or will be changed in accordance with the described operation and input parameters.

Familiar acronyms such as SEGA, SEGB, SEGY, modified-SEGY, SEG2, etc., describe individual variations in data format.

The key information necessary to process seismic data using *WinSeis 1.8* is contained within the 240-byte trace header (120 16-bit words) preceding the seismic data itself, which is represented by 2 bytes per sample word (i.e., 500 sample/trace data represent a block of 1000 bytes). Each header location is identified by a number (1-120). *WinSeis 1.8* expects to see a header at the beginning of each trace (240 bytes) followed by a data block (length dependent on number of samples). The header contains the information at the designated word locations shown in Table 4 below.

DATA FORMAT

Raw unformatted data on the hard disk (HDD) will be in the form of a sequence of files with identical prefixes and/or extensions, where each file represents a unique field file recorded on the seismograph used and downloaded onto a computer's hard disk. The naming process was done during either the downloading of the data to a computer's hard disk or at the time of acquisition and storage of the data in the field. The total number of these individual sequential files will be equal to the number of field files copied onto the hard disk. Once the data are on the hard disk of the computer (in most cases this involves a simple copy command), the appropriate conversion routine should be executed to correctly format the data for future processing with *WinSeis 1.8* software. After completing the formatting operation, all the individual field files should be contained in a single MS-DOS file.

Table 4—Trace-header descriptions. WinSeis 1.8

All words in the header are 16-bit words; ms = milliseconds. Feb 2015

Word#	Description
1	Data type: 0 = raw field 1 = CDP gather 2 = CDP stacked 3 = record order (record-number index and trace-number index based on values in trace-header words 3 and 4, respectively) 4 = velocity-scan data
2	Total recording channels
3	Trace-header word of record number for this data set: 8 = common recording channel number 12 = common depth point 19 = common offset 86 = common receiver station number 87 = common source station number 92 = common source sequence number
4	Trace-header word of trace number within each record (0 = input order of seismic input data to be sorted)
5	Trace-direction flag for sorted traces within each record: 1 = ascending -1 = descending
6	Original field-record number
8	Recording-channel number
10	Repeated shot number (at the same station)
11	Time/depth flag and multiplication factor (about 1000) to fit word 57 into 16 bits: 0 = time 1 or more = depth
12	CDP number
14	Trace number within each record
15	Trace-identification code: 1 = seismic data 2 = dead 9 = velocity flag

16	Number of vertically summed traces yielding this trace
17	Number of horizontally summed traces yielding this trace
18	Feet/meter distance dimension flag: 0 = feet 1 = meters
19	Offset (distance from source to receiver) after multiplication by word 35
21**	Receiver-group elevation
23**	Source elevation
27**	Datum elevation
35	Multiplication factor for horizontal distance
36-38	SEG-2 X, Y, Z receiver locations
39-41	SEG-2 X, Y, Z source locations
48	Measured first arrivals (milliseconds)
49	Measured first arrivals, the microseconds component only (<1 ms)
50*	Source static correction (milliseconds)
51*	Receiver-group static correction (milliseconds)
52*	Total static correction (in number of samples) that has been applied to this trace (zero if no static has been applied)
53	Calculated first arrivals (milliseconds)
54	Calculated first arrivals, the microseconds component only (<1 ms)
55	Recording-delay time (milliseconds)
57	Distance sample interval (in m or ft) [the true value was multiplied by word 11 to fit a 16-bit word]
58	Number samples in this trace
59	Sample interval in microseconds for this trace
60	Integer/floating point data flag: 21930 = floating point any other value indicates integer data
70	Analog low-cut frequency (Hz)
71	Analog high-cut frequency (Hz)
75	Applied digital low-cut frequency (Hz)
76	Applied digital high-cut frequency (Hz)
82	Minimum receiver-station number
83	Maximum receiver-station number
84	Minimum source-sequence number
85	Maximum source-sequence number
86	Receiver-station number for this trace
87	Source-station number for this trace
88	Last trace flag: 0 = not last trace 1 = last trace of this gather
89*	Surface-consistent residual-receiver static (in number of samples) that has been applied to this trace
90*	Surface-consistent residual-source static (in number of samples) that has been applied to this trace
92	Source-sequence number (SSN)
93	Processing-history file flag: 0 = no history non-zero = number of characters in file name that follows
94-120	Reserved for processing-history file name; packed ASCII, two ASCII characters per word

*Convention for static corrections: POSITIVE value implies static shift (DOWN) away from zero-time, NEGATIVE value implies static shift (UP) toward zero-time.

**Elevation can be either absolute (i.e., positively above sea level) or relative (with reference to fixed altitude). In both cases, the orientation is such that higher elevation is positive. Therefore, increasing depth is indicated by the smaller value for elevation.

Formatting of seismic-reflection data involves **organizing trace headers and data bytes into a specific pattern and sequence recognizable by *Winseis 1.8***. The formatting utilities available for *Winseis 1.8* require raw unformatted data to be present on hard disk. The formatting utilities (conversion routines) are designed to operate on raw data input from hard disk and output back to hard disk. Getting the raw data from the seismograph's preferred storage media onto the hard disk requires procedures, software, and/or hardware that can be supplied by the seismograph manufacturer.

The particular formatting routine necessary for any raw unformatted data depends on the seismograph with which it was collected. Until a standardized format can be established and agreed upon by all seismograph manufacturers and software developers, a different conversion routine will be necessary for most new and existing seismographs.

DISPLAY

After the data are in KGS format, examination of a variable-area wiggle-trace display of all the unprocessed data will allow the user to verify proper formatting as well as to get a general feel for the quality and quantity of data.

It is possible to display records and sections by using the "Winview.exe" tool, which can be found in the *WinSeis 1.8* installation folder (e.g., "WSeis18"). The following the file path will guide the user through the display module: double click on "Winview.exe". Then select from the menu: ***File* > *Open* > *Select .dat file* > *Open***. Visual graphics can be altered by selecting graphics from the ***Options*** tab. Here the user may change the parameters to adjust viewing preferences (Figure 1).

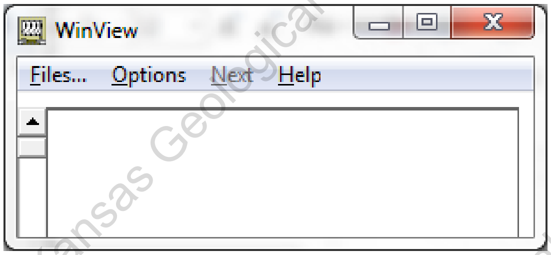


Figure 1. Winview.exe main menu.

Once the .dat file is open and displayed (Figure 2), select ***Options*** (from the drop down menu), followed by ***Change Graphics***. A "View Select" window will be displayed (Figure 3), which will allow the user to specify the viewing parameters they wish. Once all the parameters have been specified to the user's preference, click on the **"Done"** button and the settings will be applied

The raw England field data (dengland.dat) should contain 20 files identified by the source sequence number in the upper righthand corner of each file. The data were collected on a 24-channel seismograph, therefore, there will be 24 individual traces within each field file. The traces within each field file are identified by original channel numbers, starting with channel 1 on the left-hand side of the field file, and channel 24 on the far right.

The field file displayed here has all the major types of seismic energy arrivals one will encounter on most seismic data sets (Figure 4). Identified on the plot of field file 5 is each trace number, time in milliseconds, refraction energy, air-coupled waves, ground roll, and of course reflection events. Of interest for later processing steps, two dead traces are identified at trace numbers 8 and 23. The field file displayed has been scaled to enhance the seismic energy, making it easier to identify the various types of arrivals.

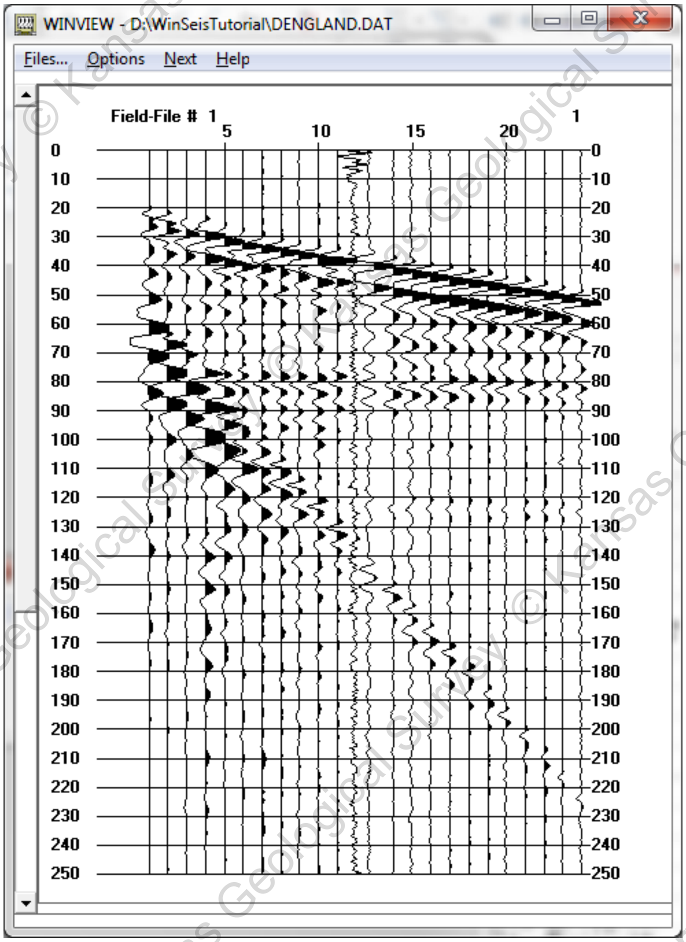


Figure 2. Field-file 1 graphical display using WinView.exe.

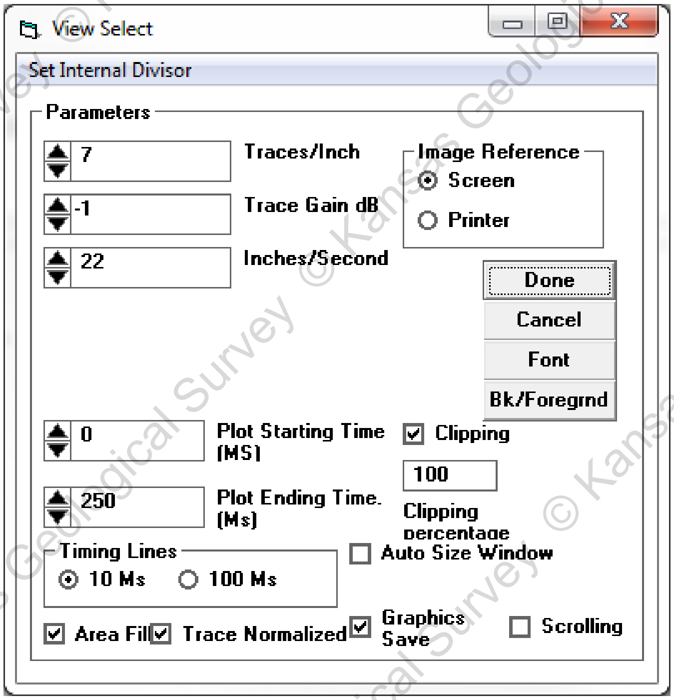


Figure 3. WinView, "View Select" window for display parameters.

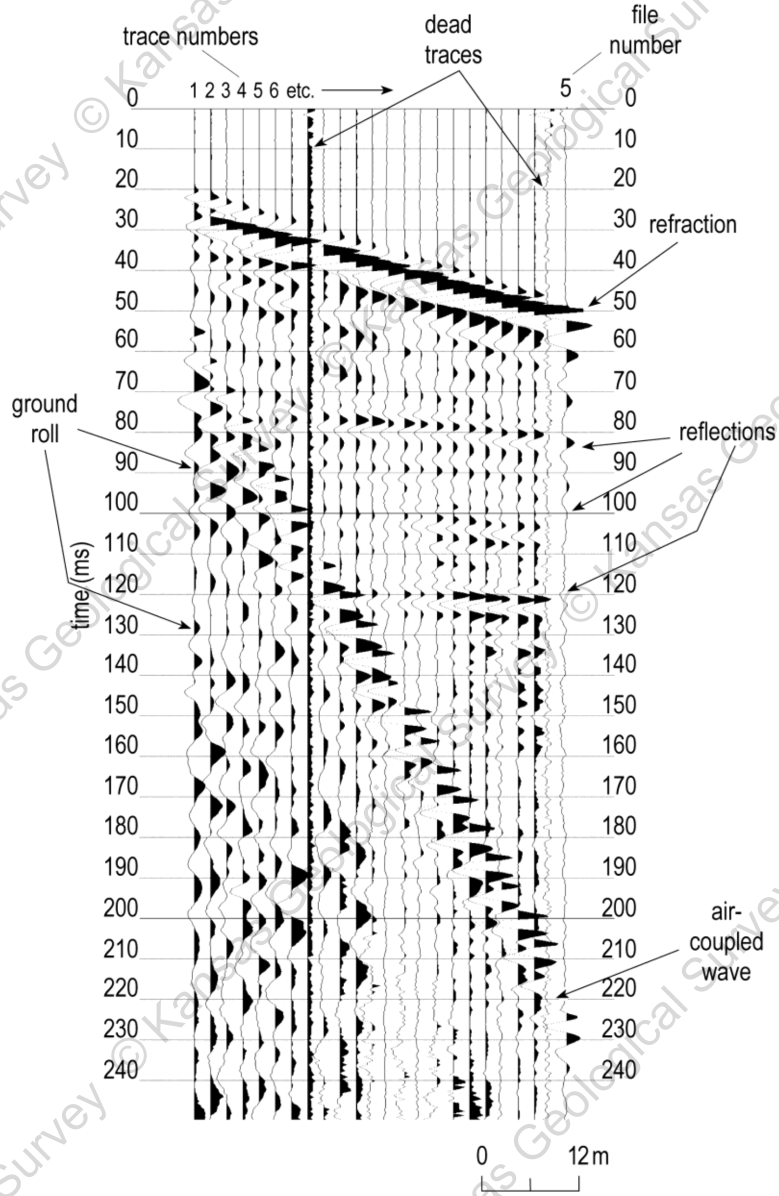


Figure 4. Traces 8 and 23 of the displayed source sequence file 5 are bad traces.

EDIT TRACES

The next step in a standard processing flow involves the removal of **bad traces** (generally caused by dead geophones, bad geophone plants, seismograph amplifier failure, cultural noise, or poor near-surface conditions), **bad parts of traces** (generally resulting from air-coupled wave or ground roll), and **energy arriving prior to the first identifiable reflection signal** (generally refraction and direct-wave energy).

Manual Bad-Trace Edit

Removal of dead or bad traces is the first editing step. This can be accomplished in two different ways. The first way (the more standard technique) involves the manual entering of each trace (to be removed) into a text-editor-built edit deck using the ***EDKL** procedure. The second way uses an automatic whole-trace-editing routine ***AUED** procedure designed to identify (and automatically remove, if specified) any trace that does not meet the minimum operator-specified signal-to-noise ratio (S/N). In order to develop a good working knowledge of the editing process and how it works, it is recommended that command of the manual editing technique be established prior to extensive use of the automatic editing option.

Note: For ultimate control over the data quality, using the *EDKL function is preferable.

A plot of the raw-field data is critical at this step. **Careful examination of each trace of every field file** will allow the user to determine how much and what type of editing will be necessary. The object of this stage is to remove all traces and parts of traces with an unacceptable signal-to-noise ratio (S/N). Determination of useless traces is subjective and depends on the ability of the user. Traces 8 and 23 of the displayed source sequence file 5 (Figure 4) are bad traces. It is important to remember (all things being equal) that **2 or 3 fold of high-quality reflection data are better than 48 fold of poor data**. The confidence necessary to effectively edit will come with time and exposure to a variety of data sets.

The manual editing procedure is a batch-processing operation and therefore requires a batch-processing file constructed around the ***EDKL** identification. In order to build a batch-processing file the user can employ a TEXT EDITOR. **NOTE: Any text editor that does not leave embedded commands will work** (e.g., **EDLIN**, **SIDEKICK NOTEPAD**, **XTREE**, etc.). Furthermore, for large data sets, Microsoft Excel can be used to organize information that is then copied and pasted into a text document. Using "**Save As**", save the text file with extension "**.dek**" to allow "WSeis.exe" to run the commands. Another way to build a "**.dek**" file is by using GUI routines available in the WinSeis installation folder, such as "WinEdit.exe", which can help visually .

This is the first batch processing deck described in this manual; therefore, each part will be discussed in some detail and referred to during upcoming processes.

<u>Line</u> <u>Description</u>

1 <u>**>>START**</u>

>>START simply identifies the beginning of this processing deck.

2 <u>***INPF dengland.dat**</u>

It is necessary to include the whole file path for WSEIS to properly work, (e.g., C:\Tutorial\dengland.dat). All input and output files require the full file path. Since all file paths are different, they will not be included in the descriptions here.

***INPF** command identifies the input files. The alpha character name of the input file, including any extension must follow *INPF, leaving at least one space separating the F in *INPF and the first character of the file name.

Entries following an alpha identifier (such as ***INPF**, ***EDKL**, ***AUTS**) **need only be separated by a minimum of one space**. This means that during **batch processing, any input information need only be in the correct relative sequence.** The program "WSeis.exe" is insensitive to absolute field location and lower or upper case (i.e., A or a).

3 ***EDKL 92 8**

EDKL calls the "kill trace" sub-routine. The **traces to be removed are identified by a record-number trace-number pair [92 (SSN), 8 (field trace number)].** As the processor becomes more efficient and knowledgeable, other sorting options are possible (e.g. 87, 86, etc.).

Record numbers generally identify the primary grouping order. In case of raw field data, the primary grouping is by field-file number, which is contained in **trace-header location 6**; for CDP gathers, the primary grouping is according to CDP number, which is contained in **trace-header location 12**. Trace numbers generally identify secondary grouping order. In the case of raw field files, the secondary grouping is according to seismograph channel numbers, which are contained in **trace-header word 8**. This grouping or ordering can be changed during the sorting or resorting operation.

These record/trace pairs can be thought of in a similar fashion to a deck of cards; that is, the suite (hearts, clubs, spades, diamonds) can be thought of as the record number and the value (Queen, Jack, ten, nine, etc.) can be compared to the trace number, such that any trace can be identified by record number and trace number in the same fashion any playing card can be identified by suite and value.

The program allows the user to select any trace-header word to be the record number portion as well as any trace header word for the trace number portion of the record-trace pair. In this case, we have designated the Source Sequence Number (SSN) (assigned during formatting), **header word 92**, as the **record number** portion and the trace numbers within each field record, **header word 8** (which is the seismograph's actual channel number), as the **trace number** (assigned by seismograph during acquisition).

4 **KILL 1 1 12 12**

KILL is a command operation that identifies which **trace(s)** within the specified records are **to be removed**. In the above case, trace **12** record number **1**, will be removed.

5 **KILL 2 2 11 11**
KILL 3 3 10 10
KILL 4 4 9 9 24 24 (i.e., Traces **9** and **24** of record **4** will be removed.)
KILL 5 5 8 8 23 23
KILL 6 6 7 7 22 22
KILL 7 7 6 6 21 21
KILL 8 8 5 5 20 20
KILL 9 9 4 4 19 19
KILL 10 10 3 3 18 18
KILL 11 11 2 2 17 17
KILL 12 12 1 1 16 16
KILL 13 13 15 15
KILL 14 14 14 14
KILL 15 15 13 13
KILL 16 16 12 12
KILL 17 17 11 11
KILL 18 18 10 10
KILL 19 19 9 9
KILL 20 20 9 9

6 ***OUTF EDKL.dat**

***OUTF** identifies the destination file name of the edited data. The file name can be any MS-DOS acceptable name, with or without extension. The output file name can be the same as the input. Of course, **if the input file name is the output file name**, the input data will be deleted and replaced with the edited output data.

7 **>>END**

>>END identifies the last line of this batch-processing deck.

The actual bad trace edit file just created will look like this:

>>start
**inpf dengland.dat*
**edkl 92 8*

kill 1 1 12 12
kill 2 2 11 11
kill 3 3 10 10
kill 4 4 9 9 24 24
kill 5 5 8 8 23 23
kill 6 6 7 7 22 22
kill 7 7 6 6 21 21
kill 8 8 5 5 20 20
kill 9 9 4 4 19 19
kill 10 10 3 3 18 18
kill 11 11 2 2 17 17
kill 12 12 1 1 16 16
kill 13 13 15 15
kill 14 14 14 14
kill 15 15 13 13
kill 16 16 12 12
kill 17 17 11 11
kill 18 18 10 10
kill 19 19 9 9
kill 20 20 9 9
**outf edkl.dat*
>>end

- Use the "WinEdit.exe" GUI and choose **Edit>Edit Options**>**EDKL-Kill Trace** from the main menu to visually select bad traces to be killed. Each mouse-click selection on the seismic-data image will be simultaneously written into the text file utility, "Cmdedit.exe". See WinSeis User's Manual (i.e., pages 1-13 and 1-14 of "4section1.pdf").

The batch processing file above to edit bad traces now needs to be run through "WSeis.exe" to operate on the **dengland.dat**.

Double click on the **EDKL.dek** file to launch "WSeis.exe" and run the .dek file.

The edited data will be in the file named **EDKL.dat**. The now worked-on data can be viewed using "**WinView.exe**", which can be found in the main application folder (e.g., "C:\WSeis18"). Once the bad-trace editing is complete, each field file should be missing the trace or traces the user has selected to remove (Figure 5). The trace is not displayed on the plot because the dead-trace flag (trace header word 15) has been tripped in the trace header. The file size will not change until the data are sorted or resorted, at which time the trace will be completely removed from the data set. The bad trace is still present in the data file after trace editing, but not visible on the plot.

AT THIS POINT, IF YOU HAVE MANUALLY EDITED ALL YOUR BAD TRACES, YOU SHOULD PROCEED TO THE FIRST-ARRIVAL MUTING PORTION OF THIS MANUAL WHICH FOLLOWS AUTOMATIC EDITING (*AUED). IF TIME PERMITS, USE YOUR JUST-EDITED DATA SET TO COMPARE AUTOMATIC EDITING TO MANUAL BAD-TRACE EDITING. IT MAY SERVE TO HELP YOUR CONFIDENCE AS WELL AS SAVE YOU TIME DURING PRELIMINARY BAD-TRACE EDITING ON YOUR NEXT DATA SET.

Automatic Bad-Trace Edit

Using the automatic editing routine **(*AUED)** will save time in removing obviously dead or traces of very poor quality. It should only be used, however, once you are comfortable with the manual trace editor (***EDKL)**. The ***AUED** routine is mainly designed to remove traces that are totally dead or possess a significant amount of background noise (i.e., wind, powerline, automobile, human traffic on-line, etc.). The important parameters in this operation are the noise window length (time) and the acceptable signal-to-noise ratio (S/N) value. At this point, definitions will be helpful.

NOISE WINDOW

The noise window identifies a **pre-first-break segment (before the arrival of any seismic signal)** on each trace where the **level of background ambient noise is representative** of the remainder of the trace. The **window** needs to be selected so as **to not include any source-generated seismic signal** (such as refractions, direct wave, or air wave).

SIGNAL-TO-NOISE (S/N)

The signal-to-noise value is the ratio of the whole trace average amplitude and the **average amplitude of signal in** the **noise window**. An S/N value of 1 will retain any trace with a whole trace average amplitude equal to or greater than the average amplitude of the signal in the noise window.

Experimentation with this routine is the best teacher. A few test runs varying the S/N value for a given noise window will give insight into both the utility and the limitations of this routine. A batch-processing file for doing automatic editing should look something like this:

Line		Description
1	**>>START**	See ***EDKL** for details on **>>START**.
2	***INPF dengland.dat**	See ***EDKL** for details on ***INPF**.
3	***AUED 20 0.28 1 1 1**	

***AUED** calls the auto-edit sub-routine. The **first requested parameter** is the **noise window**. Here 20 ms is used, indicating that no source-generated signal arrives on any trace before 20 ms. The **second requested parameter** is the **signal-to-noise ratio** (S/N) value. A signal-to-noise ratio of **0.28** means any trace not possessing an **average whole-trace amplitude at least 0.28 times the average pre-first-break amplitude** will be flagged. The **third requested parameter** instructs the program **to print (1) or not to print (0)** the calculated average whole trace **signal-to-noise ratios (S/N)** in the list file. The **fourth requested parameter** instructs the program to **print (1) or not to print (0)** the flagged **bad traces** in the list file. (This **fourth option** gives the user the opportunity to **examine the traces the program suspects as being bad**.) The fifth and **final option** lets the user **delete the flagged bad traces (1)** or save all the traces as inputted **(0)**. Keeping the flagged bad traces will allow examination of the suggested bad traces and readjustment of parameter 1 (noise window) and 2 (signal-to-noise ratio), or both. If the **0** option is chosen for the fifth parameter, no output file need be named.

4	***OUTF AUED.dat**	See ***EDKL** for details on ***OUTF**.
5	**>>END**	See ***EDKL** for details on **>>END**.

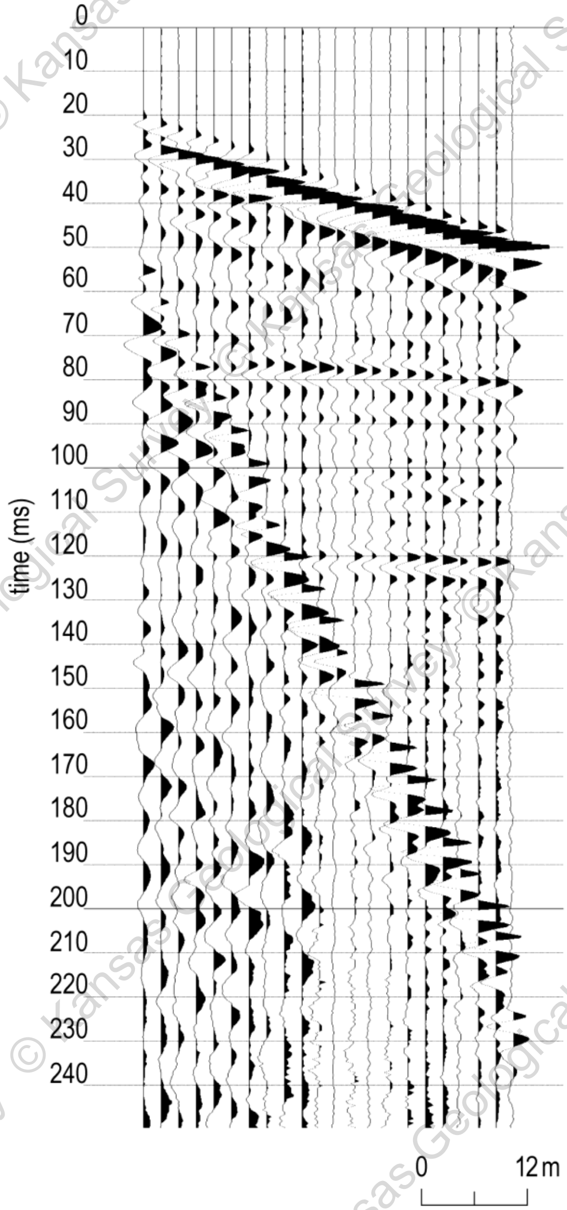


Figure 5. Bad traces have been removed.

The batch-processing file **AUED.dek** the user just saved will look like this:

>>start
**inpf dengland.dat*
**aued 20 0.28 1 1 1*
**outf aued.dat*
>>end

Double click on the **AUED.dek** file to launch "WSeis.exe" and run the .dek file.

The **AUED.lst** file monitors and records the sequence of processing events.

The following information is included to allow the user to check the contents of the list file with what should be there:

List of example of signal-to-noise ratio of SSN **4**:

4:	3.24	2.43	3.39	3.10	5.60	3.26	0.62	1.45	0.23	1.42	0.81	1.47
	0.32	0.94	0.44	0.92	2.45	1.26	1.42	0.64	2.11	1.14	0.71	0.21

List of bad traces for SSN **4** from automated editing:

4: 9 24

The edited data will be in the file named **AUED.dat**. To see the effect of the editing on the raw data, the user should first use the "Winview.exe" by selecting AUED.dat to view the plot.

First-Arrival Mute

The next step in the processing flow involves the **muting of refracted and direct-wave energy (*EDFM)**. This is necessary on most data sets to ensure that refracted and/or direct-wave energy does not appear coherent on CDP stacked sections. The high amplitude as well as the coherent nature of moved-out and stacked refraction energy is inviting, and in some situations it can be easily misinterpreted as shallow-reflection energy.

Complete identification of refracted energy is sometimes difficult on CDP stacked data. Refraction energy has theoretically linear moveout on field files. The NMO velocity correction applied to compensate for non-vertically incident reflection energy is hyperbolic. When refraction wavelets—generally non-minimum phase and rarely broadband—are NMO corrected and stacked, they can misalign in such a way as to appear as multiple, broadband, coherent reflection events very dissimilar from the original refraction wavelets on the raw field data. **The appearance of refraction energy on CDP-stacked data can be wrongfully identified and must be scrutinized carefully.** Unmuted refracted energy from a subsurface layer that varies in depth can appear to be a structurally significant, coherent reflection event on CDP stacked data. This illusion on stacked data results from the changes in the critical refraction distance and time intercept as the depth to the refracting interface varies. This pitfall may go unnoticed on some data sets, since in some geologic conditions stacked refractions may be representative, in a gross sense, of actual shallow structure. **Such stacked refractions typically have lower frequency than shallow reflections**.

Any editing operation that requires the defining of a time window or beginning and/or ending points for the zeroing of data will require the defining of a taper length (**TAPR**). The taper is intended to allow the gradual attenuation of the trace amplitudes to zero without generating an abrupt truncation point and the associated apparent high frequencies. **If the trace is filtered at any time in the processing flow without a taper, the abrupt truncation of signal resulting from a mute will produce a complex sine function with maximum amplitude at the truncation point decaying to near zero within the muted zone.** The frequency and decay length of the sinusoid is dependent on the defined filter. This decaying sinusoid is an artifact of the Fast Fourier Transformation (FFT), which is part of the spectral filtering process. Frequency filtering is often necessary to remove or attenuate unwanted noise. Choosing a taper length is a very data-dependent undertaking. **At least one cycle of the dominant-reflection frequency or center frequency of the digital bandpass filter designed for this data set is a good starting point for defining a taper length.** Fine tuning of a mute taper generally is not necessary, but in certain instances returning to this step in the processing flow to better define a taper length may be necessary. During future processing operations involving a taper, reference to this paragraph will be made. In this manual, the taper is defined according to Figure 6.

The first step in the first-arrival muting process is to identify refracted and direct-wave energy on the raw field plots (Figure 4). Once a definite identification is made, the appropriate mute can be designed. Once the mute window for each field file has been determined, a batch processing sequence similar to the following should be created.

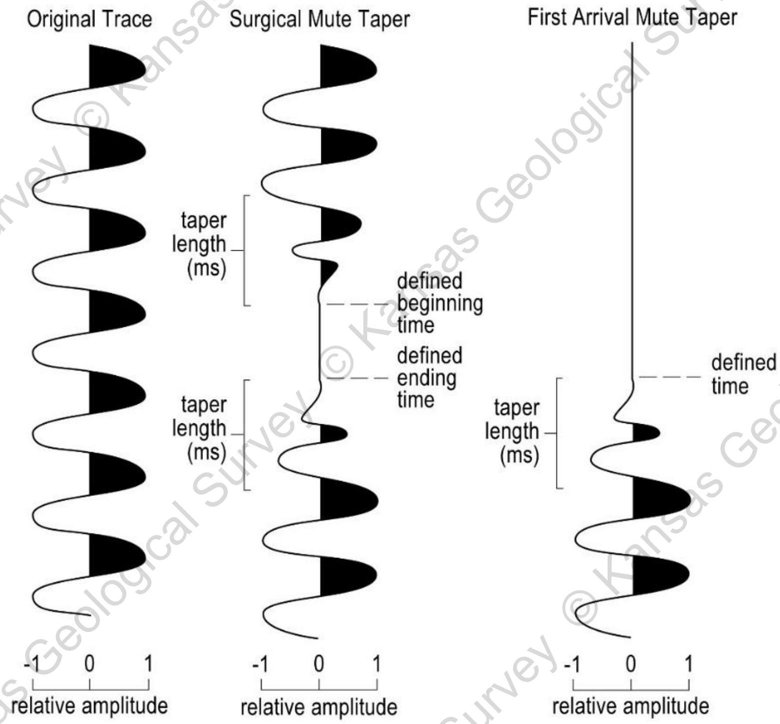


Figure 6. Definition of the taper as applies to this manual.

<u>Line</u> <u>Description</u>

1 **<u>>>START</u>** See ***EDKL** for description of **>>START**.

2 **<u>*INPF EDKL.dat</u>** See ***EDKL** for description of ***INPF**.

3 **<u>*EDFM 92 8</u>**

The ***EDFM** identifier calls the first-arrival mute subroutine. The two requested **parameters** are trace-header words that identify the **record/trace pairs** (as described during the ***EDKL** routine). The **first requested parameter** identifies the primary groups or **records** (in this case the SSN's trace-header location 92 identifies the record portion of the record-trace pair). The **second requested parameter** is the trace-header word that identifies the location of secondary groups or **traces** within the record (in this case the channel numbers of the seismograph, trace-header location 8, identifies the trace portion of the record-trace pair).

4 **<u>TAPR 10</u>**

TAPR sets the taper length, which is in ms (milliseconds). The taper slope is linear and is designed to allow a gradual transition from unaffected data to 100 percent mute. The taper's 0 percent point (total attenuation) is at the user-defined first-arrival mute value and the 100 percent point (no attenuation) is at the defined mute time plus the taper length. In this case, if the first-arrival mute extended to 30 ms on trace 1, the taper would attenuate 90 percent of the signal at 31 ms, 80 percent of the signal at 32 ms, 70 percent of the signal at 33 ms, etc., until at 39 ms 10 percent of the signal was attenuated.

5a **<u>FARM 1 1 30 2 32 3 33 4 35 5 36 6 38 7 39 8 41 9 42 10 44 11 45 12 47 13 48 14 50 15 51 16 53 17 54 18 56 19 57 20 59 21 60 22 62 23 63 24 65</u>**

FARM defines first arrival mute times according to **SSN and trace number**. The FARM operation is designed to **interpolate both in time and space**. This interpolation process makes the entry on line 5b the same as the entry on line 5a. If only line 5a or 5b FARM was defined, the entire data set would be first-arrival muted according to the defined record number-time windows. The actual mute defined by line 5a or 5b would include the entire data set and delete all data between time zero and 30 ms on trace 1, from time zero to 32 ms on trace 2, from time zero to 33 ms on trace 3, etc., out to trace 24 which will be muted from time zero to 65 ms. If more than 24 traces are present in this data set, each trace beyond trace 24 will be muted as trace 24 was. This means that trace 25 will be muted from time zero to 65 ms, trace 26 will be muted from time zero to 65 ms, trace 27 will be muted from time zero to 65 ms, etc.

5b **FARM 1 1 30 24 65**

This defines exactly the same first-arrival mute as line 5a.

† 6a **FARM 2 1 0 24 0**

† 6b **FARM 3 1 30 24 65**

† 6c **FARM 4 1 0 24 0**

† 6d **FARM 3 1 30 24 65 25 0**

† Note: Not appropriate for this data set—used here only as an example.

If **only one file of several is to be first-arrival muted (FARM)**, the series of entries on lines 6a, 6b, and 6c would be necessary. The **linear interpolation process is automatic**. The only way to stop the interpolation is to define 0 mute times just before and just after the defined mutes. The **FARM** defined by lines 6a, 6b, and 6c will mute file (SSN) 3 only, with trace 1 muted from time zero to 30 ms, trace 2 from time zero to 32 ms, etc., out to trace 24, which will be muted from time zero to 45 ms. To **stop the mute process after trace 24**, therefore retaining all the information in traces 25 to the last trace (48, 96, or whatever the number of traces on the seismograph the data came from), **line 6d** would be entered in place of line 6b.

7 ***OUTF EDFM.dat** See ***EDKL** for description of ***OUTF**.

8 **>>END** See ***EDKL** for description of **>>END**.

The **EDFM.dek** text file will contain:

```
>>start
*inpf  edkl.dat
*edfm 92 8
tapr 10
farm 1 1 30 24 65
*outf edfm.dat
>>end
```

- Use the "WinEdit.exe" GUI and choose **Edit** > **Edit Options** > **EDFM-First Arrival** from the main menu to visually select zeroing top parts of traces. Each mouse-click selection on the seismic-data image will be simultaneously written into the text file utility, "Cmdedit.exe". See WinSeis User's Manual (i.e., pages 1-13 and 1-14 of "4section1.pdf")

Double click on the **EDFM.dek** file to launch "WSeis.exe" and run the .dek file.

As before, **EDFM.lst** is simply a journal file. The muted data will be in the file named **EDFM.dat**. In order to see the effect of the mute on the input data **EDKL.dat**, the user needs to use the **WinView.exe** module. The first-arrival mute defined by the previous batch file will result in a mute on all files of the sample data set. First-arrival information on file 5 will begin at 30 ms on trace 1 and 65 ms on trace 24 with a 10 ms taper. This field file is displayed identically before and after the mute allowing direct comparison (Figure 7).

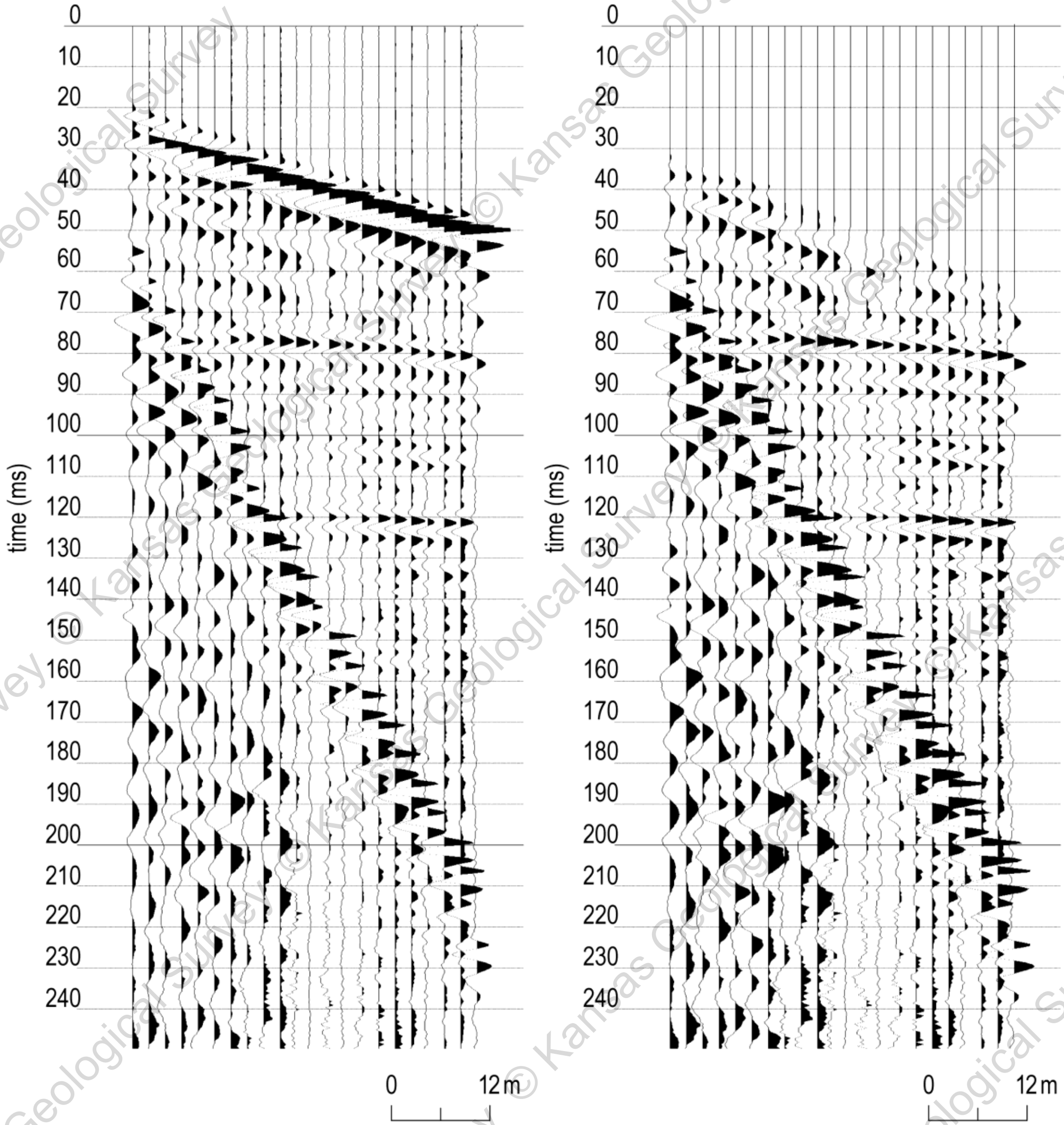


Figure 7. Field file 5 a) before and b) after first-arrival mute.

Surgical Mute

The final editing step involves the surgical removal of bad trace segments (***EDMT**). Noise resulting from the air-coupled wave, electronic interference other than power line frequencies, and ground roll are generally constrained to isolated portions of a trace. High-amplitude noise obviously dominating a well-defined time window should be removed. However, take care when removing these low S/N portions of traces because significant seismic signal could be present on unprocessed data at an amplitude level below the dynamic range of the plot. This indicates that it could go unnoticed. If the amplitude of the unwanted noise is low in comparison to signal at equivalent times on other traces, occasionally the multi-trace stacking process necessary to generate a CDP stacked section will suppress noise to an acceptable level.

Also, many times various filtering operations (discussed later in the processing flow) can attenuate noise that has unique spectral and/or phase characteristics. It must be kept in mind that removal of noise and enhancement of seismic signal to allow an accurate geologic interpretation is the ultimate goal. There is no replacement for good judgment during the preliminary stages of seismic data process.

The plot of the first-arrival muted data needs to be carefully studied and appropriate time and trace pairs selected to remove the air-coupled wave. Once the desired mute windows on the data have been defined and the trace time pairs recorded, the mute batch file needs to be created. The following sequence of entries is appropriate for our sample data set.

Line		Description
1	**>>START**	See ***EDKL** for description of **>>START**
2	***INPF EDFM.dat**	See ***EDKL** for description of ***INPF**

3 ***EDMT 92 8**

The ***EDMT** identifier calls the surgical muting subroutine. The two requested parameters are the trace-header words that identify the record-trace pairs (as described in the ***EDKL** and ***EDFM** routines). The first requested parameter is the trace-header word identifying the primary groups or records (in this case the SSN [trace-header location 92] identifies the record portion of the record-trace pair). The second requested parameter is the trace-header word that identifies the secondary group or trace location within the record (in this case the channel number of the seismograph [trace-header location 8] identifies the trace portion of the record-trace pair).

4 **TAPR 10**

TAPR sets the taper length as described in Figure 6. The units of taper length are ms (milliseconds). The taper slope is linear and is designed to allow a gradual transition from unaffected data to 100 percent mute. The taper's 100 percent point (total attenuation) is at the user-defined first-arrival mute value and the 0 percent point (no attenuation) is at the defined mute time plus (or minus, depending on which end of the mute zone) the taper length. In the case of a 10 ms taper on a mute window starting at 57 ms and ending at 70 ms, the data would experience 0 percent signal attenuation at 47 ms increasing linearly to 100 percent attenuation at 57 ms (with 100 percent attenuation between 57 and 70 ms) and the attenuation would then decrease linearly from 100 percent at 70 ms to 0 percent at 80 ms.

5a **MUTE 5 1 57 70 24 222 235** (preferred option and technically identical to line 5b).

5b **MUTE 5 1 57 70 2 64 77 3 71 84 4 78 91 5 86 99 6 93 106 7 100 113 8 107 120 9 114 127 10 122 135 11 129 142 12 136 149 13 143 156 14 150 158 171 16 165 178 17 172 185 18 179 192 19 186 199 20 193 207 21 200 214 22 207 221 23 214 228 24 222 235**

The **MUTE** identifiers on lines 5a and 5b define a **surgical mute for the entire data set.** The program will **linearly interpolate** between all defined windows throughout the entire data set. The **interpolation process is automatic** and can only be **terminated by entering zeros** (beginning and ending) within the time ranges. For the mute defined on lines 5a and 5b, the entire data set will be muted with all trace 1's zeroed (all digital information removed and replaced by zeros) between 57 and 70 ms, all trace 2's zeroed between 64 and 77 ms, all trace 3's zeroed between 71 and 84 ms, etc., out to all trace 24's zeroed between 222 and 235 ms. If more traces are present on the records, they will be muted according to the trace 24 defined mute (i.e., all trace 25's will be muted between 222 and 235 ms; all trace 26's will be muted between 222 and 235 ms, etc.).

† 6a **<u>MUTE 4 1 0 0 24 0 0</u>**

† 6b **<u>MUTE 5 1 57 70 24 222 235</u>**

† 6c **<u>MUTE 6 1 0 0 24 0 0</u>**

† 6d **<u>MUTE 19 1 57 70 24 222 235 25 0 0</u>**

† Note: Not appropriate for this data set—used here only as an example.

The **MUTE sequence** defined by lines **6a through 6c** will operate **only on record (SSN) 5**. Mutes defined for records 4 and 6 will terminate the interpolation process. The operation of the mute in regard to interpolation is very similar to **FARM** as defined in the section on ***EDKL**. Any traces within this record greater than 24 will be muted as 24. In order **to stop the interpolation beyond trace 24**, a zero mute window needs to be defined for trace 25. **Line 6d** defines a mute exactly the same as 6b, except it terminates the muting of traces beyond trace 24.

7 **<u>*OUTF EDMT.dat</u>** See ***EDKL** for description of ***OUTF**.

8 **<u>>>END</u>** See ***EDKL** for description of **>>END**.

The <u>**EDMT.dek** text file will contain</u>:

>>start
**inpf edfm.dat*
**edmt 92 8*
tapr 10
mute 5 1 57 70 24 222 235
**outf edmt.dat*
>>end

- Use the "WinEdit.exe" GUI and choose **Edit** > **Edit Options** > **EDMT-Surgical Mute** from the main menu to visually select part of traces to be zeroed. Each mouse-click selection on the seismic-data image will be simultaneously written into the text file utility, "Cmdedit.exe". See WinSeis User's Manual (i.e., pages 1-13 and 1-14 of "4section1.pdf")

Double click on the **<u>EDMT</u>.dek** file to launch "WSeis.exe" and run the .dek file.

As before, while the program is running, it updates the user of where it is in the processing sequence described in **EDMT.dek**. The **EDMT.lst** file is simply a journal file keeping track of the same information that the user will see on the screen during the actual running of Wseis.exe. To see what has been saved in the journal file, use the MS-DOS **TYPE** command. It is always good to at least briefly look at all the data after any operation. To see what the effect of the mute has had on the input data **EDFM.dat**, use the view routine as described in previous sections.

The sample data set provided was muted to remove the air-coupled wave. Anytime a mute is applied to seismic data, it should be as well defined and as tight as possible. This is to avoid removing subdued signal. The muting process zeros samples, and once a sample is zeroed, the information contained within that sample has been permanently removed. **For this reason, be extremely cautious when defining and applying a mute**. The plot of SSN 5 before and after the surgical mute (Figure 8) clearly shows the effect of the mute, as well as the narrowness of the defined mute window.

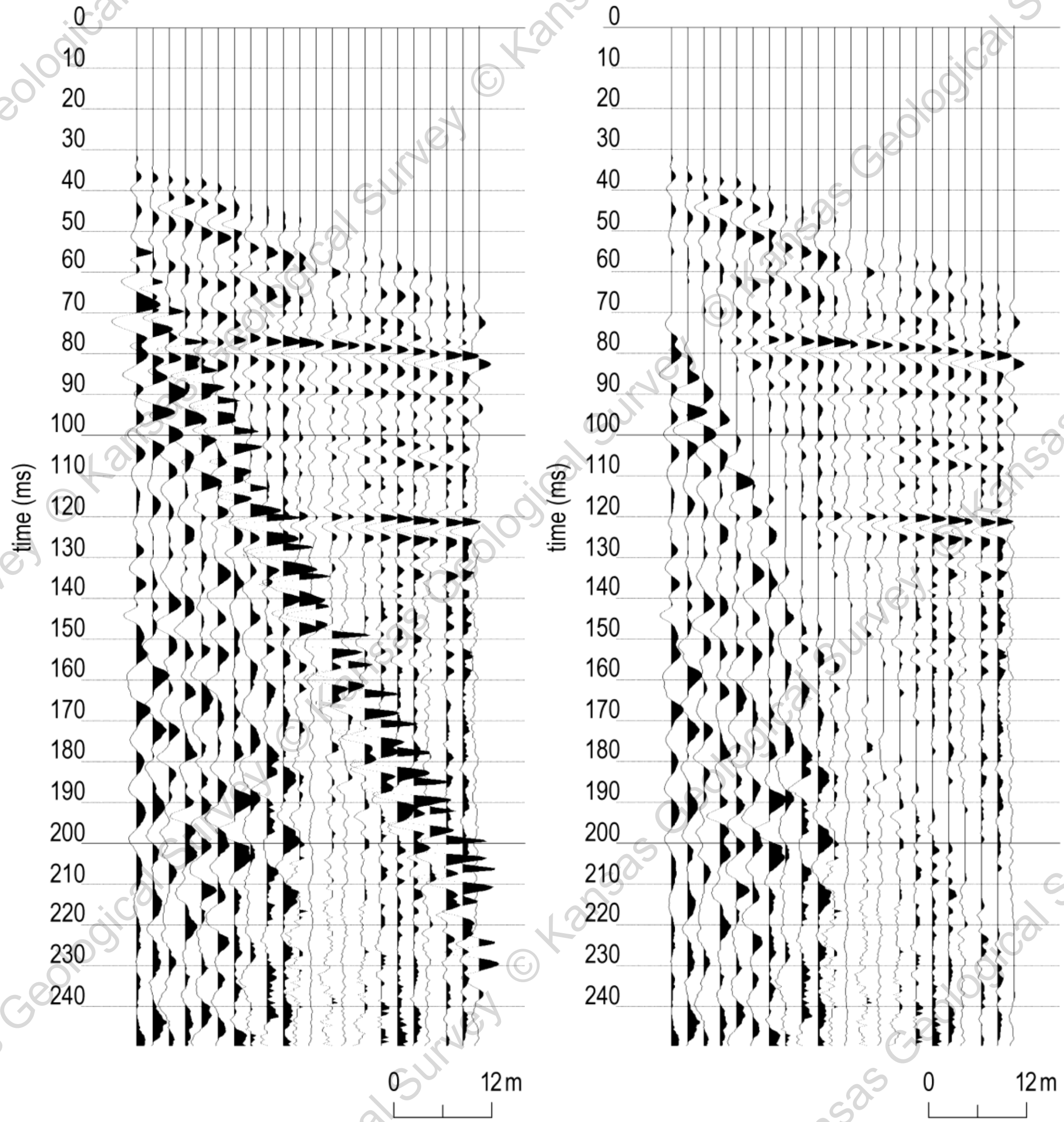


Figure 8. Field file 5 a) before and b) after surgical mute performed.

SORTING (GATHERING) INTO CDP FORMAT

The way data are organized for display and analysis is the heart of any seismic-reflection program. Having flexibility to look at data in a variety of ways is critical for future digital enhancement as well as discrimination of subtle features. The actual sorting routine is not particularly difficult from a conceptual point of view, but it does require a significant amount of information relating to the acquisition geometries of the multichannel data. The sheer number of parameters and geometric configurations that need to be defined make sorting potentially the most mistake-prone part of processing seismic data. Built into the sorting operation are several ways to cross-check the accuracy of the user input information. These processes are not completely automated, however, and the user must request and check the output of these operations to verify correctness of their parameter and geometry assignments.

Sorting any seismic data can be thought of as very similar to playing gin rummy. The main goal is to order the data or cards into a sequence likely to be of the most use later. For example, in rummy you may be collecting by suit; with seismic data you may be collecting by receiver locations. In rummy you may be collecting by face value; in seismic you may be collecting by common-midpoints. With the card game, the identification (value [numeric or other] and suit) is displayed on the face of each card; with seismic data, the identification (location and size) is contained within each trace header. In order for the data to be brought together in a meaningful fashion, you must select which particular identification (parameter) is most significant for this data set and future processing routines. The data can be gathered together, ordered, and reordered a variety of times and ways.

The two most commonly used parameters to sort are CDP (common-depth-point) sometimes referred to as CMP (common-midpoint), and common source-to-receiver offset (common offset, for short). Sorting according to common source-to-receiver offset is exactly what it sounds like. All traces are gathered according to like distances from source to receiver. For example, each of the 24 traces recorded within each field file of our sample data set is offset from the source by a unique distance. Therefore, gathering according to a common offset distance will result in 24 different primary groups (each with unique source-to-receiver offset), each containing 20 traces. In good data areas, once the appropriate corrections are made for offset and elevations, common-offset data (if collected within the optimum window) can be viewed as a geologic cross-section without future digital enhancement. However, seldom will common-offset data yield as much or as detailed information as a properly processed CDP stacked section. ***WinSeis 1.8* is specially designed to enhance reflection information once the data are in a sorted CDP format**.

Good, complete field notes are critical to correct and accurate defining of source and receiver geometries, surface features, and events significant to future analysis. The information that must be contained in the field notes for each recorded shot at each shotpoint includes:

1) shotpoint station number
2) live receiver station numbers relative to seismograph channel numbers
3) roll switch number
4) individual digital file name/number

The items listed below need to be included in field notes, but only once per day unless they change during acquisition of the data.

5) sample interval/number of samples
6) analog-to-digital filter settings
7) anti-alias filter
8) type, number, and relative orientation of sources and receivers
9) profile location and purpose
10) any unusual offsets (inline or offline)
11) comments or remarks
12) time
13) weather conditions

14) system (seismograph) error messages
15) reminder to do system QC checks

An example of a field notebook that we used quite successfully at the time this data was collected in England is displayed in Figure 9.

Figure 10 shows the field notes that were collected for the sample dataset. All significant information about the source and receiver geometries as well as acquisition parameters are provided. The 20 field files used for this example data set (615-634) were extracted from a larger data set containing 39 files (601-639). Building a batch processing file to define source and receiver geometries for our sample data set requires geometrically relating the 20 shotpoints and the 43 receiver locations used during the acquisition of the section of the line used as our sample data set.

The primary task associated with sorting the data relates to the assignment of geometries and parameters. Trace-header information plays a significant role in this operation. The following trace-header words are the most important to commit to memory.

Header Word #	Identifies
6	the field file number/name under which this trace was stored after it was recorded
8	this trace's number within the field file it was collected under (also is equivalent to the channel number this trace was recorded at)
12	this trace's corresponding CDP number (usually about twice the associated station location)
14	the order of this trace within the appropriate CDP
19	distance this trace is from the source
86	station number of the receiver that recorded this trace
87	station number of the source associated with this trace
92	the source sequence number of this trace, which sequentially relates it to individual field files collected for a particular profile

A helpful aid in defining the geometries, and to double check the accuracy of the field notes, is a stacking chart (Figure 9). The layout of the stacking chart (by design) allows visual correlation between the field notes and the sort batch file. It will simplify both visualizing and defining geometries for particular Source Sequence Numbers (SSN).

Figure 11 defines station locations on the x axis and field file numbers as the y axis. Each individual field record (file) number (y axis) has an associated set of 24 recording channels and a shotpoint. The shotpoint location for a particular field record is identified by an X located beneath the appropriate station location (x axis). Along with this X defining the shot location is the assigned source sequence number (SSN). Each live receiver location is represented along the x axis by the appropriate seismograph channel number. Notice the step-by-step progression of the shot and receivers across the line. Figure 11 was broken up into three sections to fit a normal sheet of paper. Figure 12 identifies the locations and SSN, original field channel pairs and fold (redundancy, percent coverage) for each CDP. The lower portion of the stacking chart was derived from the upper part. The CDP numbers identified along the x axis on the lower part are exactly double the surface location defined directly above in the upper portion of the chart. The number pairs beneath each CDP location identify the SSN and seismograph channel number for the trace(s) sampling this particular midway point between source and receiver (CDP). As an example, locate SSN 5 and seismograph channel number 10 on the upper portion of the stacking chart. Next, find the point which is midway between the shot for SSN 5 and the associated seismograph channel 10. Finally, extrapolate that point straight down into the lower portion of the chart and the user will find the number pair 5,10 as the fifth set of number pairs beneath CDP location 240. The numbers on the bottom row running parallel to the x axis identify the fold of the associated CDP.

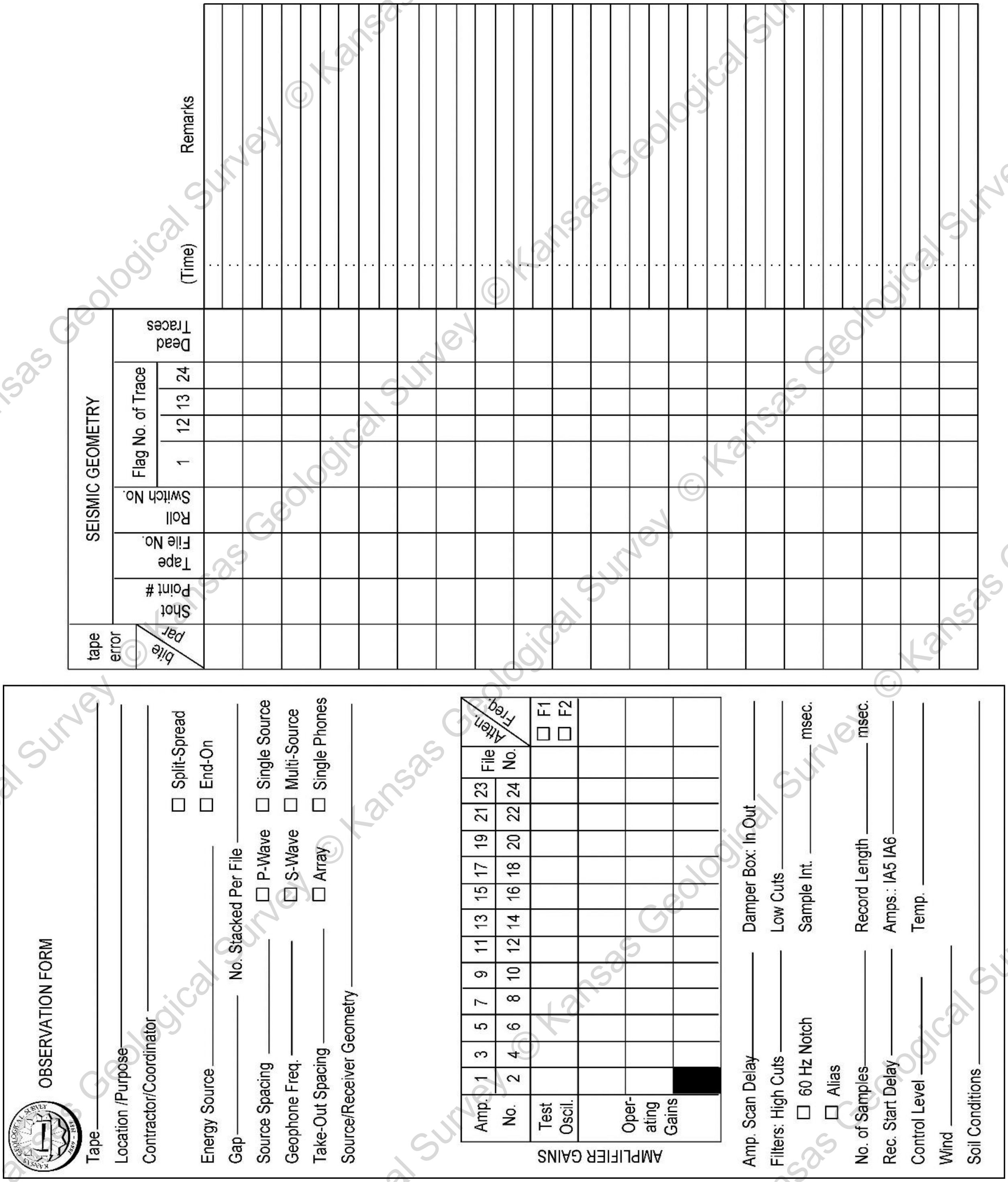


Figure 9. Sample field notebook page.

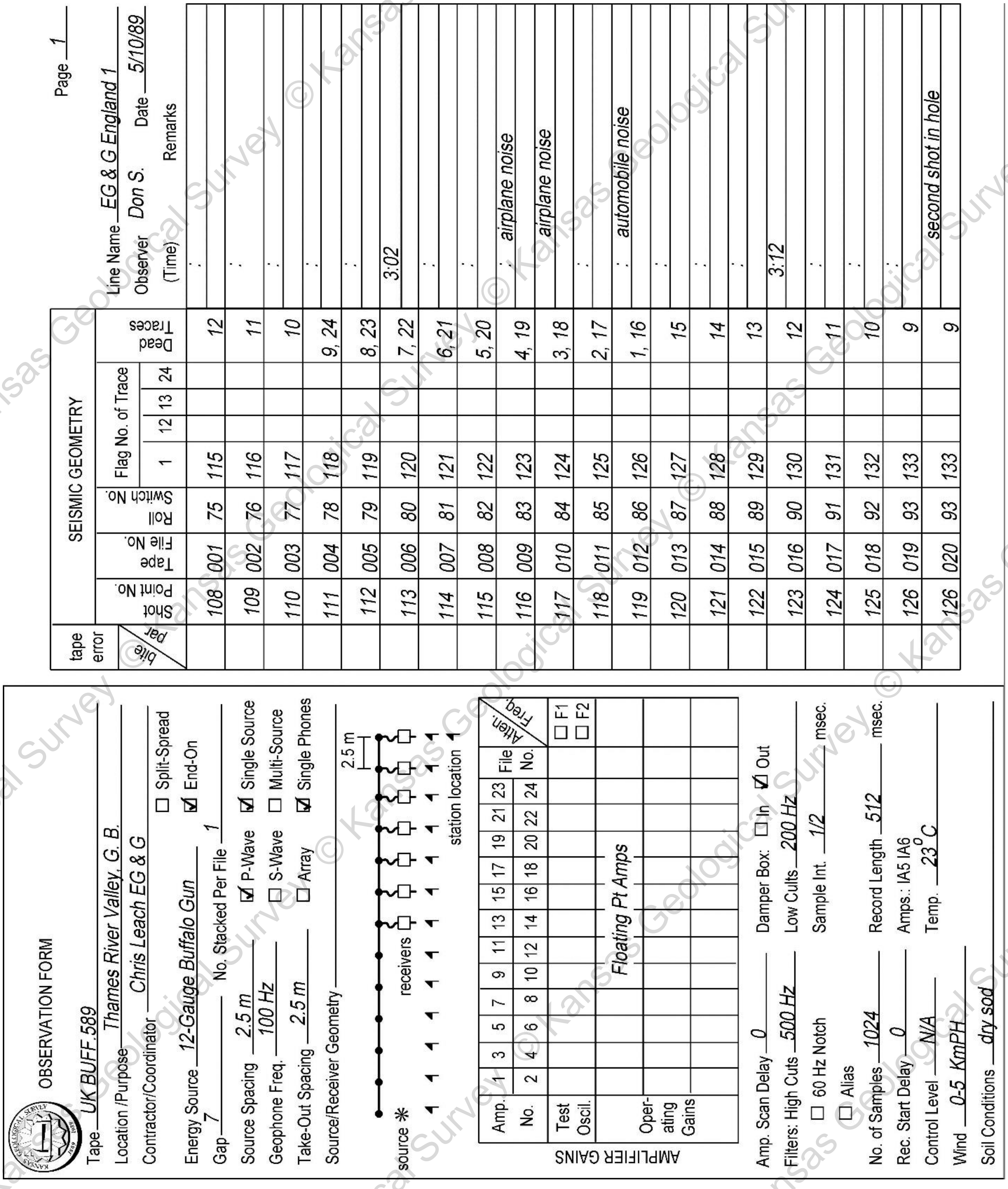


Figure 10. Sample field notebook filled with notes recorded in the field.

The fold can be figured by simply adding the number of SSN/trace number pairs beneath each CDP location. Figure 12 was broken up into three sections to fit a normal sheet of paper.

The program **WSeis** has an option to print a table which will allow the user to directly compare their hand-generated stacking chart directly from the field notes with a computer-generated chart reflecting the geometries and parameters the user defined for the ***SORT** operation. Our computer-generated chart for the sample data set will be compared to the hand-generated chart (Figure 11) after our sort deck is complete.

Station Location

field file #	SSN	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
615	1	1X							1	2	3	4	5	6	7	8	9	10	11	12
616	2		2X							1	2	3	4	5	6	7	8	9	10	11
617	3			3X							1	2	3	4	5	6	7	8	9	10
618	4				4X							1	2	3	4	5	6	7	8	9
619	5					5X							1	2	3	4	5	6	7	8
620	6						6X							1	2	3	4	5	6	7
621	7							7X							1	2	3	4	5	6
622	8								8X							1	2	3	4	5
623	9									9X							1	2	3	4
624	10										10X							1	2	3
625	11				X=source location							11X							1	2
626	12												12X							1
627	13													13X						
628	14														14X					
629	15															15X				
630	16																16X			
631	17																	17X		
632	18																		18X	
633	19																			19X
634	20																			20X

Station Location

field file #	SSN	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145
615	1	13	14	15	16	17	18	19	20	21	22	23	24							
616	2	12	13	14	15	16	17	18	19	20	21	22	23	24						
617	3	11	12	13	14	15	16	17	18	19	20	21	22	23	24					
618	4	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
619	5	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
620	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
621	7	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
622	8	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
623	9	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
624	10	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
625	11	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
626	12	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
627	13	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
628	14		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
629	15			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
630	16				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
631	17					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
632	18						1	2	3	4	5	6	7	8	9	10	11	12	13	14
633	19							1	2	3	4	5	6	7	8	9	10	11	12	13
634	20							1	2	3	4	5	6	7	8	9	10	11	12	13

Station Location

field file #	SSN	146	147	148	149	150	151	152	153	154	155	156
615	1											
616	2											
617	3											
618	4											
619	5											
620	6											
621	7											
622	8		1-24 trace# (channel#)									
623	9	24										
624	10	23	24									
625	11	22	23	24								
626	12	21	22	23	24							
627	13	20	21	22	23	24						
628	14	19	20	21	22	23	24					
629	15	18	19	20	21	22	23	24				
630	16	17	18	19	20	21	22	23	24			
631	17	16	17	18	19	20	21	22	23	24		
632	18	15	16	17	18	19	20	21	22	23	24	
633	19	14	15	16	17	18	19	20	21	22	23	24
634	20	14	15	16	17	18	19	20	21	22	23	24

Figure 11. Stacking chart.

A stacking chart may not always be necessary, but until a great deal of experience is gained processing seismic data, it is a wise aid in assuring the data the user is preparing to gather and stack are properly identified and ordered.

Once the user has a complete set of field notes and knows how to order the data for future digital enhancement and display, the user is ready to create a batch process file to sort data.

The following deck is built for CDP sorting of a sample data set that is composed of 20 shots recorded on a 24-channel seismograph across 44 receiver stations, each separated by 2.5 m. The source-to-closest-receiver distance is 17.25 m and the source stations are coincident with the receiver stations. The data were collected using a CDP-type roll-along technique. The relative source-to-receiver orientation was end-on.

Line		Description
1	**>>START**	See ***EDKL** for description of **>>START.**
2	***INPF EDMT.dat**	See ***EDKL** for description of ***INPF.**
3	***SORT 12 19**	

The ***SORT** procedure calls the subroutine responsible for **collecting traces according to indicated header words**. We have described a sorting operation here which will gather together all traces with **equivalent midpoints between shot and receiver**. The **first value** (header-word number) input designates the **primary sort grouping (trace header word 12, CMP or CDP number)**. The s**econd value** (header-word number) requested designates the **secondary grouping (trace header word 19, distance from source to receiver)**. The secondary grouping simply designates the ordering of the trace display within the primary grouping. With unprocessed field data, the primary grouping is file or source-sequence number, and the secondary grouping is according to individual trace or channel numbers.

4 **PTRN 2.5 24 1**

The **PTRN** operation defines the **distance between surface stations** and **physical seismograph parameters**. This operation must always precede the ***SORT** procedure definition. The **first requested input** is the distance between station locations **(2.5 m)**. The **second value** to be identified is the **total number of recording channels** on your seismograph **(24)**. And the **final value** represents the **units of length** used during the acquisition of the data (**1 = meters**, 0 = feet). This operation (**PTRN**) is the lead-in for the next line(s) (**PN**), which will identify all the different source and receiver geometries used throughout the collection of this data set.

		S	1	24	
		S	1	24	trace/channel
5a	**PN 1 108 115 24 1**	#	* *		
		108	115	138	surface station

Note: A piece of the stacking chart is represented above to help equate the station numbers to the actual source and receiver patterns. A stacking chart allows the user to visualize the relative locations of the shots and receivers.

PN defines each unique relative **source-to-receiver geometry**. The pattern described on line 5a is designated as **pattern number 1** (it will be referenced by that number (1) later in this batch job). It defines a **source location (108)** and its associated **first receiver location (115)** as well as indicating **consecutive receiver locations (24)**. The **fifth value** designates the amount each surface station was **incremented after each shot**. In this case, **stations were incremented by 1**. In other words, station 115 equates to trace/channel 1 of your seismograph; station 116 equates to trace/channel 2 of your seismograph.

Source Station Location (SSN)	**CDP** Number 223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242
108 = 1	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	1,10	1,11	1,12	1,13	1,14	1,15	1,16	1,17	1,18	1,19	1,20
109 = 2			2,1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
110 = 3					3,1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
111 = 4							4,1	…	…	…	…	…	…	…	…	…	…	…	…	…
112 = 5									5,1	…	…	…	…	…	…	…	…	…	…	…
113 = 6											6,1	…	…	…	…	…	…	…	…	…
114 = 7													7,1	…	…	…	…	…	…	…
115 = 8															8,1	…	…	…	…	…
116 = 9									SSN, trace #								9,1	…	…	…
117 = 10									e.g., 1,6										10,1	…
118 = 11																				
119 = 12																				
120 = 13																				
121 = 14																				
122 = 15																				
123 = 16																				
124 = 17																				
125 = 18																				
126 = 19																				
127 = 20																				
Fold	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**	**6**	**7**	**7**	**8**	**8**	**9**	**9**	**10**	**10**

Source Station Location = SSN	**CDP** Number 243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262
108 = 1	1,21	1,22	1,23	1,24																
109 = 2	…	…	…	…	…	2,24														
110 = 3	…	…	…	…	…	…	…	3,24												
111 = 4	…	…	…	…	…	…	…	…	…	4,24										
112 = 5	…	…	…	…	…	…	…	…	…	…	…	5,24								
113 = 6	…	…	…	…	…	…	…	…	…	…	…	…	…	6,24						
114 = 7	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	7,24				
115 = 8	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	8,24		
116 = 9	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	9,24
117 = 10	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
118 = 11	11,1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
119 = 12			12,1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
120 = 13					13,1	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
121 = 14							14,1	…	…	…	…	…	…	…	…	…	…	…	…	…
122 = 15									15,1	…	…	…	…	…	…	…	…	…	…	…
123 = 16											16,1	…	…	…	…	…	…	…	…	…
124 = 17													17,1	…	…	…	…	…	…	…
125 = 18															18,1	…	…	…	…	…
126 = 19																…	19,1	…	…	…
127 = 20																	20,1	20,2	20,3	20,4
Fold	**11**	**11**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**13**	**13**	**12**	**12**

Source Station Location = SSN	**CDP** Number 263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
108 = 1																				
109 = 2																				
110 = 3																				
111 = 4																				
112 = 5																				
113 = 6																				
114 = 7																				
115 = 8																				
116 = 9																				
117 = 10	…	10,24																		
118 = 11	…	…	…	11,24																
119 = 12	…	…	…	…	…	12,24														
120 = 13	…	…	…	…	…	…	…	13,24												
121 = 14	…	…	…	…	…	…	…	…	…	14,24										
122 = 15	…	…	…	…	…	…	…	…	…	…	…	15,24								
123 = 16	…	…	…	…	…	…	…	…	…	…	…	…	…	16,24						
124 = 17	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	17,24				
125 = 18	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	18,24		
126 = 19	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	19,24
127 = 20	20,5	20,6	20,7	20,8	20,9	20,10	20,11	20,12	20,13	20,14	20,15	20,16	20,17	20,18	20,19	20,20	20,21	20,22	20,23	20,24
Fold	**11**	**11**	**10**	**10**	**9**	**9**	**8**	**8**	**7**	**7**	**6**	**6**	**5**	**5**	**4**	**4**	**3**	**3**	**2**	**2**

Figure 12. CDP fold chart.

If the source was occupying (being fired) every station location but the receivers were located (live) at every other surface station, you would have used a 2 for the fifth input value to indicate the receiver spacing was twice the surface-station spacing. Then surface station 115 would equate to trace/channel 1 and station 117 would equate to trace/channel 2, etc. Another possibility is that the roll switch is wired reverse to this sequence, which means your trace/channel 1 is at surface station location 138 when surface stations 115 to 138 are selected. If this is the case, the user would want to designate a negative one (-1) increment of surface-station locations as the fifth value input of the **PN** definition. The correct **PN** definition for a reversed roll-switch would look like line 5b.

		S	24	1	trace/channel
† 5b	**PN 1 108 138 24 -1**	#	************************		
		108	115	138	surface station

This definition indicates the surface station location of the shot was 108, trace/channel 1 was 138, and **incrementing of station locations is negative (-1) with respect to the positive increasing trace/channel numbers**. Therefore, channel/trace 1 is surface station 138, channel/trace 2 is surface station 137, channel/trace 3 is surface station 136, etc. Here the same source-to-receiver maximum and minimum offsets are defined (source 108, minimum offset 115, maximum offset 138) as on line 5a, the exception of course being the decrementing surface station numbers with respect to the incrementing trace/channel numbers. This is a critical difference when the source-to-individual-receiver distances are calculated later in this batch job. All the information necessary to determine exactly how to define the trace/channel orders is contained within the trace header and is easily viewed using the trace-header-dump (TRHD) routine previously discussed.

		S	1	24	trace/channel
† 5c	**PN 1 95 99 2**	#	************************		
		95	99	122	surface station

The sorting routine **does not care** what the **actual numbers input for the source (108) and receiver (115) locations** are; **it only looks at relative differences.** What that means is the **PN** definition on line 5a is identical to the **PN** definition on line 5c. It is not necessary to define existing station numbers. It is advisable to identify the real station numbers to avoid confusion in the event that problems crop up later.

This definition of pattern is exactly the same as the one defined on line 5. The station numbers of the shot and receivers need only be relative to each other and do not need to be related to the actual values used in the field. Any arbitrary numerical representation will work.

		1	12	S	13	24	trace/channel
† 5d	**PN 1 114 101 12 1 116 12 1**	************		#	************		
		101	112		116	127	surface station

This definition is of a split-spread pattern. This definition does not apply to the acquisition parameters and geometries being defined here, but is included as an example in case you encounter a split-spread source-receiver geometry. Briefly, this is the first pattern defined (1), the shot station number is 114, the first trace/channel station number is 101, there are 12 consecutive trace/channels defined across 12 sequential surface station locations, then a 3-station skip to station location 116 which is trace/channel 13 where the remaining 12 channels are defined as starting at 116 to 127, inclusive, each sequential increase of (1) in trace/channel number corresponds to a sequential increase of 1 in the surface-station location.

† Not appropriate for this data set—used here only as an example.

6 SHOT

The alpha character descriptor **SHOT** simply **identifies the succeeding series of SN or SNSN definitions** as they relate to the shot location and source sequence numbers (SSN). This operation must follow the **PTRN** operation.

7 SN 1 108 1 0 0 1

The **SN definition input is required for each field file (source sequenced file)**. This operation matches a **source sequenced file with its appropriate shotpoint's surface station location** and source/receiver geometry, as described by the **PTRN** operation. **In this case, the SSN (Source Sequence Number) is 1, the shot station location is 108, and the source/receiver geometry is defined in PN 1**. The **fourth entry (0) is related to inline offset**; this is simply the distance from the defined surface station location to the actual location of the shot recorded along the line of the survey (parallel offset). The **fifth entry (0)** is also related to the actual location of the shot recorded at this surface location (109), and it defines the **distance off the line between the shot and actual surface station location (perpendicular offset)**. The **sixth value (1) identifies the repeat shot number**. Since we are only recording one shot per surface location, 1 is the appropriate sixth value. The repeat shot number simply identifies which shot this file represents at this location. If multiple shots are recorded individually at this location on different files, the program is capable of identifying which shot this file represents and then allows the option to later sort according to particular repetitive shot number at each location.

8 SN 2 109 1

This SN definition, as with the previous one (line 7), is required to describe the source station number and its associated live receiver pattern. This must be done for each defined SSN. The only difference between this SN definition and the one previous is that SSN 2 is defined with shot location 109, whereas the previous one was for SSN 1 with shot location 108. The last three parameters were omitted on this definition because the default values were appropriate.

The **line format was purposely changed on line 8 simply to demonstrate the flexibility of formatting within the program**. This shows the program is not field sensitive with respect to the number of spaces between input parameters. However, it should be kept in mind that **the order of the input values is critical**. If the user wishes to input values not identified as default values for the sixth and seventh requested parameters but the fourth and fifth are the same as the default values, the user must input all values from the first requested to the seventh, regardless of the default values. (See line 10).

9 SNSN < 2 19 1 > < 110 126 1 > 1

The **SNSN** definition permits the assignment of field geometries to large numbers of sequential field files possessing identical shot and receiver patterns as well as source offsets and bad traces. The < > are treated as entry parameters and therefore need to be separated from other entries by a space. Here we are defining the shot patterns for SSN 2 through 19, which relates to shot locations 109 to 126. Both shot location and SSNs increment by 1 as the source and receivers move down the survey line. Therefore, the first set of bracketed values represent the SSNs and increment of movement while the second set of bracketed values represent the associated shot locations and their increment pattern. The information within the first set of brackets is equivalent to the first entry on a normal SN definer. The second set of bracketed values is equivalent to the second entry on the normal SN definer. All parameters beyond the first two of the **SNSN** definers are identical to those of the ordinary SN definer.

10 **<u>SN 20 127 1 0 0 1 1 24</u>**

This shotpoint definition has a couple extra entries in comparison to the previous **SN** definers. The **SN** definition's **seventh value is the first dead trace/channel number** and **eighth value (24) is the last dead trace/channel number**. From the field notes for our sample data, the 19th and 20th shots were recorded at the same location. In order to retain equal weighting of all shot locations across the line, one of the duplicate shots must be removed. In this case, the second shot was deleted using the 7th and 8th values in the SN definition. The program will interpolate between the seventh and eighth input values. This means, if the seventh value is 19 and the eighth value is 22, the program will omit 19 thru 22, inclusive. The previous **SN** definers have had the same inline and offline offsets as well as repeat shot number. The information was not entered because the default values are appropriate (in other words if the user does not enter anything, or the required values, the program assumes the default values are correct).

11 **<u>TABL 1 1</u>**

The **TABL** operation is optional and allows the user to cross-check the **defined geometries** with the actual field geometries. The two input values are flags. The first (**1**) designates that the user wishes to have the receiver diagram plotted out, and the second (**1**) signals the printing of the **SORT** table. The entire **table** will be **contained** within the list file (i.e., **WINSEIS SORT.dek TABLE.lst** where **TABLE.lst** is the journal file and it can be typed out or printed using standard MS-DOS operations).

12 **<u>*OUTF SORT.dat</u>** See ***EDKL** for description for ***OUTF**.

13 **<u>>>END</u>** See ***EDKL** for description for **>>END**.

The **<u>SORT.dek</u>** <u>text file will contain</u>:

```
>>start
*inpf edmt.dat
*sort 12 19
ptrn 2.5 24 1
pn 1 108 115 24 1
shot
sn 1 108 1 0 0 1
snsn < 2 19 1 > < 109 126 1 > 1
sn 20 127 1 0 0 1 1 24
tabl 1 1
*outf sort.dat
>>end
```

- Use the "WinSort.exe" GUI to use visual tools for entering source and receiver location (i.e., geometry). Each mouse-click selection on the seismic-data image will be simultaneously written into the text file utility, "Cmdedit.exe". See WinSeis User's Manual (i.e., pages 1-11 and 1-12 of "4section1.pdf").

Double click on the **SORT.dek** file to launch "WSeis.exe" and run the .dek file.

The SORT.lst file is again a journal file that will contain not only the blow-by-blow account of the processing sequence; it will also contain the geometries and sorting sequences applied in accordance with the input information. This is intended to allow the user the option to compare the stacking chart developed from the field notes with the actual information the user coded into the various operations in the batch processing file. The journal file will be contained in the subdirectory in which the user is running the "WSeis.exe" program and can be viewed in WinView.

The stacking chart, generated by the program (assuming the user used the **TABL** option) with the information input during the sort operation, is displayed on the next page. The output from the **TABL** option will generate a table similar to the above table which contains the SSN-trace pairs with their associated RCRD (CDP #) and appropriate fold. Checking this (program generated) table against the one you constructed (Figure 9) will help verify the correctness of the sort file as well as assure you the data geometries are input correctly into the trace header.

SORTED RECORD TABLE (SHOT #1)

RCRD	FOLD	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR	SN-TR
223	1	1-1											
224	1	1-2											
225	2	2-1	1-3										
226	2	2-2	1-4										
227	3	3-1	2-3	1-5									
228	3	3-2	2-4	1-6									
229	4	4-1	3-3	2-5	1-7								
230	4	4-2	3-4	2-6	1-8								
231	5	5-1	4-3	3-5	2-7	1-9							
232	5	5-2	4-4	3-6	2-8	1-10							
233	6	6-1	5-3	4-5	3-7	2-9	1-11						
234	6	6-2	5-4	4-6	3-8	2-10	1-12						
235	7	7-1	6-3	5-5	4-7	3-9	2-11	1-13					
236	7	7-2	6-4	5-6	4-8	3-10	2-12	1-14					
237	8	8-1	7-3	6-5	5-7	4-9	3-11	2-13	1-15				
238	8	8-2	7-4	6-6	5-8	4-10	3-12	2-14	1-16				
239	9	9-1	8-3	7-5	6-7	5-9	4-11	3-13	2-15	1-17			
240	9	9-2	8-4	7-6	6-8	5-10	4-12	3-14	2-16	1-18			
241	10	10-1	9-3	8-5	7-7	6-9	5-11	4-13	3-15	2-17	1-19		
242	10	10-2	9-4	8-6	7-8	6-10	5-12	4-14	3-16	2-18	1-20		
243	11	11-1	10-3	9-5	8-7	7-9	6-11	5-13	4-15	3-17	2-19	1-21	
244	11	11-2	10-4	9-6	8-8	7-10	6-12	5-14	4-16	3-18	2-20	1-22	
245	12	12-1	11-3	10-5	9-7	8-9	7-11	6-13	5-15	4-17	3-19	2-21	1-23
246	12	12-2	11-4	10-6	9-8	8-10	7-12	6-14	5-16	4-18	3-20	2-22	1-24
247	12	13-1	12-3	11-5	10-7	9-9	8-11	7-13	6-15	5-17	4-19	3-21	2-23
248	12	13-2	12-4	11-6	10-8	9-10	8-12	7-14	6-16	5-18	4-20	3-22	2-24
249	12	14-1	13-3	12-5	11-7	10-9	9-11	8-13	7-15	6-17	5-19	4-21	3-23
250	12	14-2	13-4	12-6	11-8	10-10	9-12	8-14	7-16	6-18	5-20	4-22	3-24
251	12	15-1	14-3	13-5	12-7	11-9	10-11	9-13	8-15	7-17	6-19	5-21	4-23
252	12	15-2	14-4	13-6	12-8	11-10	10-12	9-14	8-16	7-18	6-20	5-22	4-24
253	12	16-1	15-3	14-5	13-7	12-9	11-11	10-13	9-15	8-17	7-19	6-21	5-23
254	12	16-2	15-4	14-6	13-8	12-10	11-12	10-14	9-16	8-18	7-20	6-22	5-24
255	12	17-1	16-3	15-5	14-7	13-9	12-11	11-13	10-15	9-17	8-19	7-21	6-23
256	12	17-2	16-4	15-6	14-8	13-10	12-12	11-14	10-16	9-18	8-20	7-22	6-24
257	12	18-1	17-3	16-5	15-7	14-9	13-11	12-13	11-15	10-17	9-19	8-21	7-23
258	12	18-2	17-4	16-6	15-8	14-10	13-12	12-14	11-16	10-18	9-20	8-22	7-24
259	12	19-1	18-3	17-5	16-7	15-9	14-11	13-13	12-15	11-17	10-19	9-21	8-23
260	12	19-2	18-4	17-6	16-8	15-10	14-12	13-14	12-16	11-18	10-20	9-22	8-24
261	11	19-3	18-5	17-7	16-9	15-11	14-13	13-15	12-17	11-19	10-21	9-23	
262	11	19-4	18-6	17-8	16-10	15-12	14-14	13-16	12-18	11-20	10-22	9-24	
263	10	19-5	18-7	17-9	16-11	15-13	14-15	13-17	12-19	11-21	10-23		
264	10	19-6	18-8	17-10	16-12	15-14	14-16	13-18	12-20	11-22	10-24		
265	9	19-7	18-9	17-11	16-13	15-15	14-17	13-19	12-21	11-23			
266	9	19-8	18-10	17-12	16-14	15-16	14-18	13-20	12-22	11-24			
267	8	19-9	18-11	17-13	16-15	15-17	14-19	13-21	12-23				
268	8	19-10	18-12	17-14	16-16	15-18	14-20	13-22	12-24				
269	7	19-11	18-13	17-15	16-17	15-19	14-21	13-23					
270	7	19-12	18-14	17-16	16-18	15-20	14-22	13-24					
271	6	19-13	18-15	17-17	16-19	15-21	14-23						
272	6	19-14	18-16	17-18	16-20	15-22	14-24						
273	5	19-15	18-17	17-19	16-21	15-23							
274	5	19-16	18-18	17-20	16-22	15-24							
275	4	19-17	18-19	17-21	16-23								
276	4	19-18	18-20	17-22	16-24								
277	3	19-19	18-21	17-23									
278	3	19-20	18-22	17-24									
279	2	19-21	18-23										
280	1	19-22	18-24										
281	1	19-23											
282	1	19-24											

SN = shot #
TR = trace #

>>end

It should be kept in mind that the stacking chart generated by the sorting operation (**TABL**) does not check the real input data to identify traces designated as bad. Therefore, the SSN trace pairs, output with its associated CDP number, will include values previously deleted. If your hand-generated stacking chart is correct, it will also include the dead or bad traces.

It will be beneficial at this point to generate a hard copy plot of the entire sorted data set. This will allow you to cross check your stacking chart with your sorting table printout as well as the actual sorted data. Many times problems not obvious on a sorting table will be quite obvious on a hard-copy plot of CDP sorted data.

The principal (higher amplitude) reflections identified on our raw field file (Figure 4) are still interpretable on the gathers of CDPs 245 and 246 (Figure 13).

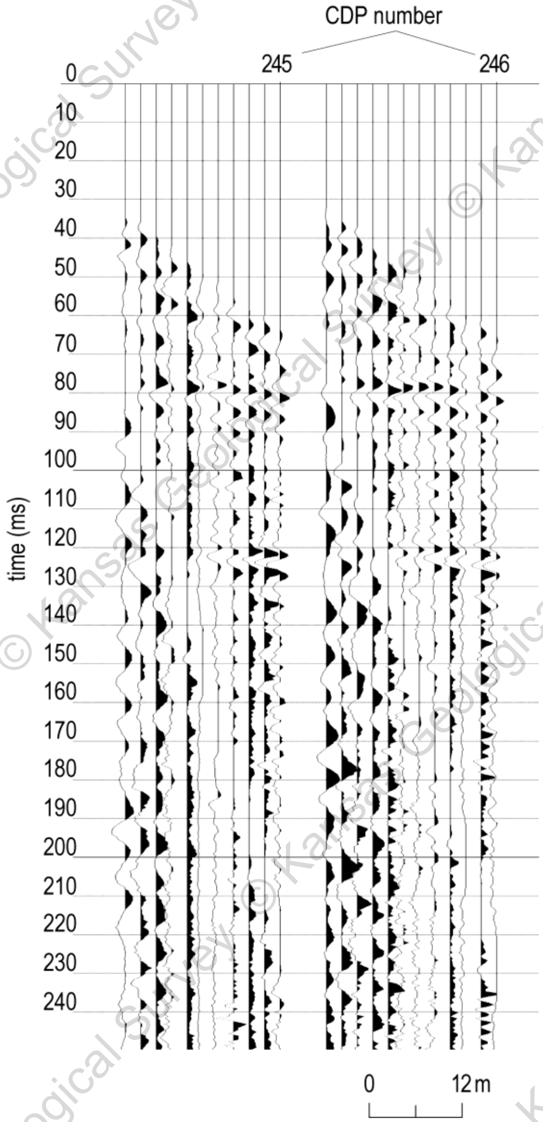


Figure 13. Shot gathers of CDPs 245 and 246.

These two gathers represent the subsurface points located beneath station locations 122 1/2 and 123. Careful examination reveals the zeroed-out portions of the traces previously occupied by the air-coupled wave. The traces are ordered within each CDP according to original source-to-receiver offset distance (trace header word 19 as defined by the *SORT). The location of the traces within each CDP is also identified by a trace header word (14). Header word 14 designates the order within the CDP gather. The numbering of traces within the CDP is from left to right with the far left trace of CDP 245 possessing a 1 at trace header location 14, while the trace on the far right possesses an 11 at trace header location 14. Header word 14 is totally unrelated to header word 8 (original seismograph channel number) and may or may not be the same value.

ELEVATION CORRECTION/DATUM ASSIGNMENT

Correcting data for a variable near surface can be one of the most difficult problems encountered while processing seismic-reflection data. Most areas on a seismic-reflection section possessing poor signal-to-noise ratios or that have resulted in an incorrect structural interpretation are pigeon-holed as related to “static problems.” These problems can be the result of anything from incorrect compensation for surface topography to uncompensated velocity irregularities in the near surface.

On any data set, the first step in eliminating static effects requires adjustment of the data to a datum. A **datum** is simply a reference line with some absolute correlation to sea level or, in some cases, average slope of the ground surface (sloping datum). Generally, on conventional data the datum is chosen beneath the weathered and within the subweathered zone. Defining the datum within the subweathered zone is necessary to ensure **all non-uniform near-surface material is above the datum**. The correction conceptually involves **removal of all material above the datum**, which in turn ultimately allows accurate time-to-depth conversions relative to sea level on interpreted CDP stacked sections. Correcting for both surface topography and a non-uniform weathered layer requires at least **relative station elevations** and a somewhat detailed knowledge of the **near-surface velocity and depth structure**. The datum correction is generally perceived as a first guess approximation and is intended to remove major static anomalies associated mainly with relative elevation changes. Discrepancies between the calculated datum correction and true datum correction are generally addressed using iterative numerical techniques at a later stage in the CDP processing flow.

Shallow high-resolution reflection profiles generally **target** geologic features **within** what conventional wisdom would suggest is the **weathered zone**. Correcting for elevation and near-surface irregularities on shallow profiles, therefore, becomes quite complicated in comparison to the previously described conventional procedure for datum corrections. Detailed knowledge of shallow velocity and depth information is critical for accurate datum corrections on shallow-reflection surveys. Subtle changes in the velocity of very-near-surface material can drastically affect the spectral as well as spatial properties of higher frequency data. For example, if you are looking for structure on the bedrock surface at a depth of 12 m with an NMO velocity of 400 m/s and dominant reflection frequencies around 200 Hz, an uncompensated 0.3-m variation in elevation or a 10 m/s velocity anomaly can result in a 100 degree phase shift in the recorded reflection wavelet. A gradual horizontally increasing near-surface velocity can be misinterpreted as a slope on the bedrock surface.

The selection of a datum for shallow-reflection surveys can greatly influence the outcome and validity of the final interpretation of the data. Many times reflection information of interest will be removed if a flat datum is chosen within the subweathered layer followed by conventional calculated removal of all overlying material. For most **shallow-reflection profiles, a datum should be chosen equal to the highest topographic feature** on the survey line. Then the **time adjustment** to compensate for the missing material should be **added to each trace** in accordance to the velocity/depth function. In areas with alluvium over bedrock, generally a direct-wave velocity can be used to determine the appropriate time correction. In areas with either a thin layer of weathered material or no weathered material at all overlying outcropping or subcropping units, a more detailed velocity function is necessary to reconstruct the material between the present ground surface and the datum. For shallow-reflection data, the datum represents a pseudo ground surface composed of actual material beneath topographic highs and the virtual material used to compensate for the distance between the ground surface and topographic lows and the datum. The sum is the time between the ground surface and the datum, allowing depth calculations to bedrock or other layers.

The **most inaccurate** part of the datum correction for shallow surveys involves the **assignment of depth/velocity pairs** to each surface station. The best way to determine these values is through **uphole/downhole surveys** in strategically placed boreholes. The *WinSeis 1.8* software will generate a near-surface model along the survey line by incorporating all the uphole-determined velocity and depth information with the spatial distribution of the holes. **Without uphole data, the only information available to approximate the near-surface velocity/depth**

structure is direct and refracted-wave information. In some cases, the values obtained using this information are sufficient to generate an acceptable near-surface model. The closer to a true near-surface velocity/depth model the user can define for the datum correction, the less dependent the user will be on iterative numerical statics routines and the more confidence the user will be able to put in depth calculations during the interpretation portion of the survey.

However, with the elevation change present as a result of the wash-out, the ***SURF** determining the appropriate values to input into, and the usefulness of the output of the ***SURF** operation requires a thorough understanding of the geologic situation as well as certain physical properties of the near-surface materials. The input **velocity function** will be **interpolated** across the entire expanse of the defined profile line. **Elevation data** input for each station location need only be **relative** within the survey (absolute elevation data are not necessary). If the datum was assigned above the highest topographic feature on the survey line, the outputted **static correction** for each receiver and shot station will be **necessary** during the later **interpretation** stages to calculate depths. If the datum was assigned within the subweathering zone, **time-to-depth conversions** can be made **without** knowledge of the amount of the **static correction** (material removed). This is because the relative elevation of the datum is known, which in turn allows accurate determination of time values between the datum and event of interest.

The necessary datum/elevation correction for our sample data set only modifies a small portion of the line. The data were collected in a river valley. River valleys often (as in this case) do not have significant changes in elevation. The majority of the sample data set was collected across a flat-lying pasture with little or no surface evidence to suggest areas of potential static anomalies. At the extreme east end of the line, however, the line crossed a wash-out extending approximately 6 m with a maximum relative depth of 1 m. If not for the washout spot on the line, no datum correction or other operation would be necessary on this line at this time.

Determination of the velocity within the very-near surface using the information provided with and contained within the sample data set is not straightforward. Therefore, we will provide you with the velocity information as well as the relative elevation data necessary to properly calculate and apply the datum correction. An uphole velocity survey in conjunction with your seismic-reflection survey is advisable whenever possible to accurately determine the near-surface velocity model.

Average velocity from the surface to approximately 3 meters of depth is: **770 m/s**

Critical elevation information includes the following:

Station Location	Relative Elevation (m)
136	0
137	0.3
138	0.6
139	0
140	-1
141	-0.3
142	-0.6
143	0

Once as much information as possible is obtained about the near-surface materials, a batch processing file must be created to **calculate** the appropriate static values for each shot and receiver station. This operation (***SURF**) does not apply the calculated shifts. This routine calculates the appropriate shift and updates the trace headers. In order to **apply** this static shift, a ***STAT 1** operation must follow the ***SURF** operation. This can be accomplished either in the same or in a separate batch job file. The following sequence of entries represents a batch processing file to calculate and apply datum corrections to our sample data set.

Line	Description
1 **>>START**	See ***EDKL** for description of **>>START**.
2 ***INPF SORT.dat**	See ***EDKL** for description of ***INPF**.

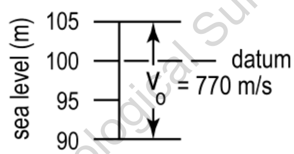
3 ***SURF 100**

The ***SURF** identifier calls up the terrain correction subroutine from within *WinSeis*. The required input value relates to defining the datum. The value of the **datum** is arbitrarily assigned as **100**. In this case, think of the data as representing absolute elevation relative to sea level.

4 **ALVF 105 770 90**

ALVF defines the average velocities and their associated depths. For the sample data set, we are defining a single velocity across the entire line and therefore the first entry identifies the maximum **surface elevation (105)** of the defined velocity function. The **second entry (770) defines the average velocity** from the maximum surface **(105)** to a **maximum depth** identified by the third entry **(90)**.

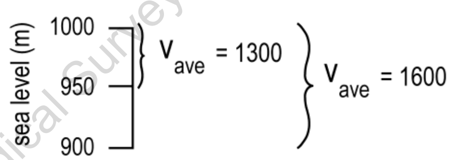
We have determined the following near-surface configuration:



The following example line 4a is appropriate for a case with multiple depth velocity pairs.

† 4a **ALVF 1000 1300 950 1600 900**

The **ALVF** operation defines the velocity model for the near-surface material down to a depth necessary to correct all station locations to the defined datum. The values requested for the **ALVF** operation are: the **surface elevation (1000)** of the defined velocity function, the **average velocity (1300) from the surface (1000) to** the elevation defined by the third numeric value **(950)**, then the **average velocity (1600) from the surface (1000) to** the elevation defined by the fifth numeric value **(900)**. This sequence of average velocity/depth pairs continues until the entire velocity function is defined. An important note at this point: the velocities defined here (ALVF) are **AVERAGE VELOCITIES FROM THE SURFACE TO THE DEFINED DEPTH.** The program will calculate **interval velocities** for the defined **intervals (1000-950, 950-900)**. This program works most effectively with uphole/downhole checkshot velocity information.



† Not applicable to this data set—used here only as an example.

5 **SE 126 97 100**

The **SE** operation defines each **station location** and its associated **source and receiver elevations**. The defined values are s**tation location (108)**, **source elevation (97)**, and **receiver elevation (100)**. The receiver elevation need not be defined if it is the same as the source elevation. A shot elevation defined at a station where no shot was recorded will be sorted out by the program and properly handled. The program interpolates horizontally and vertically between defined values and, therefore, **stations 108 through 125 are not defined since they are all the same as 126**.

6 **SE 127 100**

7 **SE 136 100**

8 **SE 137 100.3**

9 **SE 138 100.6**

10 **SE 139 100**

11 **SE 140 99**

12 **SE 141 99.6**

13 **SE 142 100.6**

14 **SE 143 100**

15 ***STAT 1**

The ***STAT** operation **applies static correction values** defined in the trace headers. These static header words are updated by other operations (***AUTS**, ***SURF**, or user input values). The ***STAT** operation can be **executed within** the **batch job** where the actual static correction values are determined or later in a separate batch job either **independently or with any other operation(s)**. The only required **input value** (1) designates the **type of operation used to define static shift values**.

16 ***OUTF SURF.dat** See ***EDKL** for description of ***OUTF**.

17 **>>END** See ***EDKL** for description of **>>END**.

At this point the user has completed the building of an executable file for the generation and application of static shifts to sorted data for the correction of elevation and near-surface irregularities across the profile.

The following commands should be in the batch file:

>>start
inpf sort.dat
**surf 100*
alvf 105 770 90
se 126 97 100
se 127 100
se 136 100
se 137 100.3
se 138 100.6
se 139 100
se 140 99
se 141 99.6
se 142 100.6
se 143 100
**STAT 1*

**outf surf.dat*
>>end

- Use the "Winstat.exe" GUI to use visual tools for near-surface information for static corrections. Each mouse-click selection on the seismic-data image will be simultaneously written into the text file utility, "Cmdedit.exe". see WinSeis User's Manual (i.e., pages 1-20 and 1-21 of "4section1.pdf")

The next step is to run the elevation correction job through the "WSeis.exe" program.

An alternative way to apply the datum/elevation statics is to use the ***STAT** operation and directly input the amount of time shift necessary to compensate for variability in velocity and/or elevation to each station location across the line. This way is very straightforward from an input point of view, but it does require significantly more work prior to interaction with the "WSeis.exe" program. Described below is the appropriate way to correct the datum using the ***STAT** operation and the sample data set:

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF SORT.dat**	See previous description of ***INPF**.
3	***STAT 4**	

***STAT** identifies a time static operation. The only entry necessary to do datum corrections is the first (4). The 4 simply indicates that the 4 option applies station corrections for both source and receiver.

4 **RECE 137 -0.30**

RECE identifies the trace header location that relates to the defined static shift. The first entry (137) is the receiver station location of the defined shift (-0.3 ms), which is the third entry. The only requirement of the RECE definitions is that the numbers increase and that they be in sequential order.

5	**RECE 138 -0.6**	
6	**RECE 139 0**	
7	**RECE 140 1**	
8	**RECE 141 0.3**	
9	**RECE 142 -0.6**	
10	***OUTF STAT.dat**	See previous description of *OUTF.
11	**>>END**	See previous description of >>END.

As with all the batch files, it is advisable to type (list) them out after they have been constructed in a **text** or **line** editor. The following is what the file **STAT.dek** should look like:

>>start
**inpf sort.dat*
**stat 4*
rece 137 -0.3
rece 138 -0.6

rece 139 0
rece 140 1
rece 141 0.3
rece 142 -0.6
**outf stat.dat*
>>end

Either the **STAT 4** or **SURF** operation are valid ways to correct for variability across the seismic line. Which operation you use with various data sets other than the sample provided with this manual is dependent on the amount of static, other information available, and probably most important, which operation you are most comfortable with.

VELOCITY ANALYSIS

The compressional-wave (P-wave) velocity through an elastic media is related to Lame's constants divided by the density of the media. Normal moveout (NMO) velocity information derived from the curvature of reflection events on seismic data is used to correct each reflection wavelet for a non-vertical incident travel path. The NMO velocity derived in this fashion can also be used as a rough approximation for the average velocity allowing a first-guess approximation of reflector depth. This correction for non-vertical incidence reflectors on seismic data (NMO correction) is one of the most critical parts of the preliminary processing flow. The summing of multi-fold data is meaningless unless all traces are corrected for their particular source-to-receiver offset to effectively simulate vertical incident energy (i.e., source and receiver located at the same point on the earth's surface).

Determining the appropriate stacking velocity (loosely NMO velocity) can be accomplished in a variety of ways. A constant velocity stack is the most commonly used method (probably because it does not require a significant amount of thought or understanding of the physics of the matter) to determine the stacking velocity of particular reflecting events on multi-fold seismic data.

A constant velocity stack simply moves out and stacks all traces within a CDP gather at a predetermined velocity. Generally, a data set will be moved out and stacked at each of a consecutive group of velocities (in some cases as many as 20). The analysis technique at that point simply involves visual inspection to determine which velocity is "best" for a particular reflector. The velocity can and many times does vary both horizontally and vertically (time). The resultant velocity function is defined by CDP, time, and velocity. Multiple reflectors should be identifiable at most CDPs on seismic reflection data collected in a geologic environment conducive to the propagation and recording of reflection energy. The velocity function for each CDP will have an optimum stacking velocity paired with the appropriate time window for each identifiable reflector. The velocity function defined for a group of reflecting events at a particular CDP may not be appropriate for the same set of reflecting events at other CDPs across the profile (as a result of horizontal variability). Stacking velocities must be analyzed using the constant velocity stack and inputting large groups of CDPs across the entire expanse of the line. It is possible and many times advisable to analyze groups of CDPs from various spots across a seismic line until trouble spots or areas with need for a more detailed analysis can be located.

Interactive Velocity Picking

The most fundamental way to determine an approximate NMO velocity for a reflector is by using the exact NMO equation and a seismic field record. This process involves defining arrival time and source-to-receiver offset distance pairs and then putting them into the appropriate equation (for the appropriate equation see Telford et al., 1976). In order to streamline this process, *WinSeis 1.8* has an interactive operation that allows the user to graphically determine the NMO velocity for a particular reflection event ("WinVelp.exe").

To start the process of determining the appropriate velocity function for our sample data set, we first will need to input a file into the "WinVelp.exe" program and determine an approximate velocity. This will allow us to optimize computer and analysis time during the constant velocity stack portion where we will define our first-pass velocity function. The "WinVelp.exe" program requires the input data to already have the field geometries in the trace headers. To be consistent with the previous portions of this manual, we will use field file 5 to determine the velocity of our primary reflectors. To get field file 5 into the correct format, we will need to resort the data from CDP to field file format so that the required header information is present. With field file data as opposed to CDP gathers we will have 24 traces, allowing us significantly more trace-to-trace coherency. More traces will also improve the statistical determination of velocity.

First, we must resort the CDP sample data. The following sequence in a batch file will accomplish this.

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF SURF.dat**	See previous description of ***INPF**.
3	***RSRT 92 8**	

The ***RSRT** operation resorts data according to any trace-header word requested. The first entry (**92**, which is the header word defining the SSN) defines the primary sort operation, which is the major groups to collect traces into (e.g., field files are grouped according to header word 6 or 92, CDP gathers are grouped according to 12; common offset gathers are grouped according to 19, etc.). The second entry (**8**, which is the header word defining the trace number within the original field file) defines the secondary sorting operation, which is the order of the traces within each of the major groups defined by the first entry (channel number with each original field file are grouped according to 8; traces with each CDP are grouped according to 14; traces within common offsets are usually gathered according to header word 6, 87, or 92).

4	***OUTF RSRT.dat**	See previous description of ***OUTF**.
5	**>>END**	See previous description of **>>END**.

The resort batch file that was created with the above instructions will appear similar to the following:

>>start
**inpf surf.dat*
**rsrt 92 8*
**outf rsrt.dat*
>>end

As with previous batch jobs, double click on the **RSRT.dek** file to launch "WSeis.exe" and run the .dek file.

At this point, the file **RSRT.dat** is in field-file format. One option at this point is to peel off only file 5 and input it into "WinVelp.exe". In "WinVelp.exe", the option exists to select the desired field file on which to work. We will remove only file 5 as an exercise in using the ***INPF** definer. The following operation will result in a file being created containing field file 5 only:

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF RSRT.dat 5 5 100**	

The three entries after the input data-file (**5 5 100**) identify the beginning and ending file numbers to operate on and record length in meters. The primary sort order of the data dictates file designation. This means that if the data are in field-file format, the user can select particular field files to operate on, i.e., 5. If the data are in CDP format, the user can select a particular sequence of CDPs to operate on. In this case, the **input data** (**RSRT.dat**) are in **field-file format**, allowing us to directly select field file 5. It is not possible, however, to select a particular CDP or group of CDPs from this particular input data file (**RSRT.dat**) since it is in field-file format.

3 **<u>*OUTF ff5.dat</u>** See previous description of ***OUTF**.

4 **<u>>>END</u>** See previous description of **>>END**.

To extract field file 5 from the rest of the data set, the previous batch processing file needs to be run as input to the program "WSeis.exe". Double click on the new **FF5.dek** file to launch "WSeis.exe" and run the .dek file.

Now, field file 5 is the lone file in the MS-DOS file **ff5.dat**.

WinVelp Tutorial

Velocity analysis can be done by using the "WinVelp.exe" tool. Also See WinSeis Turbo Users Manual, Section 1.4.1 Velocity (page 1-15).

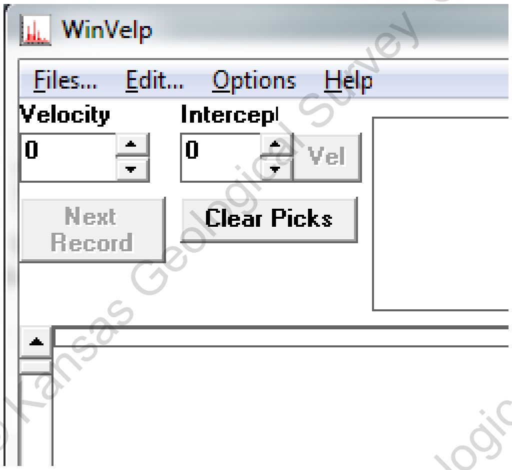


Figure 14. WinVelp main window.

To open a .dat file, select **Files > Open** (ff5.dat). Upon opening your file you will be prompted to input parameters regarding the geometry of the data. To ensure your parameters are correct, click the "**Visualize**" button (Figure 15). This sets the display of your input parameters. If everything is correct, click the "**Done**" button and your data will be displayed and ready for velocity analysis (Figure 16a).

Once data are displayed, velocity analysis can be done by picking hyperbolas. Simply click two or more wiggle traces in the shot record for a single reflection and click the "**Vel**" button for a velocity line to appear. Velocities and Intercepts (time or depth) can also be entered for analysis. Upon clicking the "**Vel**" button, WinVelp calculates the NMO velocity (Vnmo), the two-way travel time at which that velocity is calculated (TO), and the depth at which at the reflection is located (Zdist).

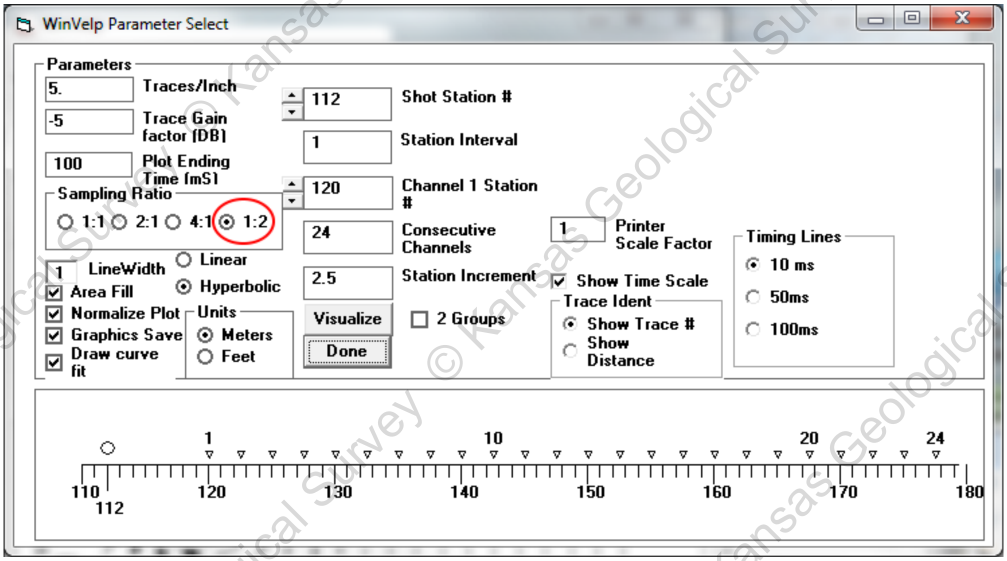


Figure 15. "WinVelp Parameter Select" window with vertical display ratio 1:2 selected.

After selecting two points along the >75 ms reflector by clicking on the image and clicking on the "**Vel**" button, the user should get a value of approximately 2400 m/s for the NMO velocity of the reflection at 75 ms, which equates to a depth-to-reflector of approximately 90 m (Figure 16b).

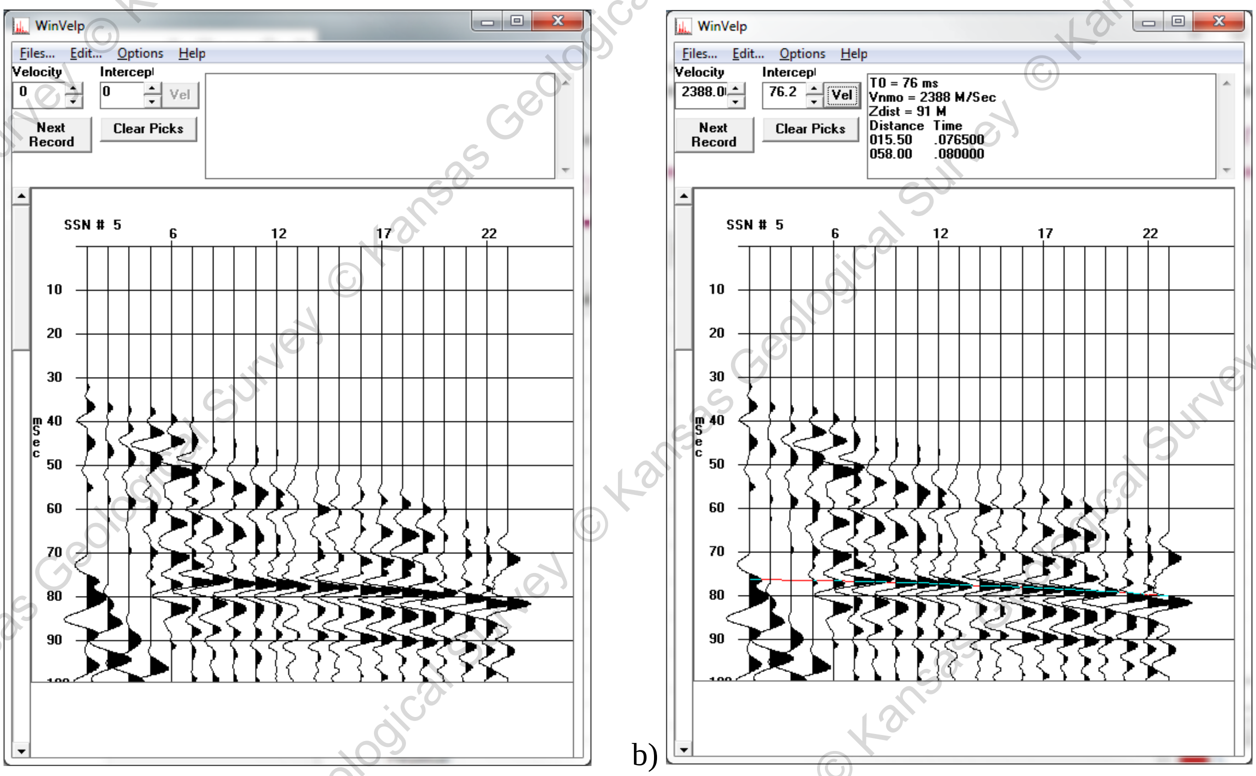
a) 

Figure 16. Field-file record 5 a) before picking a reflector and b) after picking a reflector at ~75 ms intercept time.

In a similar fashion user can use CDP data gathers (Figure 17). However, such an approach may be more difficult due to the fewer traces available for picking (i.e., the CDP fold).

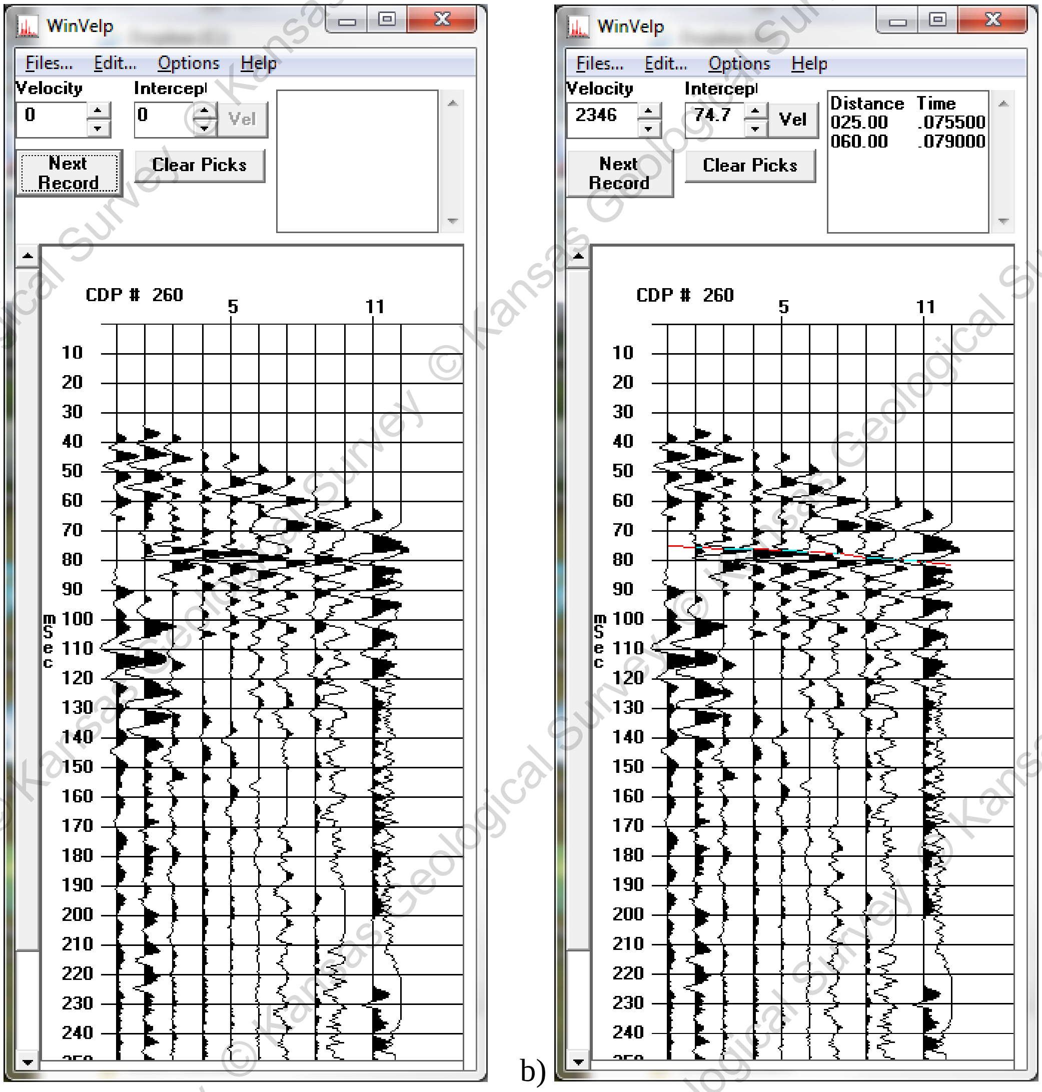


Figure 17. CDP gather 260 a) before picking a reflector and b) after picking a reflector at ~75 ms intercept time.

Constant Velocity Stack

Once an established a ballpark velocity for the major reflecting events is determined it should be efficient to run the constant velocity stack routine ("Winvscn.exe") to fine-tune the velocity function for this data set. The "Winvscn.exe" program is interactive and then once all the appropriate information is entered, it will operate on the input data as requested in a batch-type format.

Velocity Scan Tutorial

Once completing initial analysis using "WinVelp.exe", further velocity analysis can be done using "Winvscn.exe". "Winvscn.exe" has the ability to stack multiple CDPs and display multiple velocities for picking to ensure the most accurate velocity function. It will also create a ".dek" file after picks are made. "Winvscn.exe" allows for up to 20 velocities and CDPs to be evaluated at a time. To begin, open the "Winvscn.exe" and select a .dat file. For this example, **SURF.dat** from the sample data will be used. **Note: the data must be CDP (CMP) sorted for "Winvscn.exe" to work.** Upon selecting the file, the user will be prompted with an NMO Parameters screen. This is where velocities and the number of CDPs can be defined. More CDPs can be selected; however, for the purpose of this tutorial only CDP #223 and several velocities will be examined. By checking the CDPs checkbox, "Winvscn.exe" will stack each group of 10 CDPs (223-232) and return the average.

Next input all necessary parameters:

Output Length (ms) - 250

This allows the option to process a small chunk of data (starting at time zero, of course). This will be especially useful when more data are acquired than is really necessary.

NMO Stretch Ratio - 0.60

Sample stretch ratio defines the amount the user is willing to allow the wavelet to stretch as a result of the dynamic NMO correction before it is muted. This parameter requires a great deal of care and careful thought before and after application. Artifacts will be generated on stacked data if this parameter is not properly selected. The result of an improper mute can range from apparent high-frequency coherent events to anomalous low-frequency shallow wavelets. Experience and care will prevent trouble with this parameter. With the extremely site-dependent nature of velocity functions, a simple rule of thumb is not possible. This is a case where having the appropriate experience or academic background to understand the mathematics of the operation will greatly enhance the ability to properly select mutes and to know from inspection of stacked data if the mute was not properly assigned.

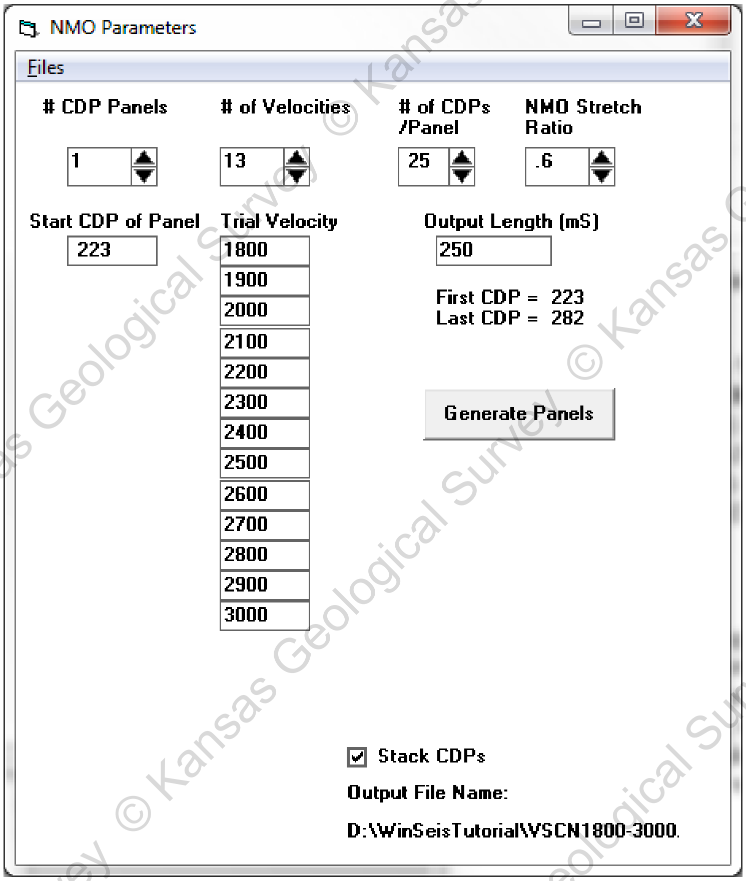
Check the "**Stack CDPs**" checkbox.

This allows inspection of data after moveout either in a stacked or unstacked form. The unstacked form is very helpful in some cases because it will show exactly how much each trace was moved out and the associated contribution of each trace to the final stacked section.

Select "# of Velocities" value, e.g., **13**, and type the velocities in the corresponding fields (Figure 18).

#1velocity = **<u>1800</u>**
#2velocity = **<u>1900</u>**
#3velocity = **<u>2000</u>**
#4velocity = **<u>2100</u>**
#5velocity = **<u>2200</u>**
#6velocity = **<u>2300</u>**
#7velocity = **<u>2400</u>**
#8velocity = **<u>2500</u>**
#9velocity = **<u>2600</u>**
#10velocity = **<u>2700</u>**
#11velocity = **<u>2800</u>**
#12velocity = **<u>2900</u>**
#13velocity = **<u>3000</u>**

When entering trial velocity values, no set pattern or limits (except for maximum number of trial velocities) need be adhered to. Finally, select **File > Output file name**, change the file type to **.nmo**, and enter a filename. Once complete, select the **Open** button in the bottom right corner and the Output filename should appear in the lower right corner of the dialog box. Click on the "**Generate Panels**" button to run the processing and the "**OK**" button once it is complete (Figure 18). Now go back to the **Files** tab, select **Open**, once again change the file type to NMO data, and select your ".nmo" file (Figure 19).

a) 

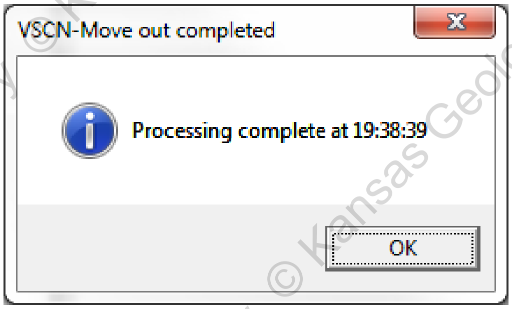
b) 

Figure 18. a) "NMO Parameters" window for entering constant-velocity-stack velocities and b) "VSCN-Move out completed" window.

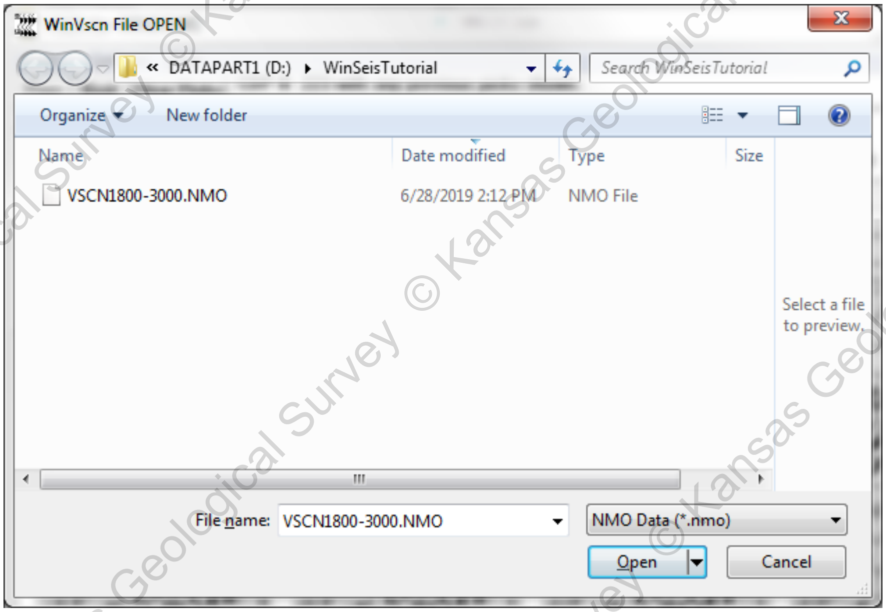


Figure 19. "WinVscn File OPEN" window before selecting an *.nmo file.

The VSCN data will be displayed and the move-out velocity of each panel will be displayed in the upper right hand corner of the group of CDPs processed (Figure 20).

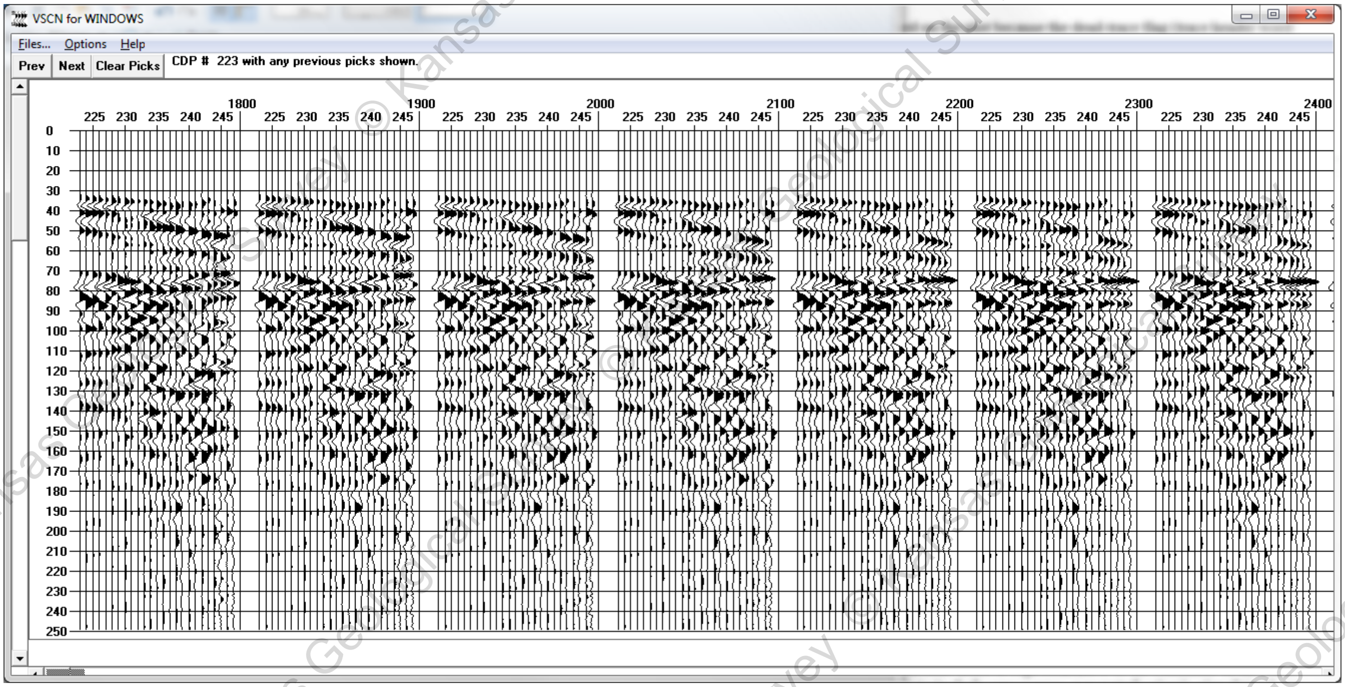


Figure 20. 1800 to 2400 constant-velocity panels.

The display format for the constant velocity stacks groups all the CDPs according to stacking velocity. The constant velocity panels will be either stacked (Figure 20) or unstacked depending on what is selected. Click on **Options > Change Graphics** to display the "Graphics Parameters" window and adjust display parameters (Figure 21).

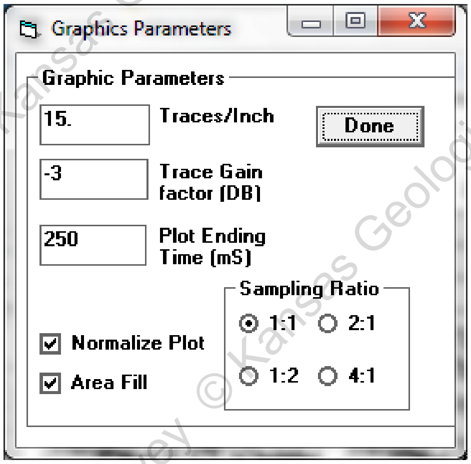


Figure 21. Constant-veloctity panels "Graphics Parameters" window.

Displaying the constant velocity stacks is critical and will be the first real glimpse of what a stacked section may look like once it has completed the processing flow. It is important to generate a hard copy of the velocity scans. This will give you a perspective of the relative quality of each reflector on each CDP at each of the selected velocities. Picking a velocity function is the most significant, pure judgment call made yet in our processing of this sample data et. Select the best velocity function (which could involve several CDP, time, and velocity groups across the expanse of the line) for the entire line. It should also be noted that at this point, a general knowledge of the geologic environment is critical to selecting a meaningful velocity model. This is mainly due to the variety of ways some reflection (or worse, noise) energy will "stack in" at different velocities. Distorting (creating) reflections as a result of incorrectly processing the data is not only possible, it is very easy if care is not taken during each step of the processing flow.

Using 50 CDPs can provide additional perspective (Figure 22). The 75 ms reflection in our sample data set changes velocity from about 1925 m/s to 2600 m/s across a distance of about 70 m. There was no surface feature that would suggest such an extreme variability. This in itself should encourage care during the velocity-analysis portion of the processing flow.

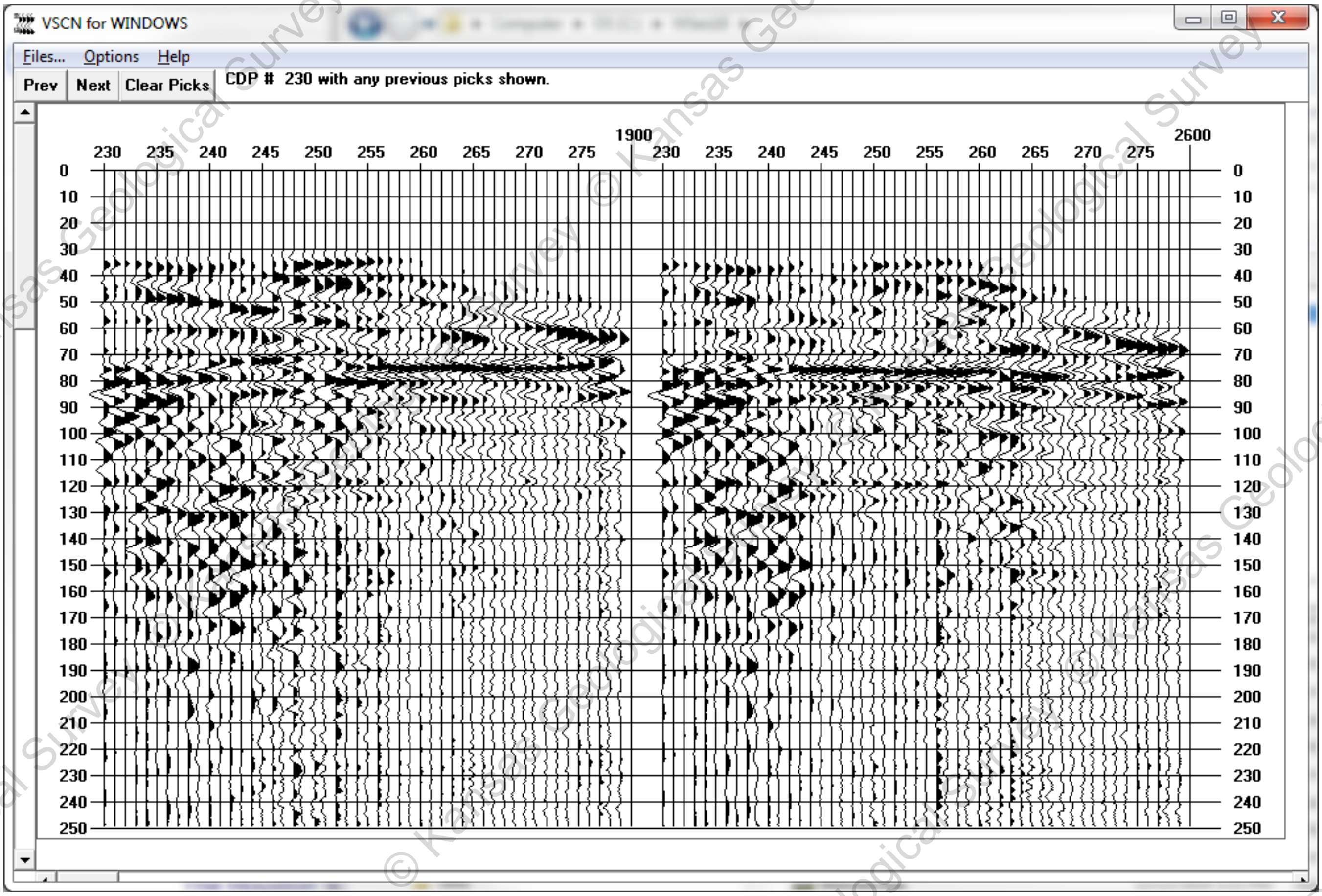


Figure 22. 1900 and 2600 constant-velocity panels using 50 CDPs.

The selection of the appropriate velocity function from constant velocity stacks is to some degree a qualitative judgment based mainly on experience and a fundamental knowledge of seismology and the site geology. The odds of avoiding bogus reflecting events are increased by studying constant-velocity gathers. Moved out gathers at this point in the processing flow are for the most part trace-by-trace the same (except for the extreme cases with a slight static shift) as the original recorded data. The only difference is the whole trace dynamic test moveout compensation (which is the variable being tested). Analysis of data in this fashion allows the user to go back to the original field files and actually follow identifiable reflection information through the velocity analysis. The velocity function that is chosen in this fashion should possess a high level of reliability once the data are actually stacked, and will reduce some of the qualitative aspects of the selection routine.

Once you have displayed your data, you may click reflections at different velocities. A cyan-red line will appear at your pick (Figure 23). Once all of your velocities have been selected for a given CDP, click the "**Next**" button to evaluate the next CDP. Once all CDPs have been analyzed and picked, select **Options** > **Make VELF commands**. This will make your .dek file for you, which would enable you to apply the different NMO velocity functions across the CDP data using the *NMOT command (*WinSeis* Turbo User's Manual, p. 5-21). You will then be asked to select an output file name to be saved for NMO corrections to be applied, the NMO stretch mute you would like to apply, if you would like to use recording delay time, and the name of the .dek file. This can be saved and run through "WSeis.exe".

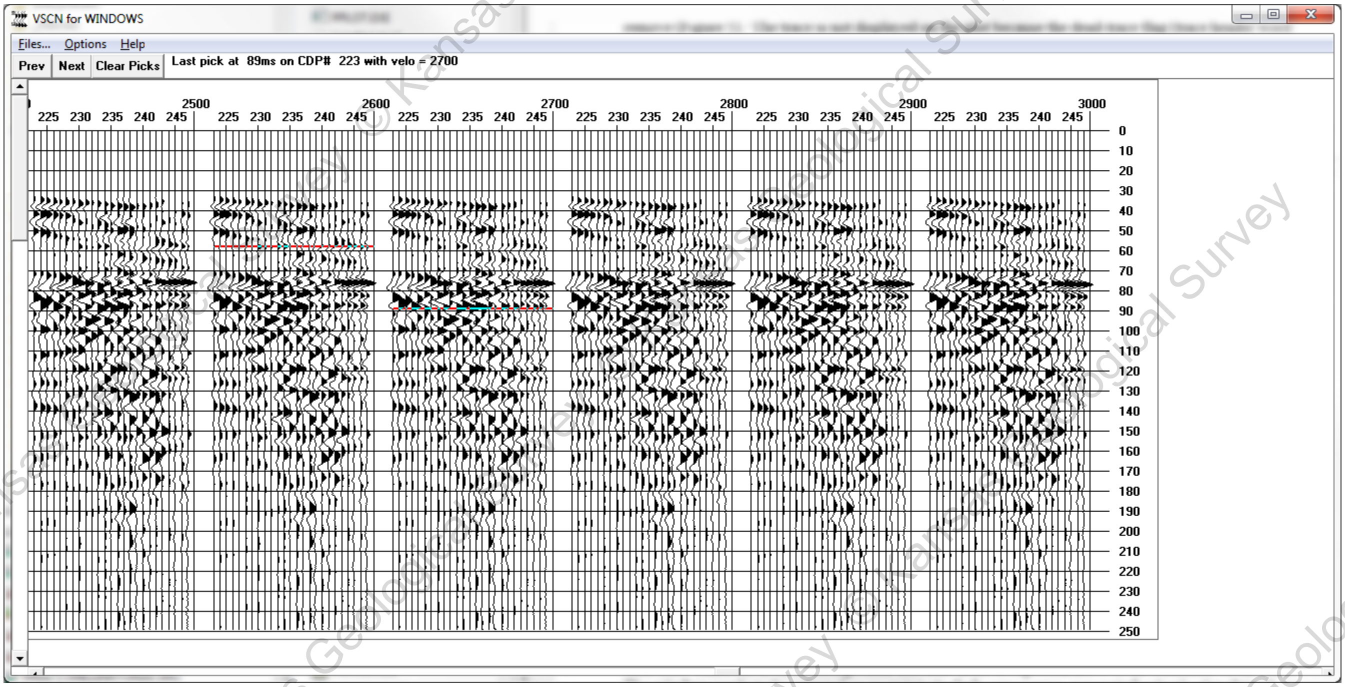


Figure 23. 2500 to 3000 constant-velocity panels with two picked velocities, 2600 at 58 ms and 2700 at 89 ms indicated by cyan-red lines.

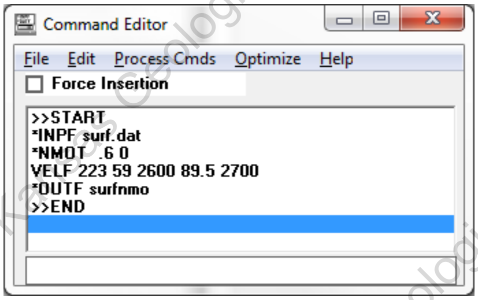


Figure 24. Saving a .dek file with NMO velocity functions.

See also *WinSeis* Turbo User's Manual, Section 1.4.

Within this tutorial, this file does not need to be saved—you are provided an NMO .dek file. It was necessary to go through these steps to learn the uses of the tool and understand how this given .dek file was created. When running the provided NMO.dek through "WSeis.exe", a 2D velocity spectrum is created and plotted for you once the .dek file has completed (Figure 25). Check the "WSEIS18Manual-Amendments.pdf" (located in your C:\WSeis18\Documents\Manual folder) for more NMO parameters in addition to the ones listed in the WinSeis User's Manual (i.e., page 5-21 of "8section5.pdf"), including the type of velocities to display (e.g., stacking vs. depth, etc.), inverse NMO, and additional NMO terms.

The number of (CDP) groups to be processed often allows the user to skip through the line and do velocity analysis on sequential groups of CDPs. If we wanted to do velocity analysis in an area we deemed to have velocity problems, or if we only wanted to do reconnaissance velocity analysis on certain portions of the line, several groups of CDPs could be selected for analysis. If velocity problems were present between CDPs 230 and 240 and between CDPs 260 and 270, a constant velocity stack on just those two sequential groups of CDPs could be performed.

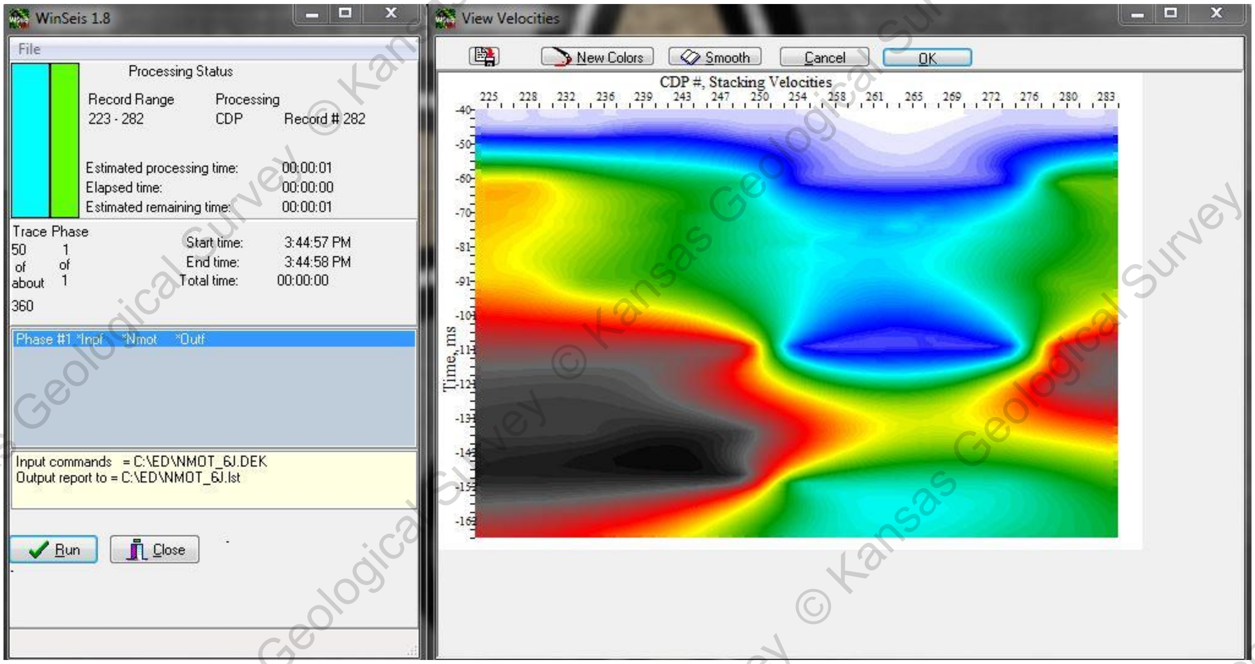


Figure 25. 2D Stacking velocities display.

Effectively, the program increments 30 from the first CDP of the first group to determine where to begin the process for the second group. Therefore, in this case the second group would start with CDP 260 and 11 CDPs would be processed (240 - 230 = 11), up to and including CDP 270. Likewise, if sufficient data existed, the third group would have started with CDP 290 and ended with CDP 300. If 15 had been selected as the increment value, CDP 245 would be the first CDP of the second group and CDP 255 would be the last. Then the third group (of the 15-increment example) would have started with CDP 260 and ended with CDP 270.

Time-Spatial Varying NMO

The velocity function we choose for this data set is listed below:

CDP Limits	Time (ms)	Velocity (m/s)
200 - 232	0.0-50	1850
	50-100	2600
	100-135	2900
	135-250	3000
232 - 246	0.0-50	1850
	50-100	2450
	100-135	2900
	135-250	3000
246 - 253	0.0-50	1850
	50-100	2450
	100-135	2900
	135-250	3000
253 - 278	0.0-50	1850
	50-140	1900
	140-250	2250

278 - 290	0.0-50	1850
	50-100	2450
	100-250	2900

The above described velocity function needs to be applied to the sorted, datum-corrected data. In order to accomplish this, a normal-moveout operator needs to be used. The batch processing file (NMOT.dek) used to apply the normal-moveout correction to our sample data set is created and dissected below:

Line	Description
1 **>>START**	See previous description of **>>START**.
2 ***INPF SURF.dat**	See previous description of ***INPF**.

3 ***NMOT .6 0 0 1**

The ***NMOT** operator adjusts each sample of each trace (dynamic correction) for a specific velocity function described by the **VELF** definer. The only entry required for the **NMOT** operator is the value of the **sample stretch ratio (0.6)**. Again, see "WSEIS18Manual-Amendments.pdf" for more NMO parameters. This value specifies the amount of mute to apply to a trace to suppress the stretching of the reflection wavelets due to the correction of non-vertically incident ray paths. By correcting to vertical incidence, all traces should be geometrically equivalent and whole-trace addition within a particular CDP should result in enhancement of reflection energy. As discussed during the **WinVSCN** operation, a proper **NMO** stretch mute is critical to generating a realistic stacked section. **An incorrectly designed and applied stretch mute can generate (depending on whether the mute is too extreme or too subtle) anything from high-frequency spikes to very distorted low-frequency wavelets**. The stretch mute is most evident on shallow low-velocity reflections. This is because the most extreme stretch results from lower NMO velocities (as is intuitively obvious from a hyperbolic curvature perspective). The more severe hyperbolic NMO curvature (lower average velocity) is generally associated with the low-velocity material in the near surface.

4 **VELF 230 45 1850 60 2600 90 2600 110 2900 135 3000**

The **VELF** definers are grouped according to CDP locations. The velocity function is input in time/velocity pairs. The first entry after the **VELF** definer is the **CDP** number **(230)**, for which this velocity function is defined. The **second (45, in units of ms)** and **third (1850, in units of m/s) entries** identify the **first time/velocity pair** of the velocity function at this CDP. The program uses the first pair to define a consistent velocity window from 0 ms to the first identified time (45). The velocity function is then interpolated between 45 and the third entry (60), which is the time value for the second time/velocity pair, with 1850 m/s defined as the velocity at 45 ms, gradually changing sample by sample until at **60 ms** the **NMO** velocity is **2600 m/s**. This process continues in exactly the same fashion for all the defined time/velocity pairs down to the bottom of the record. In this case, the **velocity is constant (2600 m/s) between 60 and 90 ms**. Then, **between 90 and 110 ms, the NMO velocity changes from 2600 m/s to 2900 m/s**. Finally, between **110 ms and 135 ms the NMO velocity is defined to change from 2900 m/s to 3000 m/s**, where it remains constant to the end of the record. It should be noted that the last time/velocity pair initiates a **constant velocity** correction that begins at the last time identified and continues **to the end of the record** (Figure 26).

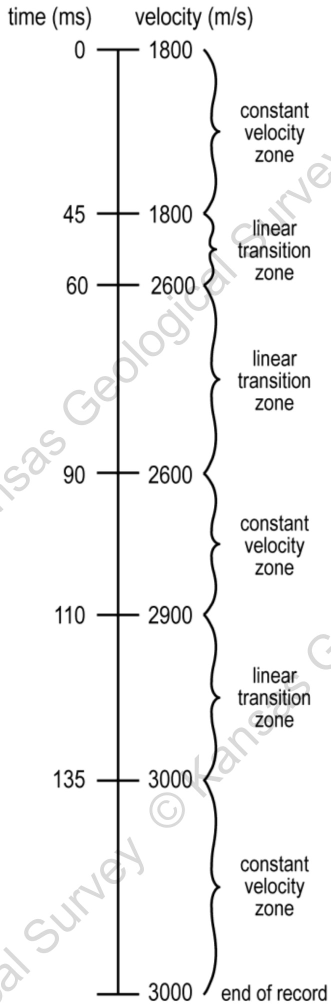


Figure 26. NMO velocity function at CDP 230.

As you can see, the velocity function as it is defined here is not identical to the velocity function determined from the constant velocity stacks (listed in the table at the start of the Velocity Analysis Section). The reason for this is related to the interpolation process operating both vertically in time and horizontally in space. Analysis of the data suggested specific time windows where the stacking velocity seems to be relatively constant and other time windows where, simply from a physically realistic point of view, the average velocity through the rock must be changing at a significant rate. With this in mind, the program must be instructed as to which time windows have relatively constant velocities and which windows have a significant amount of change/unit time (depth). The assigning of a realistic velocity function that possesses significant variability in time and space is a skill (knack) that will develop with time and experience.

5 **VELF 235 45 1850 60 2450 90 2450 110 2900 135 3000**

The velocity function for this **VELF** definer is for CDP 235. The vertical (time) interpolation process is identical here as it was with line 4 (previous VELF definer). The significant thing to note here is the **interpolation between CDP 230 and 235**. The interpolation process is uniform between lines 4 and 5 with the velocity defined at **60 and 90 ms gradually changing at each CDP between 230 and 235 from 2600 to 2450 m/s**. This will be true for all velocities defined at each **VELF** definer. The velocity will be interpolated in both time and space.

6 **VELF 250 45 1850 60 2300 90 2300 110 2900 135 3000**

7 **VELF 255 45 1850 60 1900 110 1900 150 2250**

8 **VELF 275 45 1850 60 1900 110 1900 150 2250**

9 **VELF 280 45 1850 60 2450 90 2450 110 2900**

10 ***OUTF NMOT.dat** See previous description of ***OUTF**.

11 **>>END** See previous description of **>>END**.

It is wise to double check that the batch file has been created and saved the way it was intended. The batch file should appear similar to the following:

>>start
**inpf surf.dat*
**nmot 0.6*
velf 230 45 1850 60 2600 90 2600 110 2900 135 3000
velf 235 45 1850 60 2450 90 2450 110 2900 135 3000
velf 250 45 1850 60 2300 90 2300 110 2900 135 3000
velf 255 45 1850 60 1900 110 1900 150 2250
velf 275 45 1850 60 1900 110 1900 150 2250
velf 280 45 1850 60 2450 90 2450 110 2900
**outf nmot.dat*
>>end

Applying the defined velocity function (making the dynamic correction for non-vertical incidence) requires the execution of the batch processing file we just created called **NMOT.dek**. Double click on the **NMOT.dek** file to launch "WSeis.exe" and run the .dek file.

As before, the program will notify as to its progress. In order to see the results of the velocity correction, use the view routine on the CDP gather. The velocity function we just applied will correct the reflection for non-vertical incidence. The result of this dynamic correction is quite evident when comparing corrected to uncorrected field files.

The optimum stacking velocity should remove the hyperbolic curvature of a reflecting event (Figure 27a). The result of the correct velocity on raw field files is trace-by-trace consistency in the time and wavelet characteristics of the reflecting event (Figure 27b). It is possible to examine NMO corrected data in field file format and compare it to data before the NMO correction (Figure 27a), as record gathers. For that the NMO output file, "nmo.dat", can be reordered/resorted the from CDP gathers to common shot gathers, similar to the use of the *RSRT command in the "Interactive Velocity Picking" section.

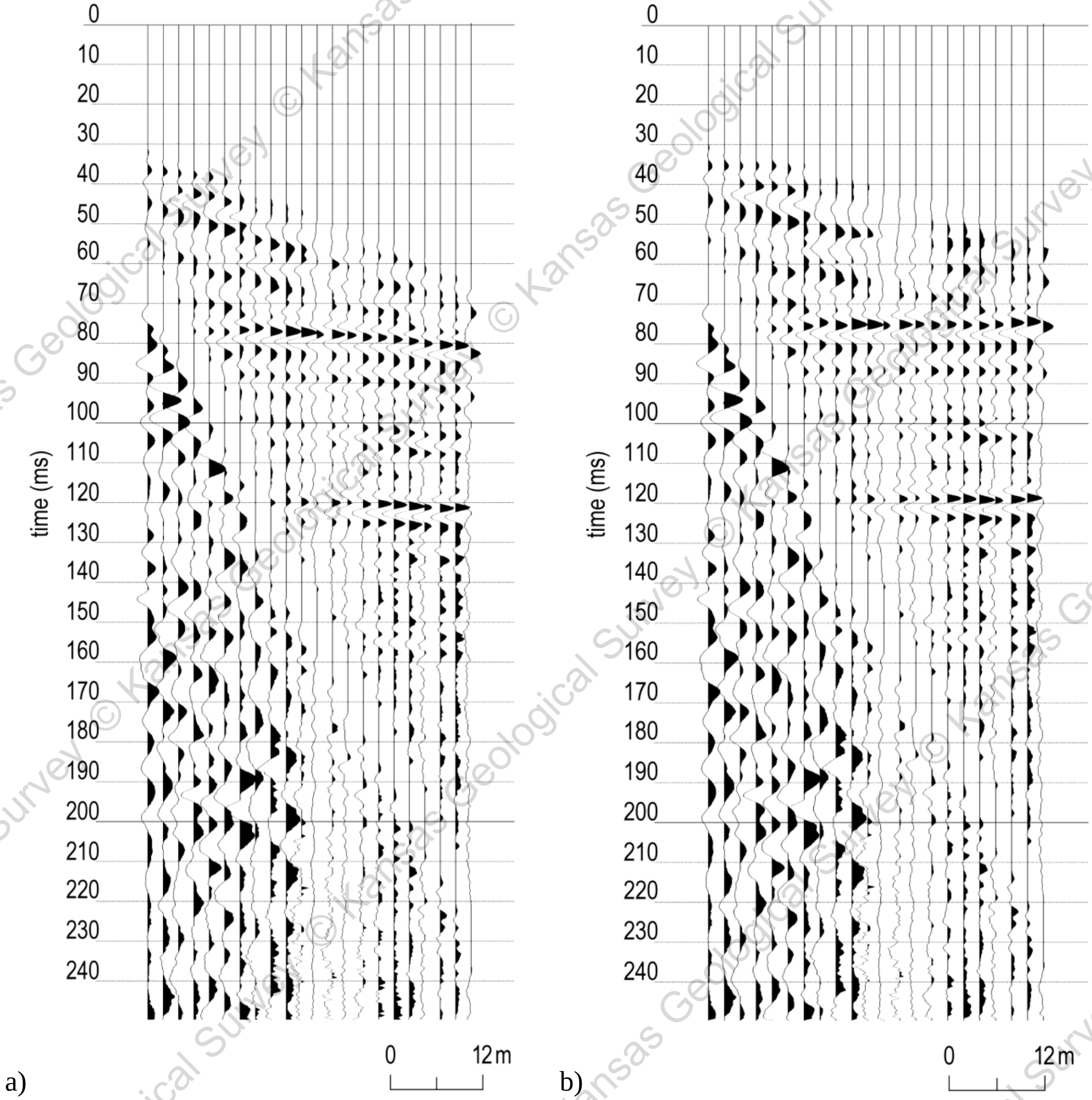


Figure 27. Field-file 5 a) before and b) after NMO correction for comparison (from Figure 8).

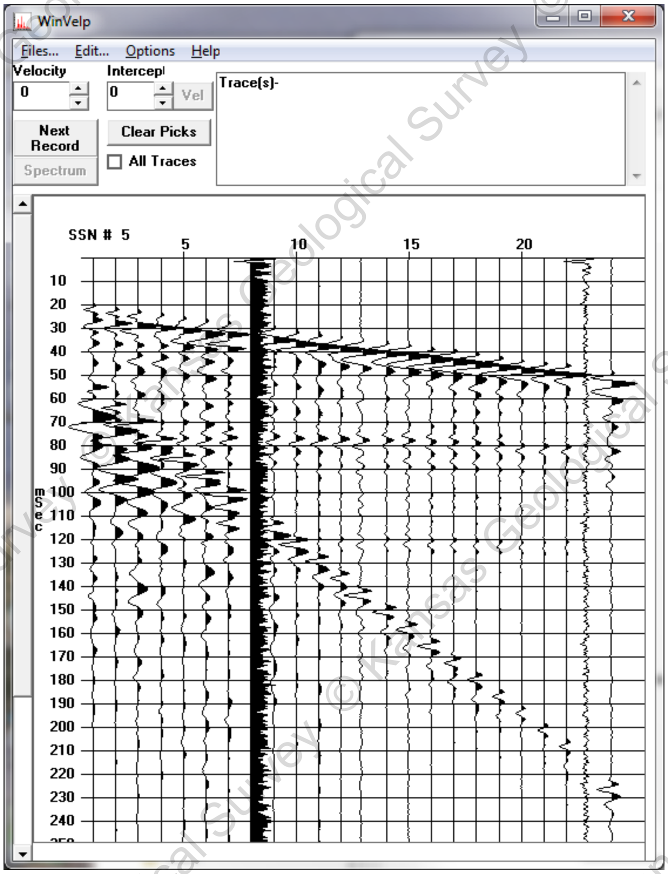
SPECTRAL ANALYSIS

The spectral characteristics of a raw seismic data trace are dependent on the acquisition parameters (and equipment) as well as the surface and subsurface characteristics of the site. During the spectral analysis portion of the processing flow, the frequency characteristics are determined with respect to the various types of seismic energy present on the data. A frequency filter is then designed to enhance the favorable spectral characteristics and attenuate the undesirable ones. The amount and type of spectral analysis necessary for a particular data set is totally dependent on that data set.

Frequency vs. Amplitude

Depending on the data set, the first step in determining the spectral characteristics of seismic data is to define the dominant frequency and bandwidth of the entire data set. This is most effectively done with an amplitude-versus-frequency display. This analysis technique relies on an **FFT** to compute the amount (amplitude) of information on a seismic trace at each particular frequency. This operation will become less necessary (depending on the data set) as the user gains more experience looking at seismic data and identifying particular types of energy and their dominant frequencies. Until that point, amplitude-versus-frequency plots may be required to determine the spectral characteristics of the air wave, ground roll, refractions, and reflections.

Launch "WinVelp.exe", choose **Files…** > **Open** from the main menu, select Dengland.dat, and input parameters, similar to the WinVelp Tutorial on page on page 48. Choose **Options** > **Spectrum Analysis** from the main menu. For this example we will move to SSN 5 by clicking the "**Next**" button (Figure 28a). Click trace 18 and then click the "**Spectrum**" button to display the frequency vs amplitude spectrum of the selected data (Figure 28b). After the spectral information has been calculated, it will automatically be displayed on the screen—if system requirements are met.

a) 

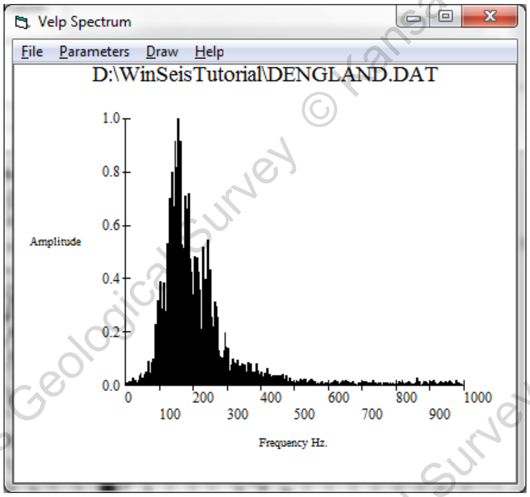
b) 

Figure 28. Winvelp program displaying a) SSN# 5 seismic record after selecting "Options" and "Spectrum Analysis" from the main menu and b) frequency spectrum of trace 18.

Visual options may be changed by clicking the **Parameters** menu of the "Velp Spectrum" window. For example, change the "End Frequency" from 1000 to 500, the "Color Value" from 0 to 3, and click the "**Done**" button (Figure 29a) to see a modified "Velp Spectrum" window (Figure 29b).

Choose **File > Save Graph as File** from the menu of the "Velp Spectrum" window to save the spectrum image as a .bmp or .wmf file.

The Figure 30 images are examples of a good series of analysis runs necessary for helping decide on the appropriate digital filters.

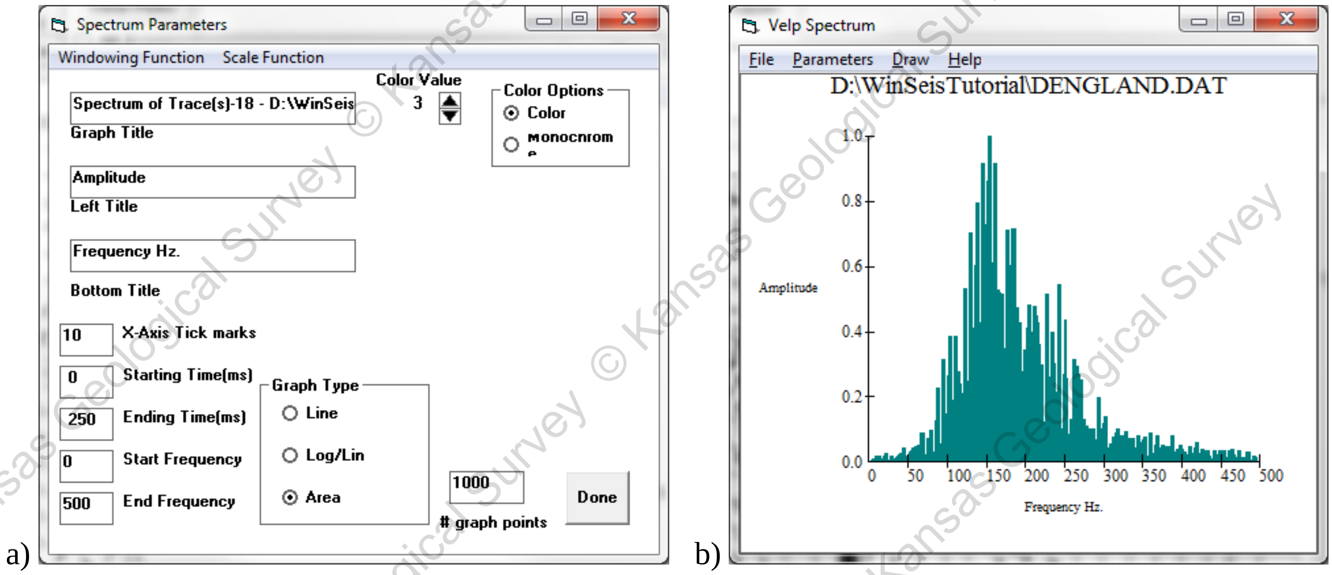


Figure 29. a) Changing values on the “Spectral Parameters” window and b) updated frequency spectrum of trace 18.

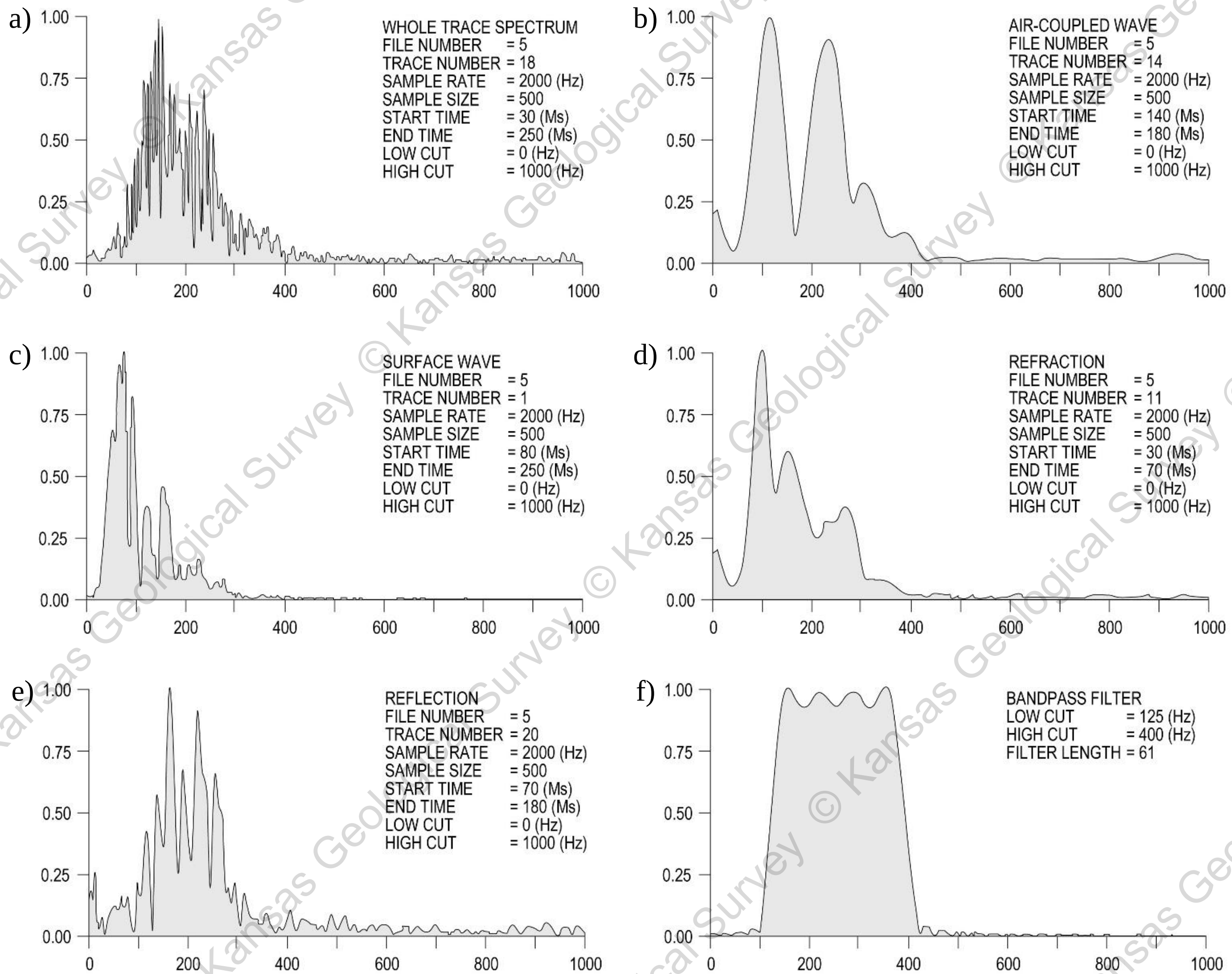


Figure 30. Field-file 5 spectrum plots with a) whole trace spectrum and predominantly b) air-wave, c) ground-roll, d) refraction, and e) reflection energies compared to f) a possible bandpass filter.

Filtering

Analysis of the spectral plots allows the designing of an appropriate digital filter to enhance reflection energy. The most common type of digital filter and the most appropriate for our sample data set is a digital bandpass filter. This filter by its nature will attenuate all energy with spectral values outside a defined window. The window is defined in the frequency domain and is shaped in accordance with predefined front and rear slopes. All of the filtering options available in WinSeis 1.8 have front and rear slopes that can be thought of in a very similar fashion as the taper previously discussed for the muting operation. Without these slopes, when the transformation from the frequency domain to the time domain is made after filtering, sinusoidal artifacts will be injected into the seismic data. The frequency of these artifacts will be related to the frequency of the defined high- and low-cut filter values of the bandpass.

For the sample data set, it appears from spectral analysis that the dominant frequency of the reflection information is approximately 250 Hz. The bandpass filter design must not attenuate any signal within one-half octave of that frequency. The air-wave information ranges from about 50 to 400 Hz. Of course, that frequency band is coincident with the reflection information. The muting operation performed early on in the processing flow removed the majority of the air-coupled waves. The ground-roll frequencies, on the other hand, fall mainly within a band from about 25 to 250 Hz. With the amplitude of the high-frequency ground roll being small relative to the reflection information, the low-cut side of a bandpass filter should attenuate the majority of the ground roll. The refraction energy is large amplitude and possesses about the same spectral characteristics as the reflection signal. Once again, muting was essential, this time in removing the effects of the refracted energy. From the spectra of the various types of seismic energy arrivals, the optimum digital bandpass filter for the sample data set will be something in the range of 125 to 400 Hz.

As with most seismic data processing, selecting a bandpass filter, whether from spectra plots or directly off raw field data, becomes easier with experience and a broader knowledge of the basic physical principles of seismic data processing. There is also no substitute for a proper math and physics background.
To build the batch processing file to operate on the seismic data from our sample data, the following sequence of parameters needs to be defined:

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF NMOT.dat**	See previous description of ***INPF**.
3	***F_FILT bp 80 125 400 500**	

***F_FILT** operation initiates the frequency-filtering operation. The first input parameter **(bp)** designates a bandpass filter. The second and third parameters **(80,125)** designate a **low-cut (high pass)** frequency. The fourth and fifth parameters **(400,500)** designate a **high-cut (low pass)** frequency. In our case, we are doing a **band pass,** but in certain instances the enhancement of reflection signal may involve the rejecting of a particular frequency window. For more information see WinSeis User's Manual (i.e., page 5-20 of "8section5.pdf").

Line		Description
4	***OUTF FILT.dat**	See previous description of ***OUTF**.
5	**>>END**	See previous description of **>>END**.

- Use the "winfilt.exe" GUI to use visual tools for entering filtering parameters (i.e., geometry). Each selection will be simultaneously written into the text file utility, "Cmdedit.exe". See WinSeis User's Manual (i.e., pages 1-23 and 1-25 of "4section1.pdf").

As with all other batch processing files, double click on the **SORT.dek** file to launch "WSeis.exe" and run the .dek file.

Again, the program will update its progress through the input data set. As with previous operations, the list or journal file **FILT.lst** will still possess all the processing history as well as any errors or abnormal terminations. Once complete, the "WinView.exe" routine should be used to display at least a couple of files to ensure the results of the filtering operation were what was desired. The cleaning up of the data after filtering should be quite evident (Figure 31).

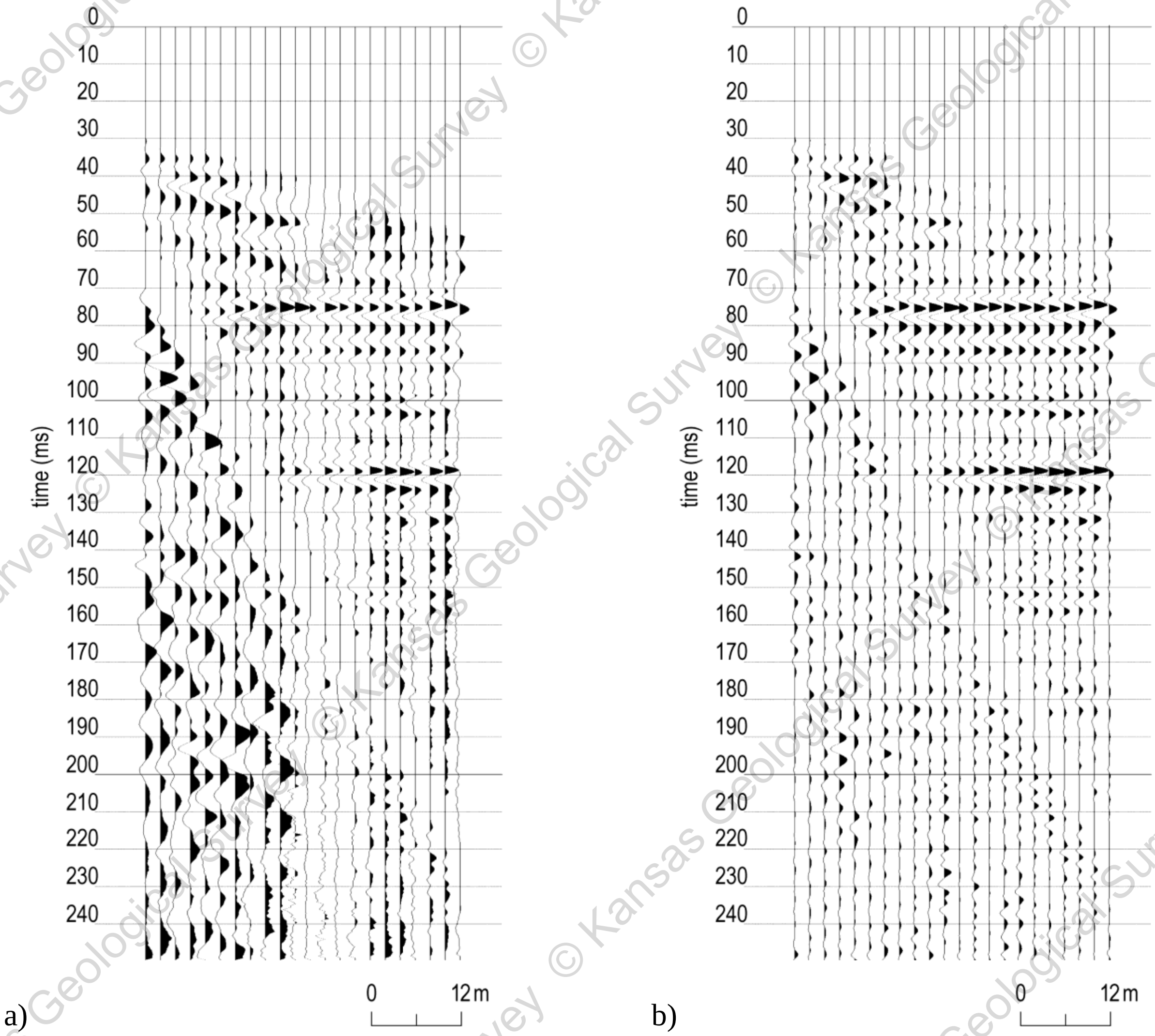


Figure 31. Field-file 5 a) before and b) after filtering.

The bandpass filtering of our sample data set not only improved the signal-to-noise ratio, it also removed DC bias present on the raw field data. DC bias is related to wander in the analog side of the seismograph and appears on raw field data as over- or undershading of the variable area wiggle-trace. The removal of DC bias is critical to the effective stacking of seismic data. Comparing the images before and after filtering (Figure 31), it is possible to identify the DC bias. The amplitudes of the reflection wavelets have much more trace-to-trace consistency after the filtering operation. The low-cut filter is actually responsible for the removal of the DC bias.

AMPLITUDE BALANCING

The relative amplitude of each sample recorded on a seismic trace is dependent on several properties and parameters. The **properties** that dictate amplitude response are related to the earth and the propagation of acoustic waves through the earth. The **parameters** that influence the amplitude of any one sample are related to acquisition equipment and the settings of that equipment. Therefore, to generate a CDP stacked section with relatively equal contributions from all traces summed within a particular gather, some trace-equalization is necessary. It should be noted at this point that for some analysis techniques (AVO, amplitude vs. offset, for example) retaining absolute amplitude with increased offset is critical. Correction for spherical divergence is necessary, but global trace equalization as is suggested for our sample data set would be detrimental to meaningful conclusions.

Automatic Gain Control (scale)

An Automatic Gain Control (AGC) should next be applied to the sample data to boost the amplitudes of the reflection information relative to the higher amplitude, ground roll, air-wave, and refraction energy. The purpose of this scaling operation is to maximize the potential of the stacking process to enhance the reflection information. This can be clearly visualized by plotting the raw data without any normalization or scaling. Display with no normalization or scaling is called plotting relative. This means that true amplitude information is preserved and present on the plot. By modifying "**Trace Gain dB**" value of "Winview.exe" "View Select" window options (shown in Figure 3), the user can boost the display gain uniformly for the entire data set until it is up to a desirable level. Now observe the amplitude of the reflection event at 75 ms on all 24 traces (Figure 31). It is quite clear that if all 24 traces were added together and their amplitudes divided by 24, a disproportional amount of the final stacked data is from the contribution of the few traces on the inside with significant amounts of high-amplitude ground roll and air-coupled waves. The best way to correct for this inequality is by applying a time-varying trace-by-trace gaining function. In the *WinSeis* package, this operation is called ***SCAL** (meaning scale).

Selection of the appropriate AGC window is at least partially qualitative, requiring experience and a thorough understanding of the mathematics of the operation. Assigning the AGC window to be about **twice the repetition time of** identifiable **reflecting events** is a rule of thumb that we have found to be generally effective.

In the case of the sample data set, the strong reflecting events at approximately 75, 100, 120, and 150 ms seem to have a repetition time of around 25 to 30 ms. This suggests that, in order for the AGC window to detect the presence of at least three of the reflecting events within a single window, the window size should be somewhere around 50 ms. So, 50 ms will be used for a first-pass trial scaling window. Basically, the scale window must be **small enough** that subtle reflecting events do not get overpowered by the more high-amplitude events, **yet large enough** that localized comparisons of relative amplitude between reflecting events at various times can be made. Final interpretation of the stacked data must be made with the AGC processing parameters taken into consideration.

A couple of warnings:

1) An inappropriate AGC window can generate artifacts on stacked seismic data. Most notable are the effects of a window that is around twice as long as the time difference between the high-amplitude first-arrival and ground roll or air-wave information. Due to this longer window, the contribution of the lower-amplitude energy located between the first arrival and ground roll or air wave is insignificant in comparison to the effects of the first arrival and ground roll or air wave. The resulting stacked data could possess a high-amplitude band of information with spotty coherency that is nothing more than stacked ground roll or air wave.
2) An AGC is most effective when the amplitude of noise is high on a few traces relative to signal at an equivalent time on other traces. In such a case, not using the AGC on unstacked data could result in data with a significantly lower signal-to-noise ratio than is truly representative of the data.

For our sample data set, the following batch processing file will most effectively boost the signal-to-noise ratio, retain some relative amplitude information, and improve the interpretability of some of the subtle reflecting events identifiable on the field files.

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF FILT.dat**	See previous description of ***INPF**.
3	***SCAL 50**	

The ***SCAL** identifier initiates the scaling operation within **SEIS**. The first entry **(50)** determines the **window length** of the scaling operation. This value is in milliseconds (ms). There are other entries associated with the scaling operation (see page 5-29 of WinSeis User's Manual "8section5.pdf" file), but for the data set we are processing here the default values are adequate. One of the other potential variable parameters allows the user to choose either **absolute value mean or root mean square**, with a user-definable reference mean. The particular type of statistical technique used to determine the amount of gain necessary for each sample results in subtle differences on most data sets. A discussion of which type is best and for which type of data is not appropriate for this manual. The **reference mean is a value set for 16-bit data** and variation of this value will affect the amount of gaining necessary relative to maximum possible deflection. A third parameter relates to delay time in the initiation of the scaling operation.

4	***OUTF SCAL.dat**	See previous description of ***OUTF**.
5	**>>END**	See previous description of **>>END**.

As before, the batch processing file just created to automatically gain individual samples relative to nearby samples on the same trace within the defined window will operate on the previously filtered data by double clicking on the **SCAL.dek** file to launch "WSeis.exe" and run the .dek file.

The effects of the scaling operation are most likely not worth plotting the entire data set to see. The "WinView.exe" display routine will give a sufficient look at the data to determine if the window is correct and if the operation was complete and correct. The effect of the scaling is actually quite evident on our sample field file (Figure 32).

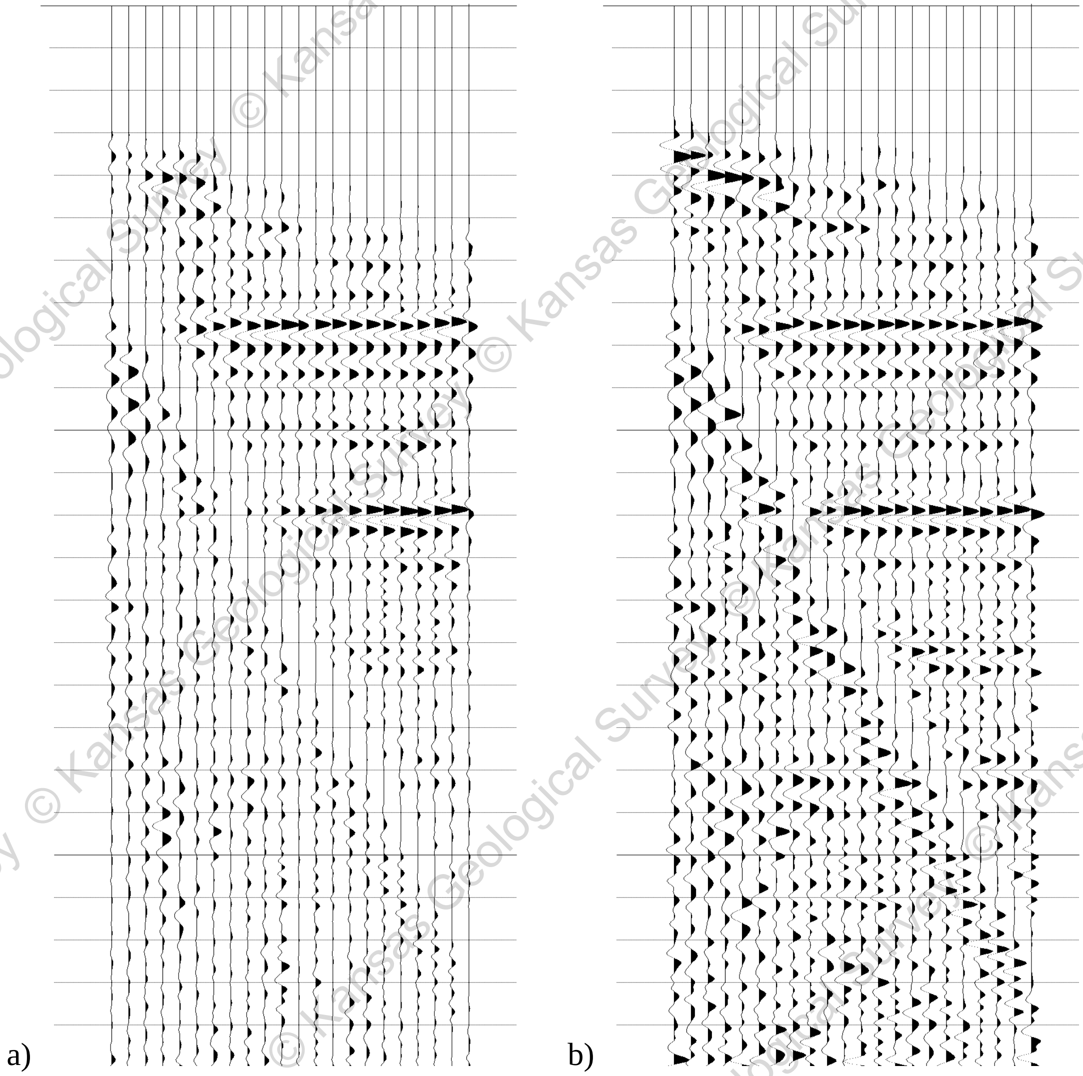


Figure 32. Field-file 5 a) before and b) after AGC.

STACK

The CDP stacking or summing process is the culmination of most modern digital seismic data processing. CDP-stacked multi-fold seismic data are generally the most useful and most common final form of seismic reflection data. A properly processed stacked section can be used to interpret a significant amount of geologic information. The stacking process, if all previous processing operations and parameters have been appropriate and in a logical sequence, will enhance seismic-reflection information. The processing flow prior to stacking is solely intended to manipulate and prepare reflection information to be added constructively, while all other energy (noise) adds destructively.

The CDP stacking of reflection data amounts to the summing all traces with the same midpoint between source and receiver (after correcting for different source-to-receiver distances), and dividing by the number of traces summed (or some other logical dividing screen). This process is conceptually quite simple.

Line		Description
1	**>>START**	See previous description of **>>START**.
2	***INPF SCAL.dat**	See previous description of ***INPF**.
3	***STAK 1**	

The ***STAK** operator initiates the CDP stacking process. The first entry **(1)** identifies the **divisor** after the summation process necessary to return the amplitude levels to near pre-stack values. The divisor can be selected as the actual number of input traces (fold) or the square root of the fold. The square root option will simply result in an increase in the relative significance (from an amplitude perspective) of higher fold gathers.

4	***OUTF STAK.dat**	See previous description of ***OUTF**.
5	**>>END**	See previous description of **>>END**.

The CDP stacking file operates on the scaled data by double clicking on the **STAK.dek** file to launch "WSeis.exe" and run the .dek file.

Viewing/Plotting the output is a must (especially since this is the conclusion of this basic processing flow). The plotting parameters used on stacked data are very dependent on interpretation preference. The larger the number of traces per inch the more apparent coherency is on the stacked section. In addition, the larger the number of seconds per inch, the harder it is to detect small variations in depth as well as a decrease in apparent resolution. It is good to experiment with the plotting parameters on the finished stacked section until the image is appropriate for the needs of the user.

The final stacked data set plotted should be quite similar to the one displayed in Figure 33.

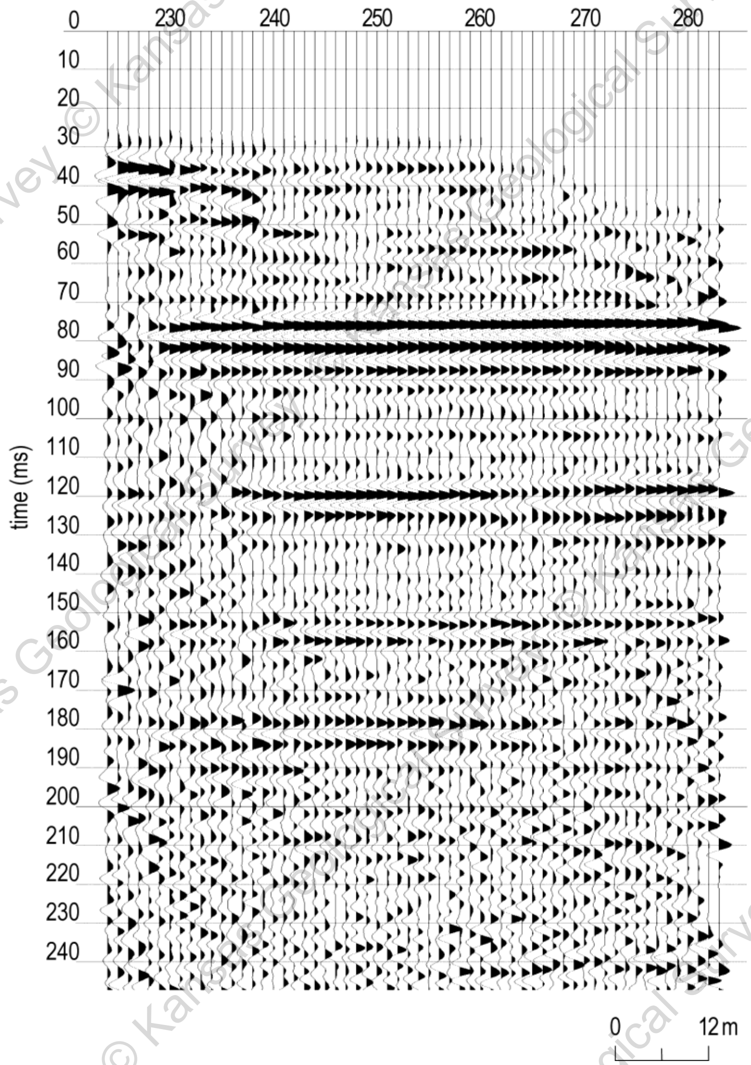


Figure 33. Final CDP stacked section.

Simply to show the true power of *WinSeis 1.8* and the batch-processing mode operation, the following batch processing file could have been set up for the sample data set at the very beginning and executed. The input to this batch job is the raw formatted data and the output is a stacked section all in one deck. The appropriate sequence would look like this:

>>start
**inpf dengland.dat*
**edkl 92 8*
kill 1 1 12 12
kill 2 2 11 11
kill 3 3 10 10
kill 4 4 9 9 24 24
kill 5 5 8 8 23 23
kill 6 6 7 7 22 22
kill 7 7 6 6 21 21
kill 8 8 5 5 20 20
kill 9 9 4 4 19 19
kill 10 10 3 3 18 18
kill 11 11 2 2 17 17

```
kill 12 12 1 1 16 16
kill 13 13  15 15
kill 14 14  14 14
kill 15 15 13 13
kill 16 16 12 12
kill 17 17 11 11
kill 18 18 10 10
kill 19 19 9 9
kill 20 20 9 9
*edfm 92 8
tapr 10
farm 5 1 30 24 65
*edmt 92 8
tapr 10
mute 5 1 57 70 24 222 237
*sort 12 19
ptrn 2.5 24 1
pn 1 108 115 24 1
shot
sn 1 108 1 0 0 1
snsn < 2 19 1 > < 109 126 1 > 1
sn 20 127 1 0 0 1 1 24
tabl 1 1
*surf 100
alvf 105 770 90
se 126 99 100
se 127 100
se 136 100
se 137 103 100.3
se 138 106 100.6
se 139 100
se 140 99
se 141 99.6
se 142 100.6
se 143 100
*nmot 0.6 0 0 1
velf 230 45 1850 60 2600 90 2600 110 2900 135 3000
velf 235 45 1850 60 2450 90 2450 110 2900 135 3000
velf 250 45 1850 60 2300 90 2300 110 2900 135 3000
velf 255 45 1850 60 1900 110 1900 150 2250
velf 275 45 1850 60 1900 110 1900 150 2250
velf 280 45 1850 60 2450 90 2450 110 2900
*f_filt bp 80 125 400 500
*scal 50
*stak 1
*outf stak.dat
>>end
```

This batch file is included with the demo and can be run by double clicking on the **PROCESS.dek** file to launch "WSeis.exe" and run the .dek file.

FURTHER PROCESSING/ADVANCED TECHNIQUES

Other operations available in *WinSeis 1.8* include deconvolution, surface-consistent statics, residual statics, f-k migration, and f-k filter.

In summary, a wide variety of processing-flow options is available with *WinSeis 1.8* after the data have been sorted. Inexperienced analysts are encouraged to refer to books on seismic-data processing and to experiment with the program prior to processing data that are critical to a specific project. The technical user's manual will provide the necessary mechanical guidance to work through the many program options. It is not appropriate, however, to use the program without some knowledge of why various processes are used.

SUGGESTED READING

There is abundant literature on seismic reflection data processing (Mayne, 1962; Robinson and Treitel, 1980; Waters, 1987; Whiteley et al., 1998; Yilmaz, 2001).

REFERENCES

Mayne, W.H., 1962, Common reflection point horizontal data stacking techniques: *Geophysics*, **27**, 927-938. https://library.seg.org/doi/abs/10.1190/1.1439118.

Robinson, E.A., and S. Treitel, 1980, *Geophysical signal analysis*: Prentice-Hall, Inc., Englewood Cliffs, NJ, 466 p.

Waters, K.H., 1987, *Reflection seismology—A tool for energy resource exploration*, 3rd ed.: John Wiley and Sons, New York, 538 p.

Whiteley, R.J., J.A. Hunter, S.E. Pullan, and P. Nutalaya, 1998, "Optimum offset" seismic reflection mapping of shallow aquifers near Bangkok, Thailand: *Geophysics*, **63**, 1385-1394. https://library.seg.org/doi/abs/10.1190/1.1444440.

Yilmaz, O., 2001, *Seismic data analysis*: Soc. Explor. Geophys., Tulsa, OK, 526 p.