KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 1999-32

3D Seismic Interpretation

In Conjunction with
AAPG Mid-continent Section Meeting
August 28, 1999

PTTC
Petroleum Technology Transfer County
North Midcontinent Region

KANSAS GEOLOGICAL SURVEY
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047

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KANSAS · GEOLOGICAL · SURVEY

The Goals

In a one-day course we will cover data loading and an introduction to 2D/3D interpretation. The course is conducted on a PC with hands-on exercises and workshops.

Data Loading - How do I get the seismic, geologic and cultural data into the machine?

- Culture (geographic) data input: map coordinate projections, and file sources.
- Well data input: map coordinate projections, file sources, loading of locations, formation tops, log curves, etc.
- SEG-Y header viewing of 2d and 3d data: understanding what is where 2D & 3D data loading from files and demonstration of loading.

Introduction to 2d/3d Seismic Interpretation - Designed for person familiar with computers but who is not familiar with interpreting seismic data on a workstation. We will have a suite of maps and displays by the end of the day.

- Fault interpretation
- Horizon interpretation
- Picking methods (manual, fill, semiautomatic and automatic methods)
- Maps - structure in time and depth, amplitude, combination maps
- Generating a synthetic
- Conversion of Time to Depth

Questions and/or problems about interpretation methods and philosophy will be covered during the day. Questions about hardware and software will also be covered.

Seismic Interpretation

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

Kansas Geological Survey

Acknowledgements

- Access to Software

Seismic Micro-Technology

digiRULE

- Demo software used in problem sets is available at: http://www.digirule.com/ and http://seismicmicro.com/
- Murfin Drilling
- Kirk Rundle

Seismic Interpretation: Logistics

- Course will run from 8:30 AM to 5:00 PM
- Lunch from 12:00 PM to 1:00 PM
- 10 minute break after each major session
- **Bathrooms (Location, Location, Location)**
- Course Notes
    - Copies of Slides
    - Selected Text

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Seismic Interpretation: Goal

- One Day Course
- Data Loading -

    How do I get the seismic, geologic and cultural data into the machine?

- Data Interpretation

    Picking methods (manual, semiautomatic and automatic)

    Maps - structure in time and depth, amplitude, etc.

    Generate a synthetic

    Conversion of Time to Depth

Seismic Interpretation: Outline

Outline

8:30 - 9:00	Introduction
9:00 - 10:30	Data Loading
10:30 - 12:00	Introduction to Interpretation
12:00 - 1:00	Lunch
1:00 - 2:00	Generating a Synthetic
2:30 - 4:00	Converting Time to Depth
4:00 - 5:00	Seismic Modeling

Seismic Interpretation: Introduction

- Background
  - Goal of Course
- 3D Seismic Data
- Hardware and Software Requirements
- Kansas Examples
  - Incised Valley Fills
    - Morrow
    - Chester
  - Erosional / Structural Remnants
    - Arbuckle

Background: History

- Early 80's
  - Main Frame Computers
  - High Acquisition, Processing and Interpretation Costs
- Mid 80's - 90's
  - UNIX Workstations
  - More Moderate Costs
- Mid 90's - Present
  - PC's
  - Decreased Costs

Background: Bottom Line Impact

- Adding Value
  - Find More Hydrocarbons
- Preventing Loss / Cutting Costs
  - Optimizing Field Development

Background: Questions

- What is Technically Feasible?
- What is Affordable?
- What can 3D Contribute?
- What is the Level of Technical Understanding?
- How do You Manage Risk with 3D?

Background: Approach

- Mix of Contractors, Consultants and In-House Personnel
- Integration of Technical Expertise and Area/Play Experience
- Concentrate on Introduction to Interpretation
  - PC based
  - Not an Introduction to Geophysics
  - Geological / Empirical Approach

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Background: Steps

- Survey Design
- Quality Control
- Processing / Reprocessing
- Interpretation
- Re-Interpretation
  - Integration
  - Post-Mortem

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Background: Philosophy

- What is Seismic Interpretation?
  - Process
  - Result
- The process of seismic interpretation can be thought of as analyzing and constraining geophysical errors in order to generate a geologic model of the subsurface.

Hardware and Software

Software and Hardware Recommendations - 1

- Processor

  Get as much as you can for the price you are willing to spend

  400 MHz or better

- Memory

  Get as much as you can for the price you are willing to spend

  256 - 512 Mb

- Hard Disk Drive

  One or more 9+ Gigabyte SCSI Hard Drives

- External Drive

  8 mm Tape Drive

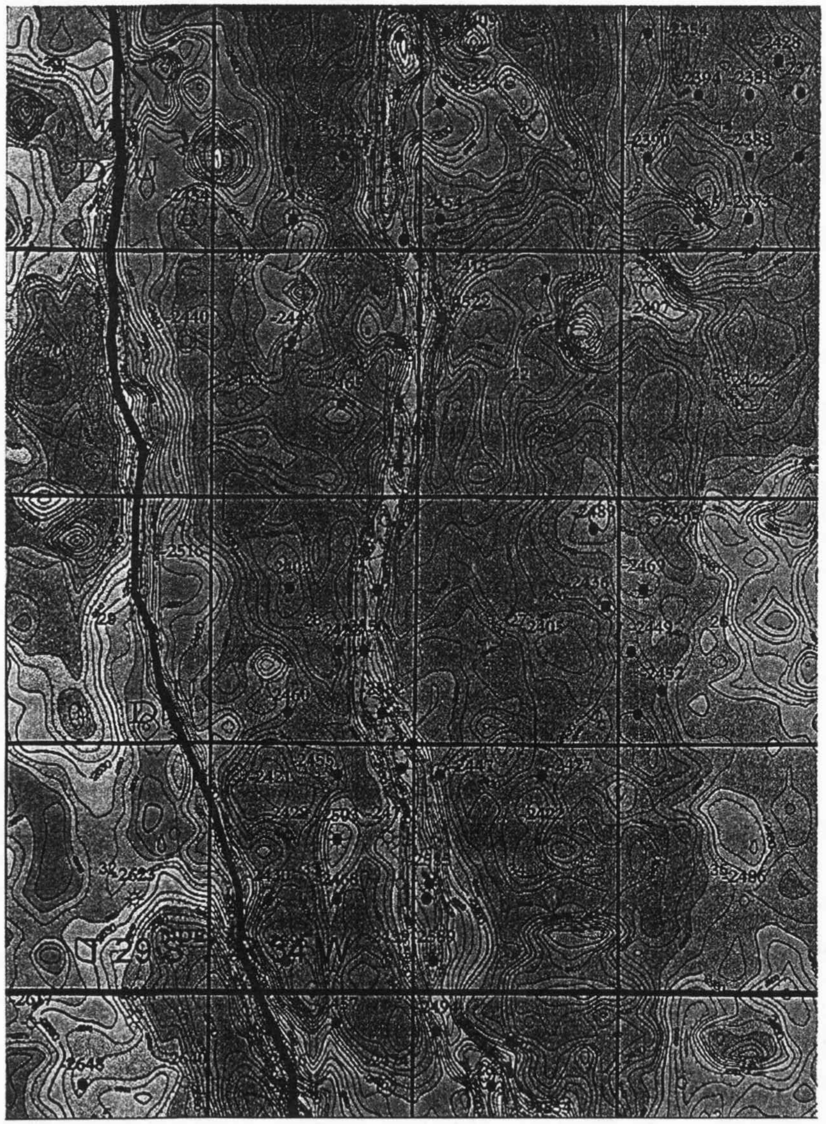
  ZIP and CD-R drives

Hardware and Software

Software and Hardware Recommendations - 2

- Monitor
  - Highest resolution (1280 x 1024 pixels)
  - Size: The biggest you can afford
  - Video Card (Maximize VRAM and Refresh Rate of 60Hz)
  - Dual monitors or more
- Printer
  - 11” X 17” Color Printer
  - Software for plots bigger than 36”X48”
- Operating System
  - Windows NT
  - Windows 98 Partition (if needed)

Kansas Examples: Chester



- 14 Successful Wells in Succession
  - Haskell County
  - Eubank and Victory Fields
- Structure Map
  - 3D Seismic
  - 10 ft. Contours

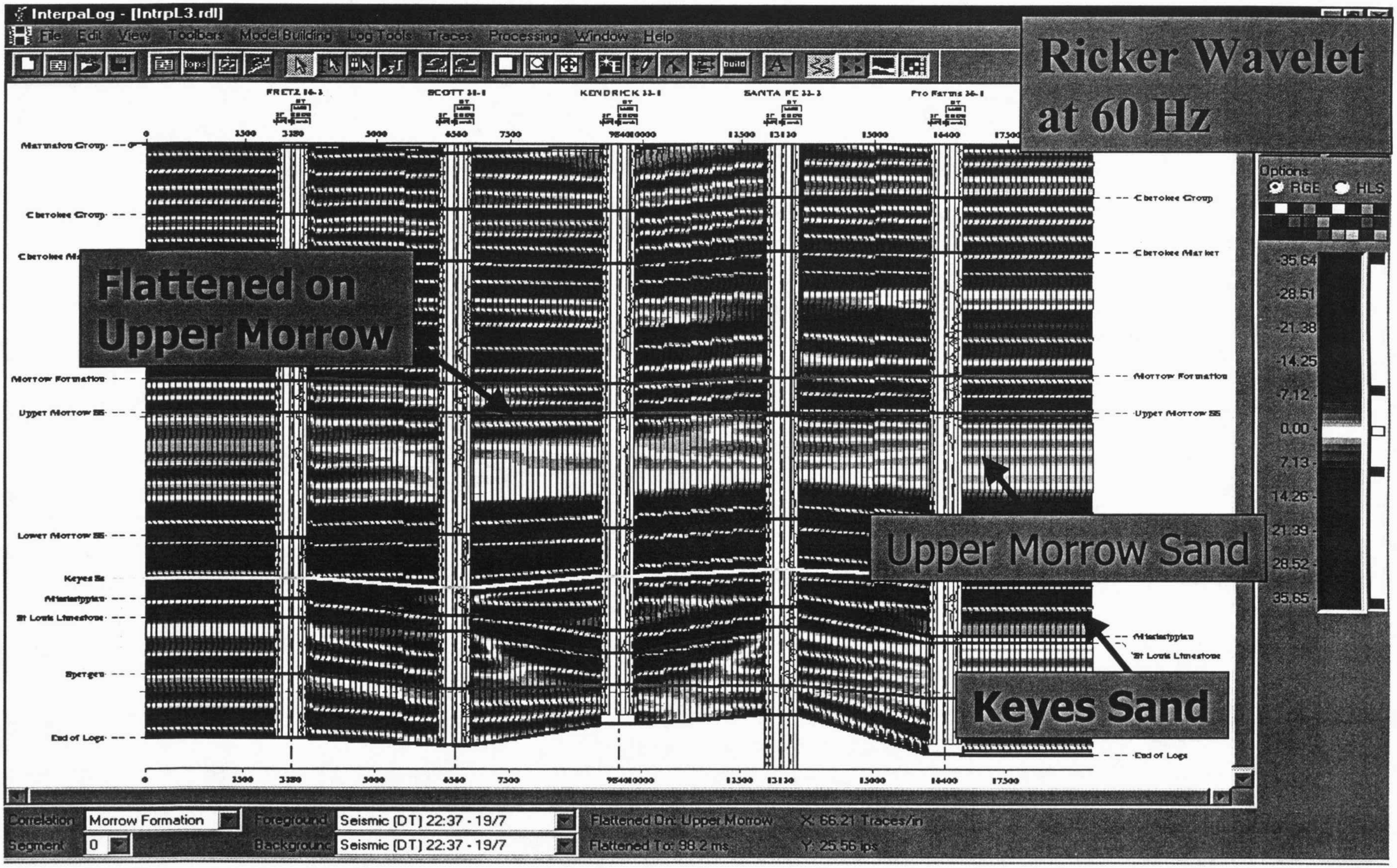
Ernie Morrison and Mike Crouch

Kansas Examples: Chester

- Isopach Map
  - 3D Seismic
  - 10 ft. Contours

Ernie Morrison and Mike Crouch

Arroyo Field: Lower Morrow



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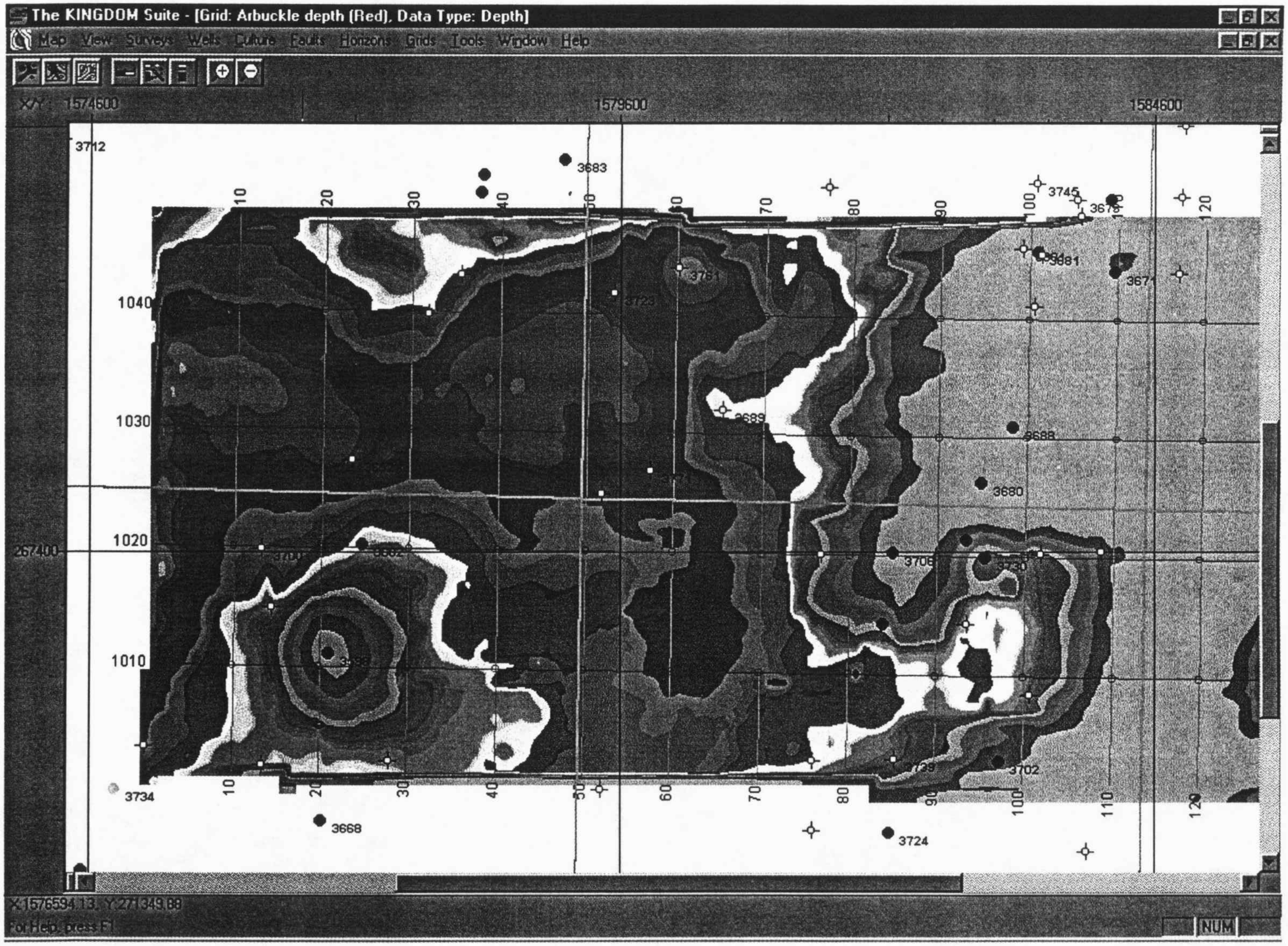
Central Kansas Uplift: Arbuckle Hills



Hardware and Software

Modified from FAQ's at Seismic Micro-Technology Web Site (http://seismicmicro.com/)

What type of PC do you recommend?

First, the PC industry is becoming more complex with the release of newer chips for different markets. Intel has released a new chip called the Pentium III XEON, which is for workstations. They also have the plain Pentium III and Celeron chips, which is for the home consumer market. These processors are replacing the Pentium series of processors. The difference between these chips is what is known as a cache and megahertz. Cache is memory that resides directly on the processor itself and makes instructions run faster. The Pentium III and XEON will have a variety of cache configurations - 512Kb, 1024Kb, etc. The Celeron will have little or no cache. The Pentium III has processor speed of 500 megahertz and more. A 1000-megahertz (gigahertz) processor is scheduled for later this year.

Intel is also scheduling release of the Merced chip in late 2000. The Merced will have a significant impact on the industry, because it is built on a 64-bit processing and bus architecture. Once the chips and backplane bus that wires everything together start to utilize the 64-bit computer architecture, some form of Windows operating system will quickly follow. At this time however, only Unix processors and their software make use of 64-bit technology.

What should you do about a NEW computer system? At this moment, the Pentium III or the XEON chips with a bus of 100M-bit and processing power of at least 400 MHz for seismic interpretation. The 100M-bit bus will increase processor I/O throughput speed and therefore decrease I/O bottlenecks. The 300MHz and slower chips are using 66M-bit bus and are somewhat slower for interpretation work. The most important part of a high-end graphics computer is the horsepower of the processor. Get as much as you can for the price you are willing to spend, and your machine will be remain valuable for a longer period of time.

This recommendation does not mean that older machines will not function, quite the contrary. Our software currently runs on PC's with CPUs ranging from 90MHz to 450MHz. We are making these suggestions to ensure that your PC will meet your needs into the future. Customers running on 486 processors will not take advantage of newer performance enhanced code.

We also recommend your computer be Windows 2000 compliant.

SMT is implementing more and more multi-tasking operations into the application everyday. Dual processors can definitely be a benefit, especially if you are going to use VuPAK for visualization.

How much memory should I buy?

This is dependent upon how large your data sets are and how many windows you have open. Typical high-end systems are going to come standard with 128Mb of RAM. However, memory is inexpensive at this moment, so an increase in memory capacity would be advised. We currently use several 400MHz machines with RAM ranging from 384 to 512Mb for demonstrations. You can safely reason that if SMT is willing to demo their software with this configuration, it must be adequate. However, please realize that if you are working a truly mammoth project, you may need more RAM than this.

When you purchase memory, you should acquire the largest DIMM (Double Inline Memory Module), so that there is room to expand. You should also be sure to obtain 100M-bit (backplane speed) compatible memory. Be on the lookout for the new faster Rambus memory (RIMM).

How much disk space should I buy?

Data sets are again the controlling factor for disk capacity. It is not uncommon for a typical geophysical workstation to employ multiple disks. A 4 GB disk is used to store the operating system and software applications and a 9 GB disk house project, which include data and interpretation. The fastest drives use the SCSI (Small Computer System Interface) interface. The SCSI (pronounced skuz-ze by the in-crowd) hard disk is attached to a SCSI adapter with a ribbon cable. The SCSI adapter sits in one of your bus slots. Today (February 1999) systems are shipping with 18 and 20+ gigabyte drives. We recommend the SCSI 3 LVD drives.

Another reason to purchase a SCSI disk is compatibility with an 8mm-tape drive. Please see the discussion below on tape drives for further details. These tape drives require a SCSI adapter, so the extra cost of a SCSI hard disk is usually justified. Now do not be intimidated by the varieties of SCSI. There's SCSI, Wide SCSI, Ultrawide SCSI, etc. Of course, the fanciest one is the fastest. Be sure that your SCSI devices are compatible with your SCSI adapter. The SCSI Bus is based on a 32-bit architecture and is only slightly higher in price than the standard 16 bit IDE (Intelligent Disk Environment) Bus.

Windows NT allows you to logically connect several hard disks so they appear as a single disk. Details are beyond this article, but you should look at the Windows NT documentation on Volume Sets. It's easy to hook together several 9Gb disks.

If you have a great deal of data that requires very fast disk access to pull large volumes of data into RAM, you might consider RAID (Redundant Array of Inexpensive Disks) technology. There are five levels of RAID and RAID is basically designed to help you save data if one disk of your volume set goes bad. However, a side benefit of RAID technology is that several levels of RAID use disk "striping" which will actually help disk I/O performance. Your computer vendor can help with the type of RAID that is best for you.

The release of TracePAK has promoted the need for additional disk space. You can conveniently reprocess your survey as more than one "flavor." The KINGDOM Suite calls these different data types of the same survey. You can reprocess 2D or 3D surveys. Of course, if you do much TracePAK processing, you need extra disk space.

It should also be noted that you do not have to have TracePAK for reprocessing. You can display and autopick many dynamically computed attributes such as Hilbert transform, envelope, phase rotation, etc. However, these dynamic trace calculations apply only to vertical seismic displays. If you want to look, for example, at time slices of an envelope attribute, you will need TracePAK to prepare an envelope data type for the 3D survey.

Do I need a tape drive?

Generally, seismic surveys are distributed as files in SEG-Y format. Many times these files are written on 8mm tape cassettes. The SEG-Y file on an 8mm tape is identical to file format on the older 9-track tapes for which the SEG-Y format was really designed. The 8mm tape drives for reading and writing 8mm Exabyte, Inc of Boulder, Colorado, USA, manufactures tape cassettes. Sony provides the tape transports to Exabyte, and is currently developing its own tape drive for this market. Incidentally, the tape transport is the same mechanism as that used in the common 8mm Camcorder.

We recommend the Eliant 820 Exabyte tape drive. The drive holds up to 14Gb and is twice as fast as the model it replaced, the EXB-8505 XL. Current street price of the Eliant 820 is US$1400. Now there are several Exabyte tape drives that differ mainly on the sophistication of the electronics. One of the distinguishing factors is hardware compression of data. We are aware that Exabyte has four levels of compression. Different models support different compression schemes. Do not suppose that a higher model number supports more compression and do not suppose that newer drives are backward compatible with older models. It just gets a little disgusting.

An extra benefit of an Exabyte 8mm tape if you are running in Windows NT, is that NT recognizes the tape drive for making Windows NT backups. A number of clients use Windows NT backups to transcribe entire projects from one computer to another.

You may also want to consider ZIP, Jazz and CD-R drives. These nifty devices are relatively inexpensive, can both read and write and have a storage capacity of 1Gb, 2Gb and 650Mb, respectively. In a pinch, they can even be used as project drives.

So, do you need a tape drive? Well, the answer is probably. They are the most universal, but beware of compression schemes!

Which operating system should I use?

We recommend Windows NT. The current Windows NT with Service Pack 3 appears to offer the best combination of stability and robustness. We have heard rumors that Service Pack 4 includes as many bugs as fixes. This particularly makes us wince, since we develop software too.

One of the robust features of Windows NT is support of NTFS file systems. Windows 95, and the old man, DOS, supports the more familiar FAT file system. NTFS includes tighter security than FAT file systems and volume sets also require NTFS. FAT file systems are also limited to a disk capacity of 2Gb. Just to keep you from figuring all this out, there is an operating system manufacturer who also offers a newer FAT16 file system. Hint – the manufacturer lives in a cold, wet climate. Perhaps it affects their outlook on life.

Perhaps you have some older ("legacy") software that will not run in Windows NT. If it is important to you to have both Windows NT and Windows 95 (or 98) then, we recommend setting up the computer for what is called a dual boot. You can choose which operating system you want to start when you switch on the computer.

Basically, Microsoft has designed Windows NT for business applications and Windows 98 for the home market.

NT also includes native support for Exabyte tape drivers. Windows 98 does not include native support. However, both operating systems have backup programs. Third party software drivers for the Exabyte can be purchased for about US$600.

What kind of video display should I buy?

First, it is generally regarded that eyestrain is related to a balancing act of two factors – screen size and number of pixels. PC Magazine published an interesting article in April 21, 1998 in which they recommended the following combinations of monitor size and resolution for optimum comfort.

Monitor Size	Best Resolution
14 inch	640 x 480 (VGA)
15 inch	1024 x 768 (XGA)
17 inch	1024 x 768 (XGA)
19 inch	1280 x 1024 (VESA1024)
21 inch	1280 x 1024 (VESA1024)
> 21 inch	1600 x 1200 (VESA1280)

Most seismic interpreters have a further requirement that they see as much data as possible. (Gee, this isn't hard to guess.) This point then results in two further factors to consider – highest resolution per monitor and at least two monitors. We recommend dual monitors of the same size. How big should they be? The biggest you can afford so long as you do not have to hold one in your lap.

If you are also concerned about the number of colors that can be displayed, you are showing your age. For the past few years, monitors and video cards support a large palette of colors. However, there is an issue of colors that will be discussed in this section shortly.

One of the nice features of the Windows operating systems (NT, 95 or 98) is that they all support a virtual display area. Microsoft likes to call this the desktop. You can drag a window across the desktop and watch it move continuously across adjacent monitors.

An additional feature of hardware from many special video manufacturers is that each monitor displays with full resolution. That is, if you set the monitor resolution to 1280 x 1024, each monitor is being drawn with this many pixels.

For dual monitors, we recommend a special video card manufactured by Colorgraphics. The Colorgraphics Evolution 2 video card is inserted in one of the slots in your computer and each monitor is connected to external connectors on the card. Some seismic interpreters have even purchased Colorgraphics Evolution 4 video cards and, as you guessed it, they can operate with four monitors. At SMT we occasionally demonstrate our software with four monitors but we must admit that it is a little theatrical. We know of several interpreters, however, who claim that they cannot get along without three monitors.

If you are an SMT customer, ask Colorgraphics for a discount. Incidentally, SMT does not benefit in any financial way by this discount. They do answer our calls quickly, however.

Colorgraphics is not your only choice, however. Other manufacturers of special video card also are compatible.

The Matrox Millenium series uses dual monitor cards to obtain a multi-monitor setup. This is typically not a problem, unless the amount of PCI slots is limited on the bus of the PC.

STB / 3dfx (3dfx recently bought STB) also offers a good single slot dual / four monitor card called the STB MVP Pro.

The video cards that have been known to exhibit video problems are the Diamond Multimedia and Appian series of Open GL cards. Their single slot cards double the horizon resolution in order to obtain a dual monitor display. Instead of a typical resolution of 1024 x 768, they use 2048 x 768. Therefore, the aspect ratio is changed and circles become ellipses. Squares become rectangles.

We have contacted Diamond several times and their latest response is as follows.

> "Thanks for Contacting Diamond Technical Support.
>
> This will happen in applications that will not allow you to change the relationships for dual monitors like our FireGL 3000 Does. Basically, it makes the screen as 1280x480 (an example). So, in their program, they have a relation ship to draw a square, based on 640x480. When you use the same relationship to draw the square at 1280x480, you get a rectangle. This is nothing we can do in our drivers to fix this. If it's a problem, you will need to run their application with on monitor. There are quite a few applications that have a setting in them that will change the relationship based on your resolution. So, in those applications, it will not use the 640x480 relationship, but will default to a 1280x480 one, and that will produce a square with dual monitors in those programs. You can contact your software maker again and see if they are willing to add that feature. But, if they do not have that feature, there is nothing we can do at Diamond about it.
>
> Thanks,
>
> Rome Eselin
> Diamond Multimedia Systems
> PC Video Technical Support
> Tech Support Phone: 541-967-2450"
> Please contact SMT for the latest evaluation.

Tired of the video display issue yet? Well, you shouldn't get tired yet because we all spend so much time looking at them. An important additional item to consider is the amount of video RAM on the video card. This is called VRAM. The suggestion here is to purchase as much VRAM as possible. In particular, you will want to avoid what Microsoft calls Technicolor. Technicolor only appears when the number of colors you select to display is set to 256 or less. Microsoft considers Technicolor a natural limitation of the hardware. Consider two windows in the workspace and each window displays 150 DIFFERENT colors. When you try to display these with a video display supporting 256 colors, something must yield. The solution, simply, is to honor the 150 colors in the selected window and do your best to choose colors for the window that is not currently selected. The result is called Technicolor since windows in the workspace flicker in color as you select different windows.

Now the amount of VRAM per monitor controls the resolution and number of colors that can be displayed. The VRAM is simply carved up into a number of pixels and the number of bits in each pixel controls the number of different colors that can be displayed. That's why you should maximize the VRAM in your video card. And one final comment. We recommend that you choose a video refresh rate at least 60Hz or higher.

Should I buy a flat panel screen?

Flat panel displays are relatively new and can be expensive. However, as new manufacturers come on the seen the prices are dropping.

What kind of printer should I buy?

That depends on the type of print output you desire. If you do not need large plots, then a multi-thousand dollar whiz-bang plotter is not necessary. HP, Epson, and Calcomp make great printers that can print up to 11" X 17".

If you are getting a printer that has expandable memory slots, it is advisable to max out the printer RAM. Printer RAM is inexpensive. This follows our typical philosophy, get as much as you can for what you are willing to spend, because it will be more valuable longer.

Since most plotters are used only a few times a day or week, many customers consider refurbished models.

Whatever type of printer that you choose remember that Windows has a 48 x 36 inch print limitation. If you have plots that are longer than this limit, you may want to consider our DirectPLOT option. DirectPLOT takes the plotting calculations out of Windows and allows the printer to accept plots longer than 48 inches.

Also, we have discovered that some plots with lots of detail cannot be rastered in the plotter RAM. This problem is not apparent if the plotter manufacturer is accustomed to working with clients who draw large blueprints. Vertical seismic displays and horizon maps with lots of colors both contain graphical information that is at least an order of magnitude larger than any blueprint. For cases of plots with unusual information density that exceeds the plotter RAM, we recommend DirectPLOT.

Who can you recommend for computer hardware?

You might first consider a mail order manufacturer. If your head starts to swim with the bewildering array of choices, take heart. We have all gone through this stage.

If you are not interested in a standard system, there are several vendors who will configure a system for you. They can handle anything from complete systems to bare bone peripherals. Call SMT for references. SMT does not benefit in any financial way from these specialty vendors. We have enough problems just trying to develop software.

How much should I expect to spend?

Prices range from inexpensive to costly, depending upon the brand name, capacities of disk and memory, number of monitors, and peripherals desired. But excluding software, a functional dual monitor geophysical workstation should run you about $5,000 to $6,000.

How large a project can you handle on a PC Workstation?

During our SMT User Meetings that were held across North America earlier this year, we asked our clients about their largest projects. Here are the results.

Largest 3D survey in area – 585 mi2 (1515 km2)
Largest 3D survey in disk size – 55Gb
Largest number of separate 3D surveys in a single project – 13
Largest number of 2D lines in a single project – 900
Largest number of wells in a single project – 16,000

3D Seismic: Seismic Data Loading

PTTC Petroleum Technology Transfer Council North Midcontinent Region

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Seismic Data Loading: Outline

- The SEG-Y File
  - Finding the Necessary Parameters
- Creating a Project
- Loading SEG-Y Data
- Loading Culture Data
- Loading Well Data

Introduction: SEG-Y

- SEG-Y (2D or 3D)
  - Society of Exploration Geophysicists Y Format
  - Petroleum Industry "Standard"
  - Composed of:
    - 3600 byte Identification Header
      - 3200 bytes of EBCIDIC text
      - 400 bytes of binary information
    - Seismic Traces
      - Trace Header (240 bytes)
        - Identifies Trace and Location
      - Trace Amplitudes (32-bit IBM floating point

3D SEG-Y Trace Headers

- Identify Trace Location
  - Identified by Grid of Lines and Traces
    - Rectangular Area - CDP Bin
      - e.g., 110 feet X 110 feet
      - Bin Dimensions Are Constant
    - Border of Survey May be Irregular
  - Also Identified by Map Coordinates
    - Oriented with a Reference Angle to North
    - Anchored to Known Survey Locations

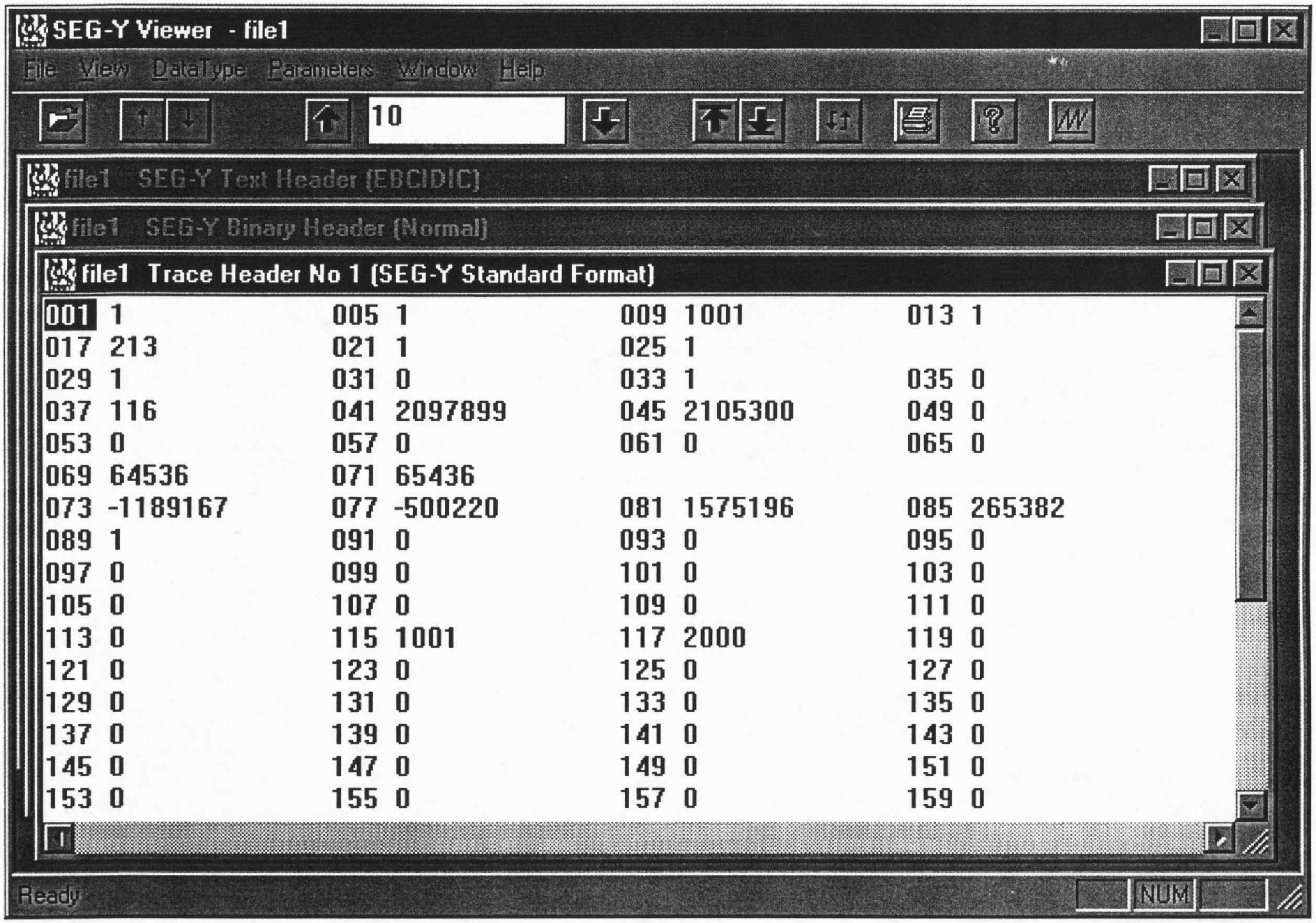
3D SEG-Y Trace Headers

- External Documentation
  - Loading Sheet
- Use SEG-Y File Viewer to Find
  - Line Numbers
  - Trace Numbers
  - Stored in Trace Headers
  - Position is Not Specified in SEG-Y Format

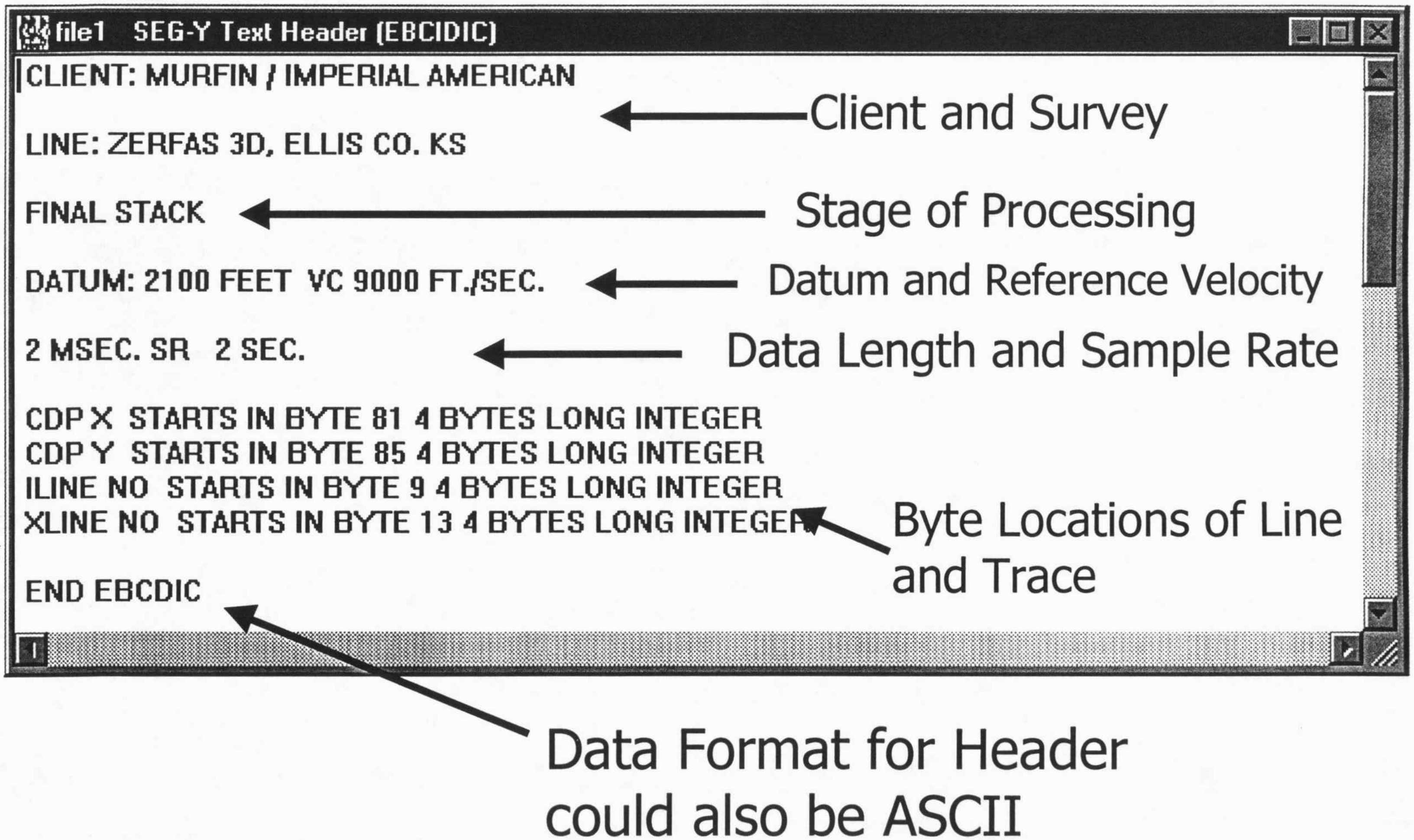
3D SEG-Y Trace Headers

- NEED TO KNOW
  - Starting byte of line number
    - Line number should change only occasionally
    - Trace number will regularly change and repeat itself when line number changes
  - Format of line number
  - Starting byte of trace number
  - Format of trace number
- Use Load Sheet and Readers

SEG-Y Viewer


SEG-Y Viewer - file1
File View DataType Parameters Window Help
10
file1 SEG-Y Text Header (EBCIDIC)
file1 SEG-Y Binary Header (Normal)
file1 Trace Header No 1 (SEG-Y Standard Format)
001 1 005 1 009 1001 013 1
017 213 021 1 025 1
029 1 031 0 033 1 035 0
037 116 041 2097899 045 2105300 049 0
053 0 057 0 061 0 065 0
069 64536 071 65436
073 -1189167 077 -500220 081 1575196 085 265382
089 1 091 0 093 0 095 0
097 0 099 0 101 0 103 0
105 0 107 0 109 0 111 0
113 0 115 1001 117 2000 119 0
121 0 123 0 125 0 127 0
129 0 131 0 133 0 135 0
137 0 139 0 141 0 143 0
145 0 147 0 149 0 151 0
153 0 155 0 157 0 159 0
Ready
NUM

SEG-Y Text Header



SEG-Y Master Header (Binary)

file1 SEG-Y Binary Header (Normal)

Job ID:	9999
Line number:	9999
Reel number:	1
No of data traces/record:	144
No of auxilliary channels:	0
Sample interval:	2000
Number of samples/trace:	1001
Format code (1=flt32, 2=int32 , 3=int16, 5=int8):	1
CDP fold:	0
Measurement system (1= metric, 2 = feet):	2

Binary Header Dump - first 48 words

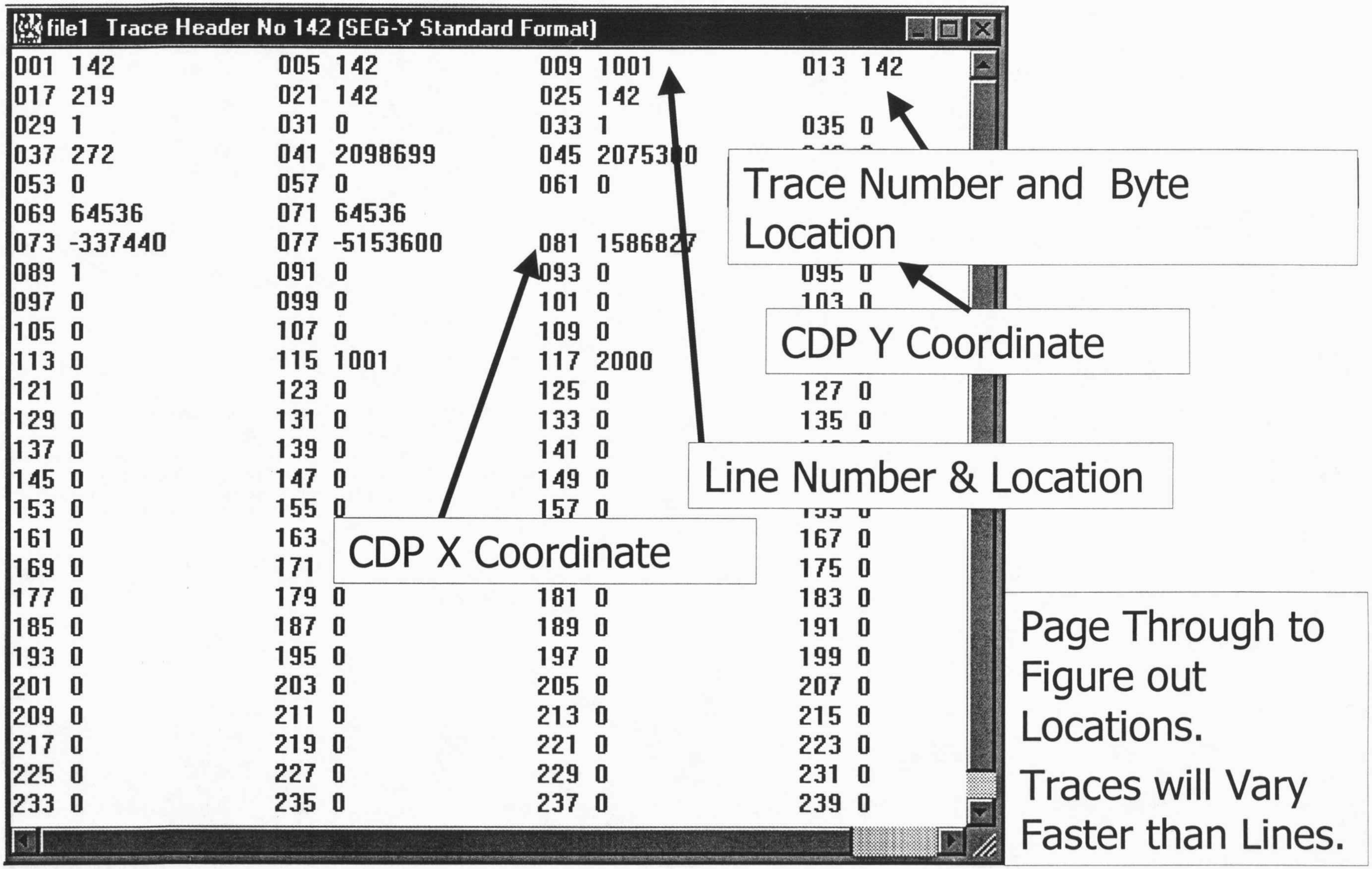
001	9999	005	9999	009	1
013	144	015	0	017	2000
019	0	021	1001	023	51614
025	1	027	0	029	1
031	0	033	0	035	0
037	0	039	0	041	0
043	0	045	0	047	0
049	2	051	1	053	4
055	2	057	1	059	0
061	0	063	0	065	0
067	0	069	0	071	0
073	0	075	0	077	0
079	0	081	0	083	0
085	0	087	0	089	0
091	0	093	0	095	0
097	0	099	0	101	0

Sample Interval 2 ms

Number of Samples Per Trace

Format Code for Trace Amplitudes

SEG-Y Trace Headers (Binary)



file1 Trace Header No 142 (SEG-Y Standard Format)

001 142	005 142	009 1001	013 142
017 219	021 142	025 142	
029 1	031 0	033 1	035 0
037 272	041 2098699	045 20753[illegible]0	049 0
053 0	057 0	061 0	
069 64536	071 64536		
073 -337440	077 -5153600	081 1586827	
089 1	091 0	093 0	095 0
097 0	099 0	101 0	103 0
105 0	107 0	109 0	
113 0	115 1001	117 2000	
121 0	123 0	125 0	127 0
129 0	131 0	133 0	135 0
137 0	139 0	141 0	143 0
145 0	147 0	149 0	
153 0	155 0	157 0	159 0
161 0	163 [illegible]		167 0
169 0	171 [illegible]		175 0
177 0	179 0	181 0	183 0
185 0	187 0	189 0	191 0
193 0	195 0	197 0	199 0
201 0	203 0	205 0	207 0
209 0	211 0	213 0	215 0
217 0	219 0	221 0	223 0
225 0	227 0	229 0	231 0
233 0	235 0	237 0	239 0

Loading 3D SEG-Y Data

- NEED TO KNOW
  - Geometry
    - Trace Spacing (Distance between each Trace)
    - Line Spacing (Distance between each Line)
    - Coordinates of at least 3 CDP Stations
      - UTM, Lat./Lon., etc.

Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin / Imp. American Geophysicist: Kirk Rundle

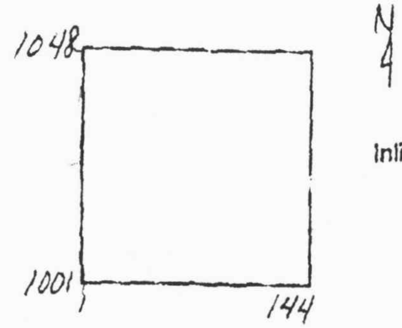
Project Name: Zerfas 3D State and Zone: Ellis Co. KS

Township: ______ Range: ______ NAD: ______

Projection: ______ UTM ______ Mercator ______ Lambert ______

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28

Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec



Inline Bearing: 0.86 Degrees

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	1586992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet

Number of Traces: 144 Cross-line spacing (interval) 110.0 feet

Reel # ______ Data Length (ms.): 2000 Sample Rate: (2ms)

Format: (SEGY) ______ Vest ______ Kingdom ______ Grits ______

Media: 9 track ______ (8mm) ______ CMS___ Floppy___ ______4mm______

(2.5gig)

Header Information

	Byte Location	Length (Bytes)		
Line:	9	4	Integer ✓	IBM FL______
Trace:	13	4	Integer ✓	IBM FL______
CDPX Coord:	81	4	Integer ✓	IBM FL______
CDPY Coord:	85	4	Integer ✓	IBM FL______

Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin / Imp. American Geophysicist: Kirk Rundle

Project Name: Zerfas 3D State and Zone: Ellis Co. KS

Township: ____ Range: ____ NAD: ____

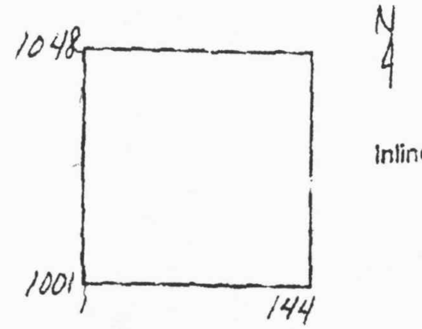
Projection: ____ UTM ____ Mercator ____ Lambert ____

Upper Left Line: 1048 Upper Right Line: 1048

Upper Left Trace: 1 Upper Right Trace: 144

X: 1575273.38 X: 1587069.50

Y: 270551.06 Y: 270374.28



Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Number of Traces

1001

Lower Left Trace: 1

X: 1575195.88

Y: 265381.66

Lower Right Line: 1001

Lower Right Trace: 144

X: 1586992.00

Y: 265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet

Number of Traces: 144 Cross-line spacing (interval) 110.0 feet

Reel # ____ Data Length (ms.): 2000 Sample Rate: (2ms)

Format: (SEGY) ____ Vest ____ Kingdom ____ Grits ____

Media: 9 track ____ (8mm) ____ CMS___ Floppy___ ____4mm____

(2.5gig)

Header Information

	Byte Location	Length (Bytes)		
Line:	9	4	Integer ✓	IBM FL____
Trace:	13	4	Integer ✓	IBM FL____
CDPX Coord:	81	4	Integer ✓	IBM FL____
CDPY Coord:	85	4	Integer ✓	IBM FL____

Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin/Imp. American Geophysicist: Kirk Rundle
Project Name: Zerfas 3D State and Zone: Ellis Co. KS
Township: Range: NAD:
Projection: UTM Mercator Lambert

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28

1048 / 1001 / 1 / 144 / N

Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Trace Spacing

Number of Traces

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	1586992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet
Number of Traces: 144 Cross-line spacing (interval) 110.0 feet
Reel # Data Length (ms.): 2000 Sample Rate: 2ms
Format: SEGY Vest Kingdom Grits
Media: 9 track 8mm CMS Floppy 4mm
2.5gig

Header Information

	Byte Location	Length (Bytes)	Integer	IBM FL
Line:	9	4	✓	
Trace:	13	4	✓	
CDPX Coord:	81	4	✓	
CDPY Coord:	85	4	✓	

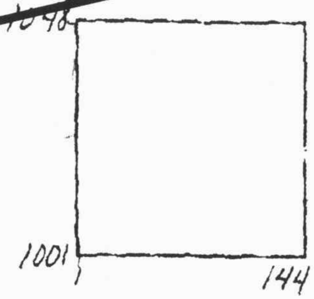
Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin./Imp. American Geophysicist: Kirk Rundle
Project Name: Zerfas 3D State and Zone: Ellis Co. KS
Township: Range: NAD:
Projection: UTM Mercator Lambert
Upper Left Line: 1048 Upper Right Line: 1048
Upper Left Trace: 1 Upper Right Trace: 144
X: 157[illegible]8.38 X: 158[illegible]69.50
Y: 270551.06 Y: 270374.28

Trace Values (Min-Max)



Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Trace Spacing

Number of Traces

Lower Left Line: 1001 Lower Right Line: 1001
Lower Left Trace: 1 Lower Right Trace: 144
X: 1575195.88 X: 1586992.00
Y: 265381.66 Y: 265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet
Number of Traces: 144 Cross-line spacing (interval) 110.0 feet
Reel # Data Length (ms.): 2000 Sample Rate: 2ms
Format: SEGY Vest Kingdom Grits
Media: 9 track 8mm CMS Floppy 4mm
2.5gig

Header Information

	Byte Location	Length (Bytes)	Integer	IBM FL
Line:	9	4	✓	
Trace:	13	4	✓	
CDPX Coord:	81	4	✓	
CDPY Coord:	85	4	✓	

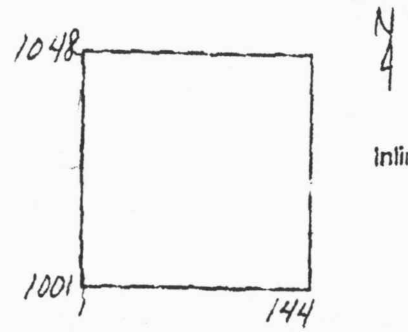
Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin / Imp. American   Geophysicist: Kirk Rundle
Project Name: Zerfas 3D   State and Zone: Ellis Co. KS
Township: ______   Range: ______   NAD: ______
Projection: ______ UTM ______ Mercator ______ Lambert ______

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28



Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Number of Lines

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	1586992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48   In-line spacing (interval) 82.5 feet
Number of Traces: 144   Cross-line spacing (interval) 110.0 feet
Reel # ______   Data Length (ms.): 2000   Sample Rate: 2ms
Format: SEGY ______   Vest ______   Kingdom ______   Grits ______
Media: 9 track ______   8mm ______   CMS___ Floppy___ ______4mm______
2.5gig

Header Information

	Byte Location	Length (Bytes)	Integer	IBM FL
Line:	9	4	✓	
Trace:	13	4	✓	
CDPX Coord:	81	4	✓	
CDPY Coord:	85	4	✓	

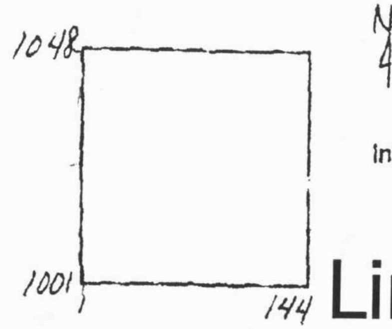
Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin./Imp. American Geophysicist: Kirk Rundle
Project Name: Zerfas 3D State and Zone: Ellis Co. KS
Township: ______ Range: ______ NAD: ______
Projection: ______ UTM ______ Mercator ______ Lambert ______

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28



Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Line Spacing

Number of Lines

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	158?992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line, the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet
Number of Traces: 144 Cross-line spacing (interval) 110.0 feet
Reel # ______ Data Length (ms.): 2000 Sample Rate: (2ms)
Format: (SEGY) ______ Vest ______ Kingdom ______ Grits ______
Media: 9 track ______ (8mm) ______ CMS___ Floppy___ ______4mm______
(2.5gig)

Header Information

	Byte Location	Length (Bytes)		
Line:	9	4	Integer ✓	IBM FL______
Trace:	13	4	Integer ✓	IBM FL______
CDPX Coord:	81	4	Integer ✓	IBM FL______
CDPY Coord:	85	4	Integer ✓	IBM FL______

Loading Sheet

3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin / Imp. American Geophysicist: Kirk Rundle
Project Name: Zerfas 3D State and Zone: Ellis Co. KS
Township: Range: NAD:
Projection: UTM Mercator Lambert

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28

Line Values (Min-Max)

1048 N

1001 1 144

Datum 2100 ft.
Wx Vel 5000
Ref Vel 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Line Spacing

Number of Lines

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	1586992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line, the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet
Number of Traces: 144 Cross-line spacing (interval) 110.0 feet
Reel # Data Length (ms.): 2000 Sample Rate: 2ms
Format: SEGY Vest Kingdom Grits
Media: 9 track 8mm CMS Floppy 4mm
2.5gig

Header Information

	Byte Location	Length (Bytes)	Integer	IBM FL
Line:	9	4	✓	
Trace:	13	4	✓	
CDPX Coord:	81	4	✓	
CDPY Coord:	85	4	✓	

Loading Sheet

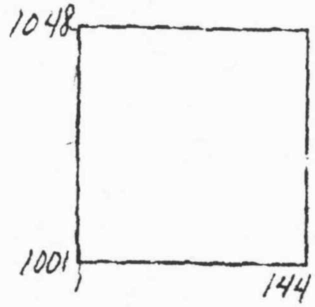
3-D SEISMIC LOADING INFORMATION

Date: 1/17/97

Client: Murfin / Imp. American Geophysicist: Kirk Rundle
Project Name: Zerfas 3D State and Zone: Ellis Co. KS
Township: ____ Range: ____ NAD: ____
Projection: ____ UTM ____ Mercator ____ Lambert ____

Upper Left Line:	1048	Upper Right Line:	1048
Upper Left Trace:	1	Upper Right Trace:	144
X:	1575273.38	X:	1587069.50
Y:	270551.06	Y:	270374.28

Coordinates of CDP Stations



...m 2100 ft.
...el 5000
...el 9700
VC 9000 ft/sec

Inline Bearing: 0.86 Degrees

Lower Left Line:	1001	Lower Right Line:	1001
Lower Left Trace:	1	Lower Right Trace:	144
X:	1575195.88	X:	1586992.00
Y:	265381.66	Y:	265204.88

(only three X, Y pairs need to be specified. Two X, Y pairs must be on one line; the third X, Y pair can be on any other line/traces.)

Number of Lines: 48 In-line spacing (interval) 82.5 feet
Number of Traces: 144 Cross-line spacing (interval) 110.0 feet
Reel # ____ Data Length (ms.): 2000 Sample Rate: (2ms)
Format: (SEGY) ____ Vest ____ Kingdom ____ Grits ____
Media: 9 track ____ (8mm) ____ CMS ____ Floppy ____ ____ 4mm ____
(2.5gig)

Header Information

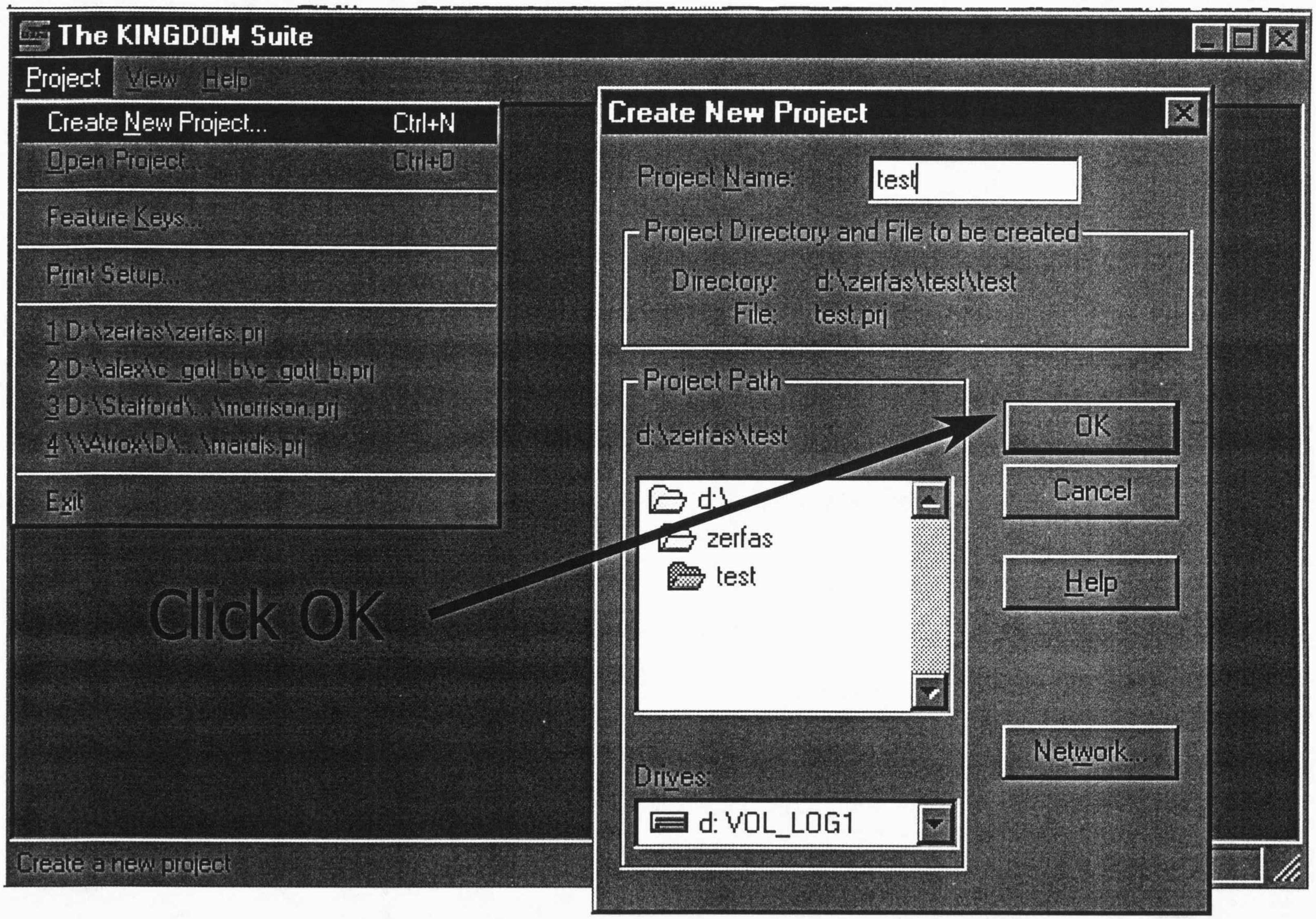
	Byte Location	Length (Bytes)	Integer	IBM FL
Line:	9	4	✓	
Trace:	13	4	✓	
CDPX Coord:	81	4	✓	
CDPY Coord:	85	4	✓	

Starting A New 2D/3D Pak Project

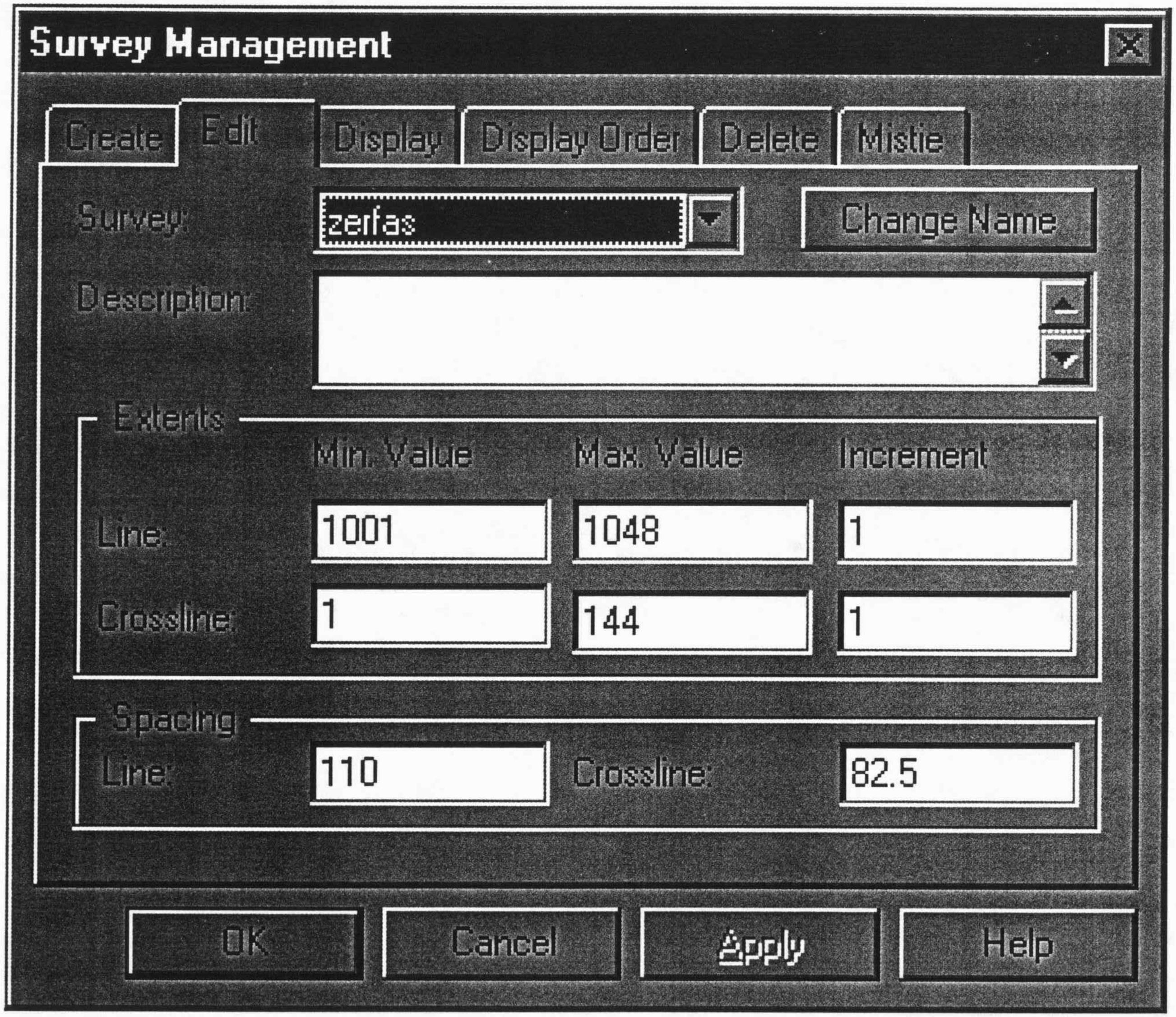
- Double Mouse Click
  - Kingdom-Seismic Icon

- Left Click on <u>Project, Create New Project</u>

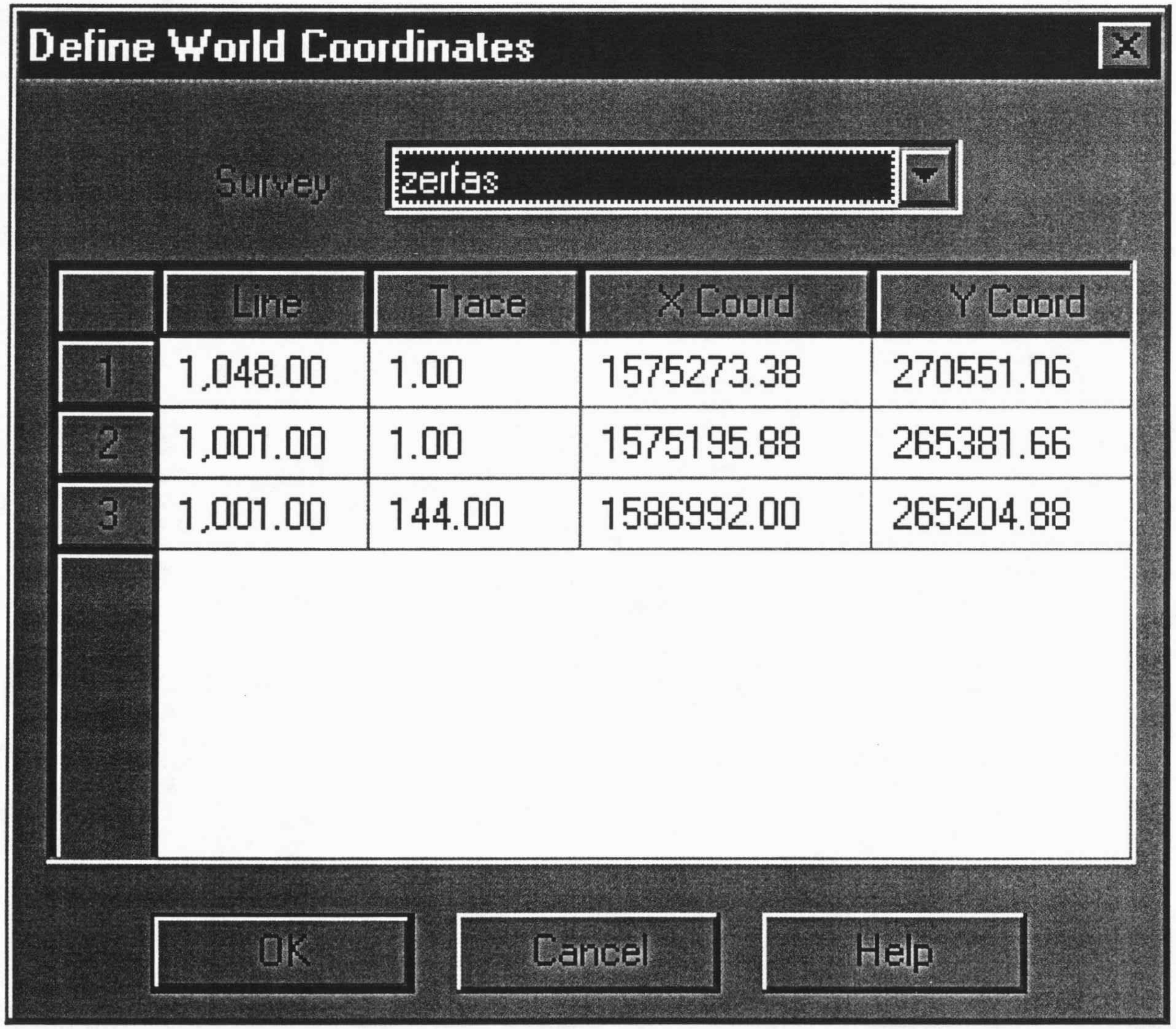
Create a Project -1



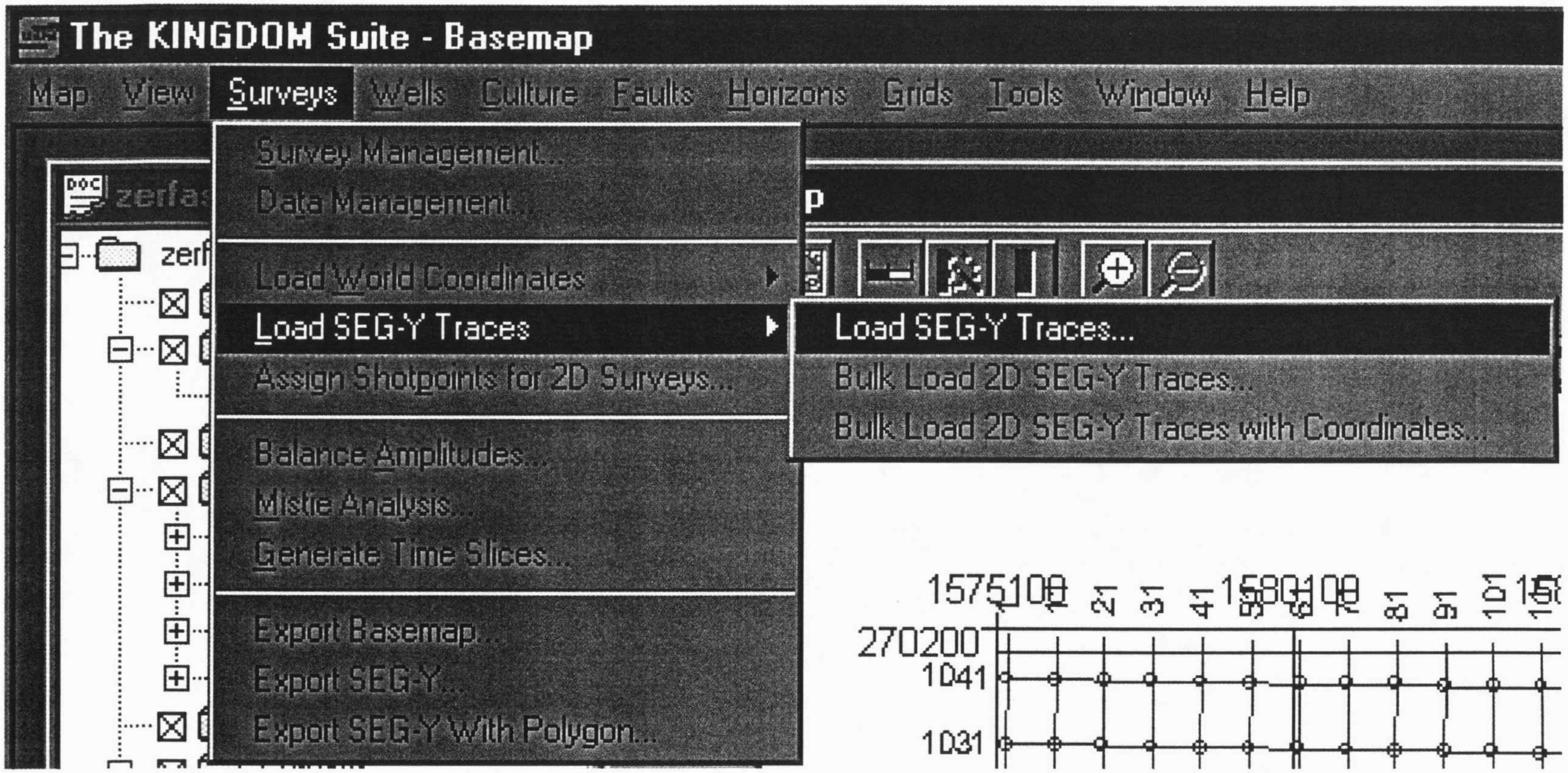
Create a Project -2



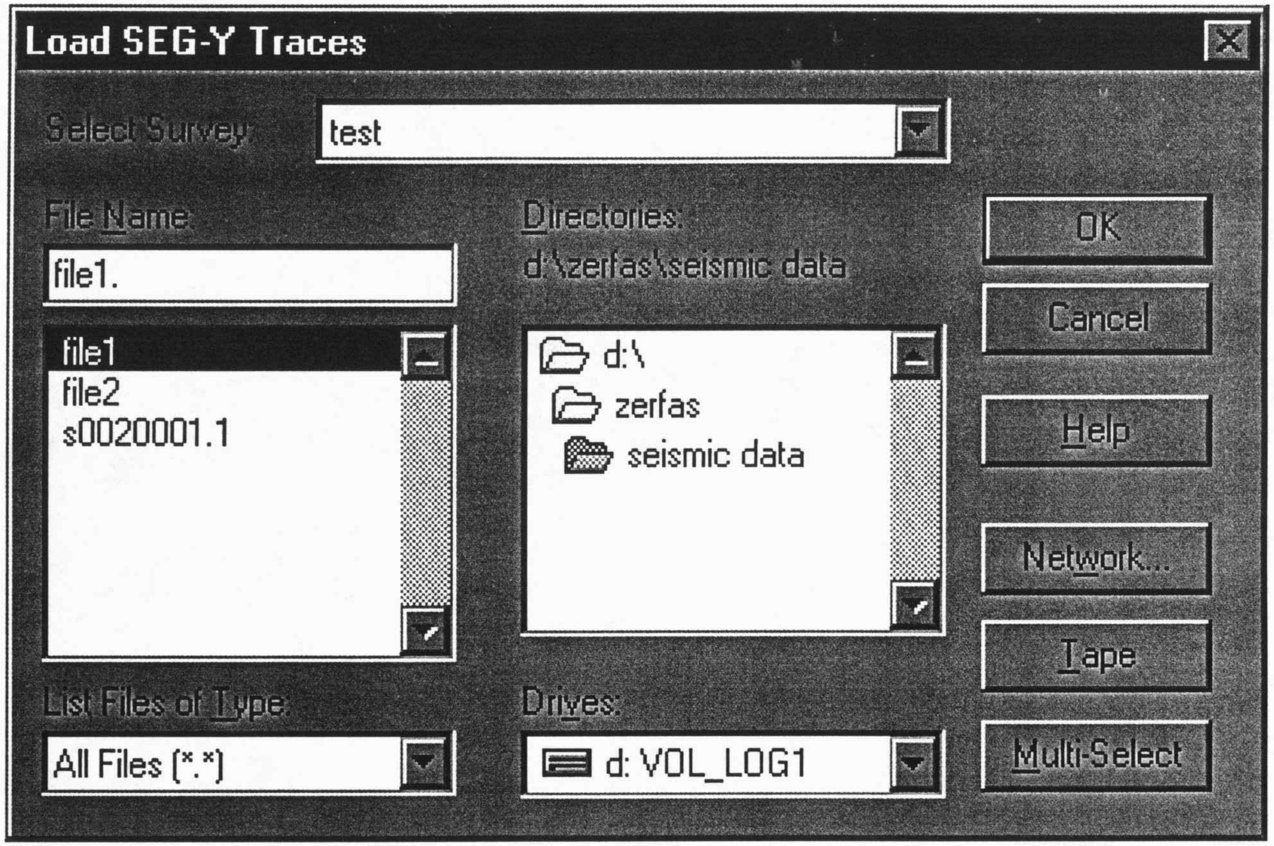
Loading World Coordinates



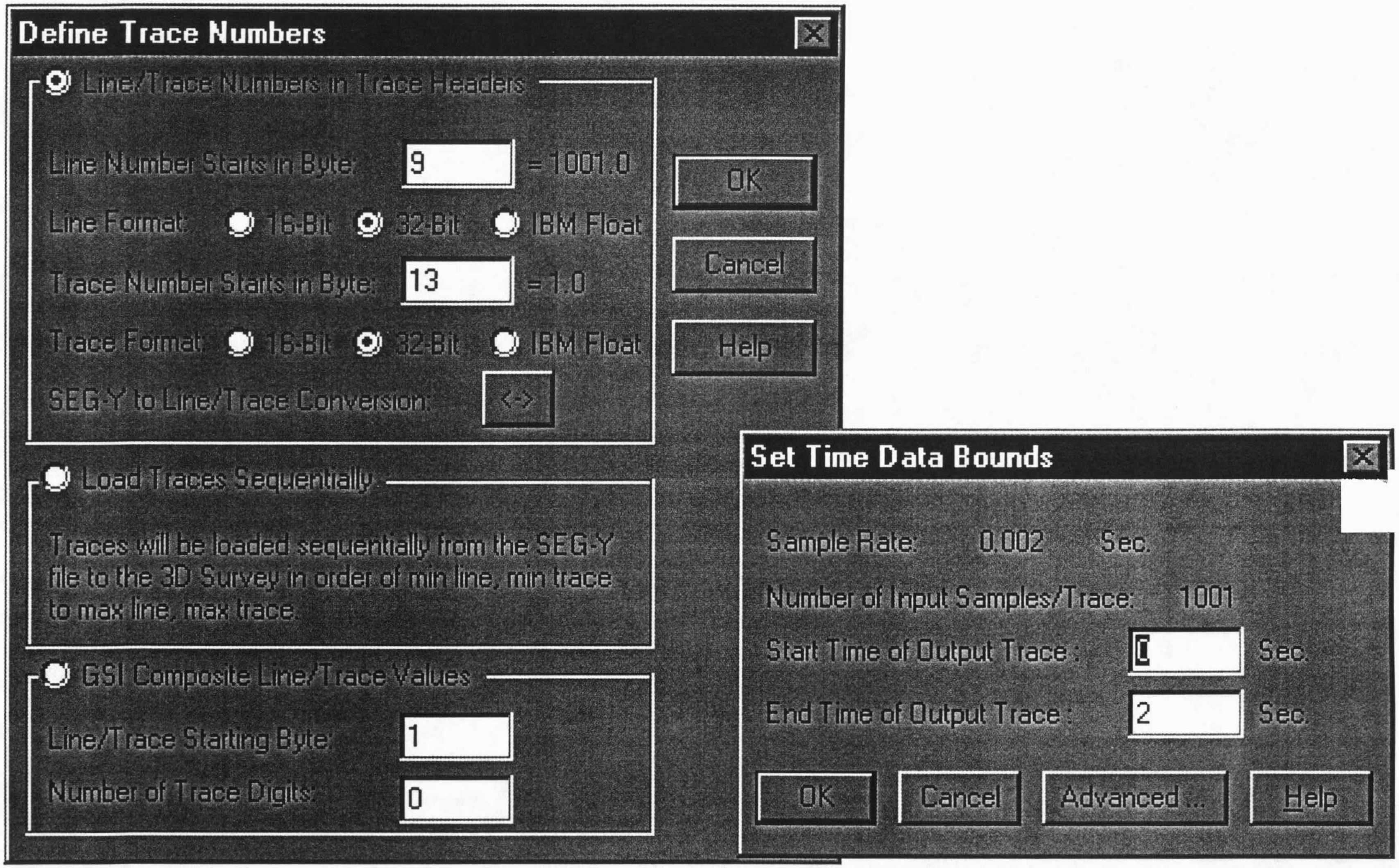
Loading 3D SEG-Y Data - 1



Loading 3D SEG-Y Data - 2



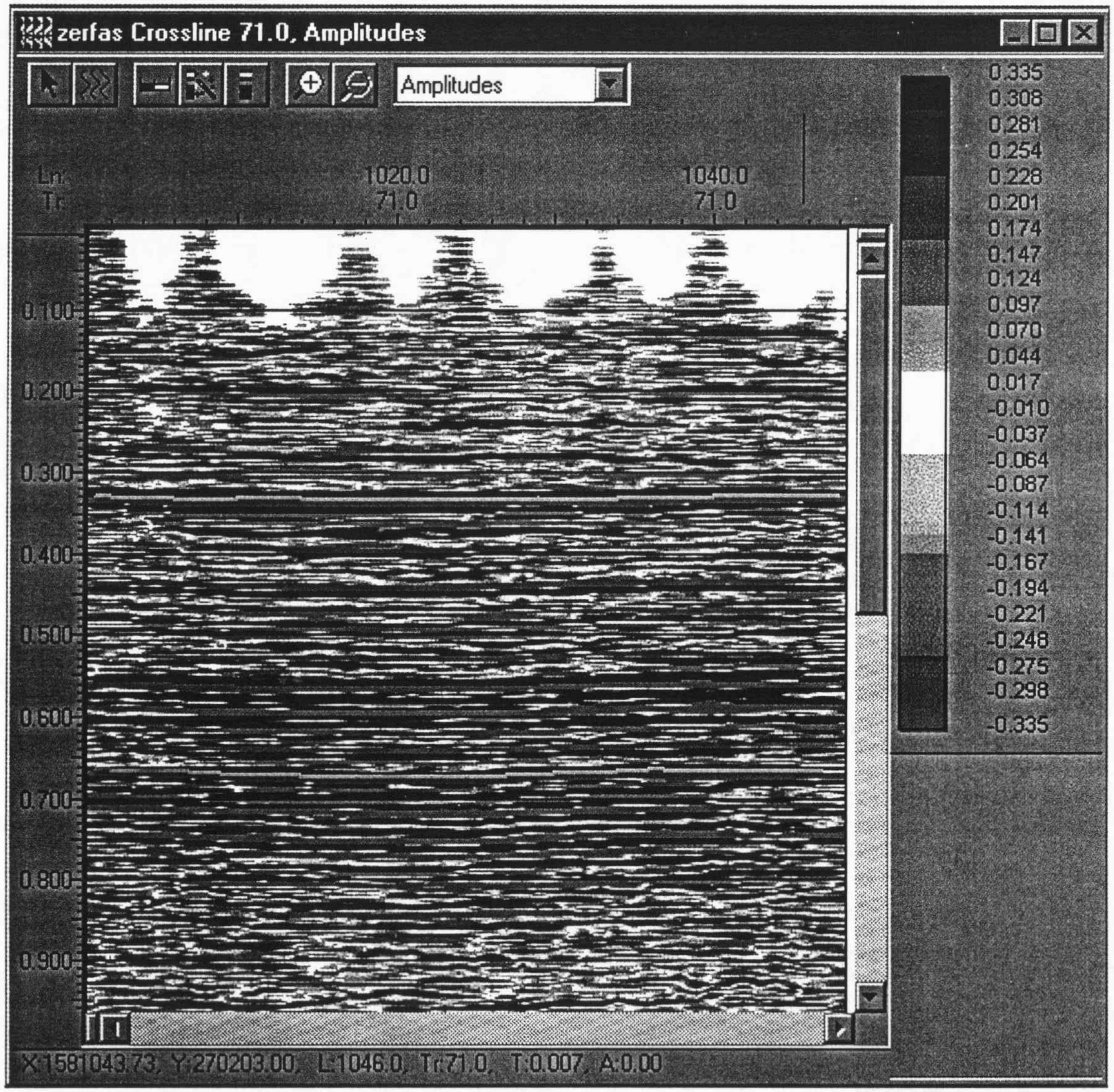
Loading 3D SEG-Y Data - 3



The Result

- Click on zerfas.prj window, then click on Basemap window
  - Menu bar at top of window changes
  - Only tools associated with window appear
- Place Cursor on 3D grid and RIGHT click
  - Select a Line or Crossline to Display

The Result


zerfas Crossline 71.0, Amplitudes
Amplitudes
Ln:
Tr:
1020.0
71.0
1040.0
71.0
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
0.335
0.308
0.281
0.254
0.228
0.201
0.174
0.147
0.124
0.097
0.070
0.044
0.017
-0.010
-0.037
-0.064
-0.087
-0.114
-0.141
-0.167
-0.194
-0.221
-0.248
-0.275
-0.298
-0.335
X:1581043.73, Y:270203.00, L:1046.0, Tr:71.0, T:0.007, A:0.00

Workshop Project 1.0

- Use Data Viewer to Examine SEG-Y Data
  - D:\seismic data\file1.sgy
- Examine Loading Sheet
- Create Project
- Create Survey
- Load SEG-Y Data
- Examine Lines

The SEG-Y Format

In the early 1980's, the most common data storage format was SEG-Y. This is the Society of Exploration Geophysicists Y format which is described in the SEG's publication Digital Tape Standards. The format is still widely used, today, though there is no guarantee that the format is used ``by the book."

The SEGY data format consists of 3 parts. The first part is a 3200 byte EBCDIC card image header that contains 40 cards (i.e. 40 lines of text with 80 characters per line) worth of text data describing the tape. The second part is a 400 byte binary header containing information about the contents of the tape reel. The third portion of the SEG-Y format consists of the actual seismic traces. Each trace has a 240 byte trace header. The data follow, written in one of 4 possible 32 formats in IBM floating point notation as defined in IBM Form GA 22-6821. (Note, this ``IBM format" is not the common IEEE format found on modern IBM PC's.)

3D Seismic:Culture Data Loading

PTTC Petroleum Technology Transfer Council North Midcontinent Region

KANSAS · GEOLOGICAL · SURVEY

Culture Data Loading: Outline

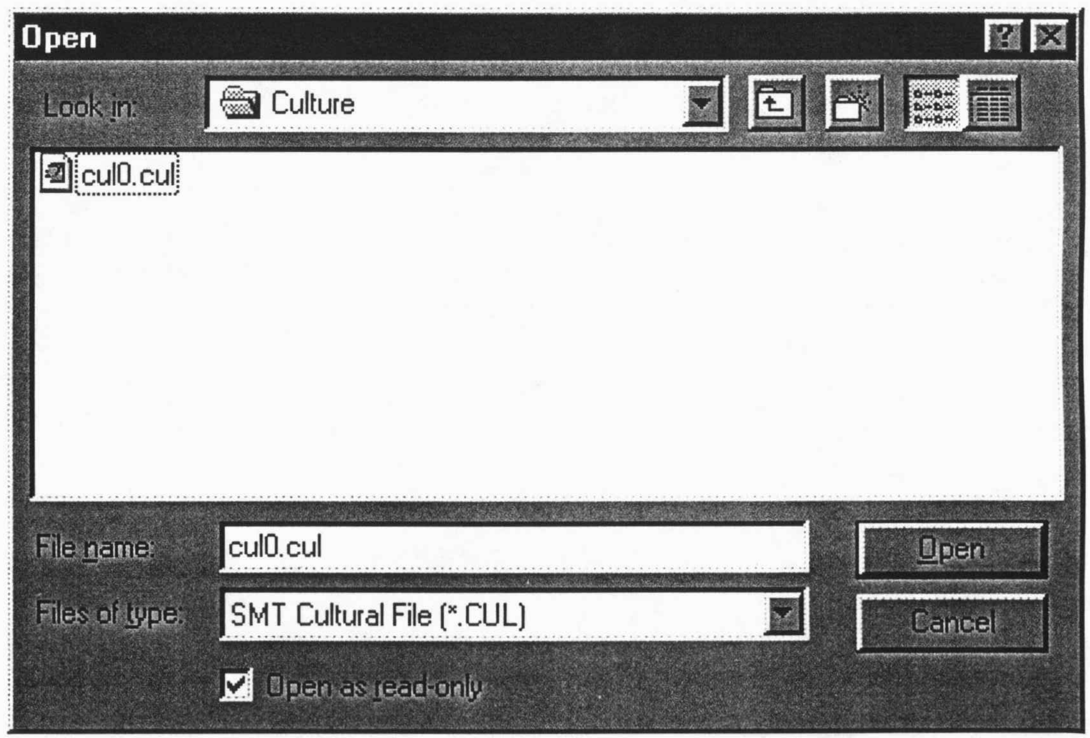
- Import Data File
- Create Culture Items Interactively

•
•
•

Culture Data Loading: Import -1

- From the Basemap Window menu bar
  - Select Culture, Import Culture
  - Path D:\zerfas\Culture\cul0.cul
- Import Formats

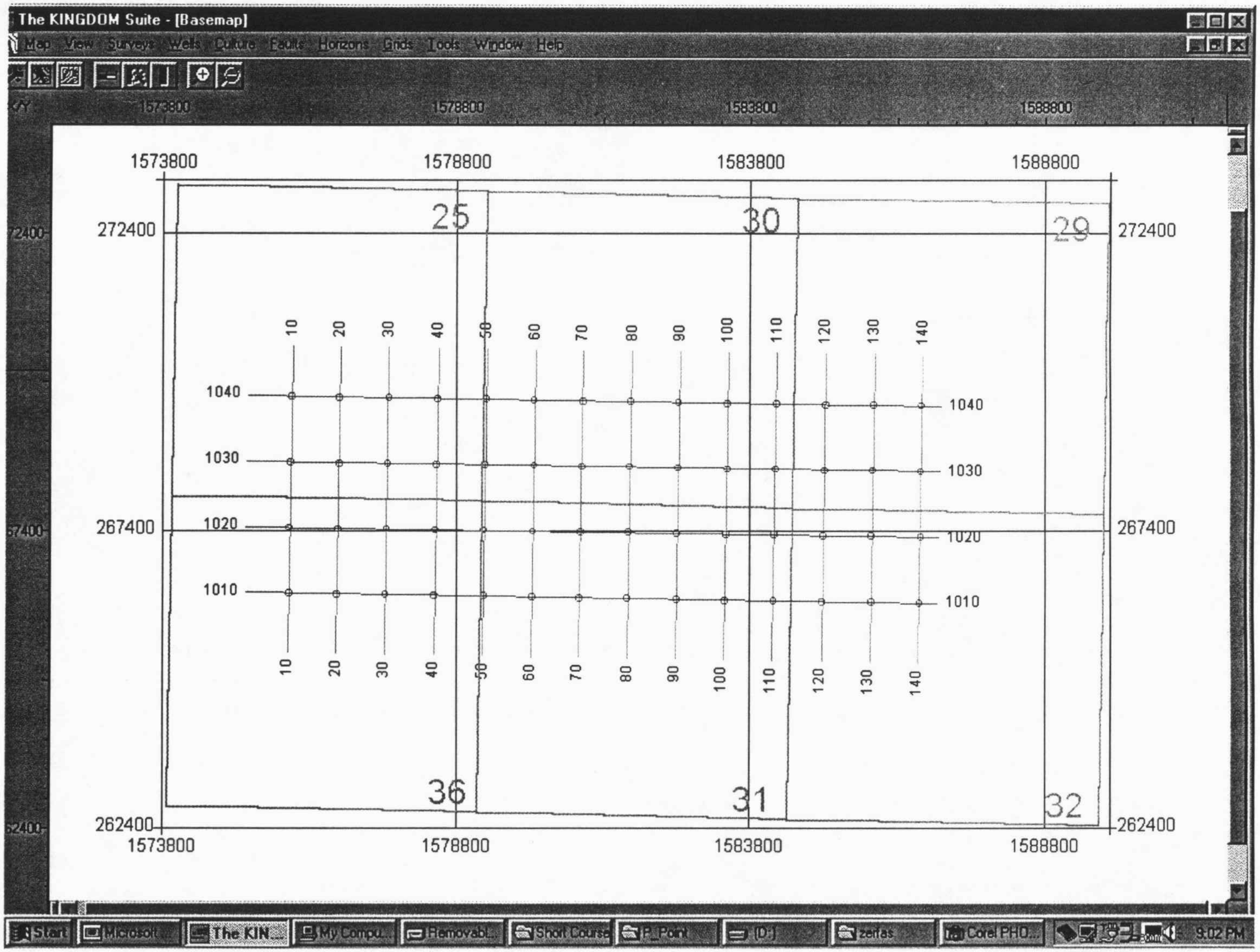
  Landmark
  SMT
  DXF
  GCS
  Tobin



Culture Data Loading: Import - 2

- Open dialog box
  - Path to data zerfas\Culture\cul0.cul
  - Call it PLSS Click on OK

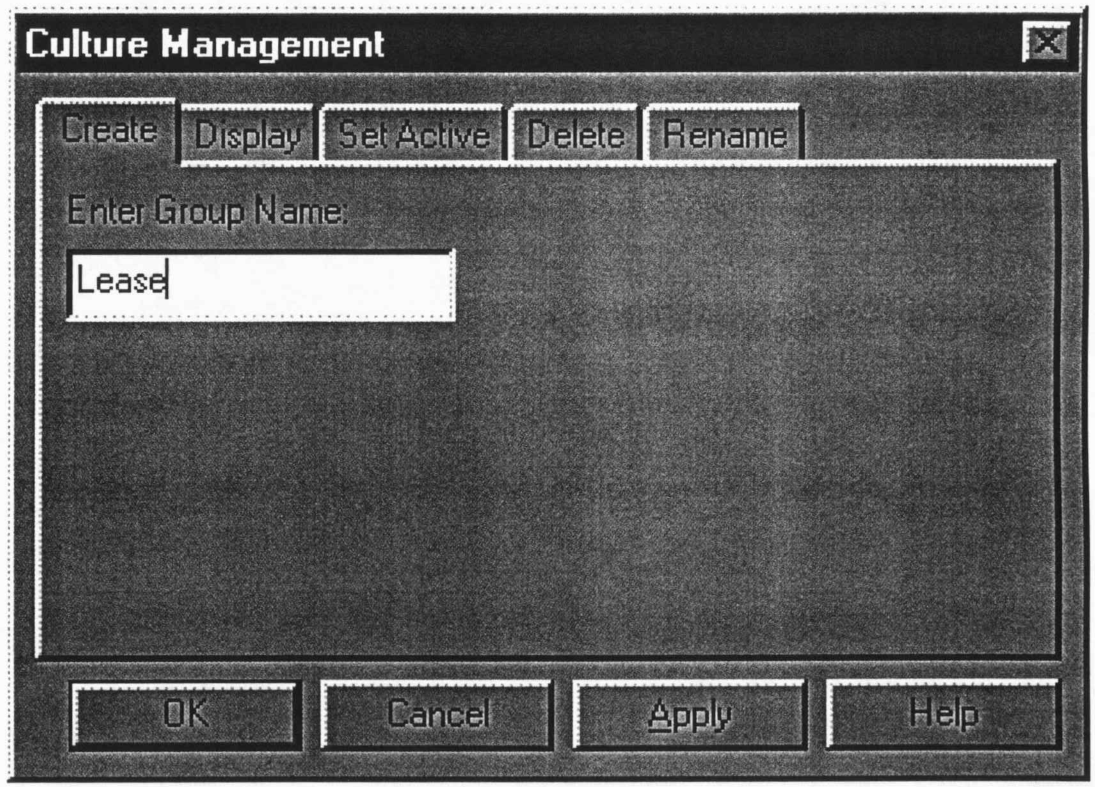
The Result



The KINGDOM Suite - [Basemap]
Map View Surveys Wells Culture Faults Horizons Grids Tools Window Help
1573800
1578800
1583800
1588800
272400
267400
262400
25
30
29
36
31
32
10
20
30
40
50
60
70
80
90
100
110
120
130
140
1040
1030
1020
1010
Start
The KIN...
9:02 PM

Culture Data Loading: Interactive -1

- From the Basemap Window menu bar
  - Select Culture, Culture Management
  - Click OK



Culture Data Loading: Interactive -1

- From the Basemap Window menu bar

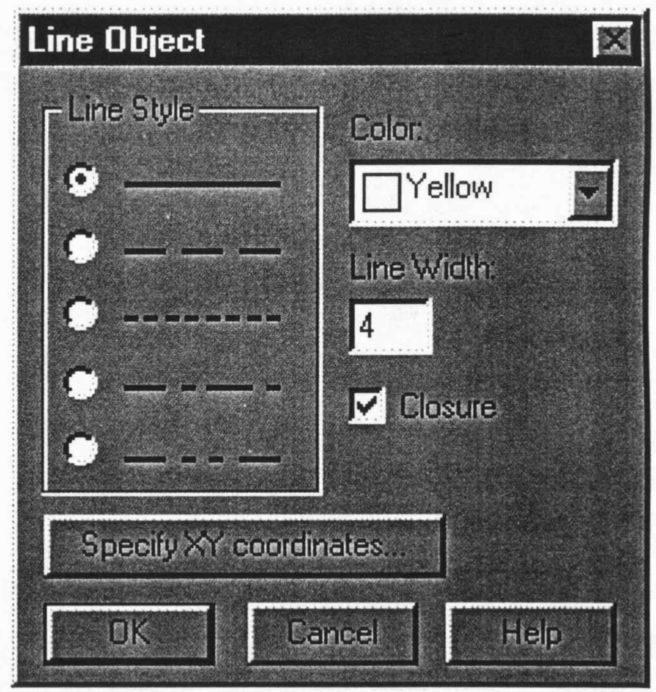
    Select Culture, Enable Editing

    Right Click Select Culture, Add Line

    Draw a 1/2 Mile Square in the NE 1/4 Sec. 36

    Double Click on the Square

    Change Color and Format



Culture Data Loading: Interactive -2

- From the Basemap Window menu bar

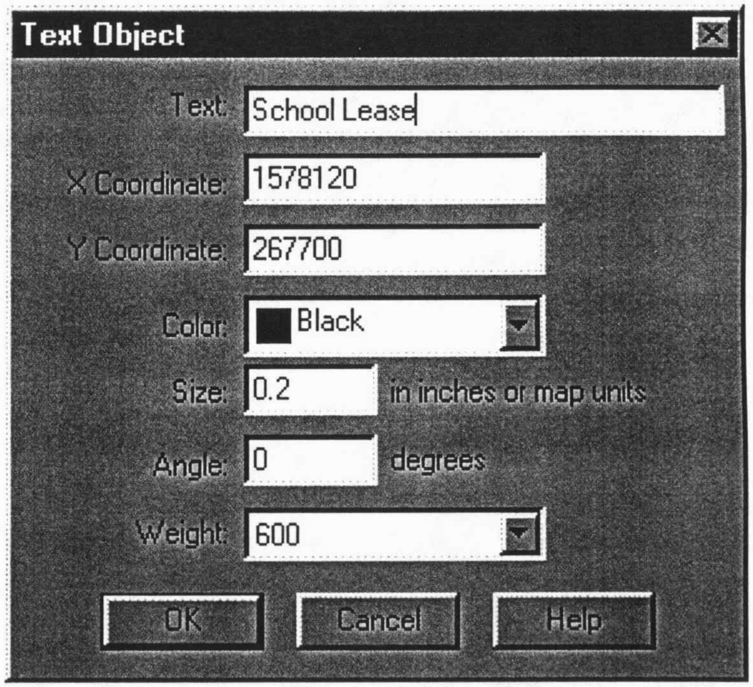
  Select Culture, Enable Editing

  Right Click Select Culture, Add Text

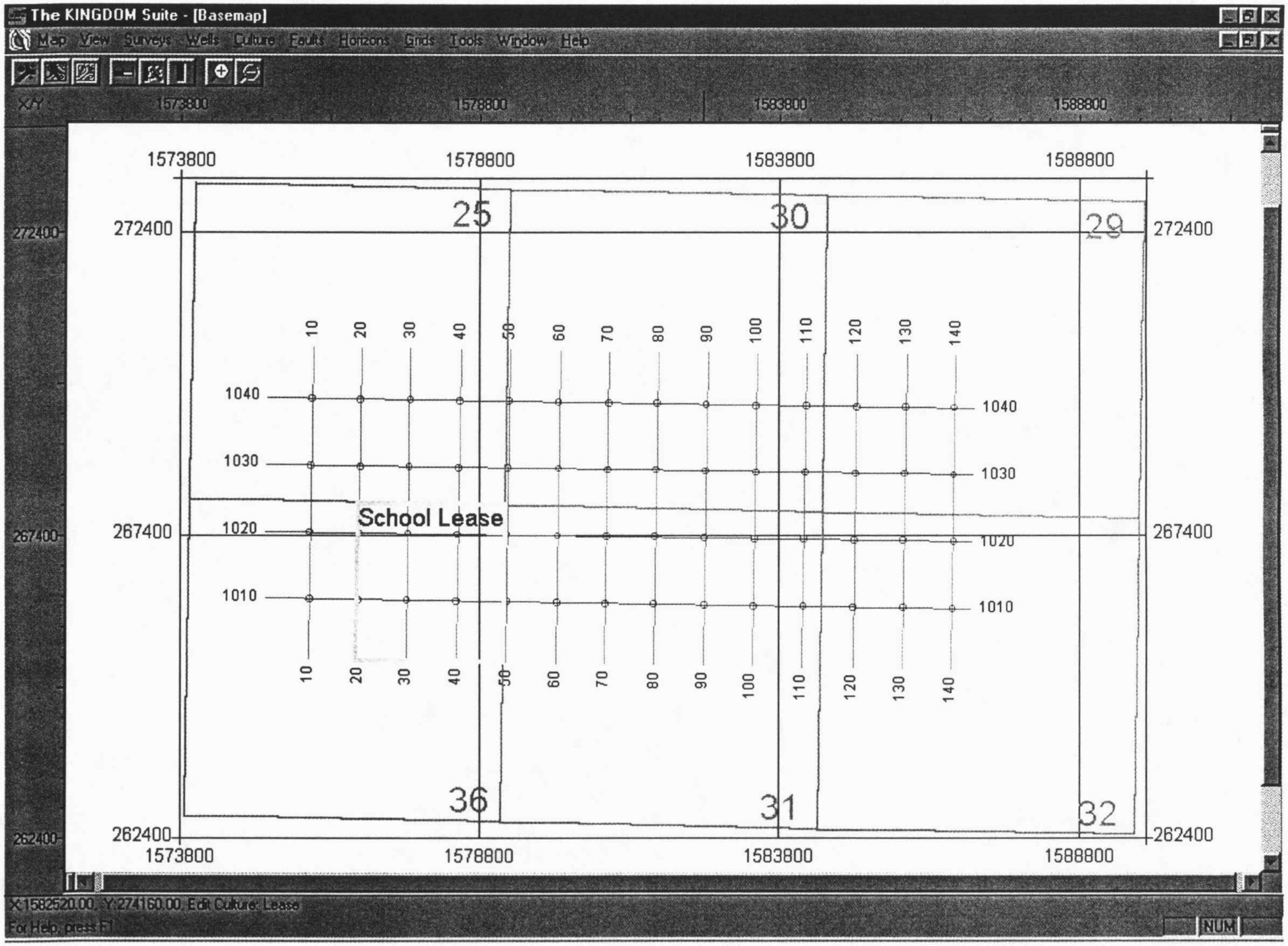
  Type Text “School Lease”

  Double Click Text

  Change Color and Format



The Result


The KINGDOM Suite - [Basemap]
Map View Surveys Wells Culture Faults Horizons Grids Tools Window Help
1573800
1578800
1583800
1588800
272400
267400
262400
25
30
29
36
31
32
School Lease
10 20 30 40 50 60 70 80 90 100 110 120 130 140
1040
1030
1020
1010
X:1582520.00, Y:274160.00, Edit Culture: Lease
For Help, press F1
NUM

Workshop Project 2.0

- Import Culture
  - D:\zerfas\Culture\cul0.cul
- Interactively Add Some Culture

3D Seismic: Well Data Loading

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

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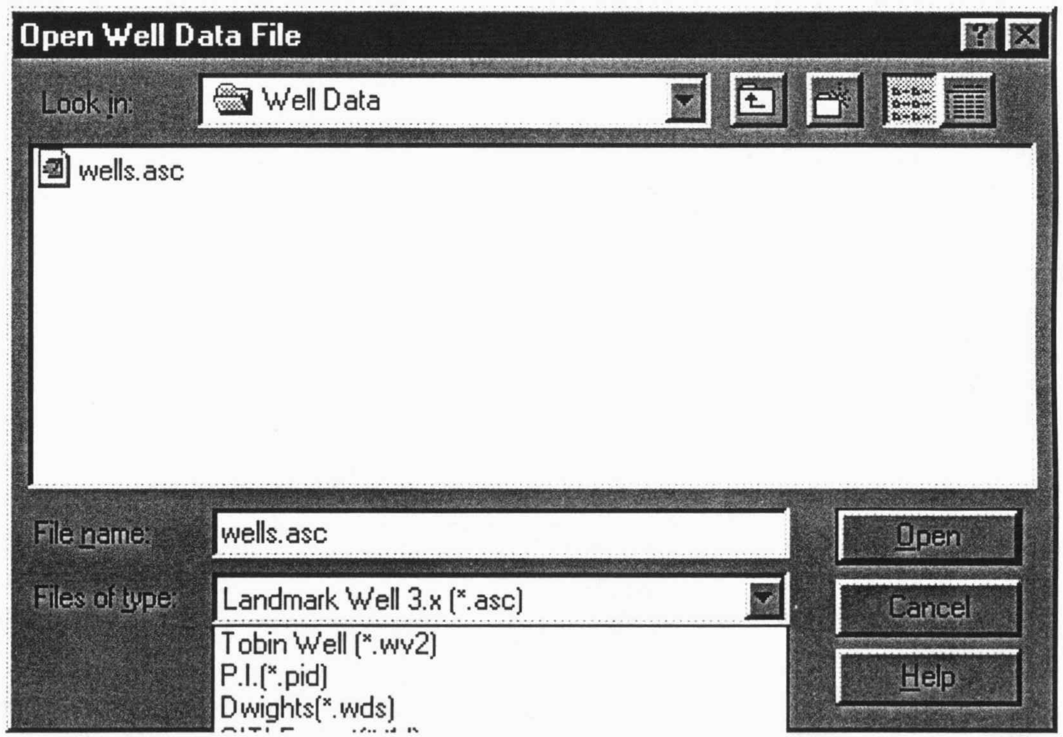
Well Data Loading: Outline

- Import Data File
- Create Wells Interactively

Well Data Loading: Import -1

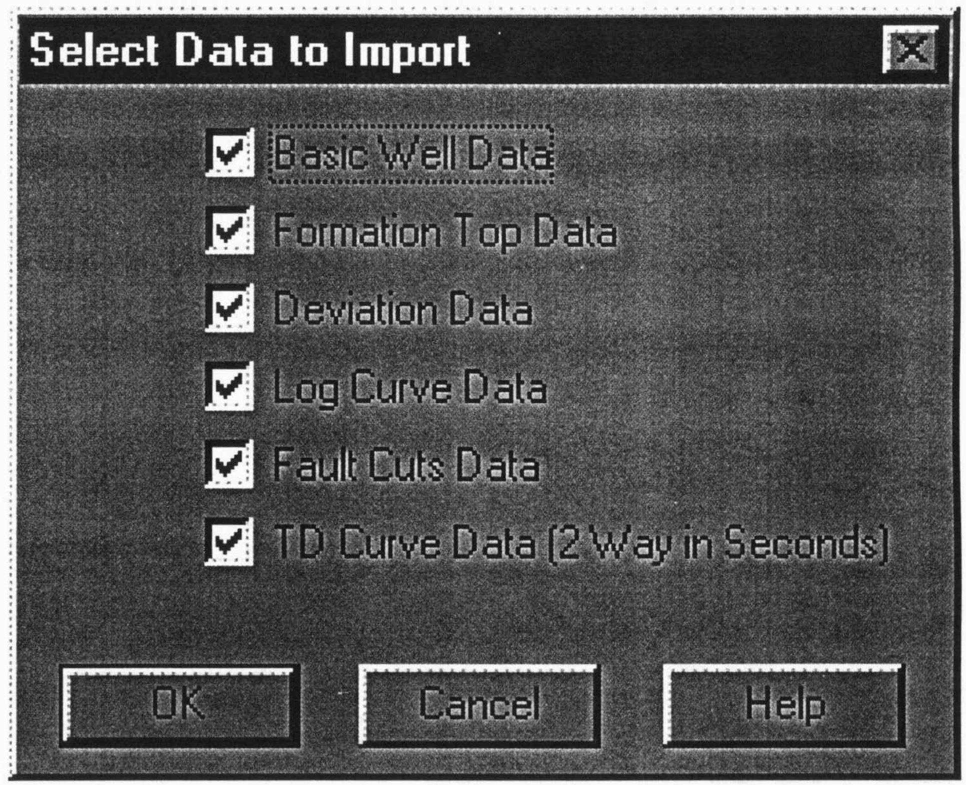
- From the Basemap Window menu bar
  - Select Wells, Add Wells, Import by file
  - Path D:\zerfas\Well Data\wells.asc
- Import Formats

  Tobin
  PI
  Dwights
  GITI
  Geographix
  GeoQuest
  Landmark
  GeoQuest IES
  Charisma
  Other

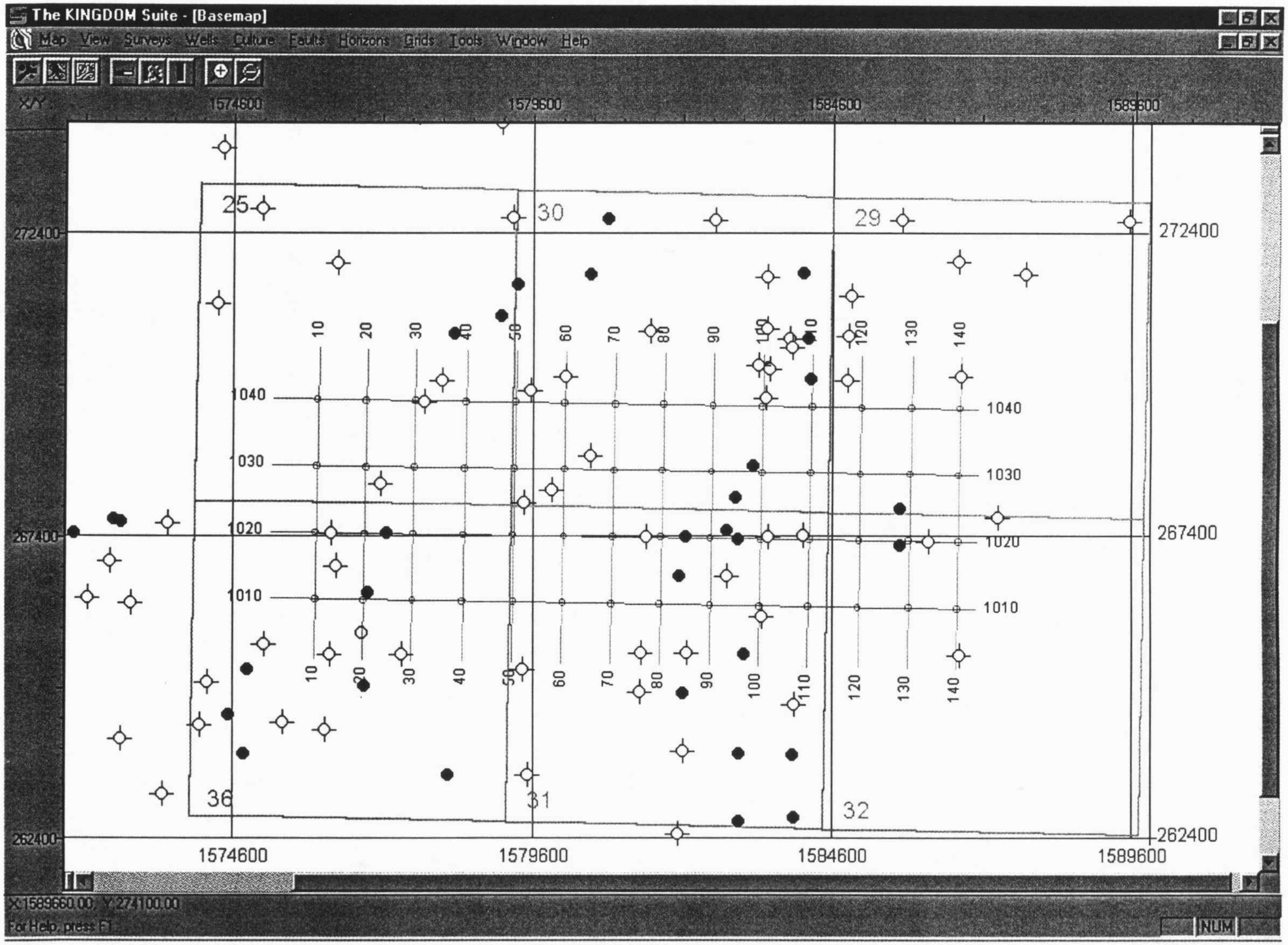


Well Data Loading: Import - 2

- Select Data Type(s) to Load
- Select Depth and Time Datums



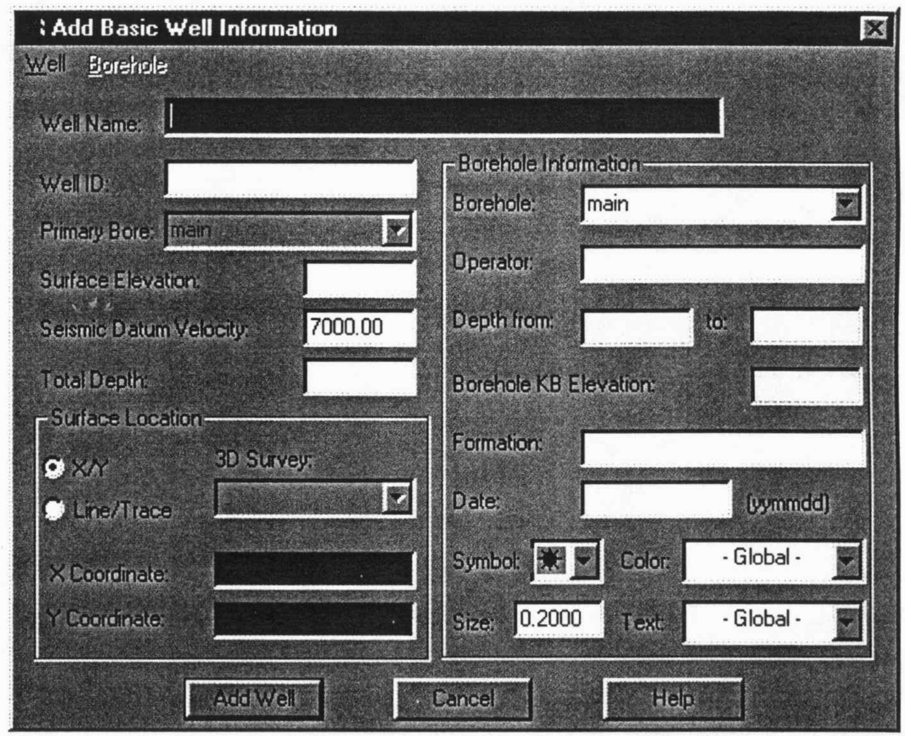
The Result



The KINGDOM Suite - [Basemap]
Map View Surveys Wells Culture Faults Horizons Grids Tools Window Help
X/Y
1574600
1579600
1584600
1589600
272400
267400
262400
25
30
29
36
31
32
1040
1030
1020
1010
X:1589660.00, Y:274100.00
For Help, press F1
NUM

Well Data Loading: Interactive

- From the Basemap Window menu bar
  - Select Wells, Add Wells, Import by dialog
  - Note red and yellow fields (REQUIRED)
    - Red for map display
    - Yellow for Seismic
  - Click Cancel



Workshop Project 3.0

- Import Culture
  - D:\zerfas\Well Data\wells.asc
- Interactively edit wells
  - Add tops
  - Change Well Spot
  - etc.

3D Seismic: Intro to Interpretation

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

KANSAS · GEOLOGICAL · SURVEY

Interpretation: Outline

- Seismic Display Modifications
- Horizon Picking (Manual)
- Horizon Picking (Semi-Automatic)
  - 2D Hunt
- Horizon Picking (Auto-picking)
  - 3D Hunt

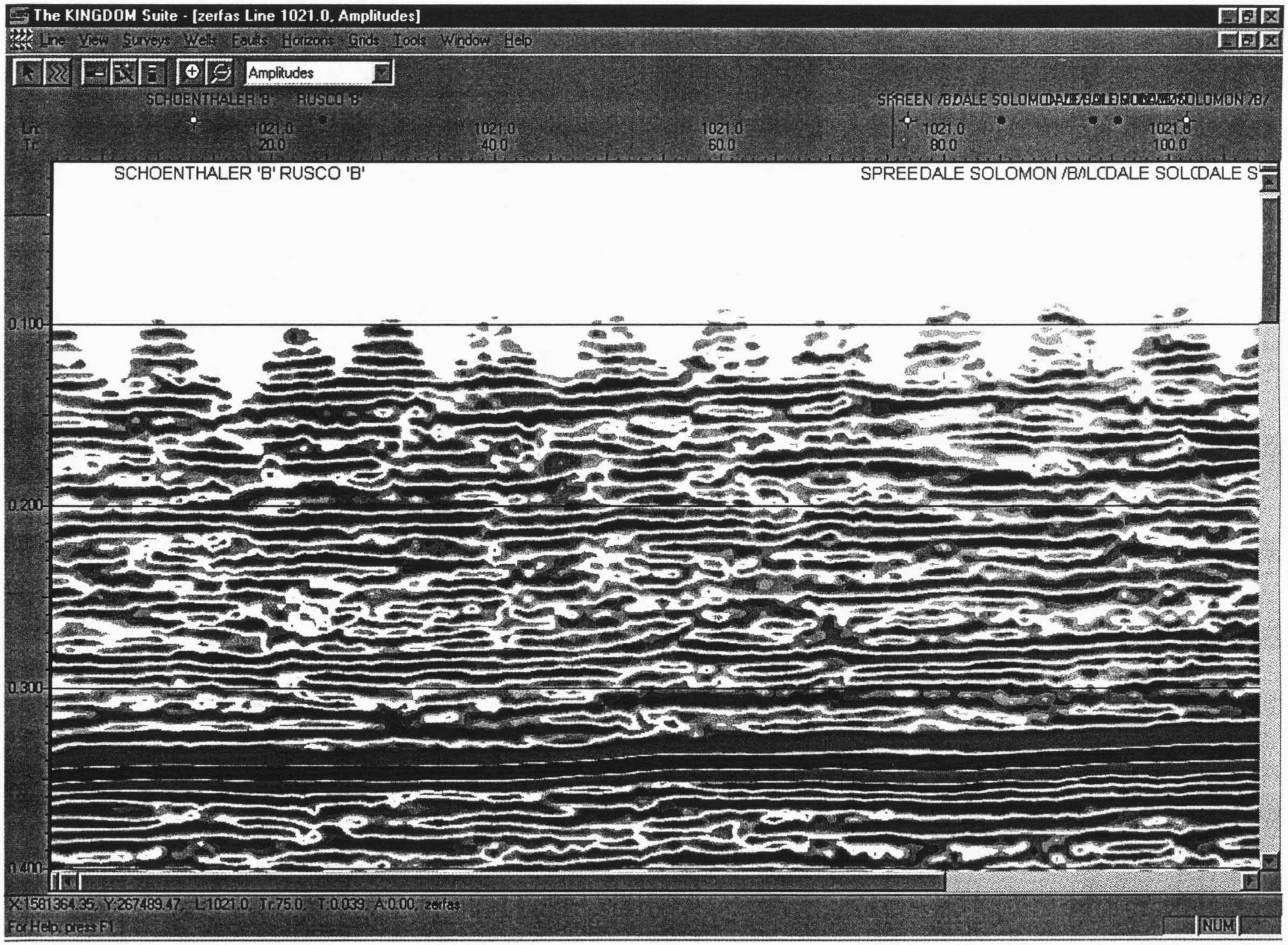
Interpretation: Notes

- *Left clicking the mouse is used to start, continue and end an activity. Right clicking is ONLY used for displaying the pop-up menu.*
- *To begin the exercise launch 2d/3dPak. An empty project window appears. To select a project, click on* ***Project*** *in the menu bar, then click on* ***Open****. A standard windows file open dialog appears. Locate the project and open.*
- *Project Path* ***D:\zerfas3\zerfas.prj***

Interpretation: Seismic Display

- Left click on the Basemap.
- Position the cursor on line 1021. Right click and select Display Line 1021. The seismic line will now appear.
- *Note: As Cursor is moved across Basemap the Line and Trace numbers appear on the lefthand bottom of Basemap window.*

The Result



The KINGDOM Suite - [zerfas Line 1021.0, Amplitudes]
Line View Surveys Wells Faults Horizons Grids Tools Window Help
Amplitudes
SCHOENTHALER 'B' RUSCO 'B'
1021.0 20.0
1021.0 40.0
1021.0 60.0
1021.0 80.0
1021.0 100.0
0.100
0.200
0.300
0.400
X:1581364.35, Y:267489.47, L:1021.0, Tr:75.0, T:0.039, A:0.00, zerfas
For Help, press F1
NUM

Interpretation: Display - Colors

- Colorbar, left click on View and Colors. Click on File and Open.
  - Select a different colorbar.
    - In most cases, the name of the colorbar describes the colors and the number of colors in the colorbar. For example, brwbl50.clm is a blue-white-brown colorbar with 50 colors.
  - Close the color editor once you are satisfied with a colorbar.
  - (You can also use the Edit Color Bar Button on top of the seismic view window).

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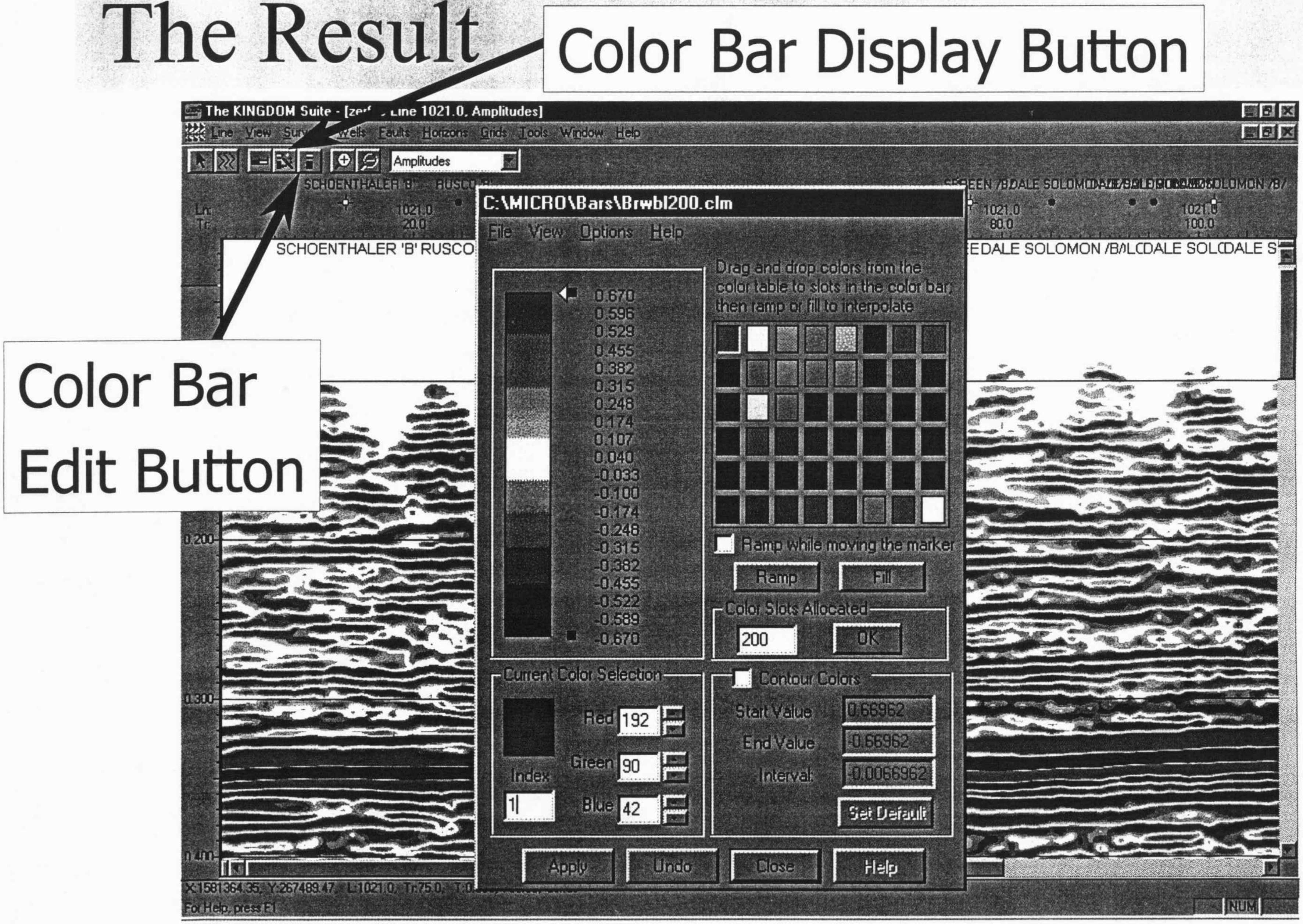
Interpretation: Display - Colors

- The colorbar may or may not be displayed on the seismic window. To toggle on or off, left click on View and Toolbars and then Color Bar. A check indicates "on". (You can also use the Show Color Bar Button on top of the seismic view window).

The Result


Color Bar Display Button
Color Bar Edit Button
The KINGDOM Suite - [zer... Line 1021.0, Amplitudes]
Line View Survey Wells Faults Horizons Grids Tools Window Help
Amplitudes
SCHOENTHALER 'B' RUSCO
C:\MICRO\Bars\Brwbl200.clm
File View Options Help
0.670
0.596
0.529
0.455
0.382
0.315
0.248
0.174
0.107
0.040
-0.033
-0.100
-0.174
-0.248
-0.315
-0.382
-0.455
-0.522
-0.589
-0.670
Drag and drop colors from the color table to slots in the color bar, then ramp or fill to interpolate
Ramp while moving the marker
Ramp
Fill
Color Slots Allocated
200
OK
Current Color Selection
Index
1
Red 192
Green 90
Blue 42
Contour Colors
Start Value 0.66962
End Value -0.66962
Interval -0.0066962
Set Default
Apply
Undo
Close
Help
For Help, press F1
NUM

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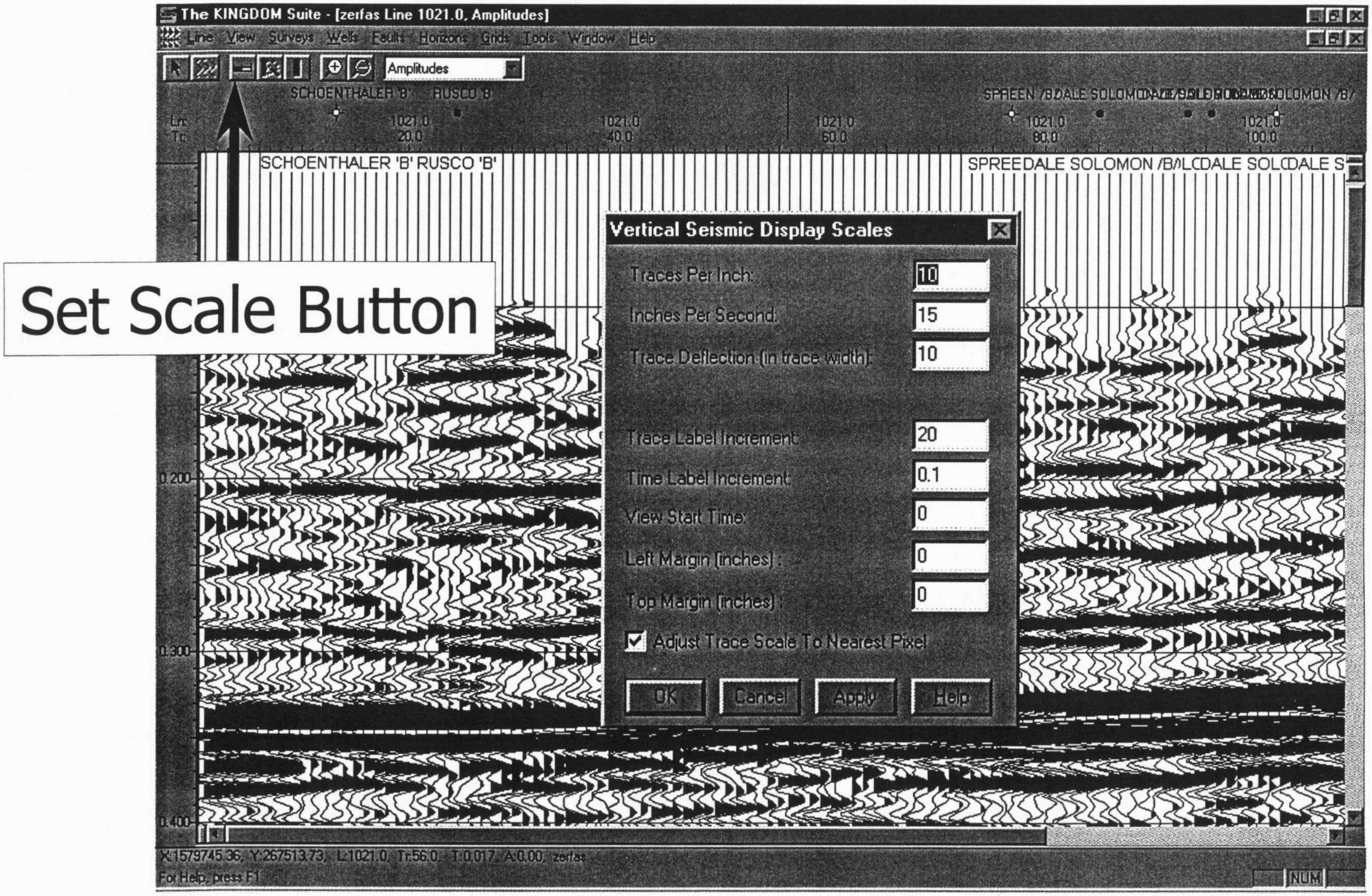
Interpretation: Plot Type and Scale

- If you're accustomed to wiggles, left click on View and Type of Plot and select Wiggle Variable Area.
- To change the display scales, left click on View and Set Display Scale.
  - 10 traces/inch and 15 inches/second is a good place to start. (You can also use the Set Scale Button on top of the seismic view window).

The Result


The KINGDOM Suite - [zerfas Line 1021.0, Amplitudes]
Line View Surveys Wells Faults Horizons Grids Tools Window Help
Amplitudes
Set Scale Button
Vertical Seismic Display Scales
Traces Per Inch: 10
Inches Per Second: 15
Trace Deflection (in trace width): 10
Trace Label Increment: 20
Time Label Increment: 0.1
View Start Time: 0
Left Margin (inches) : 0
Top Margin (inches) : 0
Adjust Trace Scale To Nearest Pixel
OK
Cancel
Apply
Help
SCHOENTHALER 'B' RUSCO 'B'
For Help, press F1
NUM

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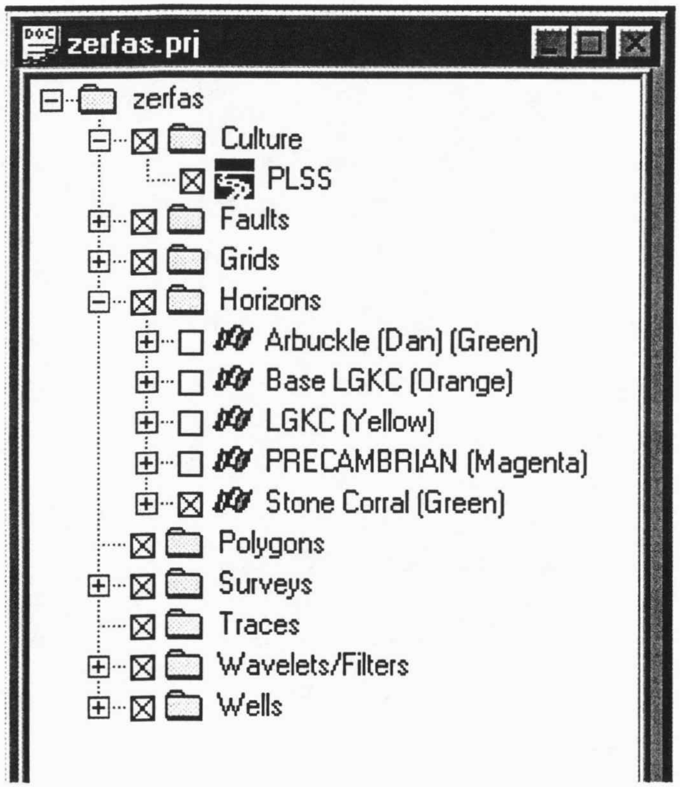
Interpretation: Display - Direction

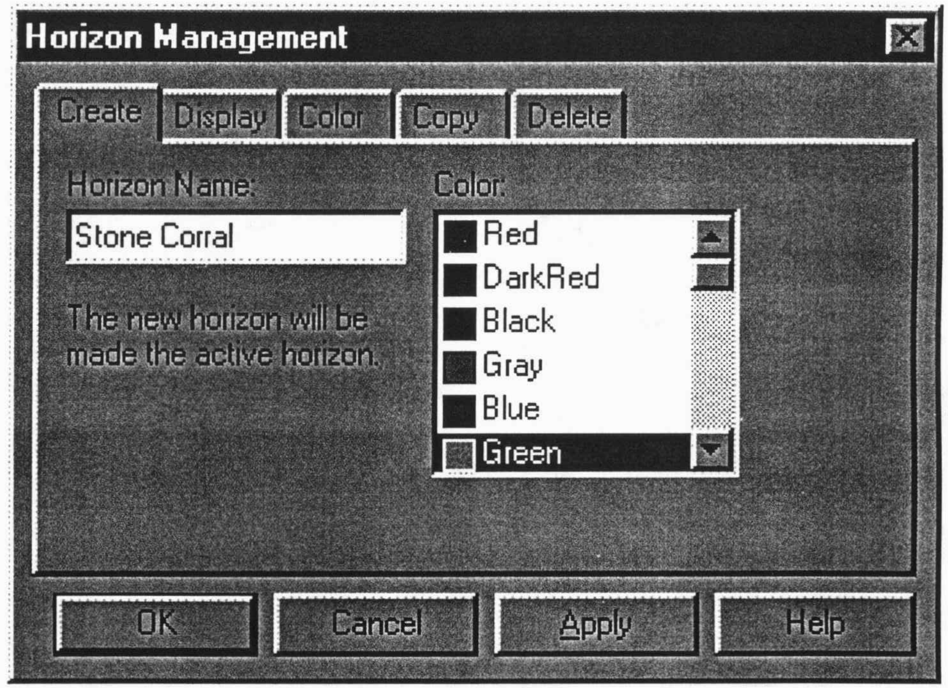
- Make sure you know which way is west. Move the cursor on the seismic window and watch the cursor movement on the map. If the direction is backwards, hit the R key on the keyboard to reverse the line display direction.
- My preference is to display north, northeast, east, and southeast towards the right.

Interpretation: Horizon Picking - 1

- Display line 1021. Scroll until the “Rusco B” well is visible and note the strong peak-trough-peak reflector at around .35 seconds.
- To create a horizon, right click anywhere on the seismic line, select Horizon Management.
  - Select the Create Tab and then enter Stone Corral for the Horizon name and then select a color. Hit OK. The Stone Corral horizon is now active.

The Result

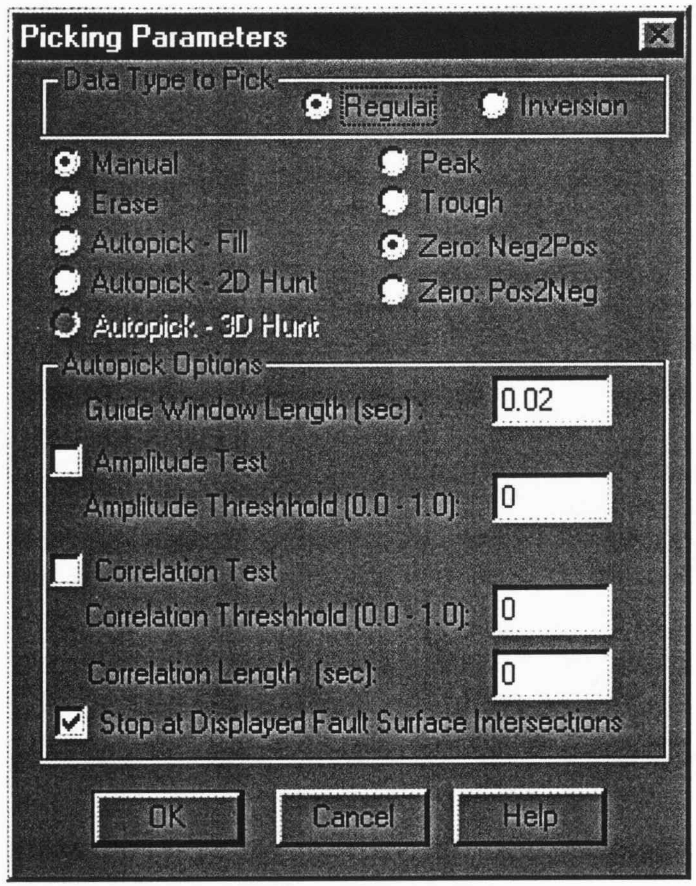

zerfas.prj
zerfas
Culture
PLSS
Faults
Grids
Horizons
Arbuckle (Dan) (Green)
Base LGKC (Orange)
LGKC (Yellow)
PRECAMBRIAN (Magenta)
Stone Corral (Green)
Polygons
Surveys
Traces
Wavelets/Filters
Wells


Horizon Management
Create
Display
Color
Copy
Delete
Horizon Name:
Stone Corral
The new horizon will be made the active horizon.
Color:
Red
DarkRed
Black
Gray
Blue
Green
OK
Cancel
Apply
Help

Interpretation: Horizon Picking - 2

- Display the horizon in map view by double clicking on the icon next to the Stone Corral Horizon on the Project Tree Window. Since no picks have been made, no horizon is visible.
- Right click on a seismic line and select Picking Parameters. Make sure that Stop at Displayed Fault Surface Intersections is enabled.

The Result

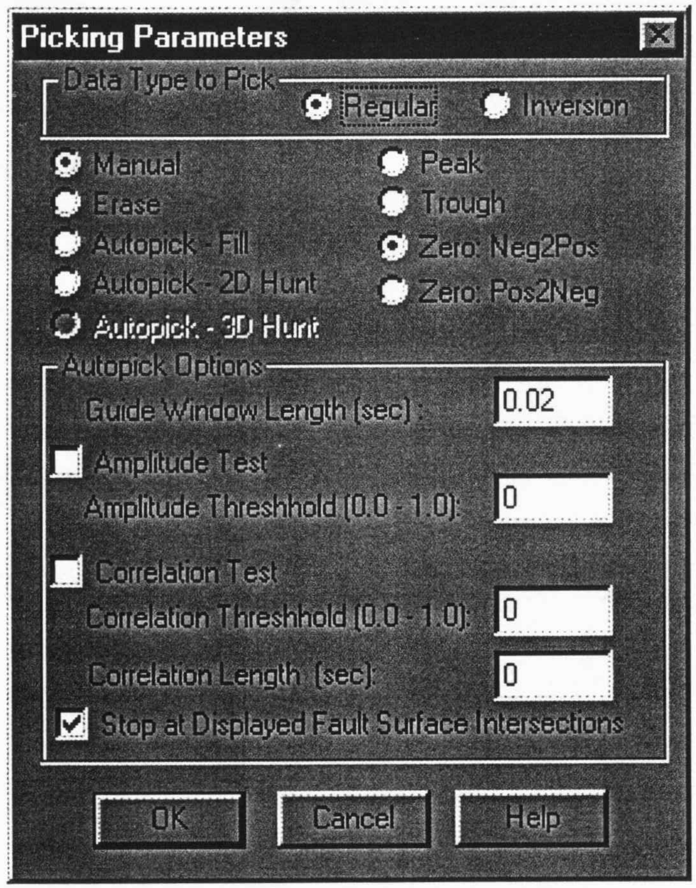


Picking Parameters
Data Type to Pick
Regular
Inversion
Manual
Erase
Autopick - Fill
Autopick - 2D Hunt
Autopick - 3D Hunt
Peak
Trough
Zero: Neg2Pos
Zero: Pos2Neg
Autopick Options
Guide Window Length (sec):
0.02
Amplitude Test
Amplitude Threshhold (0.0 - 1.0):
0
Correlation Test
Correlation Threshhold (0.0 - 1.0):
0
Correlation Length (sec):
0
Stop at Displayed Fault Surface Intersections
OK
Cancel
Help

Interpretation: Horizon Picking - 3

- Click the type of event (peak, trough, zero crossing) to pick
- Click how to pick it (manual picking, fill mode, 2d Hunt, 3d Hunt, Erase).
- Set the type of event to zero crossing negative to positive.

The Result



Picking Parameters
Data Type to Pick
Regular
Inversion
Manual
Erase
Autopick - Fill
Autopick - 2D Hunt
Autopick - 3D Hunt
Peak
Trough
Zero: Neg2Pos
Zero: Pos2Neg
Autopick Options
Guide Window Length (sec) :
0.02
Amplitude Test
Amplitude Threshhold (0.0 - 1.0):
0
Correlation Test
Correlation Threshhold (0.0 - 1.0):
0
Correlation Length (sec):
0
Stop at Displayed Fault Surface Intersections
OK
Cancel
Help

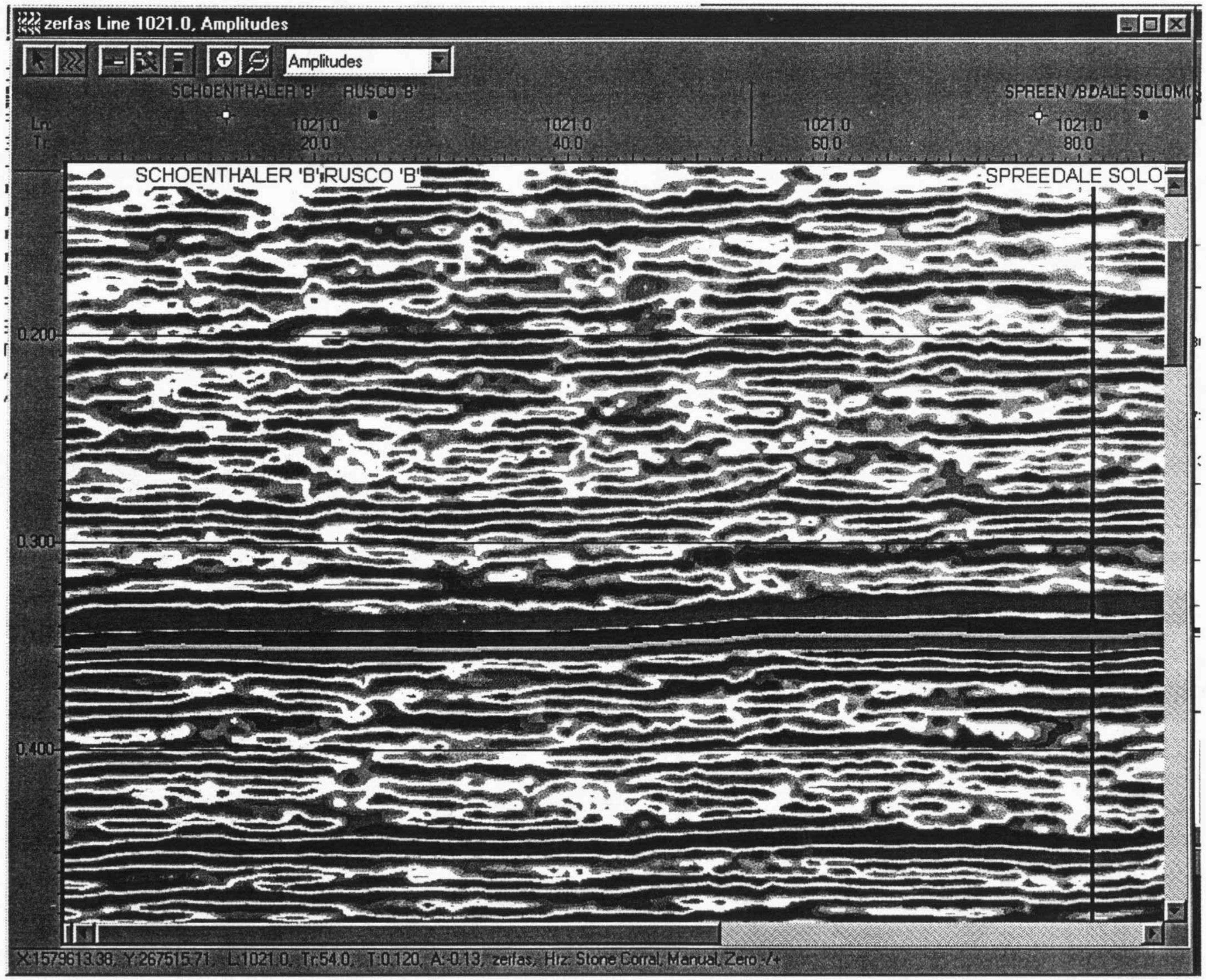
Interpretation: Horizon Picking - 4

- Display the Horizon Toolbar by left clicking on View, Toolbars, and Horizon bar. Note that the active horizon is highlighted in the toolbar.
  - Hot keys are available:
    - M = manual picking
    - F = Fill mode
    - H = 2d Hunt,
    - E = Erase,
    - P = Peak,
    - T = Trough.

Interpretation: Horizon Picking - 4

- Note: Shape of the cursor and status bar.
  - Cursor is now a "+" with either a E, M, F, or H next to it.
  - Change the picking mode to either F or H, and change the phase to zero crossing negative to positive.
  - Pick the zero crossing event at the base of the very strong trough at around 0.35 seconds as far as you can. *Note: Map display is updated immediately after picking.*

The Result


zerfas Line 1021.0, Amplitudes
Amplitudes
SCHOENTHALER 'B'
RUSCO 'B'
SPREEN /BDALE SOLOM(
Ln:
Tr:
1021.0
20.0
1021.0
40.0
1021.0
60.0
1021.0
80.0
SCHOENTHALER 'B' RUSCO 'B'
SPREEDALE SOLO
0.200
0.300
0.400
X:1579613.38, Y:267515.71, L:1021.0, Tr:54.0, T:0.120, A:-0.13, zerfas, Hrz: Stone Corral, Manual, Zero -/+

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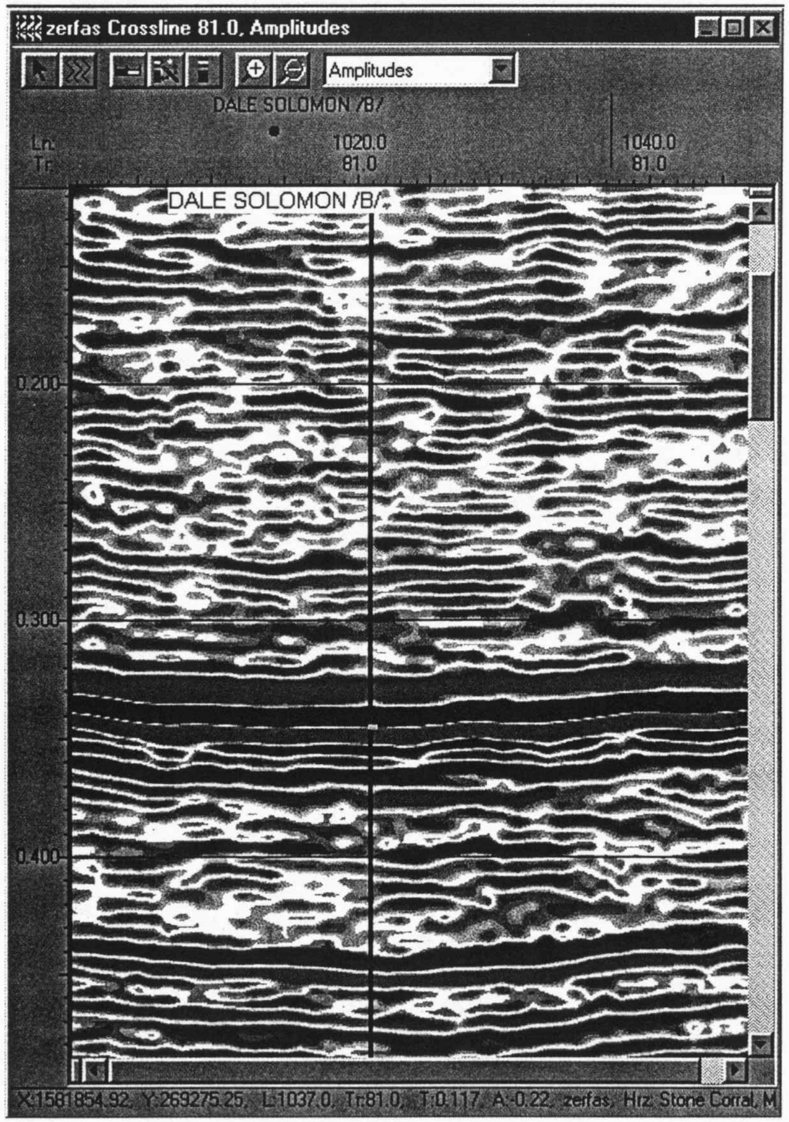
Interpretation: Semi-Auto Picking 1

- Place the cursor on crossline 81 on the seismic display, right click and display the line.
  - A small tick mark is visible where the two lines intersect. You will also see a vertical red line. This red line is a line overlay and can be disabled by left clicking on **View** and selecting **Line Overlays**. A check mark indicates "on".
- Chose the 2d Hunt mode, left click once on the tick mark and entire horizon is picked.

The Result


zerfas Crossline 81.0, Amplitudes
Amplitudes
DALE SOLOMON /B/
Ln:
Tr:
1020.0
81.0
1040.0
81.0
DALE SOLOMON /B/
0.200
0.300
0.400
X:1581854.92, Y:269275.25, L:1037.0, Tr:81.0, T:0.117, A:-0.22, zerfas, Hrz: Stone Corral, M

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•
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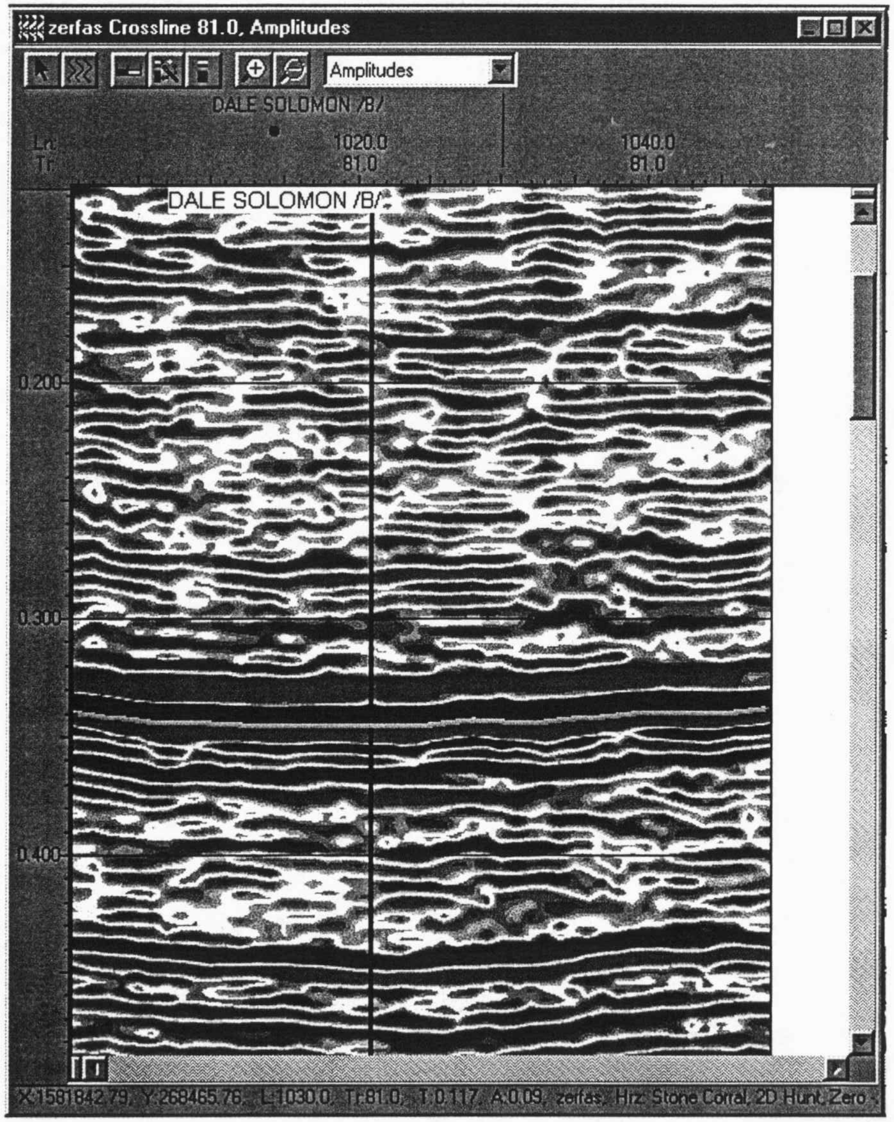
The Result


zerfas Crossline 81.0, Amplitudes
Amplitudes
DALE SOLOMON /B/
Ln:
Tr:
1020.0
81.0
1040.0
81.0
DALE SOLOMON /B/
0.200
0.300
0.400
X:1581842.79, Y:268465.76, L:1030.0, Tr:81.0, T:0.117, A:0.09, zerfas, Hrz: Stone Corral, 2D Hunt, Zero

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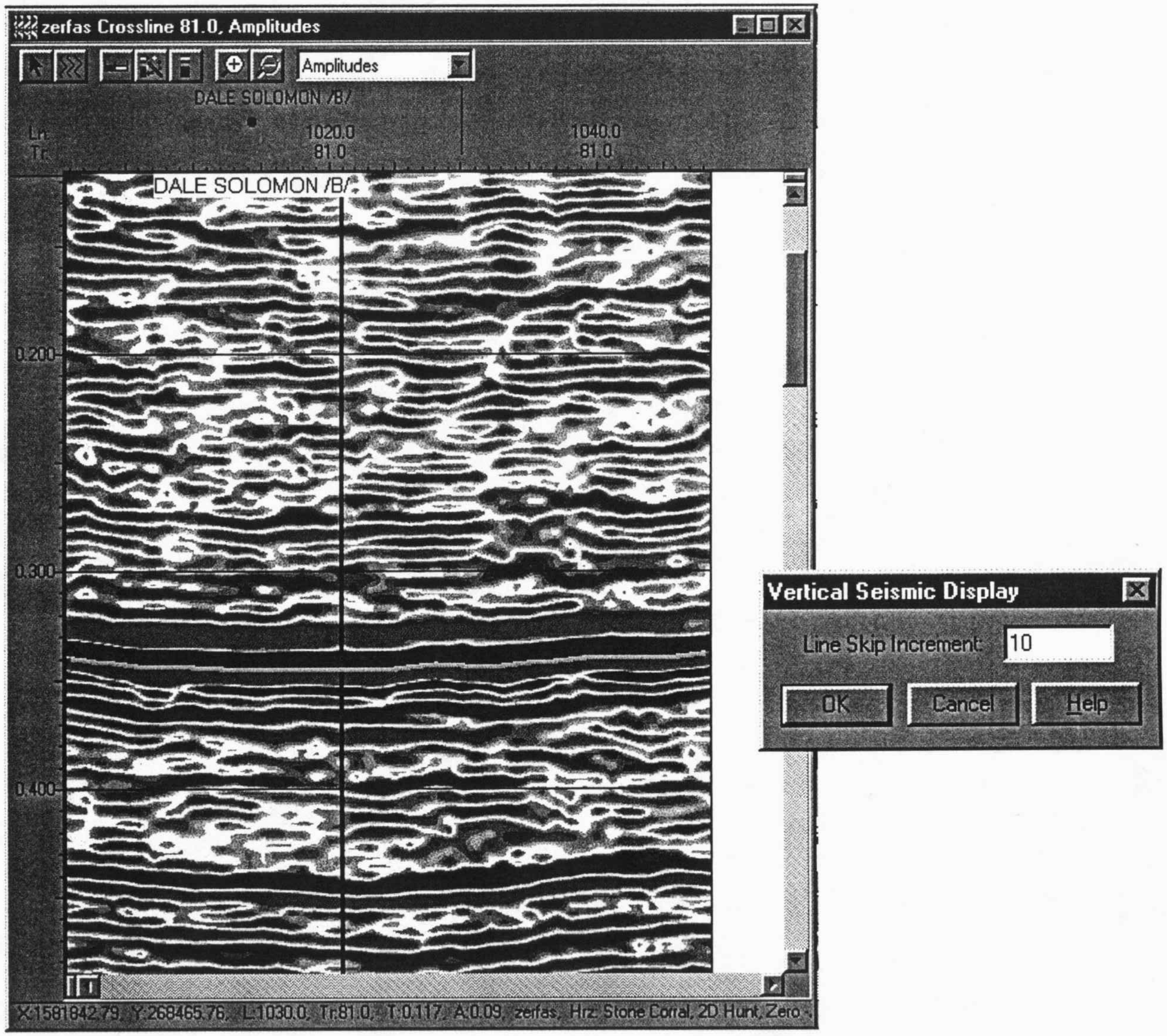
Interpretation: Semi-Auto Picking 2

- Set the Seismic line skip increment to 10 by left clicking on Line and Seismic Line Skip Increment. Increment through your data using the arrow keys and continue picking this horizon.
- You should end up with picked grid of lines for the Stone Corral horizon.

The Result


zerfas Crossline 81.0, Amplitudes
Amplitudes
DALE SOLOMON /B/
Ln
Tr
1020.0
81.0
1040.0
81.0
DALE SOLOMON /B/
0.200
0.300
0.400
X:1581842.79 Y:268465.76, L:1030.0, Tr:81.0, T:0.117, A:0.09, zerfas, Hrz: Stone Corral, 2D Hunt, Zero
Vertical Seismic Display
Line Skip Increment: 10
OK
Cancel
Help

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Interpretation: Auto-Picking - 1

- Protect picks by copying the horizon.
  - Using the Horizon Management dialog box, select the Copy tab, type new horizon name (e.g., STCRL_CPY), select the Stone Corral horizon to copy, and assign a new color.
    - Now if the autopicker runs amok, the original picks can be restored.
    - The copied horizon will be displayed on the seismic line.

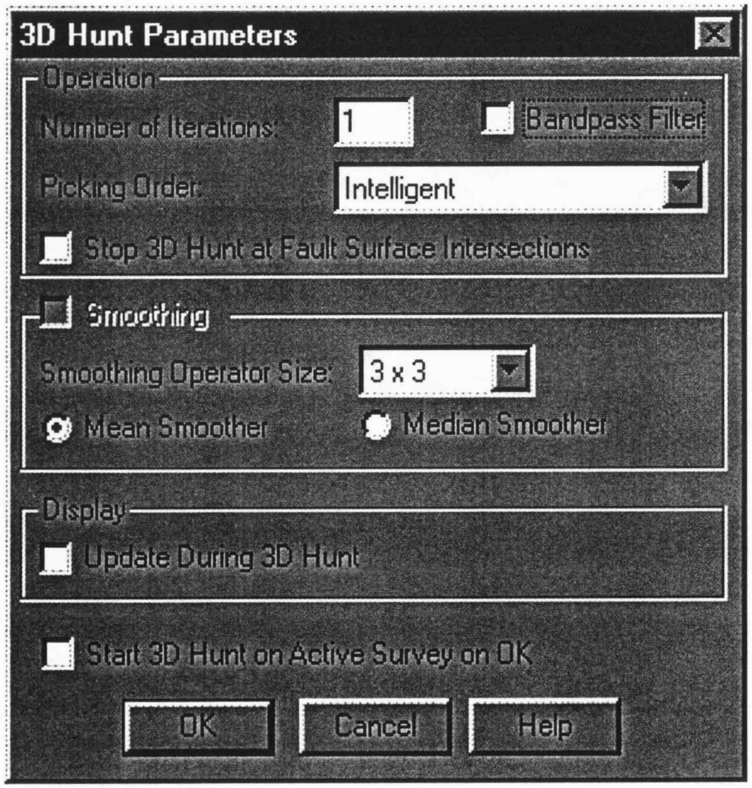
      Go to the Project Tree and find the copied horizon. Click the box in front of the copied horizon and it will be removed from displays.

      Click on Stone Corral in Horizons Tool Bar to make the active horizon.

Interpretation: Auto-Picking - 1

- Left click on Horizons on the Menu bar and select Polygon 3D Hunt. Click OK.
- Set 3d Hunt parameters to 1 iteration and 3X3 smoothing Click OK. Autopicking begins immediately.
  - Normally one giant polygon is not recommended. Instead, you can create a series of smaller polygons to constrain the 3d Hunt.

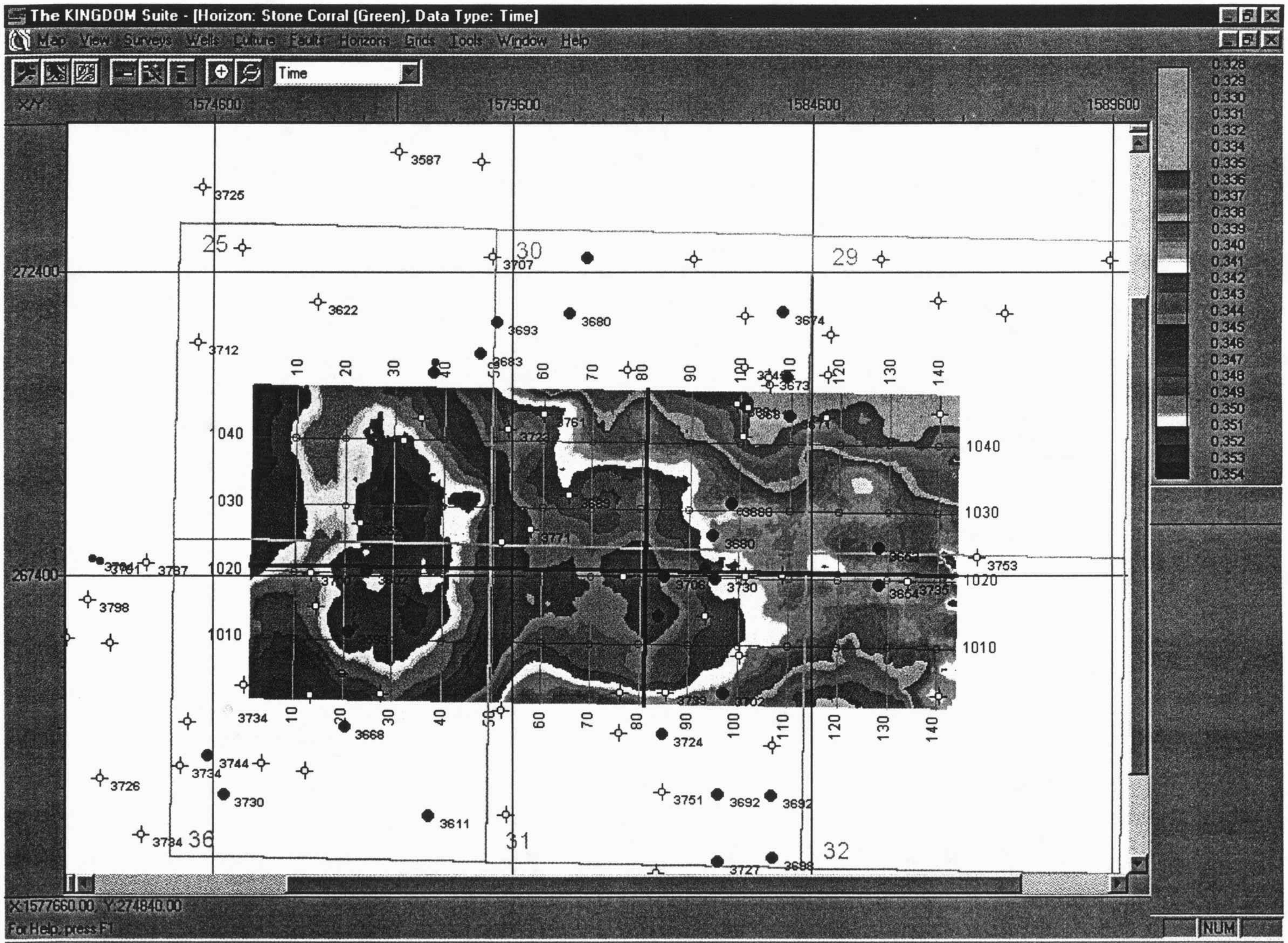
The Result


3D Hunt Parameters
Operation
Number of Iterations:
1
Bandpass Filter
Picking Order:
Intelligent
Stop 3D Hunt at Fault Surface Intersections
Smoothing
Smoothing Operator Size:
3 x 3
Mean Smoother
Median Smoother
Display
Update During 3D Hunt
Start 3D Hunt on Active Survey on OK
OK
Cancel
Help

Interpretation: Auto-Picking - 1

- Examine the basemap
  - Time structure map on the Stone Corral.
    - If you don't like the colorbar, left click on View and Colors. Click on File and Open and select a different colorbar. A selection such as Shade80.clm should give you a nice map.
- If you don't like how 3D Hunt worked in particular area
  - left click on **Horizons** and select **Polygon 3D Erase**. Using your left mouse button draw a polygon around the area of the map. Finish the polygon with a double click. You will be given the option to erase your seed

The Result - Time Structure Map



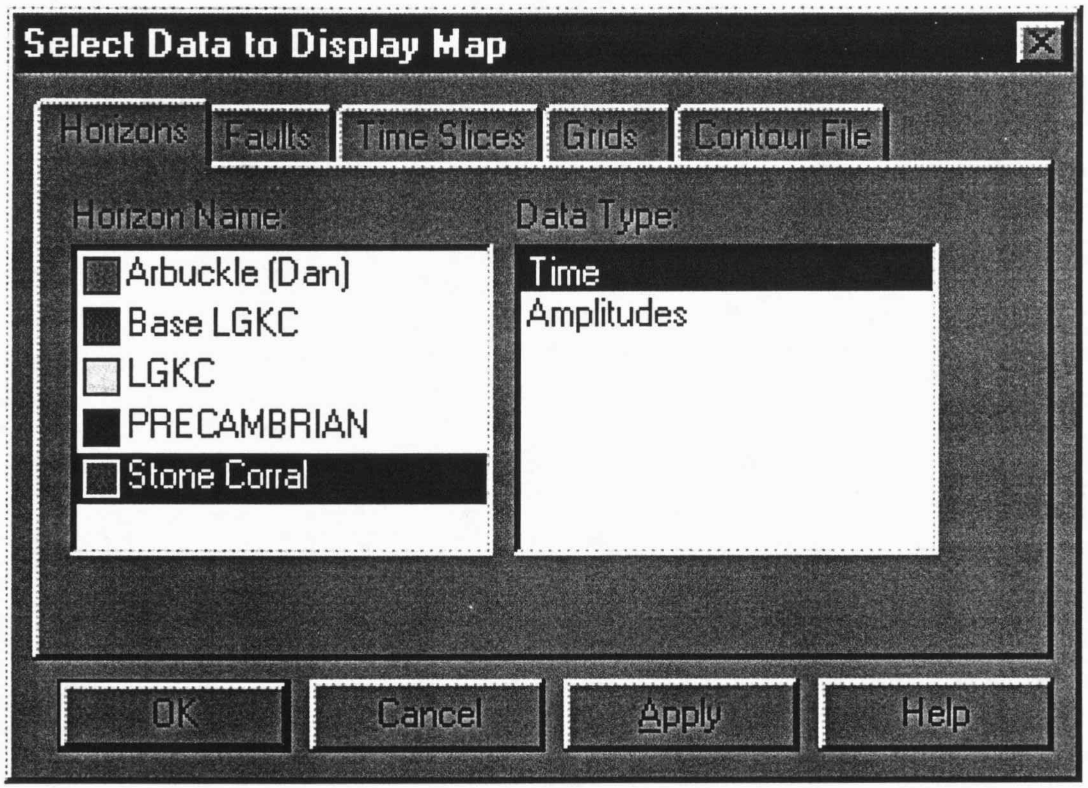
Interpretation: Auto-Picking - 2

- If you don't like how 3D Hunt worked in particular area
  - left click on Horizons and select Polygon 3D Erase.
    - Using your left mouse button draw a polygon around the area of the map. Finish the polygon with a double click. You will be given the option to erase your seed picks with the default set to do not erase. Hit Yes, and the polygonal area is wiped clean.
- Repick erased lines using 2d hunt or manual.
- Rerun the 3D Hunt.

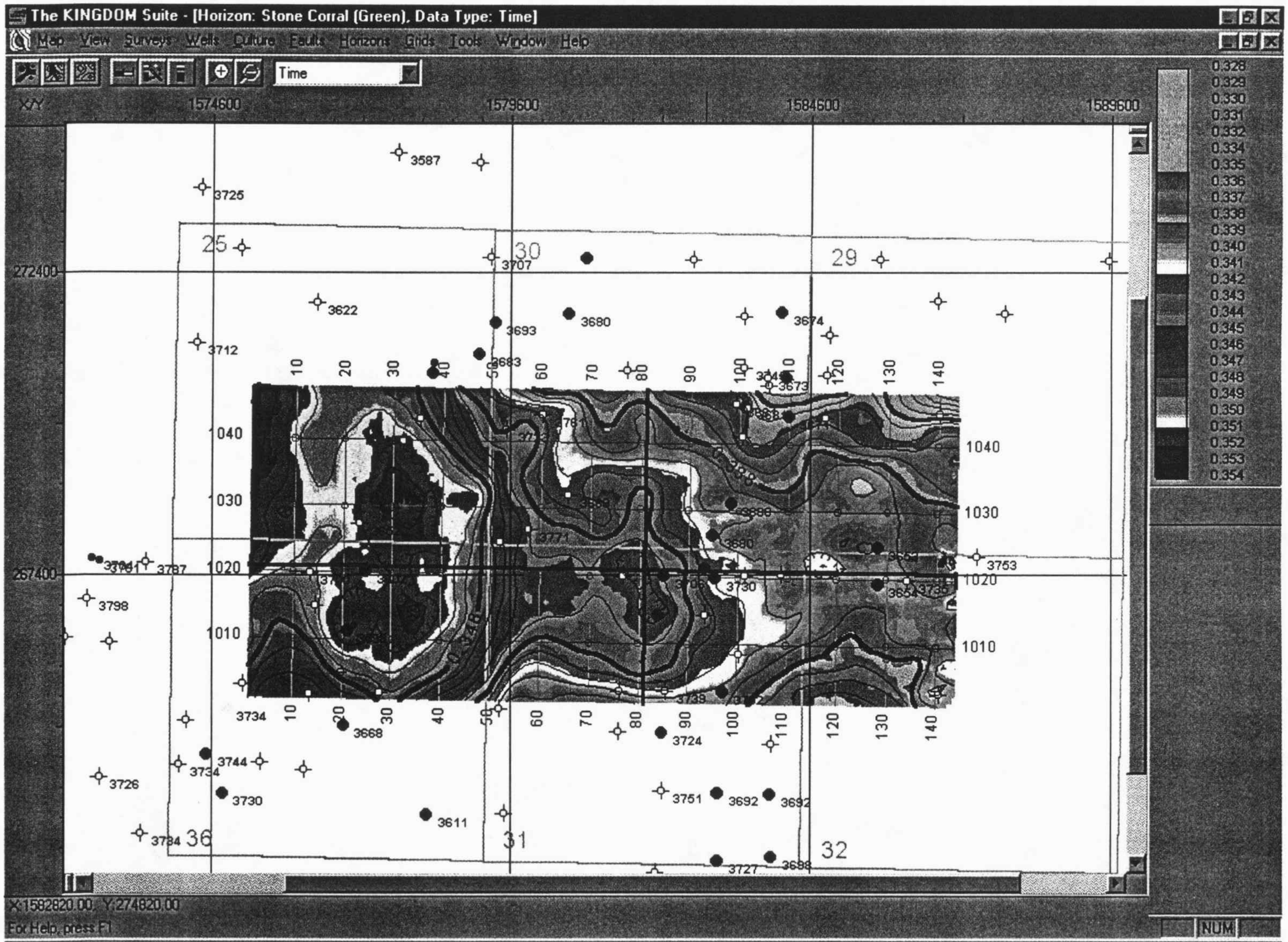
Interpretation: Make a Contour Map

- Generate a time structure contour map
- Selecting Map and Select.
  - Select the Stone Corral horizon, and data type (Time). Click on OK.
- To display contours select Map and Select Contour Overlay.
- To change contour line parameters, go to View and Contour Parameters.
  - Change parameters to see the effect.

Make Time Contour Map



The Result - Time Structure Contour



Workshop Project 4.0

- Pick Stone Corral Horizon or some other Strong Reflector
- Make Time Structure Map

Interpretation of Faults, Horizon Picking, and Basic Maps Using KINGDOM 2d3d PAK

NOTE.- Left clicking the mouse is used to start, continue and end an activity. Right clicking is ONLY used for displaying the pop-up menu.

*To begin the exercise launch 2d/3dPak. An empty project window appears. To select a project, click on **Project** in the menu bar, then click on Open. A standard windows file open dialog appears. Locate the project and open.*

1. Left click on the basemap grid to activate it. Position the cursor on line 1021. Right click and select **Display Line 1021**. The seismic line will now appear.

2. If you don't like the colorbar, left click on **View** and **Colors**. Click on **File** and **Open** and select a different colorbar. In most cases, the name of the colorbar describes the colors and the number of colors in the colorbar. For example, brwbl50.clm is a blue-white-brown colorbar with 50 colors. Close the color editor once you are satisfied with a colorbar. (You can also use the **Edit Color Bar Button** on top of the seismic view window).

3. If you're accustomed to wiggles, left click on **View** and **Type of Plot** and select **Wiggle Variable Area**. You may need to change the scale in order to display properly.

4. To change the display scales, left click on **View** and **Set Display Scale**. 10 traces/inch and 15 inches/second is a good place to start. (You can also use the **Set Scale Button** on top of the seismic view window).

5. Make sure you know which way is west. Move the cursor on the seismic window and watch the cursor movement on the map. If the direction is backwards, hit the R key on the keyboard to reverse the line display direction. My preference is to display north, northeast, east, and southeast towards the right.

6. The colorbar may or may not be displayed on the seismic window. To toggle on or off, left click on **View** and **Toolbars** and then **Color Bar**. A check indicates "on". (You can also use the **Show Color Bar Button** on top of the seismic view window).

7. Horizon picking may begin.

8. Display line 1021. Scroll until the well is visible and note the strong peak-trough-peak reflector at around .35 seconds.

9. To create a horizon, right click anywhere on the seismic line, and select **Horizon Management**. Select the Create Tab and then enter Stone Corral for the Horizon name and then select a color. Hit OK. The Stone Corral horizon is now active.

10. Display the horizon in map view by double clicking on the icon next to the Stone Corral Horizon on the Project Tree Window. Since no picks have been made, no horizon is visible.

11. Right click on a seismic line and select **Picking Parameters**. Make sure that Stop at Displayed Fault Surface Intersections is enabled. This feature, when enabled, works with the Autopick-2D Hunt mode. Picking will stop either whenever data goes away or the horizon encounters a fault surface. Click the type of event (peak, trough, zero crossing) to pick and how to pick it (manual picking, fill mode, 2d Hunt, 3d Hunt, Erase). For this exercise I would set the type of event to zero crossing negative to positive).

12. Display the Horizon Toolbar by left clicking on **View**, **Toolbars**, and **Horizon bar**. Note that the active horizon is highlighted in the toolbar. Hot keys are available: M = manual picking, F = Fill mode, H = 2d Hunt, E = Erase, P = Peak, and T = Trough. Hot keys are not available for zero crossings.

13. Note the shape of the cursor and the status bar. The cursor is now a "+" with either a E, M, F, or H next to it. Change the picking mode to either F or H, and change the phase to zero crossing negative to positive. Pick the zero crossing event at the base of the very strong trough at around 0.35 seconds as far as you can. Note that the map display is updated immediately after picking.

14. Once the inline has been picked, place the cursor on crossline 81 on the seismic display, right click and display the line. A small tick mark is visible where the two lines intersect. You will also see a vertical red line. This red line is a line overlay and can be disabled by left clicking on **View** and selecting **Line Overlays**. A check mark indicates "on". If you chose the 2d Hunt mode, left click once on the tick mark and the entire horizon segment is completed.

15. Set the Seismic line skip increment to 10 by left clicking on **Line** and **Seismic Line Skip Increment**. Increment through your data using the arrow keys and continue picking this horizon. You should end up with picked grid of lines for the Stone Corral horizon.

16. With this grid, the horizon is now ready for the autopicker. Since the horizon now consists of seed points, protect these picks by copying the horizon. Using the **Horizon Management** dialog box, select the **Copy** tab, type the new horizon name (e.g., STCRL_CPY), select the Stone Corral horizon to copy, and assign a new color. Now if the autopicker runs amok, the original picks can be restored.

17. The copied horizon will be displayed on the seismic line. Go to the **Project Tree** and find the copied horizon. Click the box in front of the copied horizon and it will be removed from the displays. Click on Stone Corral in **Horizons Tool Bar** to make the active horizon.

18. Left click on Horizons on the Menu bar and select Polygon 3D Hunt. Click **OK**. Set 3d Hunt parameters to 1 iteration and 3X3 smoothing Click **OK**. Autopicking begins immediately. Normally one giant polygon is not recommended. Instead, you can create a series of smaller polygons to constrain the 3d Hunt.

19. Examine the basemap you should have a time structure map on the Stone Corral. If you don't like the colorbar, left click on **View** and **Colors**. Click on **File** and **Open** and select a different colorbar. A selection such as Shade80.clm should give you a nice map.

20. If you don't like how 3D Hunt worked in particular area, left click on **Horizons** and select **Polygon 3D Erase**. Using your left mouse button draw a polygon around the area of the map. Finish the polygon with a double click. You will be given the option to erase your seed picks with the default set to do not erase. Hit Yes, and the polygonal area is wiped clean.

21. One the basemap select line 1021 and depressing the left button move the red line up so that it runs through your erased polygon. The appropriate line should appear. Repick the line using 2d hunt or manual. Rerun the 3D Hunt.

22. Once the map is completed, display the amplitudes. Go to the Project Tree and left click on the "+" sign next to the horizon icon. This opens the horizon showing you the additional surfaces available. Drag the amplitude icon to the map window. You will probably have a very uninteresting amplitude map (i.e., amplitude will show little variation).

23. Generate a time structure contour map by selecting **Map** and **Select**. Select the Stone Corral horizon, and data type (Time),. Click on **OK.** Change the parameters and then see what the effect is. To display the contours select **Map** and **Select Contour Overlay**. If you would like to change contour line parameters, go to **View** and **Contour Parameters**.

24. Assignment: Pick and map the base of the strong trough at around 0.60 seconds on Line 1021.

6.0 Synthetic: Time to Depth

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

KANSAS · GEOLOGICAL · SURVEY

Introduction

- What Do You Need to Tie

  Depth-Based Geologic Data from Wells to

  Time-Based Seismic Data ???
- Time-Depth Chart
- Velocity Function

  Depth = Velocity * Time

Methods

- Stacking Velocity
- Velocity Surveys
  - Check Shots
  - Vertical Seismic Profiles (VSP)
- Synthetic Seismograms

Stacking Velocities

- Essential in Frontier Areas
- Poorest Time-Depth Control
    - Limited Offsets
    - Information Loss Due to Processing

Velocity Surveys

- Best Velocity Control
- Checkshot
  - Uses First Breaks (First Reception of the Shot)
  - Compression Wave Time vs. Depth
- Vertical Seismic Profile (VSP)
  - Analyses the Full Sonic Waveform

Synthetic Seismograms

- Derived Solely From Well Data

  Usually Sonic and Density Logs

  - Visual Matching of Seismic and Synthetic to Identify Reflectors
  - Displays Expected Waveform and Amplitude Reflection Character
  - Can be Modified to Examine Possible Scenarios

Synthetic Seismograms

- **Negatives**

  No Absolute Time to Depth Equivalence

  May be a Poor Match to Seismic Data

Creating a Synthetic - 1

- Trying to Simulate Seismic Data using
  - P-Wave Acoustic Velocity at Wellbore
    - Sonic
  - Bulk Density at Wellbore
    - Bulk Density Drho
  - Correlation Log as Needed
- Acoustic Impedance
- Reflection Coefficient
- Convolution with Source Waveform

Creating a Synthetic - 2

- Run A Range of Frequency Filters
  - Bracket the Actual Frequency of Data at Target Depth
  - Compare to Seismic Data to Select Best Frequency Filter
- Apply AGC If Seismic Data has AGC
- Vary Phase
  - 0^0, 90^0, 180^0, 270^0 and minimum
  - Compare and Select

Creating a Synthetic - 3

- Select Source Waveform
  - Ormsby, O'Brien, Klauder, Butterworth, Minimum Phase, Gaussian, or Ricker
- Tie Data and Synthetic
  - Be Aware of Difference in Datums
  - Stretch or Squeeze Data

The Synthetic Won't Tie - 1

- Sampling Problem
  - Wellbore (Meter) Vs. Seismic (10's to 100's Meters)
- Inadequate Measurements at Wellbore
  - Wash-Outs in the Wellbore
  - Cycle-Skips
    - A Little Log Editing Can Really Help
  - Anisotropic Formations
  - Dispersion Effects
    - Sonic at Kilohertz Frequencies
    - Seismic 120 Hz +/-

The Synthetic Won't Tie - 2

- The Wiggles Look Different
  - Adjust Frequency and Phase
  - Filters
- Extra Reflections on Seismic Data
  - Multiples
  - You can Turn Multiples on in Synthetic
- Wiggles Are a Lot Stronger on Seismic Data
  - AGC
  - Could be an Amplitude Vs Offset Effect (AVO)

Synthetics: The Real-World -1

- Should Have Sonic and Density
  - But We Often Do Not
  - **WHAT SHOULD YOU DO!**
- No Density or Incomplete Density
  - Assume A Constant Density
    - Time Relationships Between Horizons Accurate
    - Amplitude Will Not Necessarily Be Accurate
      - Impedance (Velocity * Density)
  - Generate Density from Sonic
    - Gardner's Equation

Synthetics: The Real-World - 2

- Statistical Relationships Between
  - Velocity, Density and Resistivity
  - Can Be Checked in Area with Crossplots
- Density Can Be Used to Make A Sonic
  - Inverse Gardner Equation
- Drho (Bulk Density) can be Generated From Density Porosity if you Know the Mud Type
- Resistivity Can Be Used To Make A Sonic
  - Faust's Equation, Cline's Equation

Synthetic Seismogram: Software

- Demo software is available from a number of companies.
- This problem set uses SynPAK from Seismic Micro-Technologies, Inc.
- Demo/Evaluation software used in this problem set is available at: http://seismicmicro.com/

Acknowledgement Seismic Micro-Technology SEISMIC
provided access to software

Ellis County

- Downloaded file is an archive created with PKZIP, and needs to be unzipped.
- Obtain Well Logs
    - Use Search for Digital LAS Logs at: http://magellan.kgs.ukans.edu/Logs/index.html
    - Search on T11S R20W or Star West
    - 15-051-24970 Murfin Drlg. Rusco C1
- Stratigraphic Tops
    - Stone Corral 1452’, Topeka 2975’, Heebner Shale 3262’, Toronto 3280’, LGKC 3294, Arbuckle 3598’

Ellis County: Log Search

Kansas Geological Survey | Oil and Gas | Digital Wireline Logs

Search for LAS Files Available for Kansas

Use this form to search the KGS index of wireline logs available as LAS format files. **Not all digital logs available from the KGS have been placed in this system (early February, 1999)**. In particular, the Digital Petroleum Atlas contains logs that have not yet been transferred.

Approximately 2,393 logs are in the database (May 11, 1999). For a listing of paper wireline logs stored at the Kansas Geological Survey, please see the Wireline Log Header Database.

In Kansas, Township values vary from 1 in the north to 35 in the south, and the values for Range are from 1-43 West and 1-25 East. Values for Section are 1 to 36.

Select Data to View		
Choose a county: Allen Anderson Atchison Barber Barton Bourbon Select by County	Township: 11 Range: 20 East: ○ or West: ⊙ Section (optional): 36 Select by T-R-S	Enter a field name: Star West Select by Field

Kansas Geological Survey
Comments to webadmin@kgs.ukans.edu
Program Updated March 17, 1999
Logs added periodically.
URL = http://magellan.kgs.ukans.edu/Logs/index.html

Ellis County: Log Search Results

Kansas LAS files--T29S, R41W

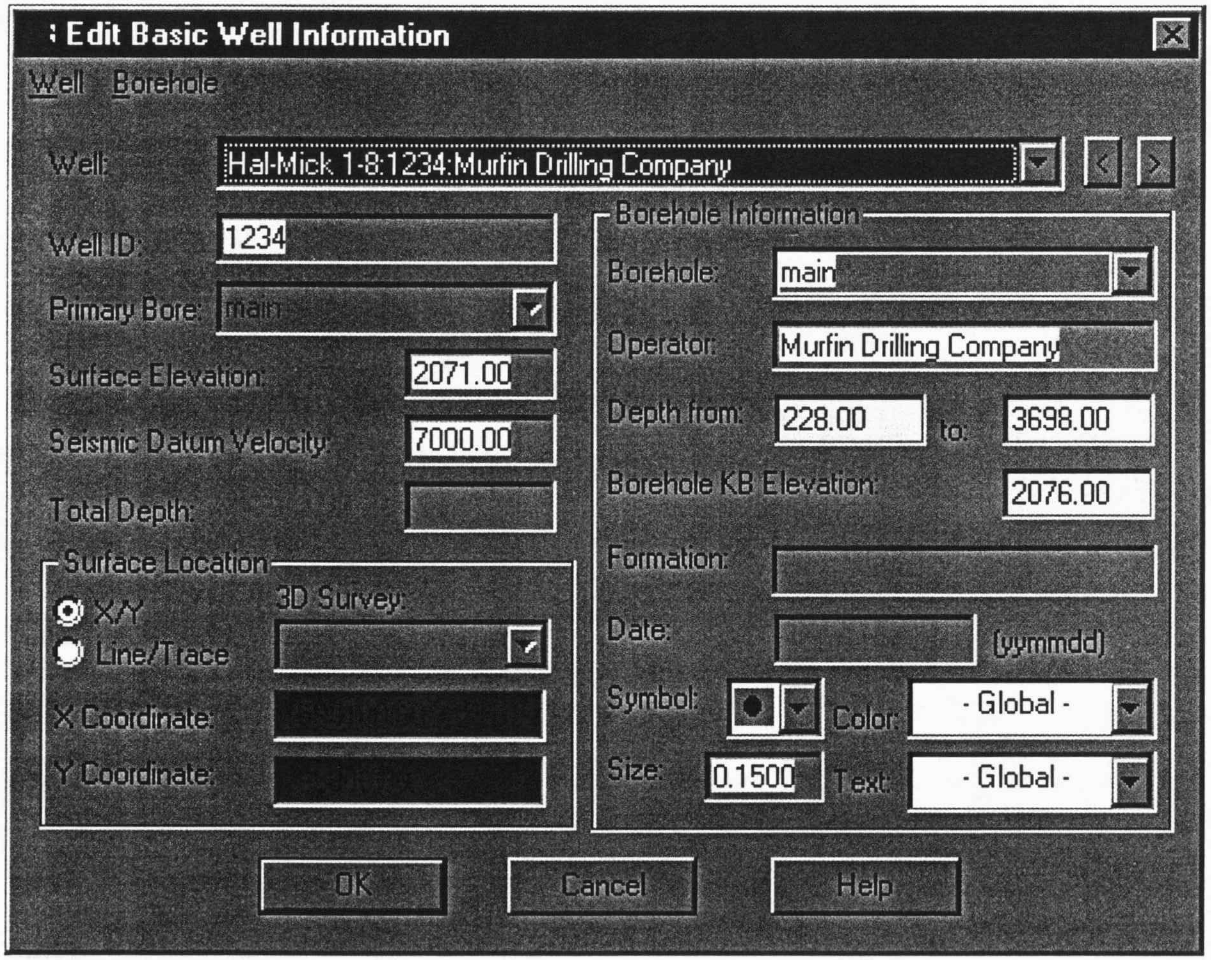
---

5 records returned.

API: 15-187-20636 **Operator:** J.M. HUBER **Service Company:** **Field:** Arroyo **Well:** PRO FARMS 26-1, Well PRO FARMS 26-1 **County:** Stanton **Location:** T29S R41W, Sec. 26, **Formation:** **Total Depth:** 5900 **Spud Date:** **Completion Date:** 02-JUN-92	Download this log The file you download is an LAS file compressed into a ZIP archive. Your browser may be already set up to decompress these files. Commercial software to perform this is available from PKWARE, Inc., the company that invented the format. A web page from a group of people creating shareware or public domain software is available at Info-ZIP.
API: 15-187-20639 **Operator:** J. M. HUBER **Service Company:** **Field:** Arroyo **Well:** KENDRICK 22-1, Well KENDRICK 22-1 **County:** Stanton **Location:** T29S R41W, Sec. 22, **Formation:** **Total Depth:** 5850 **Spud Date:** **Completion Date:** 19-JUL-92	Download this log The file you download is an LAS file compressed into a ZIP archive. Your browser may be already set up to decompress these files. Commercial software to perform this is available from PKWARE, Inc., the company that invented the format. A web page from a group of people creating shareware or public domain software is available at Info-ZIP.
API: 15-187-20650 **Operator:** J. M. HUBER	Download this log

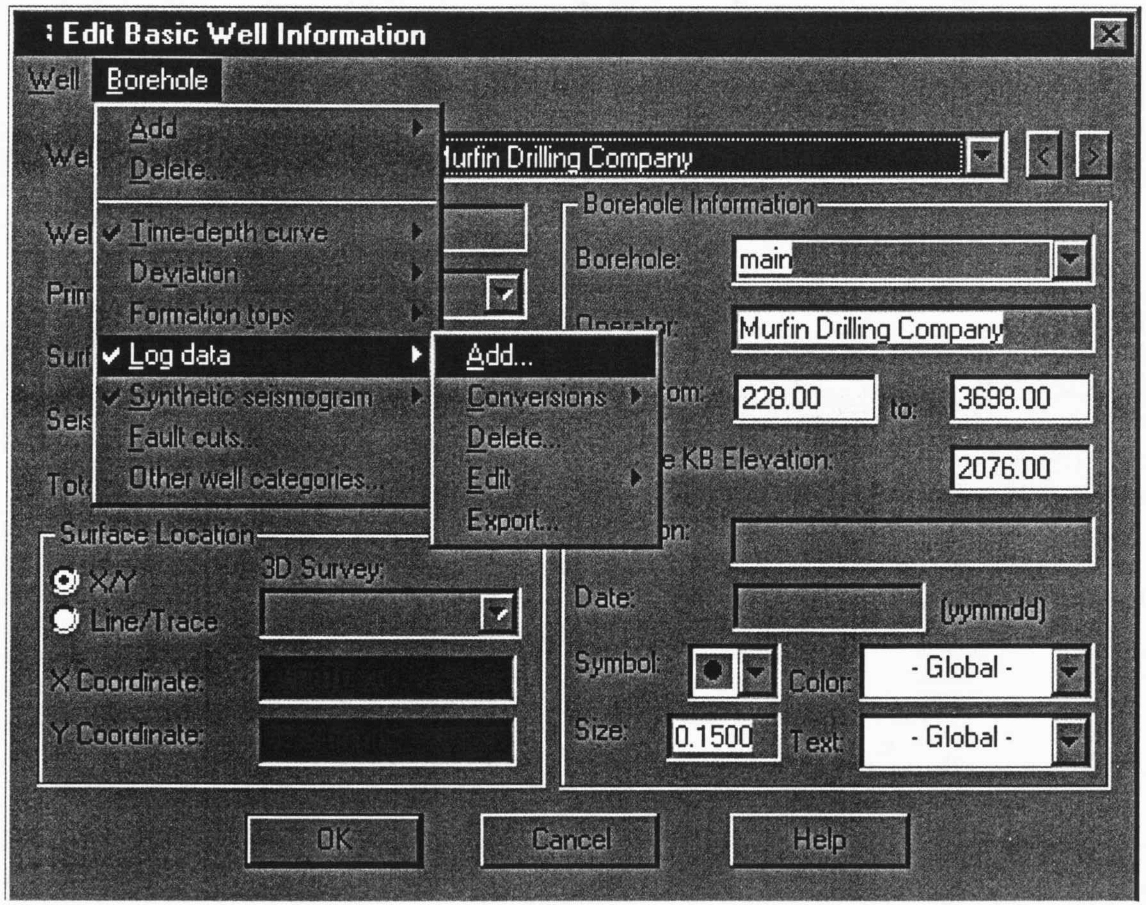
Generate a Synthetic - 1

- Select or Create Well



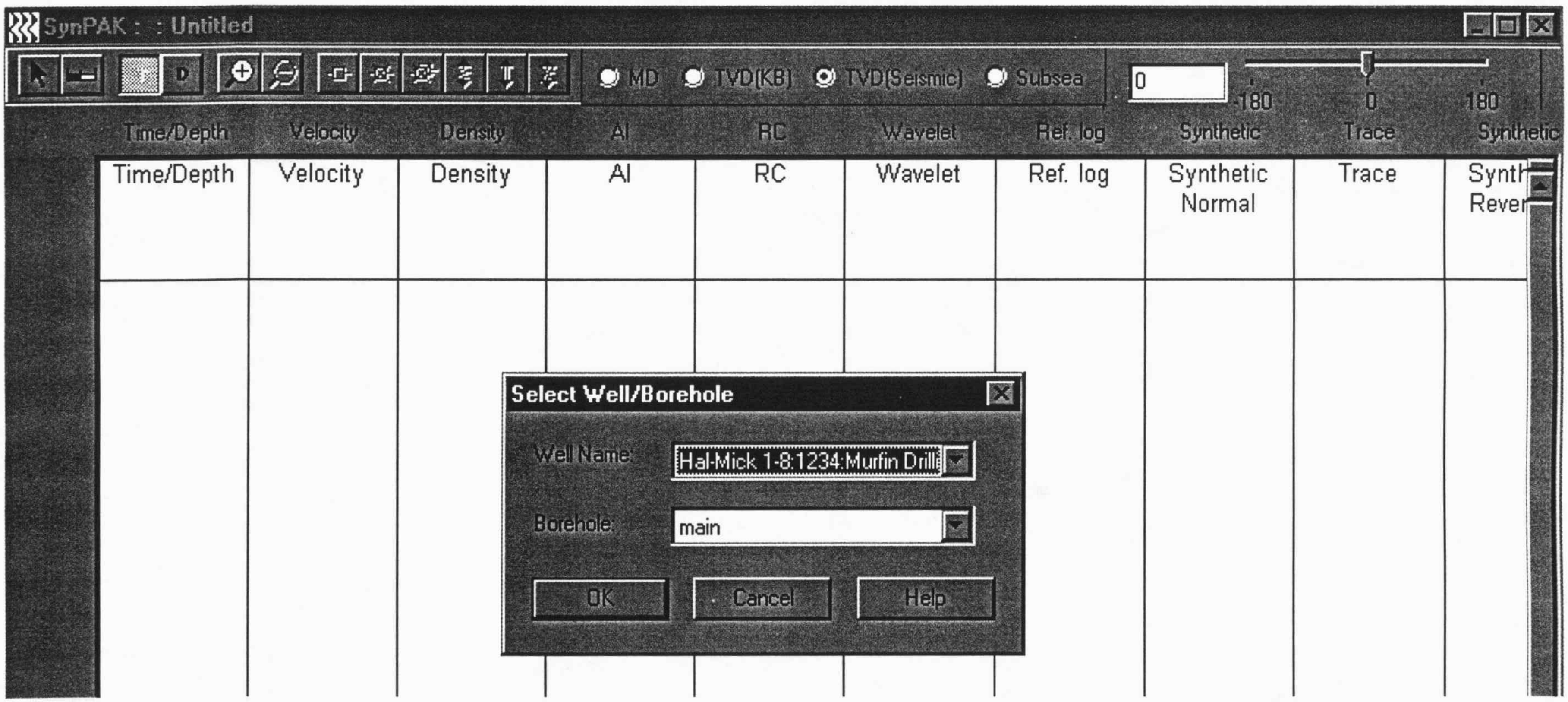
Generate a Synthetic - 2

- Add Well-Log Data



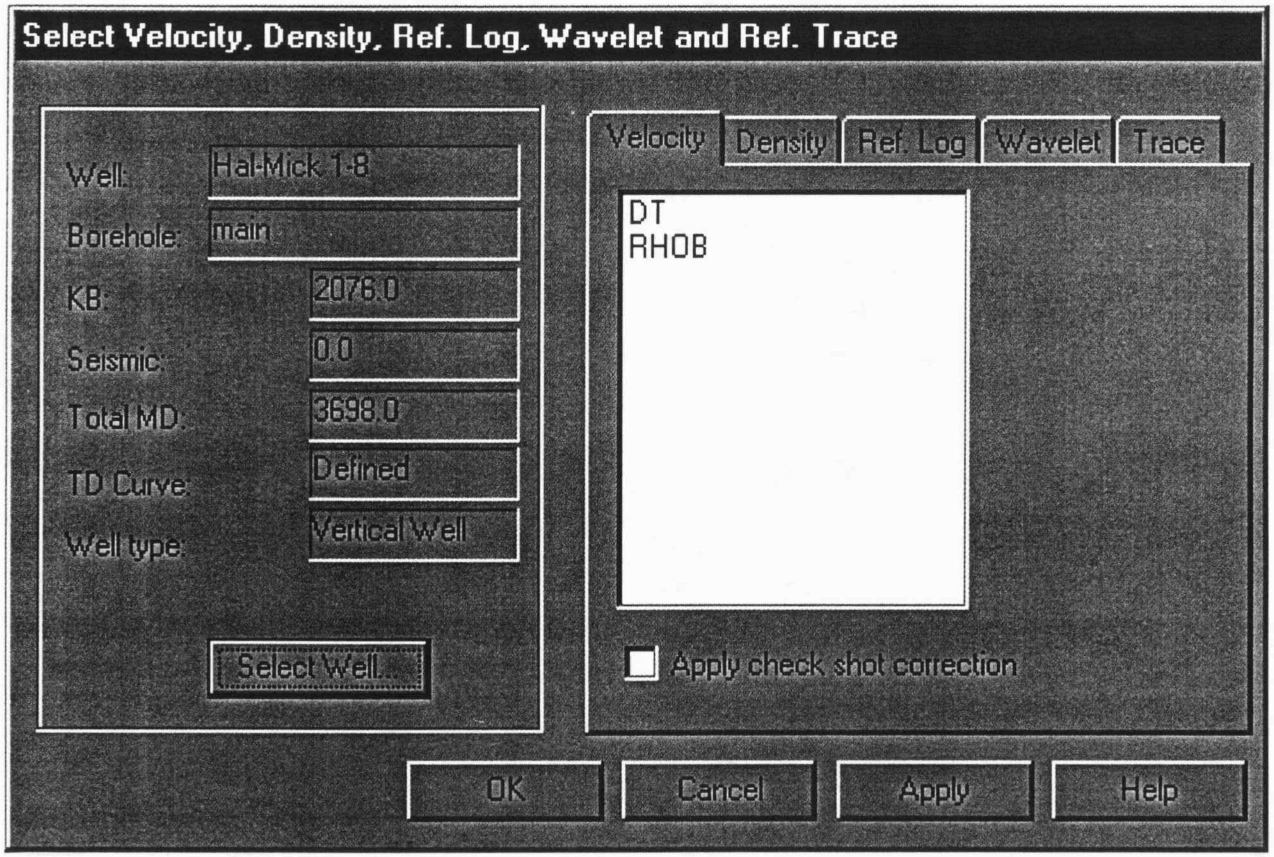
Generate a Synthetic - 3

- Wells / Generate Synthetic



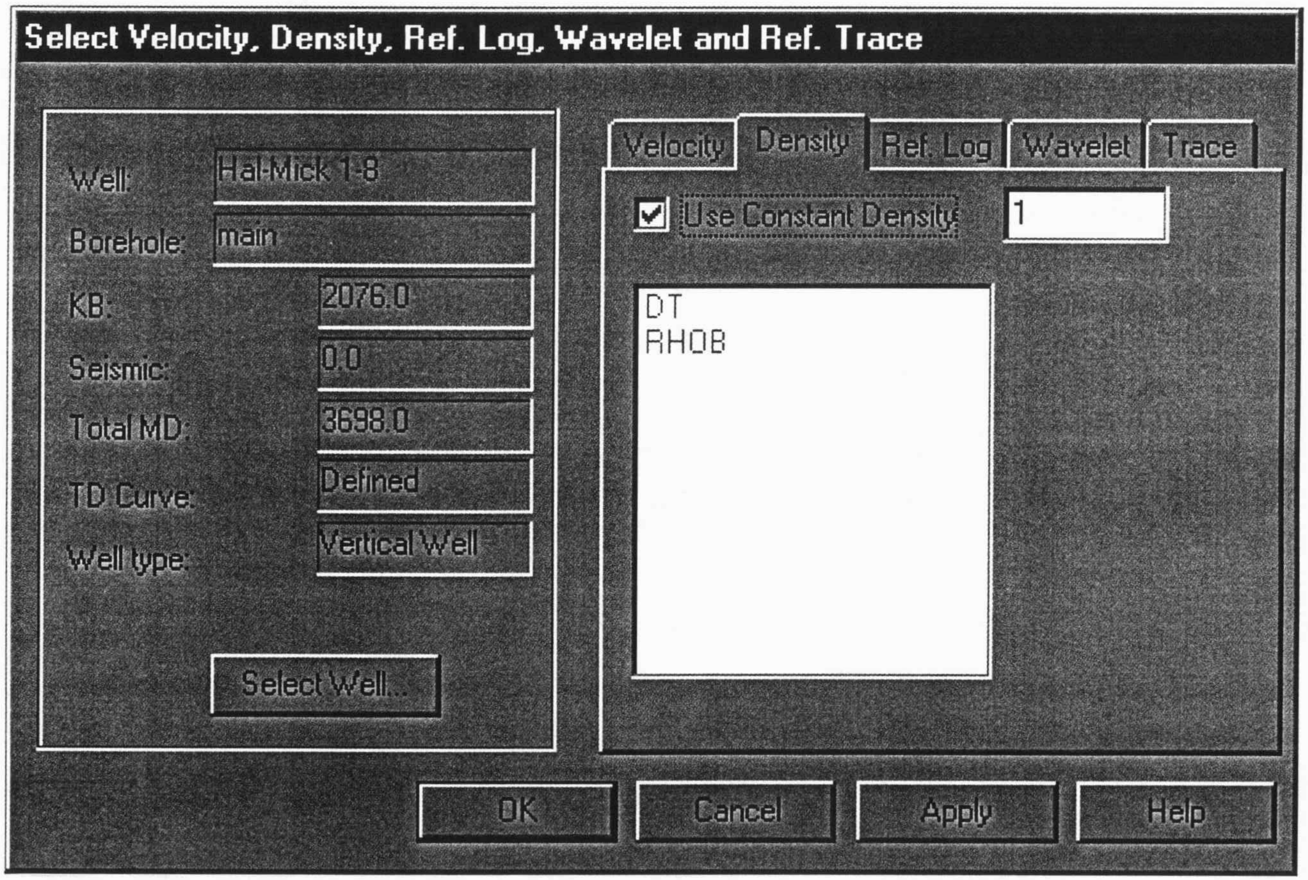
Generate a Synthetic - 4

- Select Velocity Log (DT)



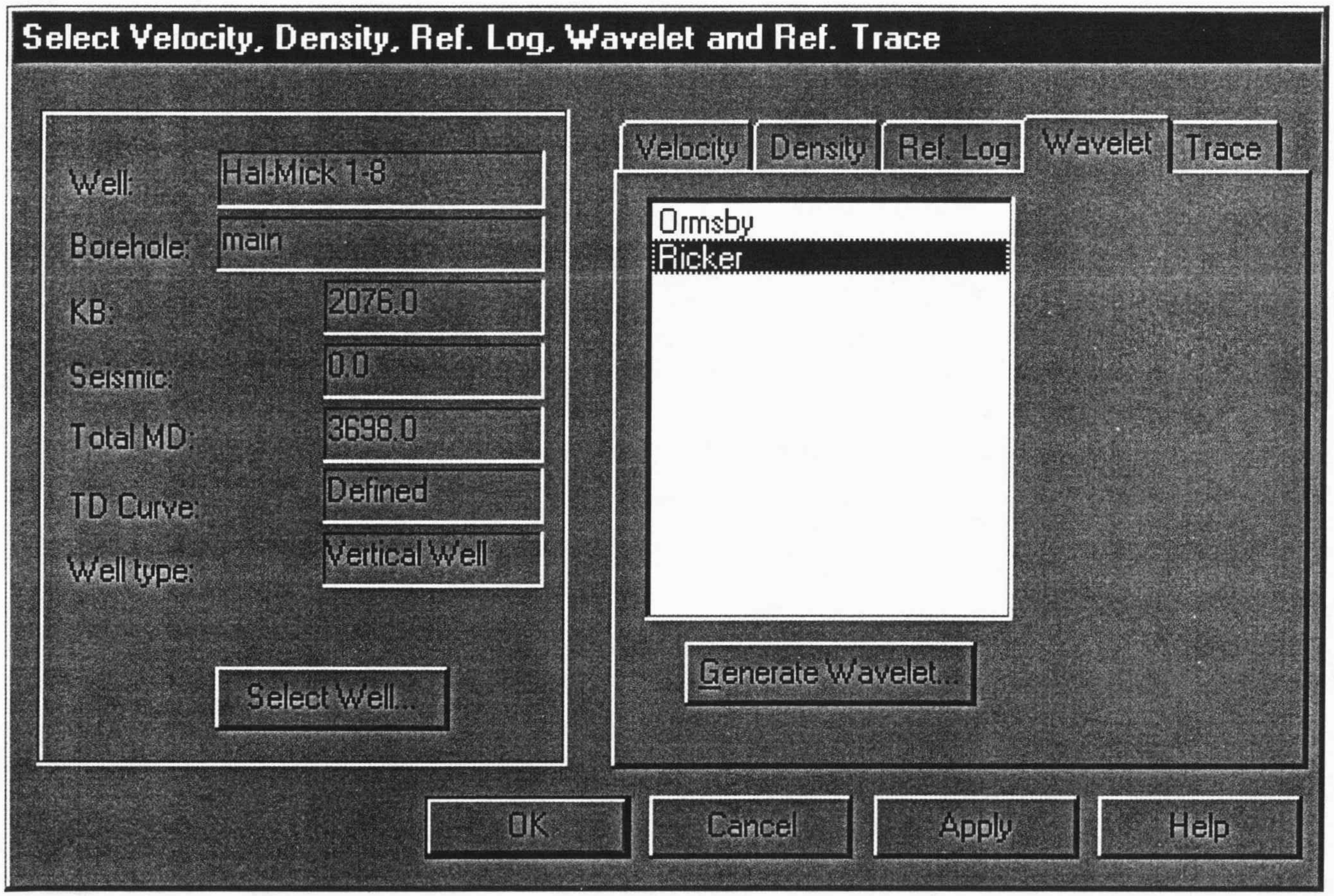
Generate a Synthetic - 5

- Select Function - Use Constant or Log



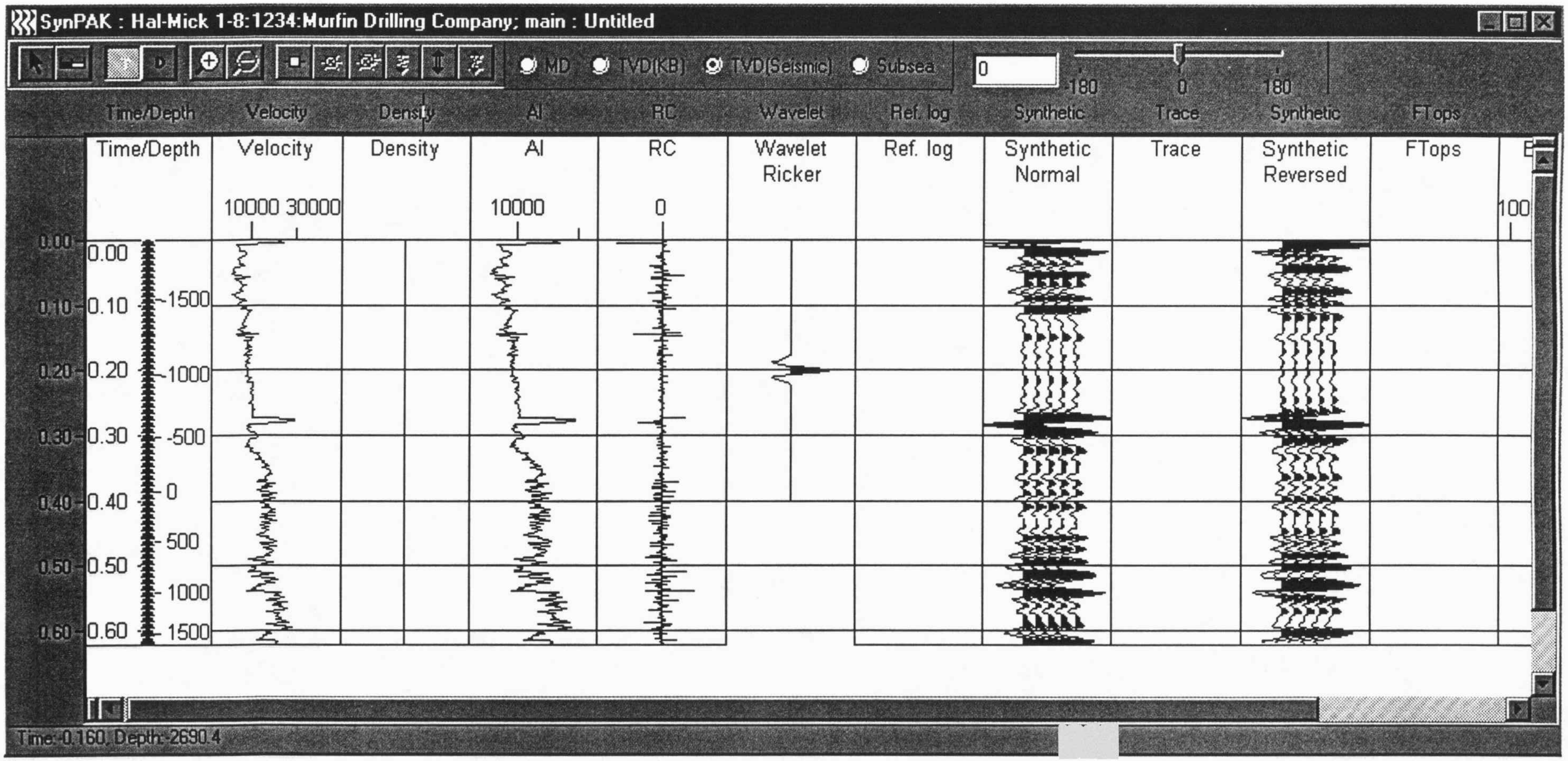
Generate a Synthetic - 6

- Select Wavelet - Use Generate Wavelet



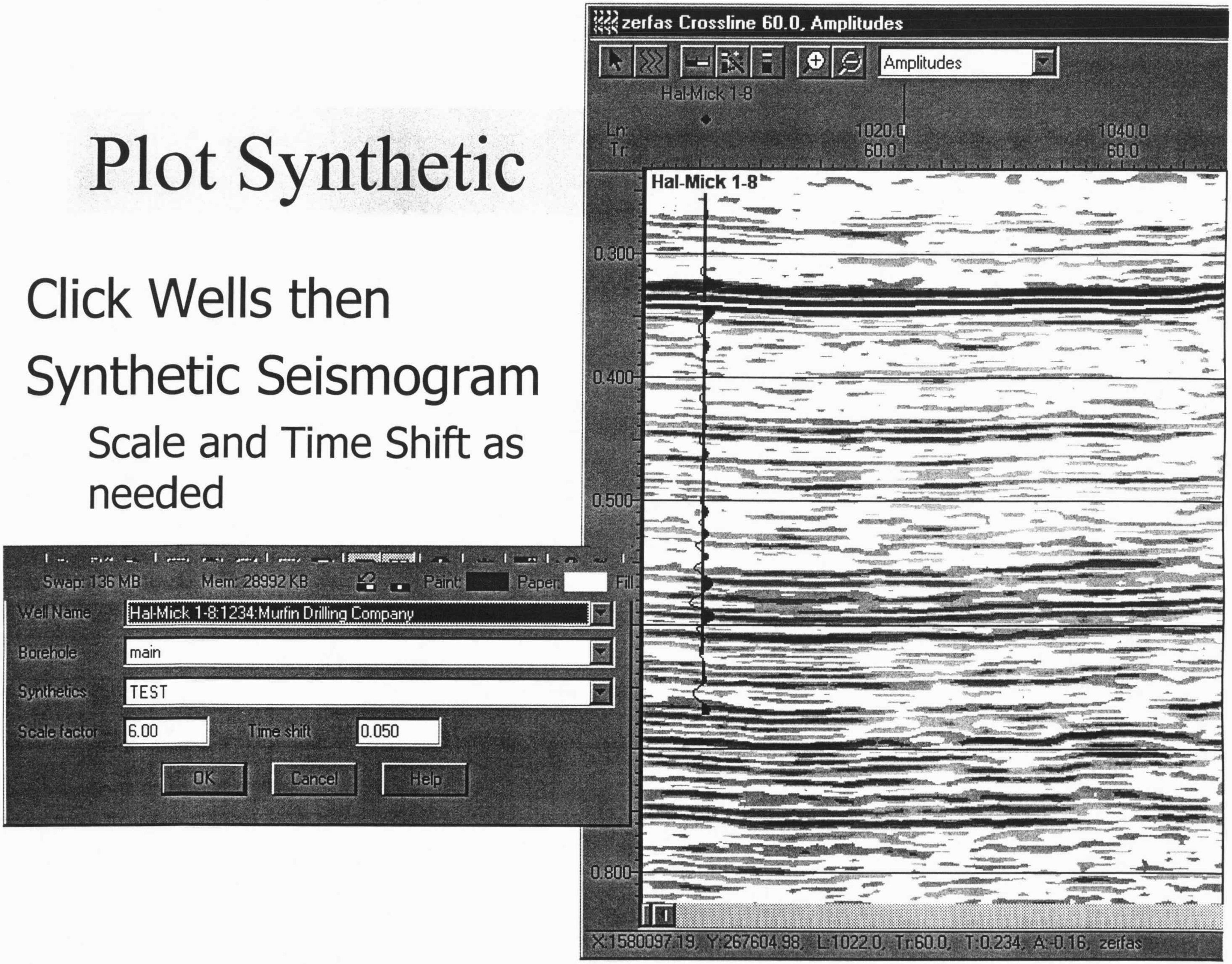
Generate a Synthetic - 7

- Click OK -- The Result



Plot Synthetic

- Click Wells then
- Synthetic Seismogram
  - Scale and Time Shift as needed



Workshop Project 5.0

- Make A Synthetic
  - Rusco 1-C
- Plot Synthetic on Seismic Line

Linking Geophysical and Geologic Data: The Synthetic

A major obstacle to accurate seismic interpretation is linking depth-based geologic data from wellbores to time-based seismic data. Tying seismic data to known geologic constraints is a critical step to success in locating the target zone or deriving a valid understanding of the subsurface geology. What is required, is an accurate velocity model from either a time-depth chart or a velocity function (Depth = Velocity * Time). Velocity models can be developed from:

Stacking (NMO) Velocities
Vertical Seismic Profiles (VSP)
Synthetic Seismograms (Synthetic)

Velocity Models

Stacking velocities are calculated from normal-moveout (NMO) assuming an earth model (i.e., usually a set of flat lying reflecting homogenous beds). Stacking velocities provide only a general solution for velocity, and result on relatively inaccurate time-depth control. The limited offsets of seismic data in the real world coupled with artifacts introduced in processing result in only an approximate velocity that is equal to or greater than true average velocity. However, stacking velocities are critical in the absence of well data (i.e., frontier plays).

Vertical Seismic Profiles (VSP) or **Velocity Surveys** (checkshot) give the most accurate velocity control. Both techniques usually use a seismic source at the surface and downhole geophones. The checkshot uses the first arrival of energy ("first breaks") at a geophone placed at selected locations in a wellbore, while the VSP uses the sonic waveform analyzed over an array of closely spaced geophone locations. Given that the depth of the well geophone is accurately known and the corresponding reflection time can be measured reliable time-depth relationships can be established. In a conventional zero-offset VSP the source is near the wellhead so that the geophone receives nearly vertical downgoing energy directly from the source and upgoing energy reflected from below. Travel paths for the seismic energy are nearly vertical. In an offset VSP, the surface source is located an appreciable horizontal distance from the receiver. The offset VSP can obtain reflection points from a region away from the borehole as the depths of the geophones are changed. An ffset VSP can provide local high resolution coverage of small faults and stratigraphic changes away from the borehole. A reverse VSP involves downhole source and surface geophones. Recent advances in reverse VSP's have used the vibrations of the drill bit and measurement while drilling.

Synthetic Seismograms (usually just referred to as a synthetic) is simulated seismic data obtained for a particular geologic model with an assumed sonic wavelet. The models are usually based on well log information, since the unknown physical properties of the subsurface geology beneath a seismic survey are known properties at the wellbore. A synthetic seismogram can be used to correlate the geologic information from well logs with seismic data. Whereas seismic data only directly provides time values, synthetics provide time and depth values. The synthetic can be used to correlate geologic horizons observed in the well bore to reflection events observed in seismic records.

A seismic compressional wave (P-wave) generated at a source travels at the acoustic velocity of the rock, which varies with lithology, and porosity. The wave bounces (reflected) off surfaces (e.g., bedding planes, faults, etc) that separate rock units across which the velocity and density varies. The contrast in velocity and density across surfaces determines the reflectivity usually expressed as the reflection coefficient (RC). The reflection coefficient is expressed in terms of velocities (V) and densities (ρ) across two mediums as

$$RC = (\rho_2 V_2 - \rho_1 V_1) / (\rho_2 V_2 + \rho_1 V_1)$$

Using the sonic velocity and density data from well logs to create a sonic-derived velocity field and the sonic and density-derived reflection series and assuming a source wave similar to the seismic data results in a synthetic seismic trace. The resulting 1D seismic model can be compared to the seismic data. The waveform and amplitude of the synthetic can visually matched to the seismic data to identify reflectors. The reflection character can be modified to examine possible scenarios.

A suggested process for generating synthetics and applying them to the interpretation is:

1) Input sonic and density logs and other log curves as required. Make sure to examine and if necessary edit curve data for spikes, cycle skips and other artifacts introduced by bad hole conditions, scale changes or tool problems. If necessary generate artificial velocity or density curves from other log data. In addition density may be set to a constant value (e.g., 1).
2) Select the source waveform and representative frequency by calculating a series of wavelets with a range of frequencies and wavelets. Use high frequencies to show the best possible resolution of events and gradually decrease the frequency to bracket the frequency of the data at the target depth. Either extract a wavelet from the seismic data or select from available theoretical waveforms (e.g., Ricker, Gausian, Butterworth, and Ormsby).
3) Run through a range of phases from zero, 90 180 (reversed), 270 and minimum phase. Most processed data will use a zero-phase wavelet because of modern seismic processing parameters. However airgun and dynamite data is likely to be minimum phase.
4) Shift synthetic and seismic data to tie major reflectors. Do not expect a one-to-one tie in time since log curves usually do not start at the surface and the seismic data can have various datums. A shift of several hundred milliseconds is normal. You can assume a reasonable velocity for the missing section from the surface to the top of the synthetic and calculate the travel time to see if the shift is reasonable.
5) Stretch and squeeze the data as needed to better fit the seismic data.

The drawbacks of synthetic seismograms are that time to depth equivalence is not absolute, and the synthetic may be a poor match to the seismic data. A synthetic may not match the seismic data for a variety of reasons. These reasons include:

1) Sampling. The synthetic is generated from wellbore data with resolution of a meter or less. Seismic traces depending on the wavelength at the target depth.
2) Another sampling problem is introduced by dispersion effect introduced by the different frequencies of sonic logs and seismic data. Sonic logs are at kilohertz frequencies while seismic data uses frequencies in the range of 120 Hz (+/-).
3) Problems and inadequacies of the log measurements as a result of washouts in the wellbore or cycle skips.
4) The rock units away from the wellbore exhibit facies changes (i.e. the units are anisotropic). There are dispersion effects.
5) There may be multiples in the seismic data. In many computer programs for generating synthetics, you can introduce (or suppress) multiples.
6) The seismic data may have automatic gain control (AGC). Again computer programs can usually apply AGC to the synthetic trace. This could also be amplitude versus offset (AVO) effect that should be investigated.

To generate a synthetic one should have both sonic and density logs. However, in a given well one is normally missing one or both of the logs at least over part of the length of the well. If the density is missing one can assume a constant density (e.g., 1). In this case the time relationships between horizons should be accurate, but the amplitude of various horizons may not be accurate. The sonic and density are related by Gardner's equation (Density in g/cc = 0.31 * Velocity in $ft/s^{0.25}$) which can used to generate one from the other. There are empirical and statistical relationships among velocity, density and resistivity that can be used to generate missing curve data. Resistivity can be used to generate a sonic using Cline's conversion formula (Velocity = 2000 * Depth ** 0.1677 * Resistivity ** 0.1667). The relationships among the proxy logs and the pseudo-velocity or pseudo density can be checked by cross plotting other wells in the area with more complete log suites.

Generating a Synthetic

A simple synthetic for a small number of reflectors can be generated by hand. However, for all serious work using wellogs and seismic data with numerous reflectors, computer packages are available for rapid generation of complex synthetic seismograms. Most computer programs that generate a synthetic require a time-depth curve and a sonic or velocity log. In addition, a density log is preferred to accurately reflect the amplitude of each horizon. However, adequate results reflecting the time relationships between horizons can be obtained from either a computed density (from sonic or resistivity), or density set to a constant value (e.g., 1).

The following problem set generates a synthetic using SynPAK from Seismic Micro-Technology, Inc. It requires the user to have access to a program to generate a synthetic seismogram and a digital well log. An evaluation copy of SynPak can be obtained from

Seismic Micro-Technology, Inc. at http://seismicmicro.com. The digital well log used in this example is available from the Kansas Geological Survey at http://magellan.kgs.ukans.edu/Logs/index.html. The well is the Murfin Drilling Rusco 1C (36-T11S-R20W) located in Star West Field of Ellis County. The log for the well includes a sonic, density porosity, resistivity and gamma-ray curves. You can locate the log by searching on S-T-R or by field. In the case of the Rusco 1C the density (Rhob) is not available, but could be derived from density porosity using the standard porosity equation

$$\phi_{den} = (\rho_{ma}-\rho_b) / (\rho_{ma}-\rho_f)$$

where:

ϕ_{den} = density derived porosity

ρ_{ma} = matrix density (2.710 gm/cc for limestone)

ρ_b = formation bulk density (RhoB)

ρ_f = density of fluid in borehole (1.1 salt mud, 1.0 fresh mud, and 0.7 gas)

In this example we will not concern ourselves with the density log, but will set density to a constant equal to 1.

The initial step is to associate the log data (Rusco 1C) with the well in the seismic project. Select the well, then under **Borehole**[1] select **Log Data – Add**. Browse and locate the LAS file for the Rusco 1C. **Select Wells - Generate Synthetic** and then from the pull down menu select the Rusco 1C.

The main SynPAK synthetic window contains eleven displays (Figure S.1) that include:

1) Time/Depth;
2) Velocity;
3) Density;
4) Acoustic Impedance (AI);
5) Reflection Coefficient (RC);
6) Wavelet;
7) Reference Log (e.g., gamma ray);
8) Synthetic Normal;
9) Trace;
10) Synthetic Reversed; and
11) Formation Tops.

When you click on **OK** a dialog appears with a series of tabs to Select Velocity, Density, Reference Log, Wavelet and Trace (Figure S.2). The dialog also contains selected well information (e.g., Well, KB, and TD).

[1] Words in underlined bold correspond to commands, menus or pull-down options in SynPAK.

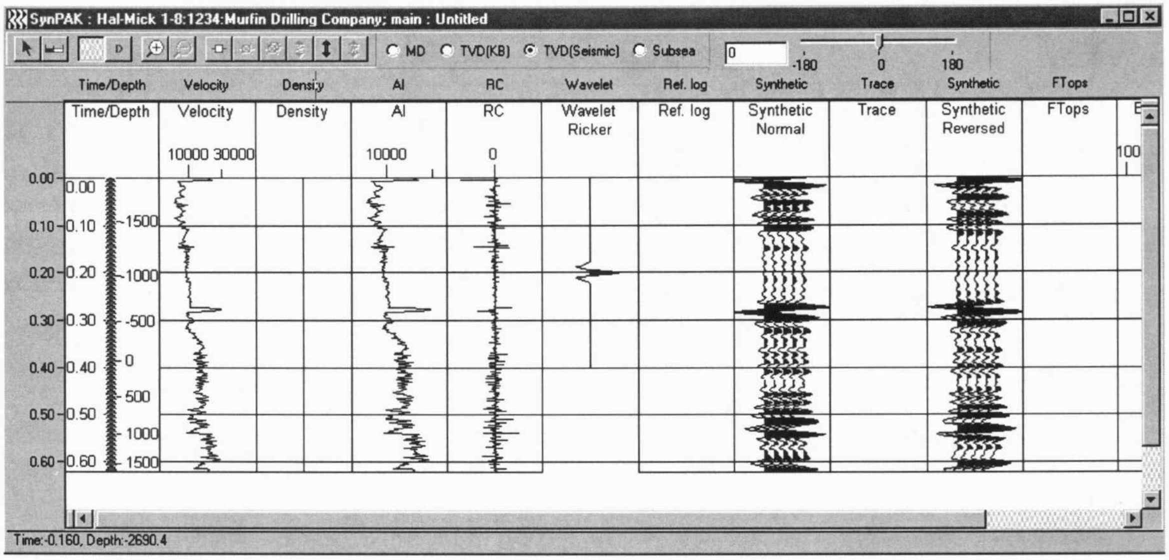


Figure S.1 The main SynPAK window showing the results of a synthetic generated for the Hall-Mick 1-8 (Ellis County, Kansas). Digital well log is available from the Kansas Geological Survey web server at http://magellan.kgs.ukans.edu/Logs/index.html.

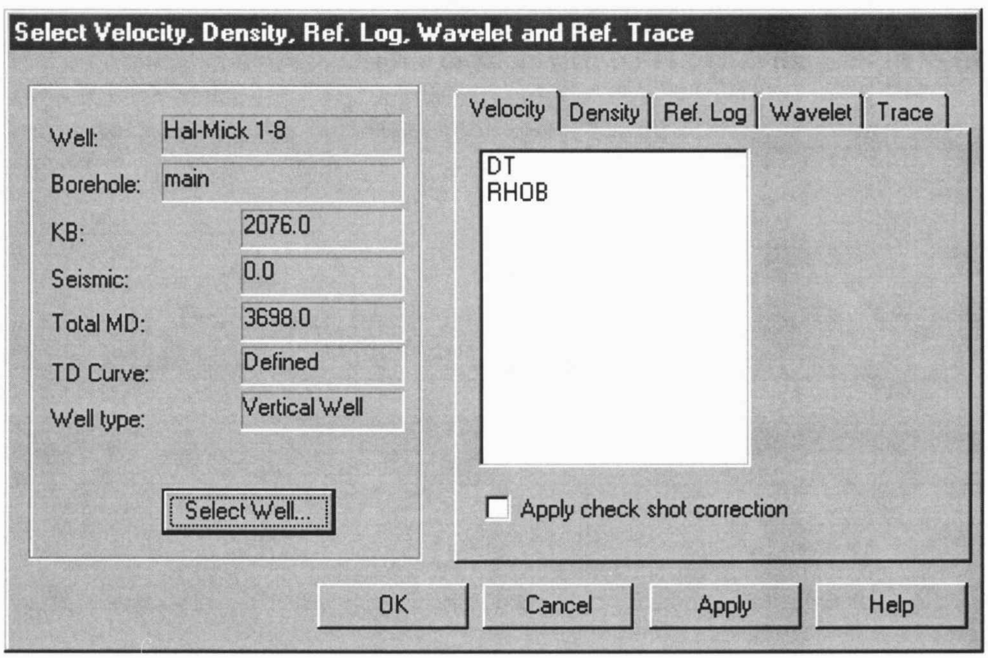


Figure S.2 Tab sections to specify data to be used for synthetic.

In the dialog box, data choices are automatically brought into the appropriate data windows. The five tabs are:

> **Velocity Tab** for selection of the velocity log (DT in this examole);
> **Density Tab** for selection of a density log or to set the density to a constant value (In this example set Use Constant Density to 1);
> **Ref. Log Tab** to select a reference log to be included in the synthetic panel (Not used in this example);
> **Wavelet Tab** to choose a wavelet that has been previously saved or to generate a new wavelet. If a new wavelet is generated a Wavelet wizard appears that permits the selection of theoretical wavelets or the extraction of a wavelet from the seismic data around the well (In this example generate a Ricker Wavelet);
> **Trace Tab** to select a previously saved trace or to extract a trace from the seismic data around the well (Not used in this example).

Click on **OK** and a synthetic should appear. Use **Save Synthetic** to specify the synthetic name and color for the synthetic trace that will be overlain on the seismic line. To plot the synthetic on a seismic line, **Select** a line passing through the well. Click on **Wells** then **Synthetic Seismogram**. Use pull down menus to select **Well Name** and **Synthetic** (Figure S.3). Use the scale factor to gain the synthetic. Time shift in seconds is used to move the synthetic up and down in time to better match the seismic data (A negative time will shift the synthetic up a positive time will shift the synthetic down). The synthetic will appear on the seismic line (Figure S.4).

There are a large number of additional options that can be used to modify and improve the synthetic. Some of the major options include stretching or squeezing all or portions of the synthetic; generating density and velocity logs using empirical equations or statistical correlation; editing logs; shaping wavelets; and adding tops. The synthetic can be printed using presentation quality graphics. The interested individual is reffered to documentation for the SynPak Modeule available from Seismic Micro-Technology at http://seismicmicro.com.

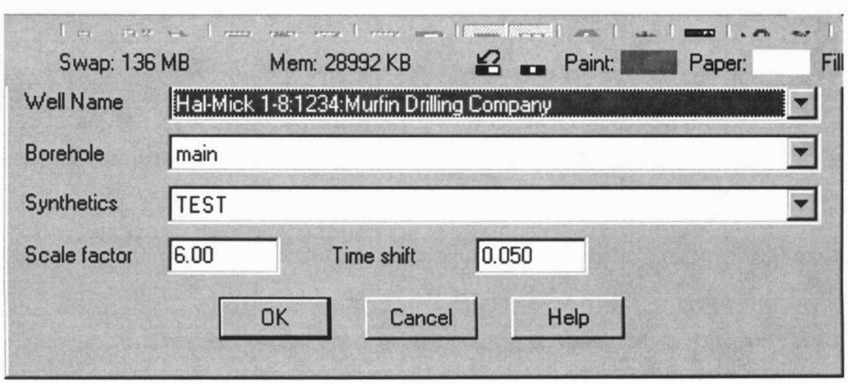


Figure S.3 Dialog to select well and synthetic to plot on seismic data. The scale factor can be used to increase the amplitude of the synthetic. Time shift moves the well up (negative) and down (positive) in seconds.

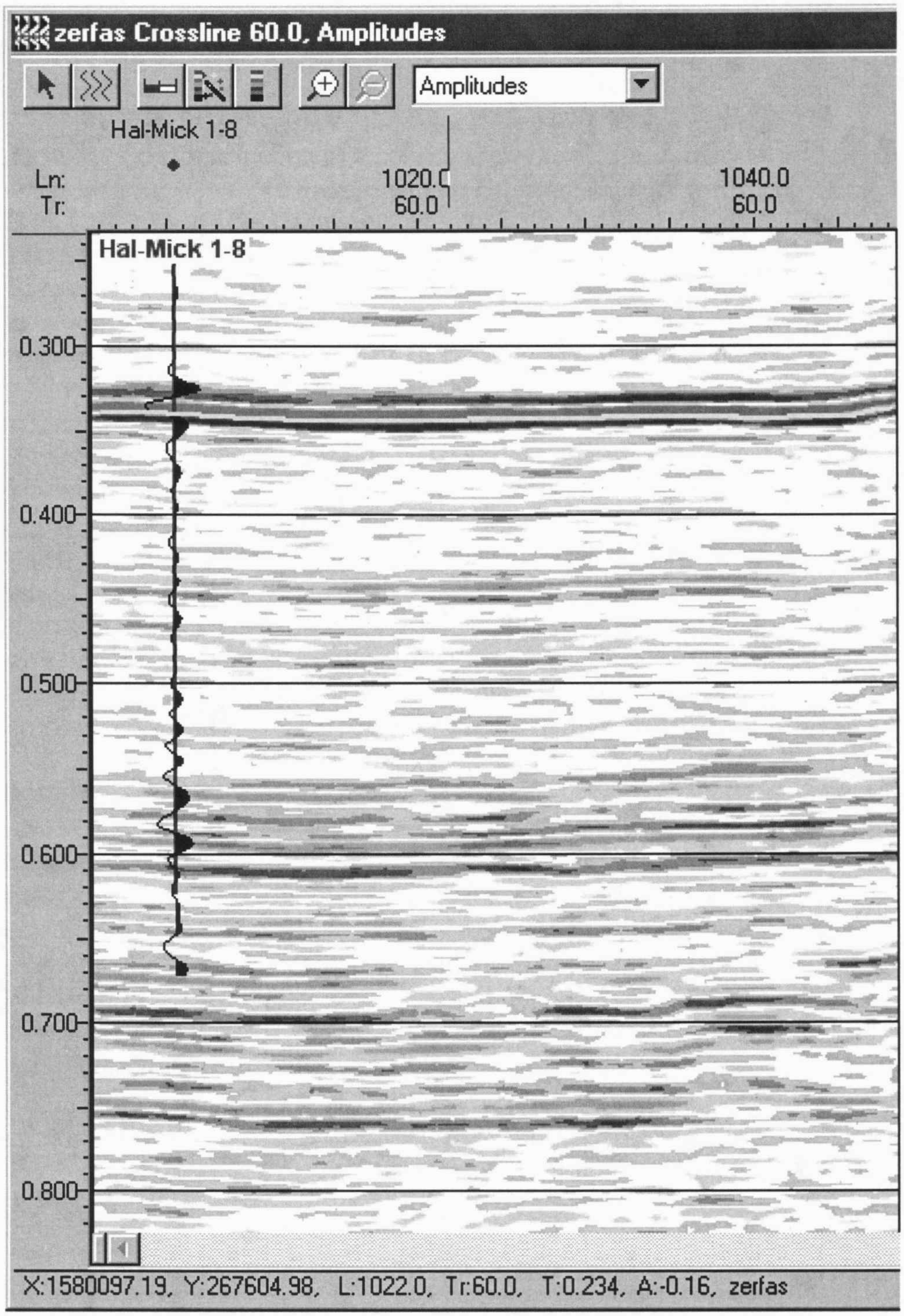


Figure S.4 Showing the synthetic plotted on the seismic data.

3D Seismic: Time to Depth

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

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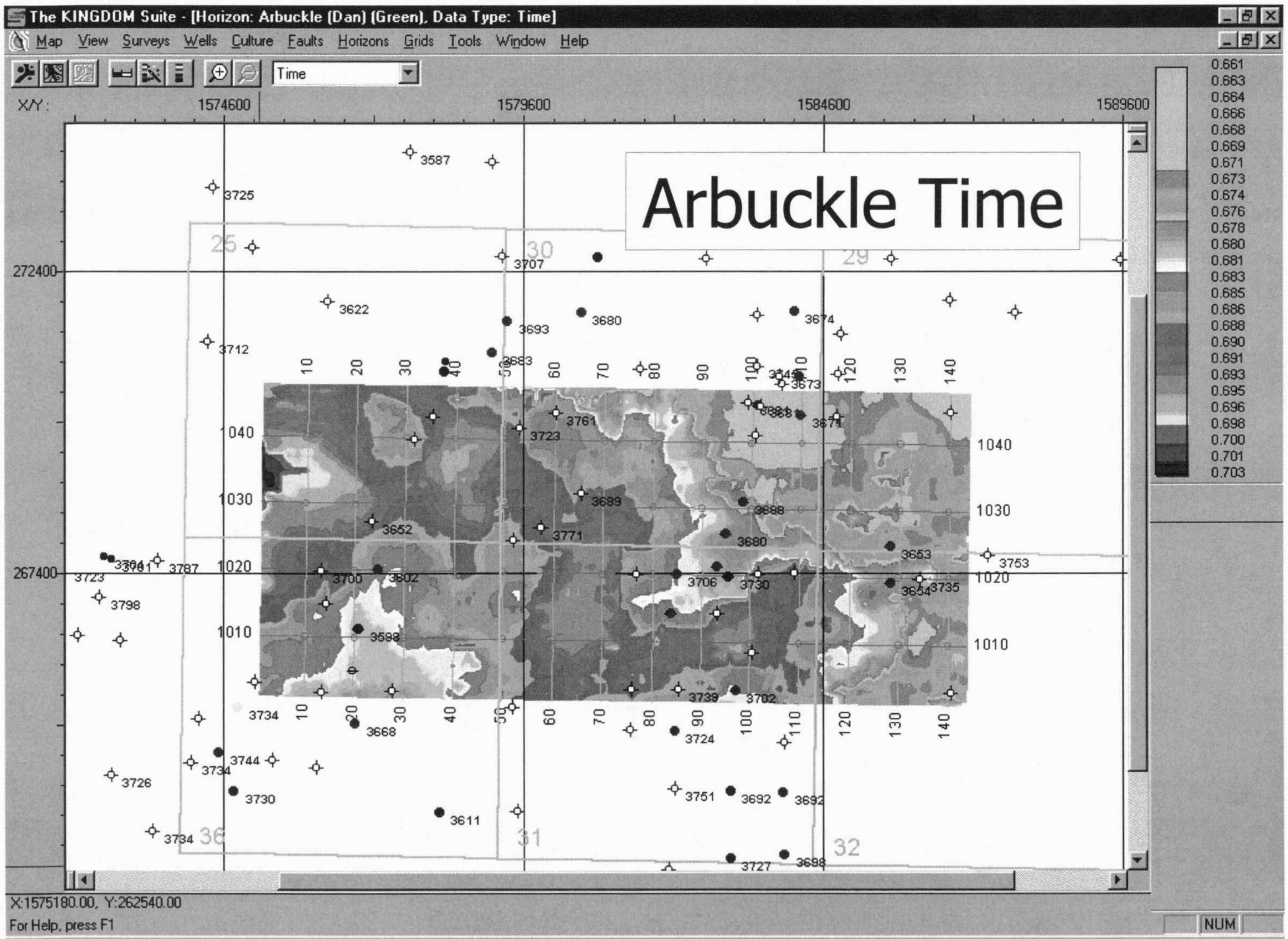
Time to Depth: Outline

- Travel Time is not Depth
  - Depth = Time * Velocity
- Arbuckle Time Map
- Methods of Conversion
- Generate a Velocity Map

Time to Depth: Time Map



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Time to Depth: Notes

- Many methods to convert time to depth.
- Average Velocity Method - Map Gridding of Wells and Velocities
  - Compute an average velocity at the intersection of the wells with the horizon, creating an average velocity at each well location.
  - Average velocity points are gridded and contoured.
  - Resulting average velocity grid (contour) map is multiplied with the horizon time map to generate a computed depth map.

Time to Depth: Method

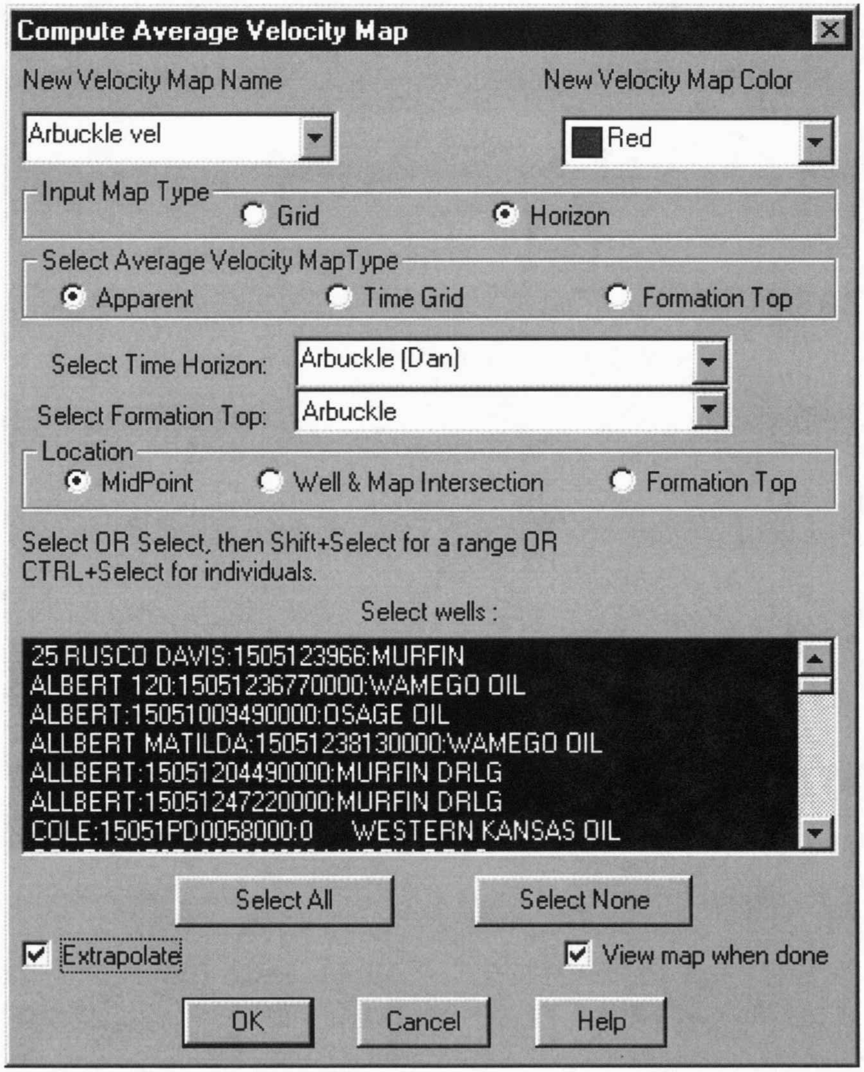
- There are three methods listed under Select Average Velocity Map Type.
  - The Apparent method
  - The Time Grid method
  - The Formation Top method

NOTE: ***If no mis-tie occurs between the formation top and the horizon, all three methods will yield similar results. If, however, there is a signfficant mis-tie between the formation top and the horizon, three distinctly different average velocity maps will result. The biggest problems occur around faults and in areas where there is not enough well control to properly define velocity gradients.***

Time to Depth: Method

- From Menu Bar, Select Tools, Depth and Compute Average Velocity Map.
- Enter the new Velocity map name and color.
- Under Input Map Type, select the Horizon radio button.
- Select Wells to Include
- Select Extrapolate
- Select View Map when completed
- Click OK

Time to Depth: Method



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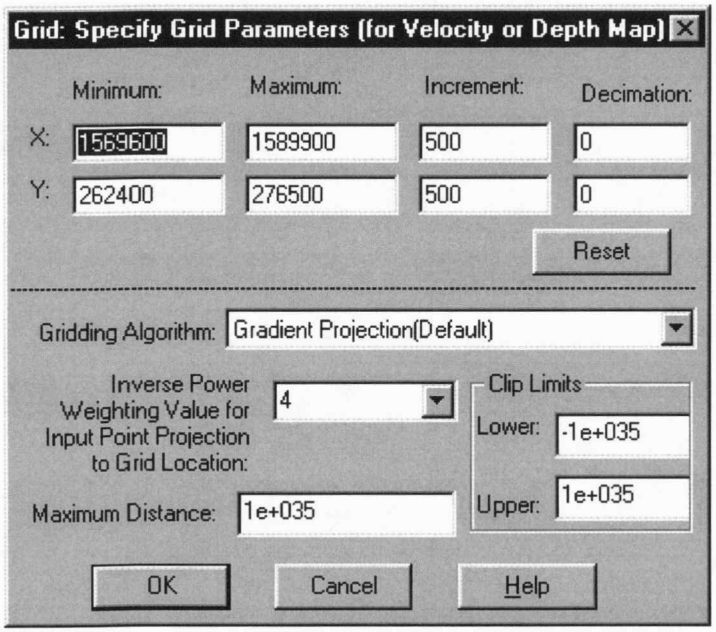
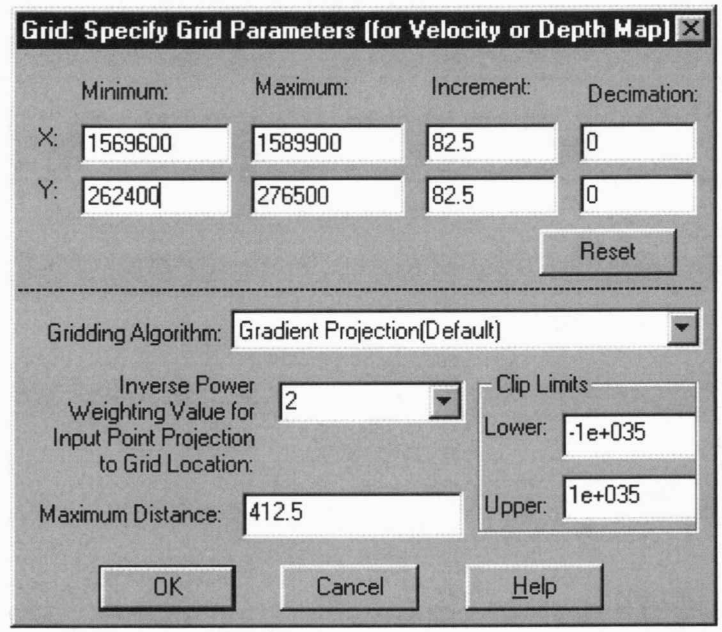
Time to Depth: Method

- From Menu Bar, Select Tools, Depth and Compute Average Velocity Map.
- Enter the new Velocity map name and color.
- Under Input Map Type, select the Horizon radio button.
- Select Wells to Include
- Select Extrapolate
- Select View Map when completed
- Click OK

Time to Depth: Method

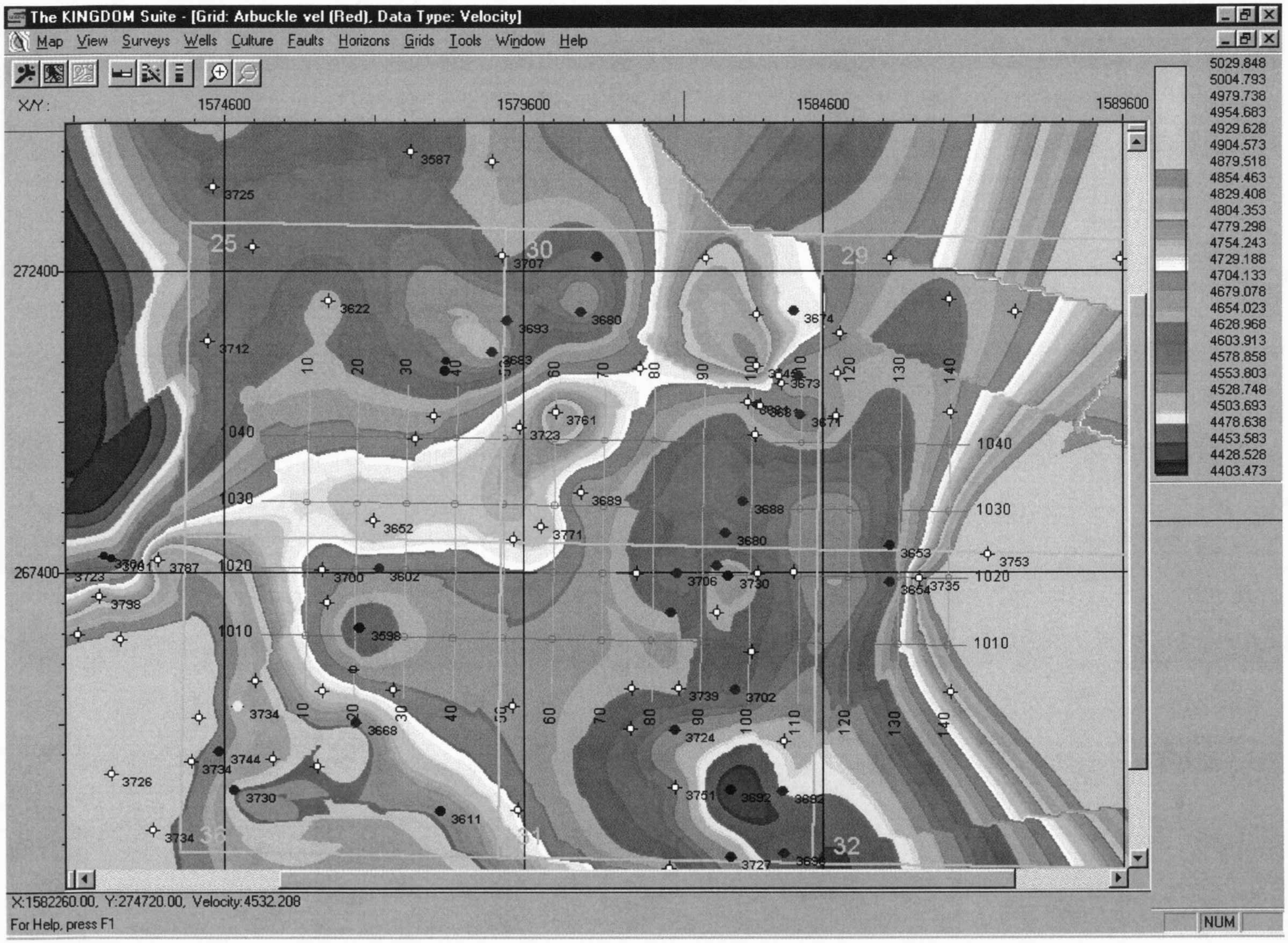




- Click <u>Reset</u> to Sample Every Bin
- You Can Change Weighting / Algorithm
- Click <u>OK</u>

•
•
•

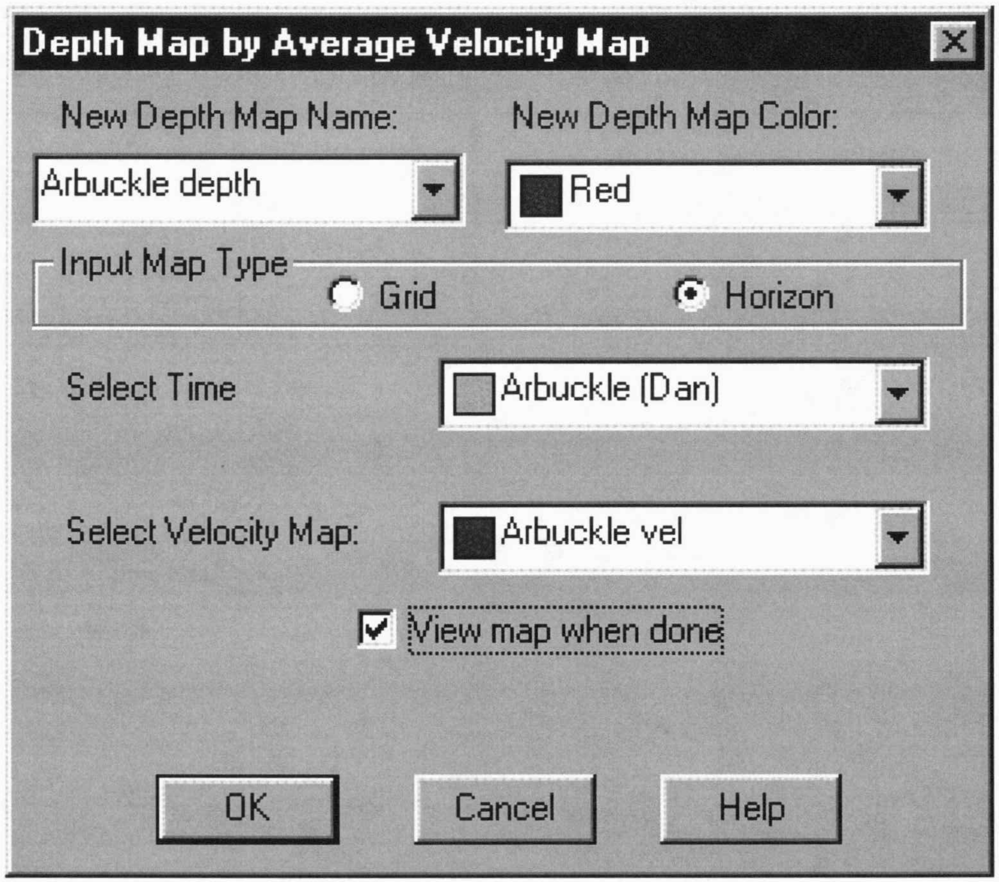
The Result: Arbuckle Velocity Map



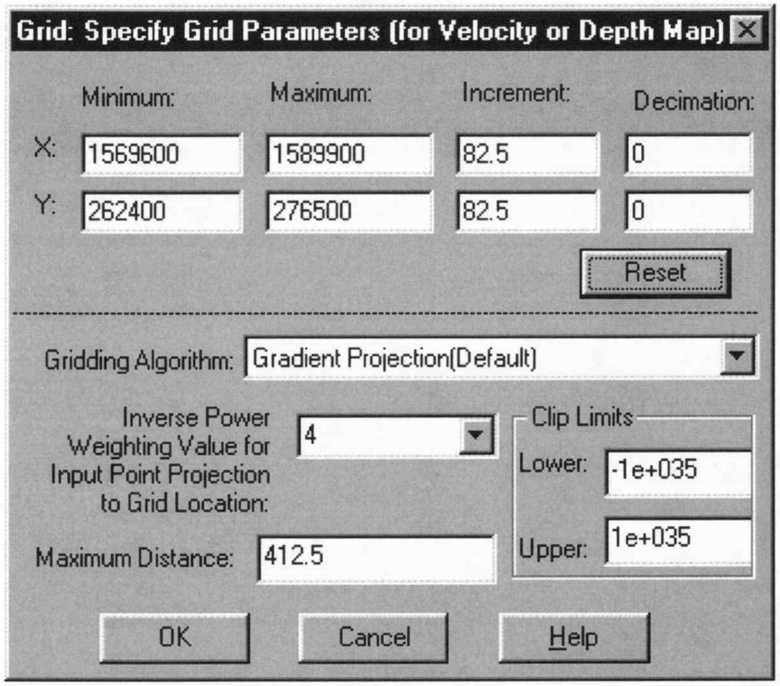
Time to Depth: The Depth Map

- From Menu Bar, Select Tools, Depth and Depth Map by Average Velocity Map.
- Enter the new Depth map name and color.
- Under Input Map Type, Click on Horizon
- Select the Time Horizon by pull down menu.
- Select the Velocity Map by pull down menu.
- Select View Map when completed
- Click OK

Time to Depth: Compute Depth Map

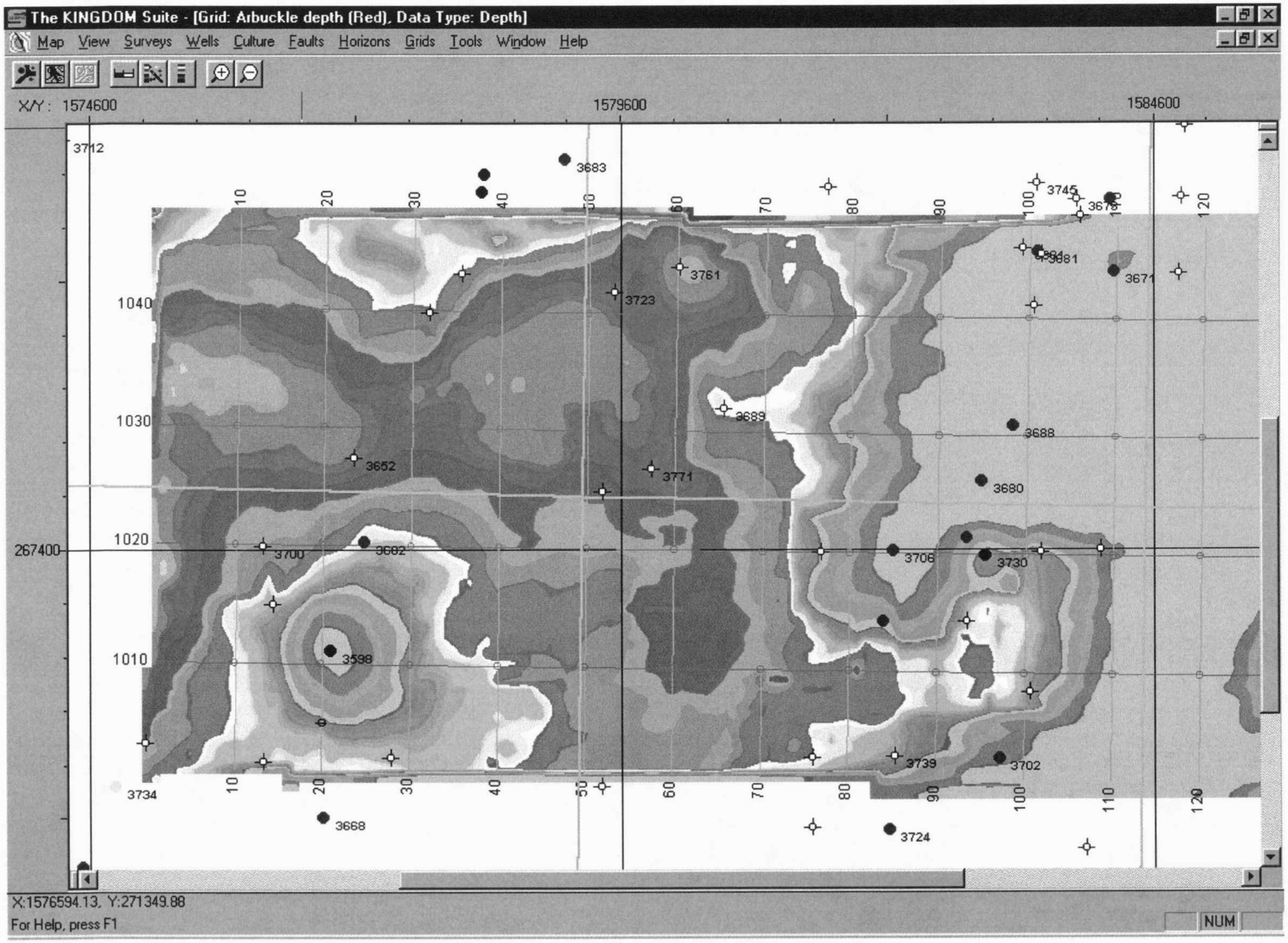


Time to Depth: Compute Depth Map



- Click Reset to Sample Every Bin
- You Can Change Weighting / Algorithm
- Click OK

The Result: Arbuckle Velocity Map



Workshop Project 6.0

- Compute a Velocity Map for the Arbuckle
- Compute a Depth Map for the Arbuckle

Converting from Time to Depth

There are many methods to convert time to depth.

Average Velocity Method - Map Gridding of Wells and Velocities

Method computes an average velocity at the intersection of the wells with the horizon, creating an average velocity at each well location. These average velocity points are then gridded and contoured by the Computer. The resulting average velocity grid (contour) map is multiplied with The horizon time map to generate a depth map.

STEP

1. From the Menu Bar, Select Tools, Depth and Compute Average Velocity Map.

2. Enter the new Velocity map name and select a color.

3. Under Input Map Type, select the Horizon radio button.
   There are three methods listed under Select Average Velocity Map Type.

   The **Apparent** method uses the *formation top depth in conjunction with the horizon time.* These two values are used to compute the average velocity at the well.

   The **Time Grid** method uses only the *horizon time* and then uses the velocity information in the well to convert the time picks to depth. The depth is then divided by the time to give an average velocity at the well.

   The **Formation Top** method starts with the *formation top depth* and converts the depth picks to time using the velocity information at the well. The depth is then divided by the time to give an average velocity at the well.

   NOTE: If no mis-tie occurs between the formation top and the horizon, ***all three methods will yield similar results. If, however, there is a signfficant mis-tie between the formation top and the horizon, three distinctly different average velocity maps will result. The biggest problem with this method occurs around faults and in areas where there is not enough well control to properly define velocity gradients.***

4. Select the Average Velocity Map Type. If using the Apparent Method, you must select a time horizon and formation top. If using the Time grid method, select only a time horizon. If using the Formation top method, select only a formation top.

5. The Location radio button is used whenever deviated wells are present. MidPoint is selected if you wish to display the velocity at the midpoint between the formation top and the horizon. Well & Map Intersection is selected if you wish to display the velocity at the take point of the

horizon *with* the well. Formation top is selected if you wish to display the velocity at the location of the formation top in the well.

6. In the Select wells box, use the Select All or Select None buttons. If a continuous string of wells are desired, click on a well, hold the shift key down and select another well ("Select, then Shift+Select for a range). This method highlights all wells between the selected wells. If random wells are to be used, click on a well, hold the CTRL key down, select any other random wells (CTRL +Select for individuals).

7. If you wish to extrapolate your map to the project boundaries, click on **Extrapolate**.

8. If you wish to view your velocity map when done, click on **View Map** when done.

9. Click on **OK**.

10. The Grid: Specify Grid Parameters dialog box for the horizon should now display.

11. As a first pass, click on **Reset**. This will sample every bin, set the increment and decimation to approximately the bin size, use the Gradient Projection gridding algorithm, use an inverse power of 2, and allow no clipping of data.

12. If you want to stop at fault polygons, click on the Stop at Fault Polygons check box.

12. Placing an 'X" in the Extrapolate Beyond Boundaries will push the grid to the limits of the project area. Click on **OK**.

14. A second dialog box appears. This box specifies the grid parameters for the wells. Again as a first pass, use the defaults. Click on OK.

15. Repeat step 6, adjusting the grid parameters until an acceptable surface is generated.

16. An acceptable velocity grid should now display. If you would like to edit this grid, click on Tools, Depth, Edit Average Velocity Map. If the velocity map requires no editing, proceed to step 27.

EDITING A MAP (Optional)

17. Select the map to edit and then OK.

18. As a first pass, verify that you are on the Compute tab. Click on Set Default and then OK. Note: If contour annotation displays vertically, that is it doesn't rotate, the font needs to be replaced with one that will rotate. To do this, go to View, Contour Parameters, the Annotation tab. Select a different font such as MS Serif.

18. To edit contours, place the cursor anywhere on the map window, right click and select Contour Editing, Edit Contour.

20. Left click on the contour you wish to edit. The editing process is similar to editing faults. That is, you may double click on a node to delete it, add points on a contour line by clicking on a node, add points where needed, and then double click on another existing node. This method also allows deleting consecutive nodes. Move points by clicking and holding and then dragging the node where you wish. Entire contour lines may be deleted by first highlighting and then hitting the Delete key on the keyboard. A new contour line may then be digitized. An entire contour line may be moved by first selecting, then while holding the CTRL key, left clicking and dragging the contour to the new location.

21. Once the ooiting is complete, save the contours as a file. From the menu bar, click on Map, Save Active Contour as, enter a file name and Save. This contoured surface is now saved as a ctr file and may be retrieved at any time.

22. With the saved contours you must now re-grid the contours to create a new grid. Open a new map window by clicking on Window, New Map Display. From the toollbar, select Contour Overlay, go to the Contour File tab, click on browse, select U?e file and click on Open. From the Select Data to Display tab dialog, clickon OK.

22. Re-grid the contours. From the menu bar, click on Grids and Grid.

23. Click on Reset and then OK.

24. Save this grid. Go to the menu bar and select **Grids** and **Save Grid**.

END OF EDITING A MAP

25. Enter a grid name and color, verify the grid type is velocity. Click on OK.

27. From the Menu Bar, select Tools, Depth, Depth Map by Average Velocity Map.

28. Enter the New Depth Map Name, select a color.

29. Select the Input Map Type. Click on Horizon.

29. Select the Time Horizon by clicking on the list arrow button.

31. Select the Velocity Map by clicking on the list arrow button.

32. Place a check at View map when done.

33. Click on OK.

33. As before, use Reset and the defaults when gridding. Check Stop at Fault Polygons if necessary. Click on OK.

35. When the second Specify Grid Parameters dialog appears, click on OK.

36. Repeat this process until an acceptable depth grid is generated.

37. Contour this depth map if desired using the method starting with step 28 above.

38. If desired, drag-and-drop an amplitude map to display with the depth contours.

Seismic Modeling

PTTC Petroleum Technology Transfer Council
North Midcontinent Region

KANSAS · GEOLOGICAL · SURVEY

Seismic Modeling: Introduction

- Identify problems (acquisition, processing, etc.) and determine the limits of resolution.
- Test design solutions (acquisition, processing, etc.) that can improve resolution.
- Identify the geologic basis for seismic responses.
- Guide an interpretation in complex geologic areas.
- Provide an accurate velocity/depth model of the geological section.

Seismic Modeling: Problem 2

- 2D Seismic Model for a Morrow Incised Valley Fill Reservoir in Southwest Kansas
- Required
  - Well-log editing and seismic modeling software
  - Digital well-log data
  - Geologic Information
    - Stratigraphic Tops
    - Well Information

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Seismic Modeling: Software

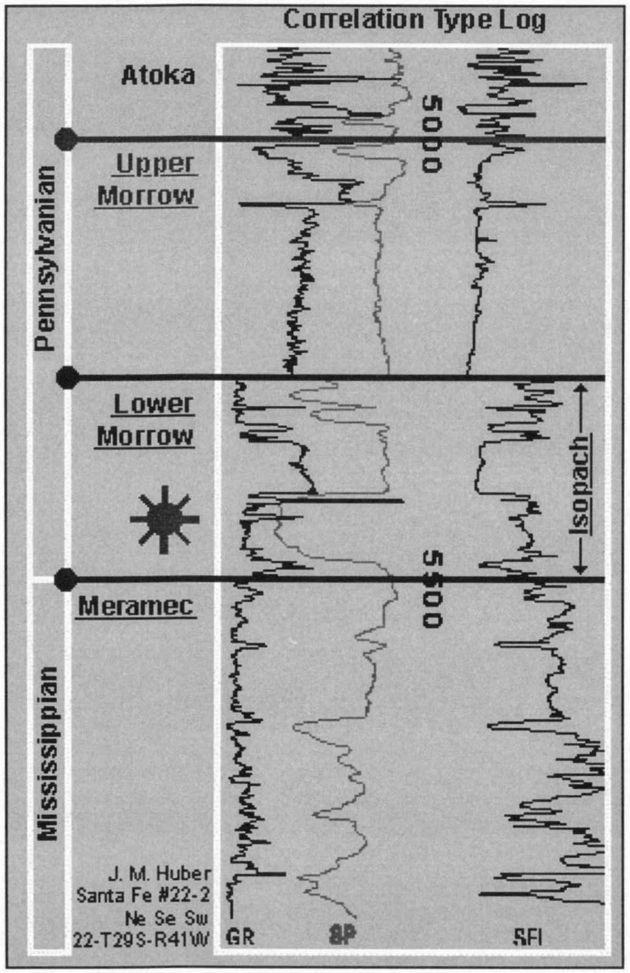
- Demo software is available from a number of companies.
- This problem set uses Log Edit and InterpaLog products of Digi-Rule, Inc.
- Demo software used in this problem set is available at: http://www.digirule.com/

Acknowledgement digiRULE provided access to software

Arroyo Field: Background

- Stanton County Kansas
- Discovery Date: April, 1990
- Producing Horizon: Lower Morrow, Keyes Sandstone (0 to 60')
- Producing Depth: 5900'
- Drive Mechanism: Gas Expansion
- Cumulative Production: 29 BCF, 872MBO
- Producing Wells: 29 (as of 1998)

Arroyo Field: Type Log



- Lower Morrow Sandstone, 0 to 60 ft.
- Deposition Environment: Fluvial and Estuarine Incised Valley Fill
- Porosity max/ave: 20% / 14%
- Initial Field Pressure: 1,434 psia

http://www.kgs.ukans.edu/DPA/Arroyo/Geology/arroyoGeol1.html

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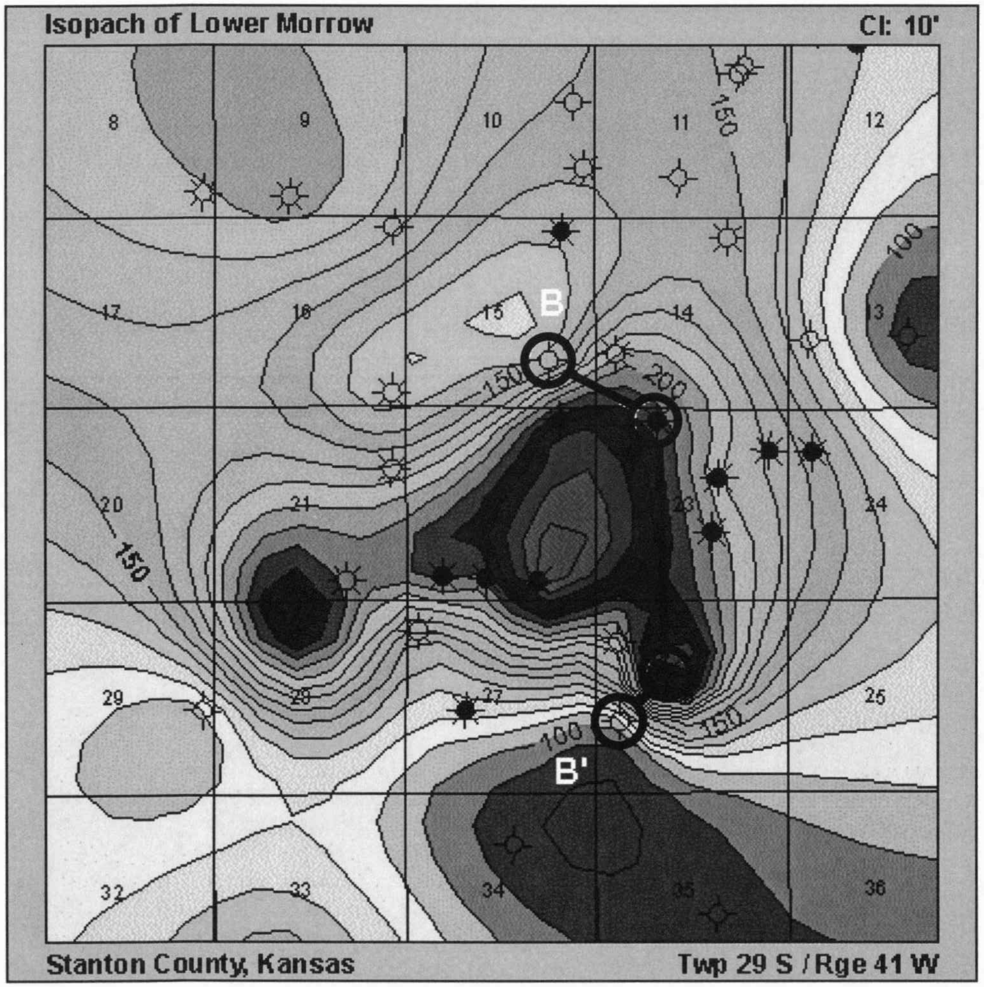
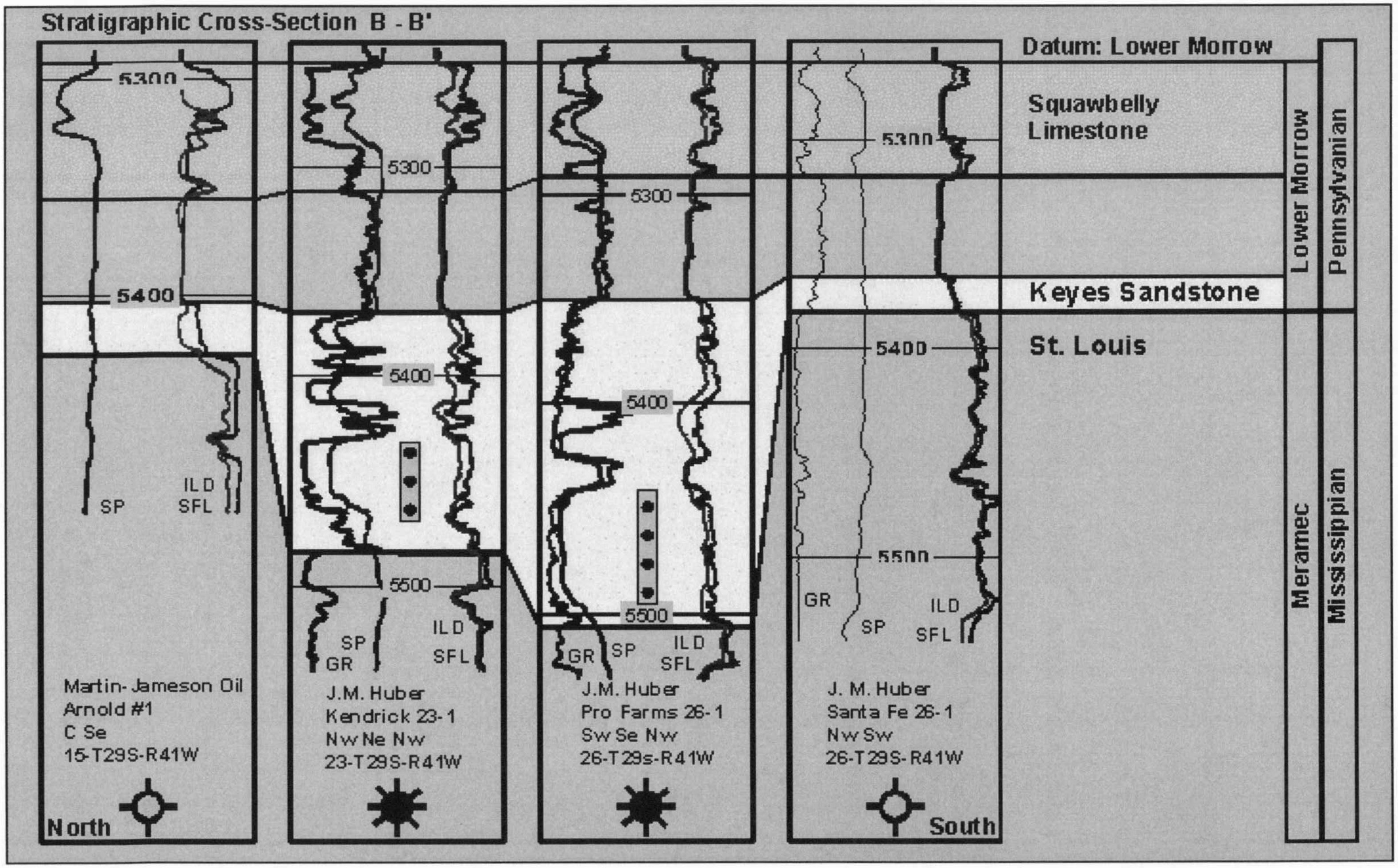
Arroyo Field: Lower Morrow Isopach



http://www.kgs.ukans.edu/DPA/Arroyo/Geology/arroyoGeol3.html

Arroyo Field: Cross-Section



http://www.kgs.ukans.edu/DPA/Arroyo/Geology/arroyoGeol3b.html

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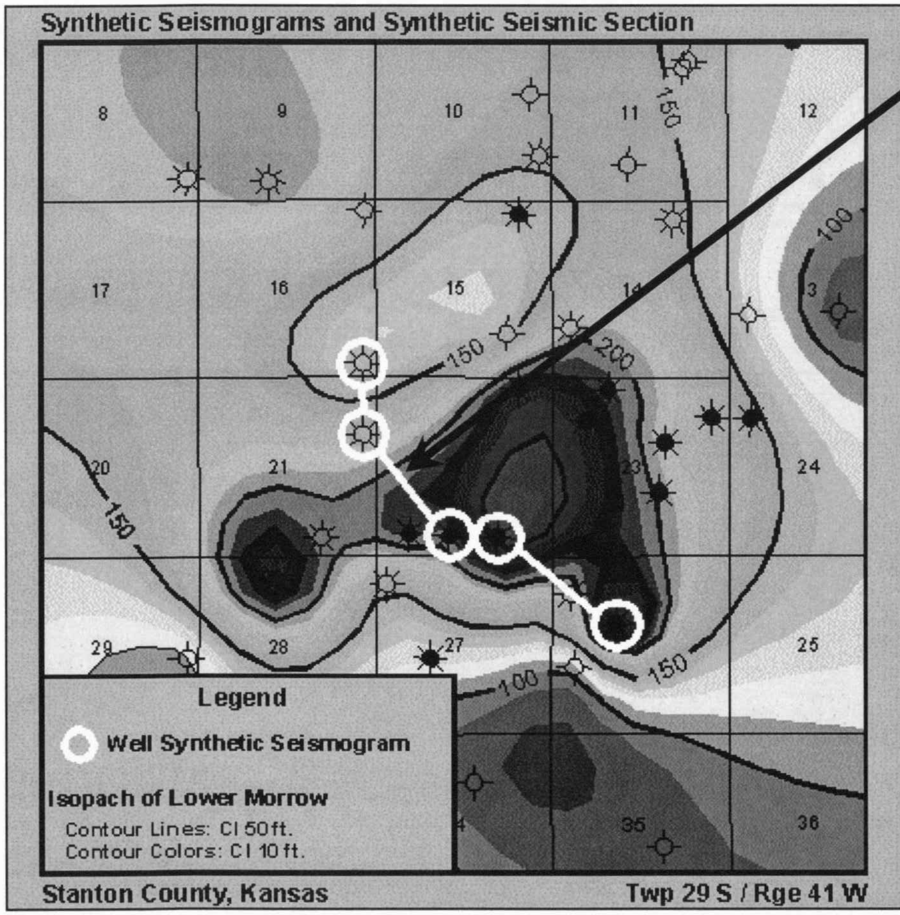
Arroyo Field



Create a Synthetic Seismic Section with the following wells in T29S R41W

- Fretz 16-2
- Scott 21-1
- Santa Fe 22-2
- Kendrick 22-1
- Pro Farms 26-1

http://www.kgs.ukans.edu/DPA/Arroyo/Geophysics/arroyoGeop1.html

Arroyo Field

- All downloaded files are archives created with PKZIP, and need to be unzipped.
- Obtain Well Logs
  - Use Search for Digital LAS Logs at: http://magellan.kgs.ukans.edu/Logs/index.html
  - Search on T29S R41W or Arroyo
- Obtain Well Data
  - http://www.kgs.ukans.edu/DPA/Arroyo/Wells/drlgcomp.zip

Arroyo Field: Log Search

Kansas Geological Survey | Oil and Gas | Digital Wireline Logs

Search for LAS Files Available for Kansas

Use this form to search the KGS index of wireline logs available as LAS format files. **Not all digital logs available from the KGS have been placed in this system (early February, 1999)**. In particular, the Digital Petroleum Atlas contains logs that have not yet been transferred.

Approximately 2,393 logs are in the database (May 11, 1999). For a listing of paper wireline logs stored at the Kansas Geological Survey, please see the Wireline Log Header Database.

In Kansas, Township values vary from 1 in the north to 35 in the south, and the values for Range are from 1-43 West and 1-25 East. Values for Section are 1 to 36.

Select Data to View		
Choose a county: Allen Anderson Atchison Barber Barton Bourbon [Select by County]	Township: 29 Range: 41 East: ○ or West: ◉ Section (optional): [Select by T-R-S]	Enter a field name: [Select by Field]

Kansas Geological Survey
Comments to webadmin@kgs.ukans.edu
Program Updated March 17, 1999
Logs added periodically.
URL = http://magellan.kgs.ukans.edu/Logs/index.html

Arroyo Field: Log Search Results

Kansas Geological Survey | Oil and Gas | Digital Wireline Logs

Kansas LAS files--T29S, R41W

5 records returned.

API: 15-187-20636 **Operator:** J.M. HUBER **Service Company:** **Field:** Arroyo **Well:** PRO FARMS 26-1, Well PRO FARMS 26-1 **County:** Stanton **Location:** T29S R41W, Sec. 26, **Formation:** **Total Depth:** 5900 **Spud Date:** **Completion Date:** 02-JUN-92	Download this log The file you download is an LAS file compressed into a ZIP archive. Your browser may be already set up to decompress these files. Commercial software to perform this is available from PKWARE, Inc., the company that invented the format. A web page from a group of people creating shareware or public domain software is available at Info-ZIP.
API: 15-187-20639 **Operator:** J. M. HUBER **Service Company:** **Field:** Arroyo **Well:** KENDRICK 22-1, Well KENDRICK 22-1 **County:** Stanton **Location:** T29S R41W, Sec. 22, **Formation:** **Total Depth:** 5850 **Spud Date:** **Completion Date:** 19-JUL-92	Download this log The file you download is an LAS file compressed into a ZIP archive. Your browser may be already set up to decompress these files. Commercial software to perform this is available from PKWARE, Inc., the company that invented the format. A web page from a group of people creating shareware or public domain software is available at Info-ZIP.
API: 15-187-20650 **Operator:** J. M. HUBER	Download this log

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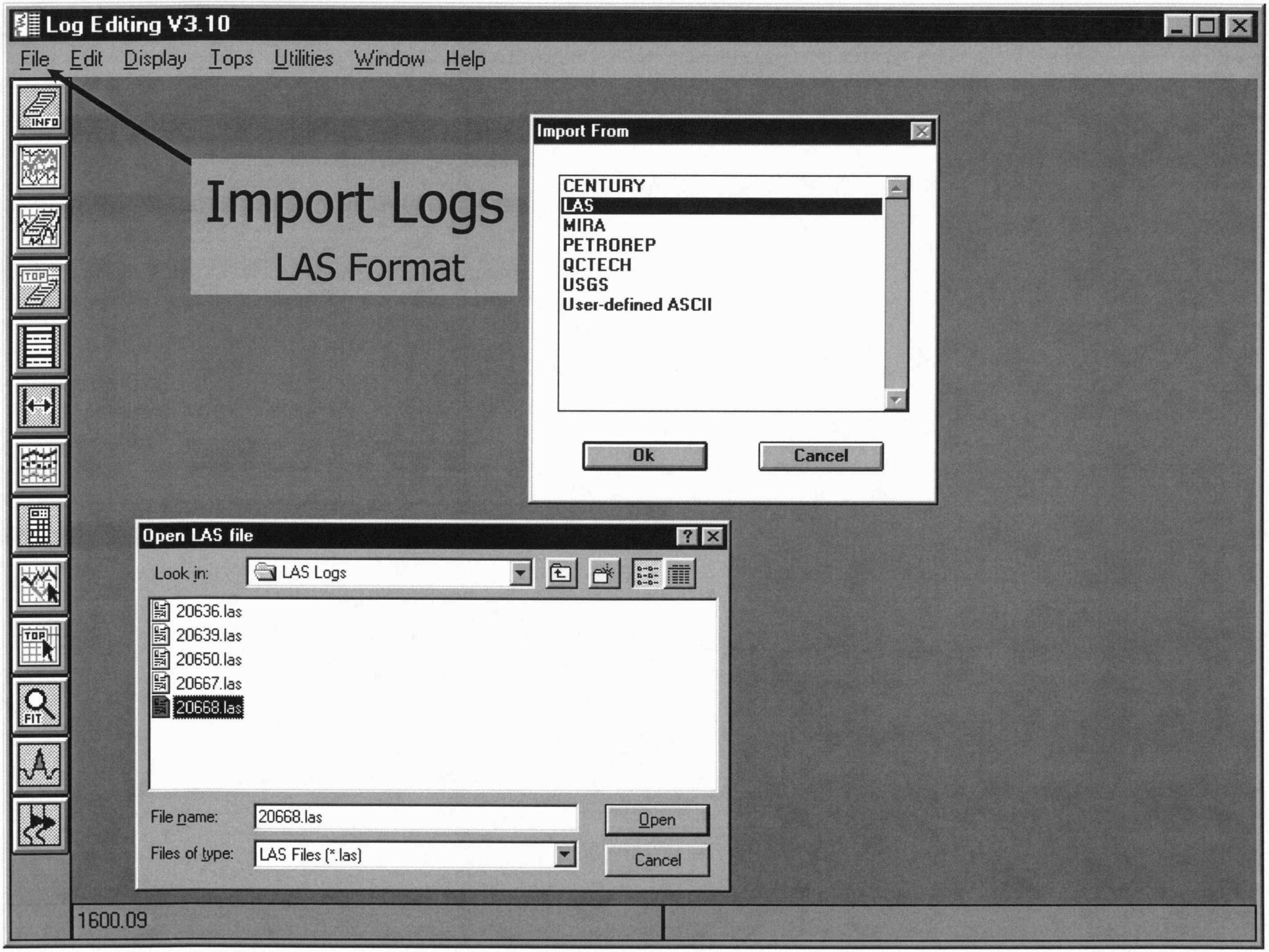
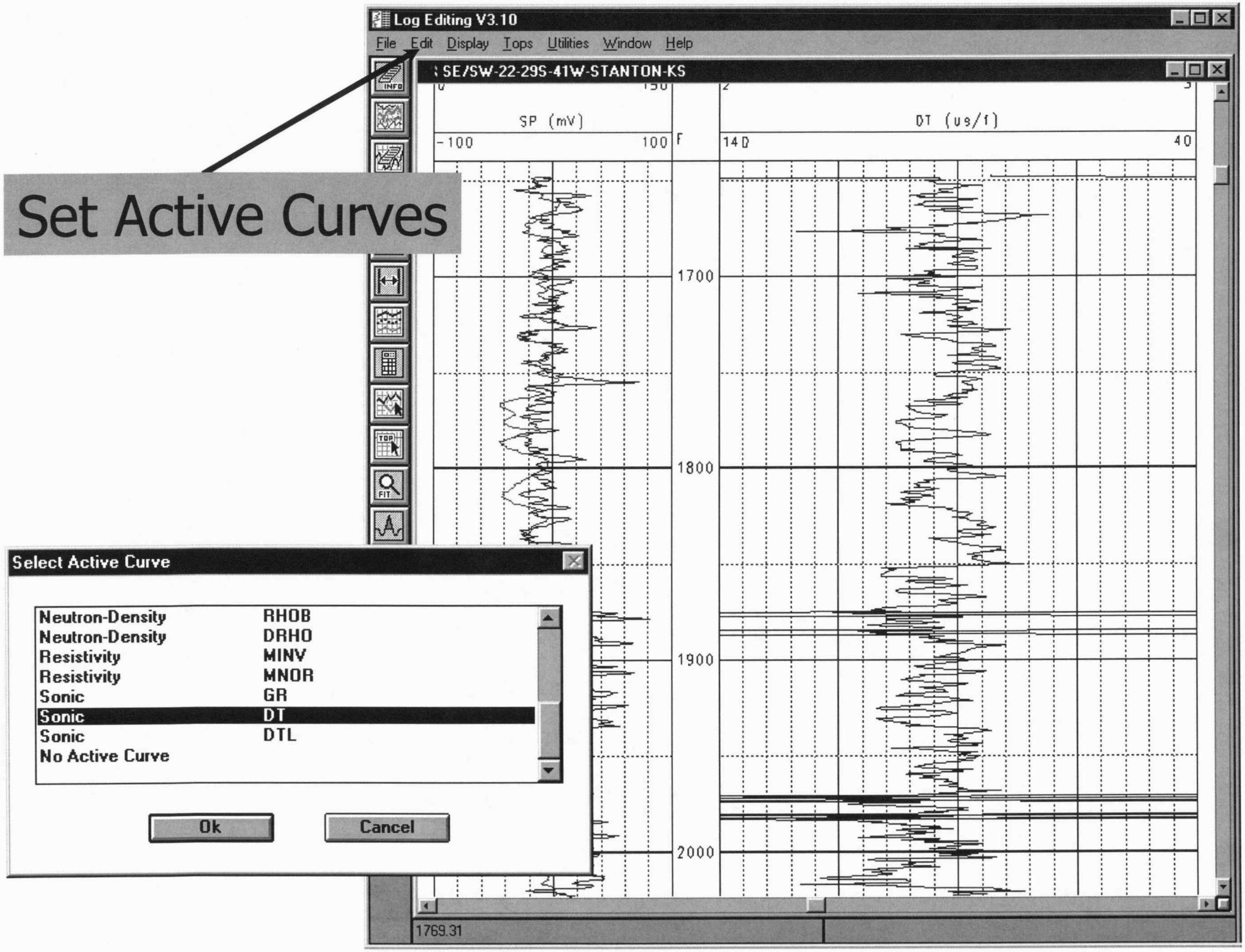
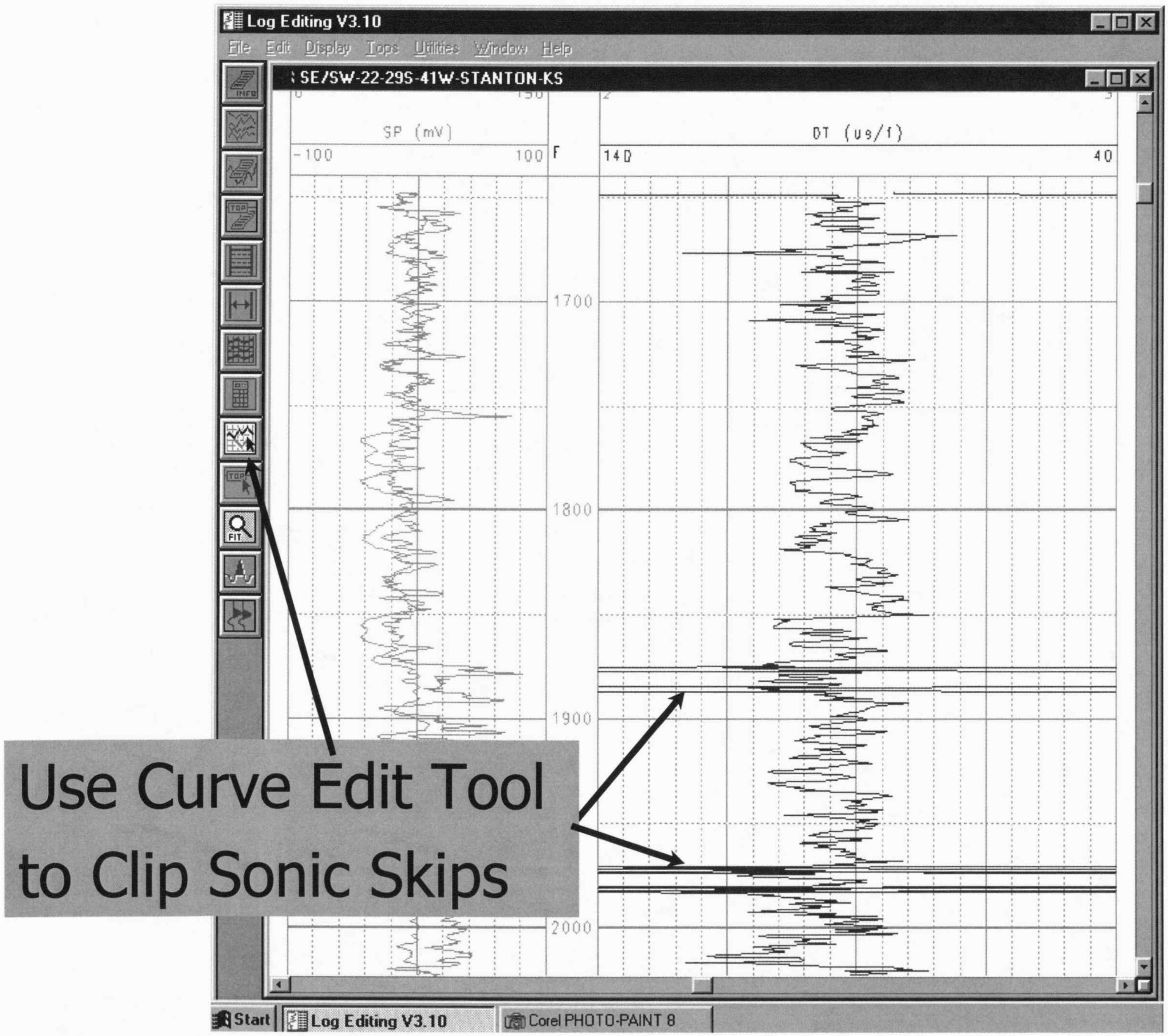
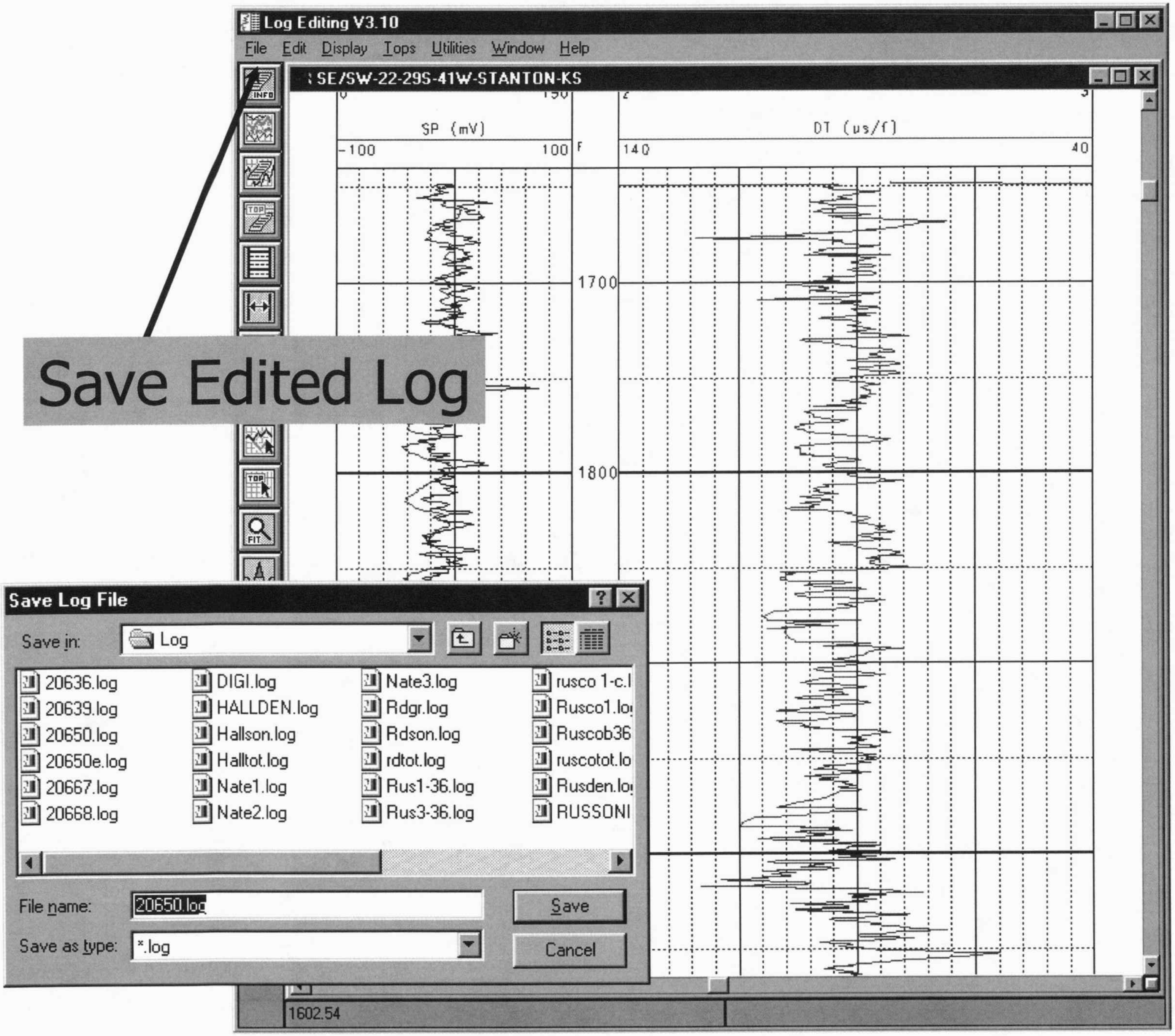
Seismic Modeling: Edit Logs

- UnZip and Import LAS 2.0 logs
  - 15-187-20636, PRO FARMS 26-1
  - 15-187-20639 KENDRICK 22-1
  - 15-187-20650 SANTA FE 22-2
  - 15-187-20667 SCOTT 21-1
  - 15-187-20668 FRETZ 16-2
- Edit Sonic Skips in 15-187-20650 SANTA FE 22-2
- Save logs in DigiRule .log format for import into 2D Seismic Modeling Program


Log Editing V3.10
File Edit Display Tops Utilities Window Help
INFO
TOP
FIT
Import Logs
LAS Format
Import From
CENTURY
LAS
MIRA
PETROREP
QCTECH
USGS
User-defined ASCII
Ok
Cancel
Open LAS file
Look in:
LAS Logs
20636.las
20639.las
20650.las
20667.las
20668.las
File name:
20668.las
Files of type:
LAS Files (*.las)
Open
Cancel
1600.09


Set Active Curves
Log Editing V3.10
File Edit Display Tops Utilities Window Help
SE/SW-22-29S-41W-STANTON-KS
SP (mV)
-100
100
F
DT (us/f)
140
40
1700
1800
1900
2000
Select Active Curve
Neutron-Density RHOB
Neutron-Density DRHO
Resistivity MINV
Resistivity MNOR
Sonic GR
Sonic DT
Sonic DTL
No Active Curve
Ok
Cancel
1769.31


Log Editing V3.10
File Edit Display Tops Utilities Window Help
SE/SW-22-29S-41W-STANTON-KS
SP (mV)
-100
100
DT (us/f)
140
40
F
1700
1800
1900
2000
Use Curve Edit Tool to Clip Sonic Skips
Start
Log Editing V3.10
Corel PHOTO-PAINT 8


Save Edited Log
Log Editing V3.10
File Edit Display Tops Utilities Window Help
SE/SW-22-29S-41W-STANTON-KS
SP (mV)
-100
100
DT (us/f)
140
40
1700
1800
Save Log File
Save in:
Log
20636.log
20639.log
20650.log
20650e.log
20667.log
20668.log
DIGI.log
HALLDEN.log
Hallson.log
Halltot.log
Nate1.log
Nate2.log
Nate3.log
Rdgr.log
Rdson.log
rdtot.log
Rus1-36.log
Rus3-36.log
File name:
20650.log
Save as type:
*.log
Save
Cancel
1602.54

2D Seismic Modeling Program

Control Position of Wells

Import or Create Stratigraphic Tops or other features

Display well logs

(drilled depth, elevation, or in seismic time)

Interpolate between wells

remove top portions (e.g. erosion) or bottom portions (e.g. onlaps)

Interpolate missing curve sections

Apply check shot corrections.

Flatten the seismic on any correlation.

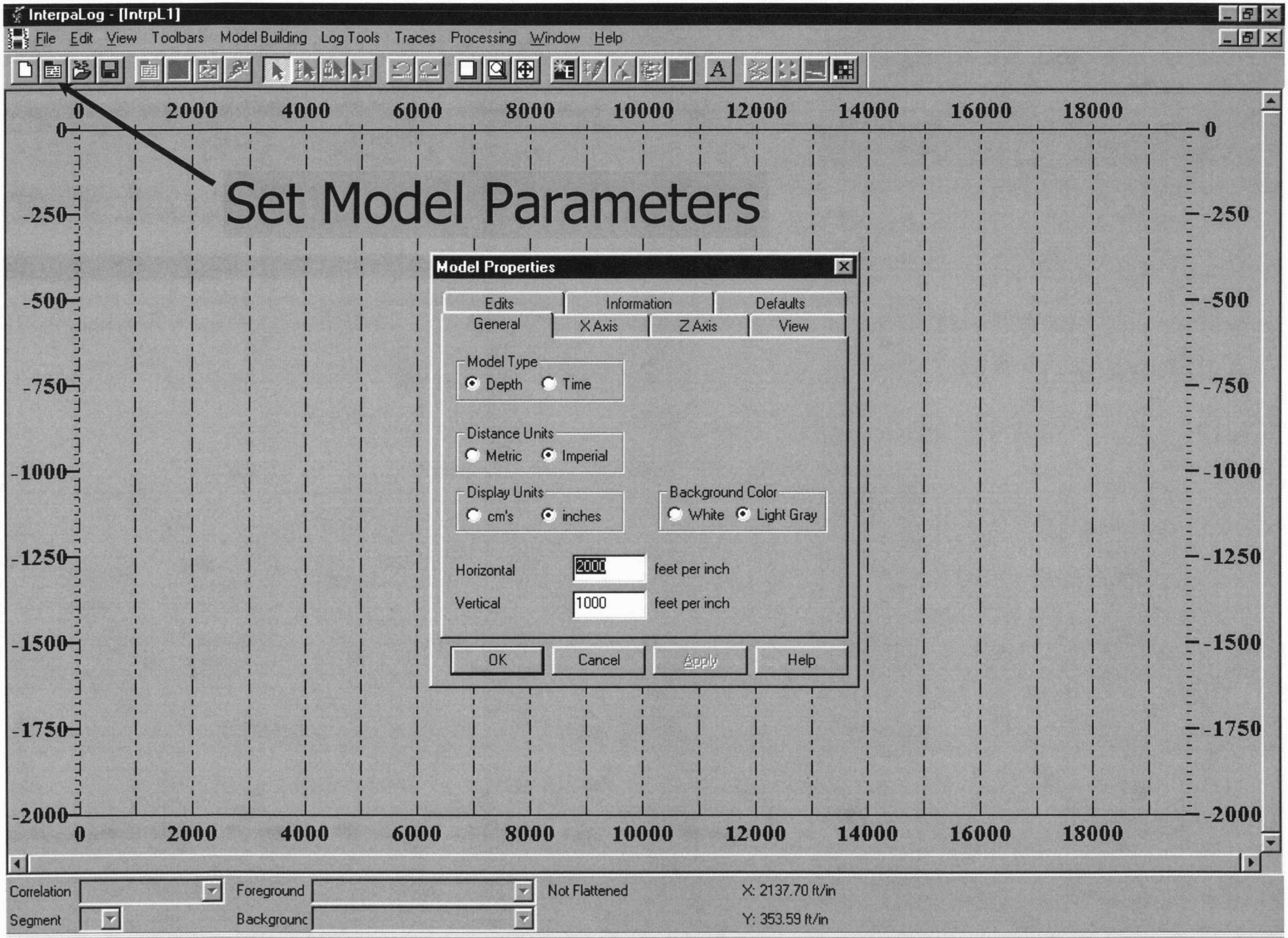
View interpolated log models and seismic trace models simultaneously.

View seismic traces in wiggle, variable density or color amplitudes

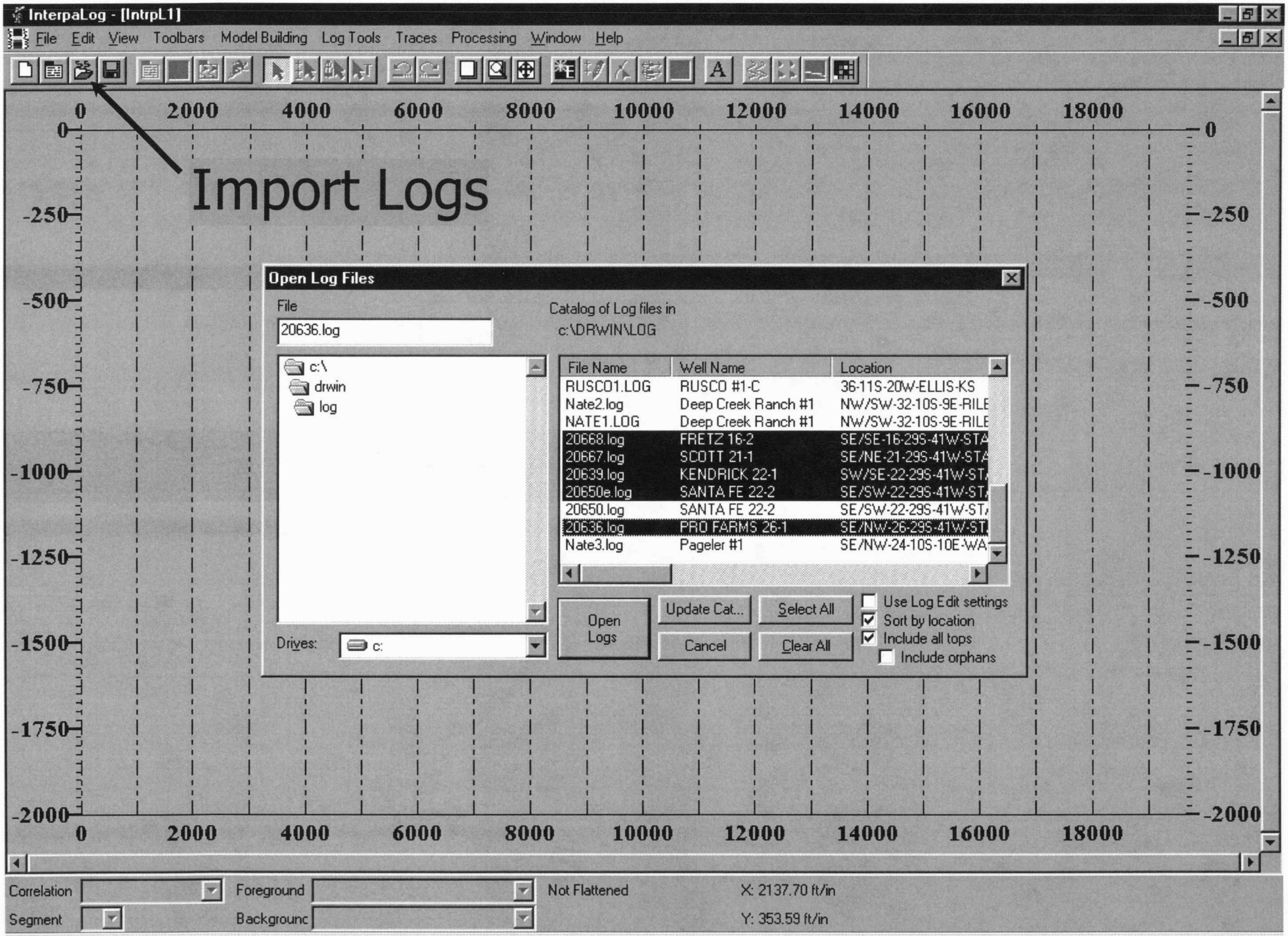
Save the seismic model in SEG-Y format

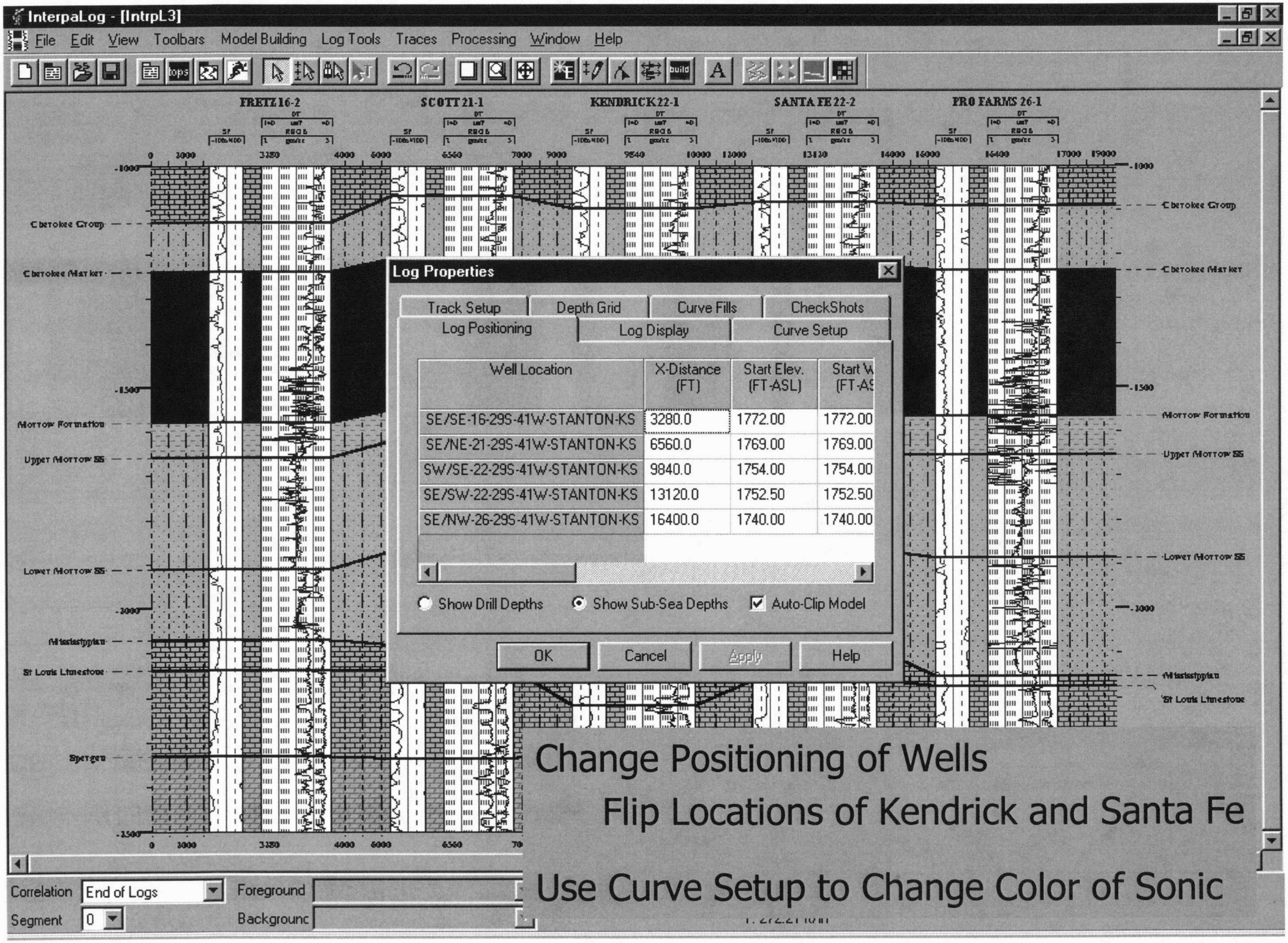
Determine Model Parameters

- Set units
  - Imperial
  - Vertical 1,000’/1”, Horizontal 2,000’/1”
- Set model axes (X and Z)
  - X= 20,000’
  - Z= -1,500’ to -2,500’
    - Set appropriate major and minor units on axes
- Set Labels on Tops (Under View Tab)
- Import Log and Well Data



InterpaLog - [IntrpL1]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
Set Model Parameters
Model Properties
Edits Information Defaults
General X Axis Z Axis View
Model Type
Depth Time
Distance Units
Metric Imperial
Display Units
cm's inches
Background Color
White Light Gray
Horizontal 2000 feet per inch
Vertical 1000 feet per inch
OK Cancel Apply Help
Correlation
Segment
Foreground
Backgrounc
Not Flattened
X: 2137.70 ft/in
Y: 353.59 ft/in

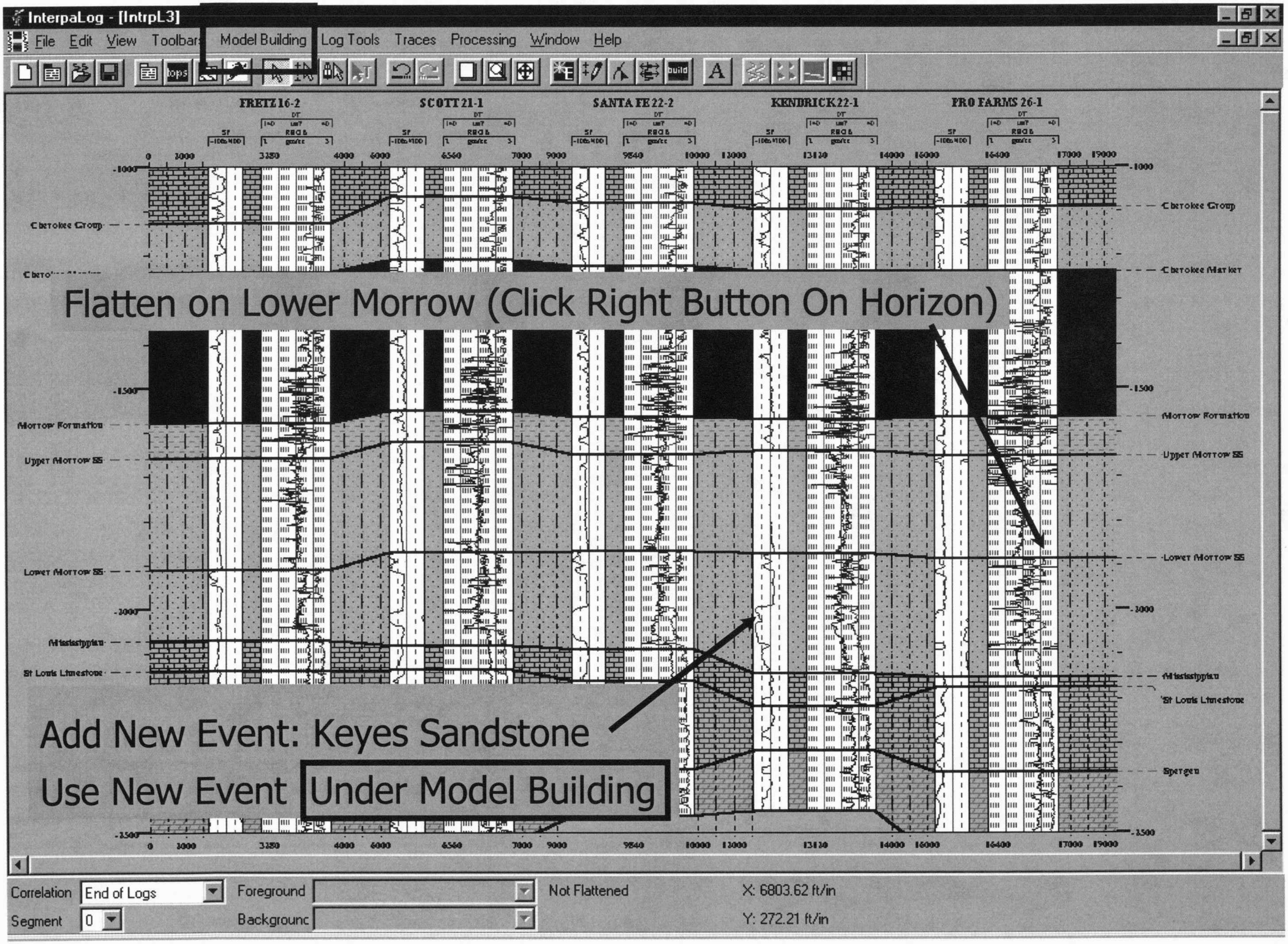

InterpaLog - [IntrpL1]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
Import Logs
Open Log Files
File
20636.log
c:\
drwin
log
Drives: c:
Catalog of Log files in
c:\DRWIN\LOG
File Name Well Name Location
RUSCO1.LOG RUSCO #1-C 36-11S-20W-ELLIS-KS
Nate2.log Deep Creek Ranch #1 NW/SW-32-10S-9E-RILE
NATE1.LOG Deep Creek Ranch #1 NW/SW-32-10S-9E-RILE
20668.log FRETZ 16-2 SE/SE-16-29S-41W-STA
20667.log SCOTT 21-1 SE/NE-21-29S-41W-STA
20639.log KENDRICK 22-1 SW/SE-22-29S-41W-ST
20650e.log SANTA FE 22-2 SE/SW-22-29S-41W-ST
20650.log SANTA FE 22-2 SE/SW-22-29S-41W-ST
20636.log PRO FARMS 26-1 SE/NW-26-29S-41W-ST
Nate3.log Pageler #1 SE/NW-24-10S-10E-WA
Open Logs
Update Cat...
Select All
Cancel
Clear All
Use Log Edit settings
Sort by location
Include all tops
Include orphans
Correlation
Segment
Foreground
Background
Not Flattened
X: 2137.70 ft/in
Y: 353.59 ft/in

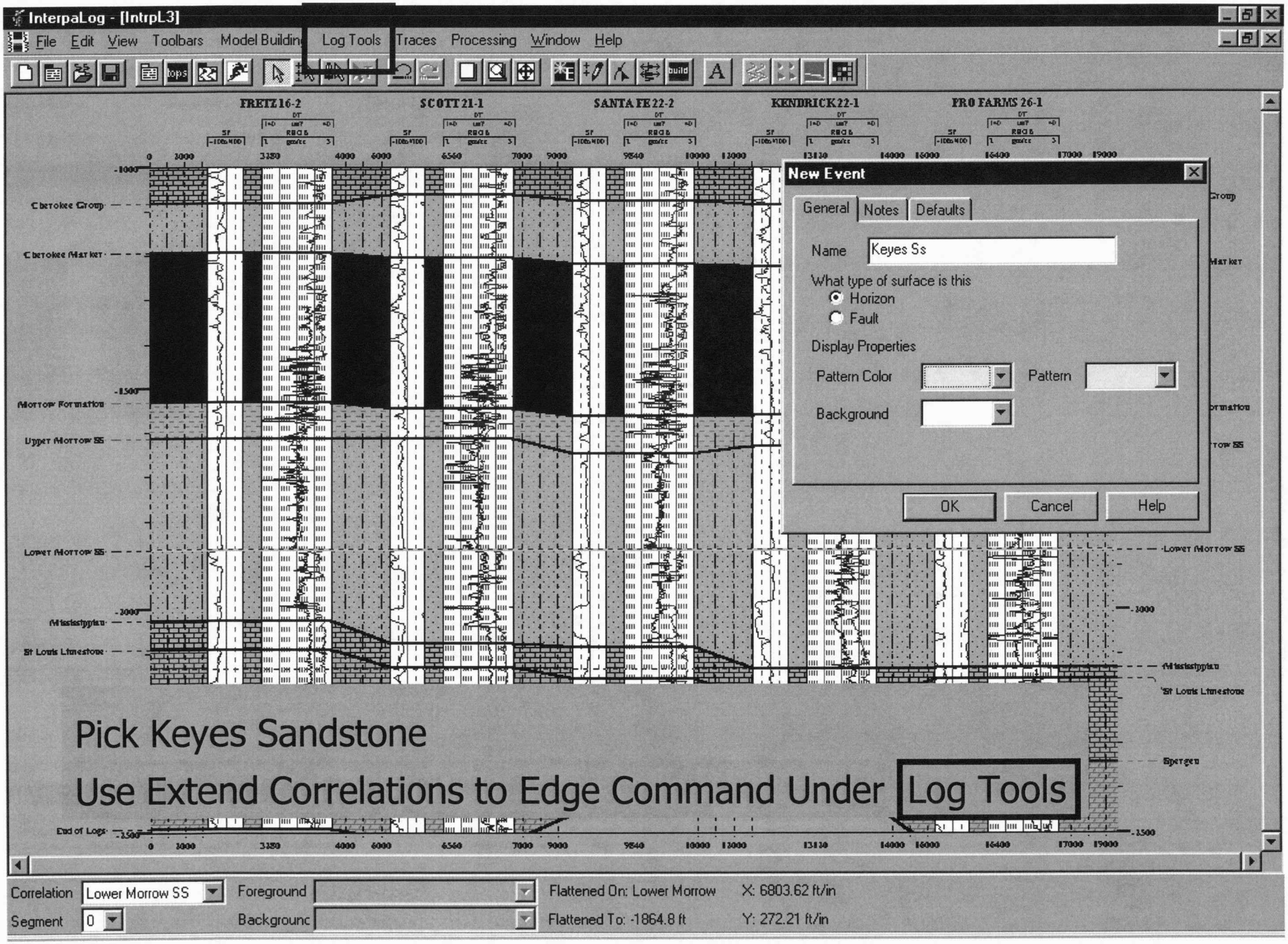


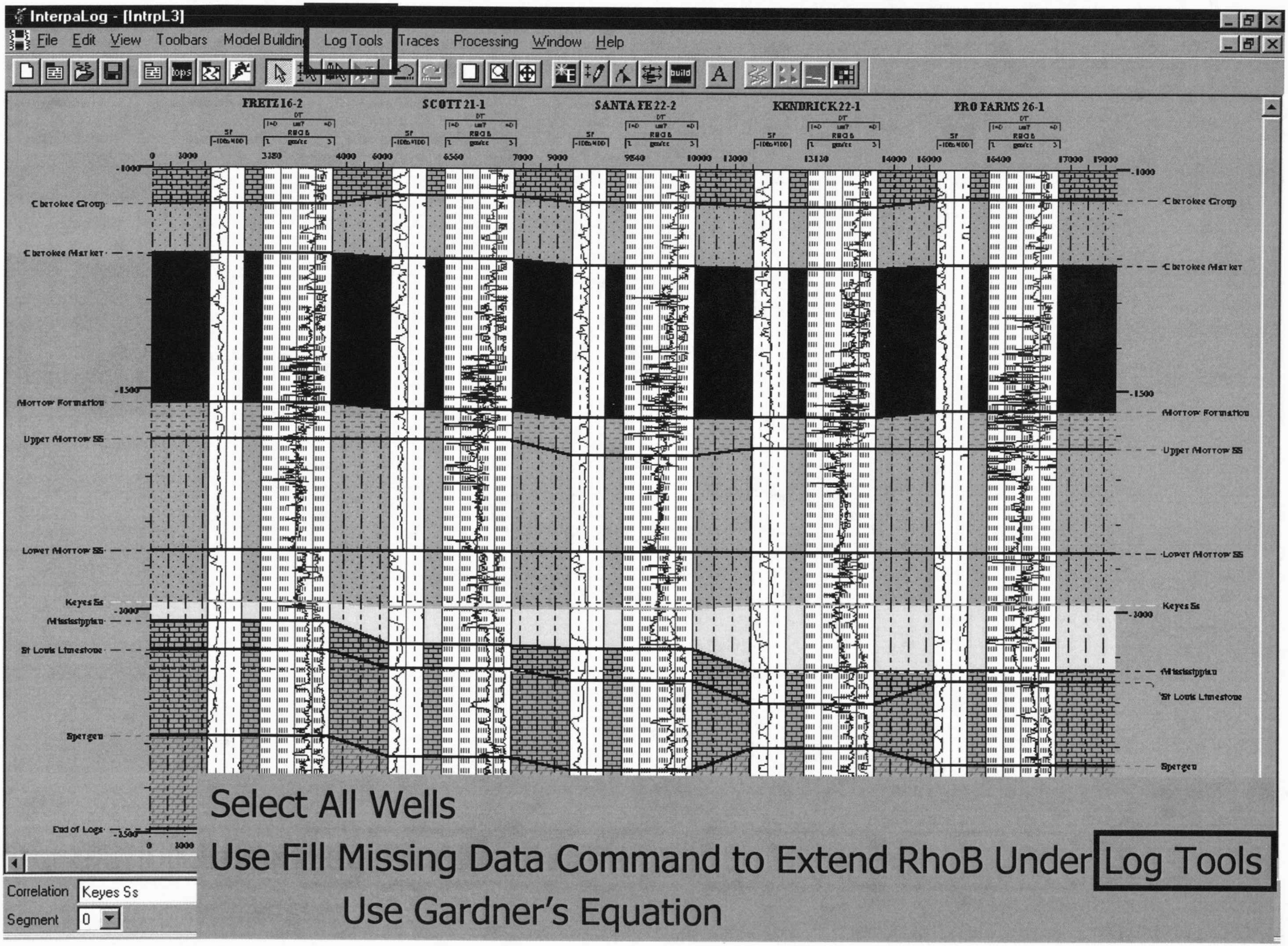
Change Positioning of Wells

Flip Locations of Kendrick and Santa Fe

Use Curve Setup to Change Color of Sonic


InterpaLog - [IntrpL3]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
FRETZ 16-2
SCOTT 21-1
SANTA FE 22-2
KENDRICK 22-1
PRO FARMS 26-1
Cherokee Group
Cherokee Marker
Flatten on Lower Morrow (Click Right Button On Horizon)
Morrow Formation
Upper Morrow SS
Lower Morrow SS
Mississippian
St Louis Limestone
Spergen
Add New Event: Keyes Sandstone
Use New Event Under Model Building
Correlation End of Logs
Segment 0
Foreground
Background
Not Flattened
X: 6803.62 ft/in
Y: 272.21 ft/in

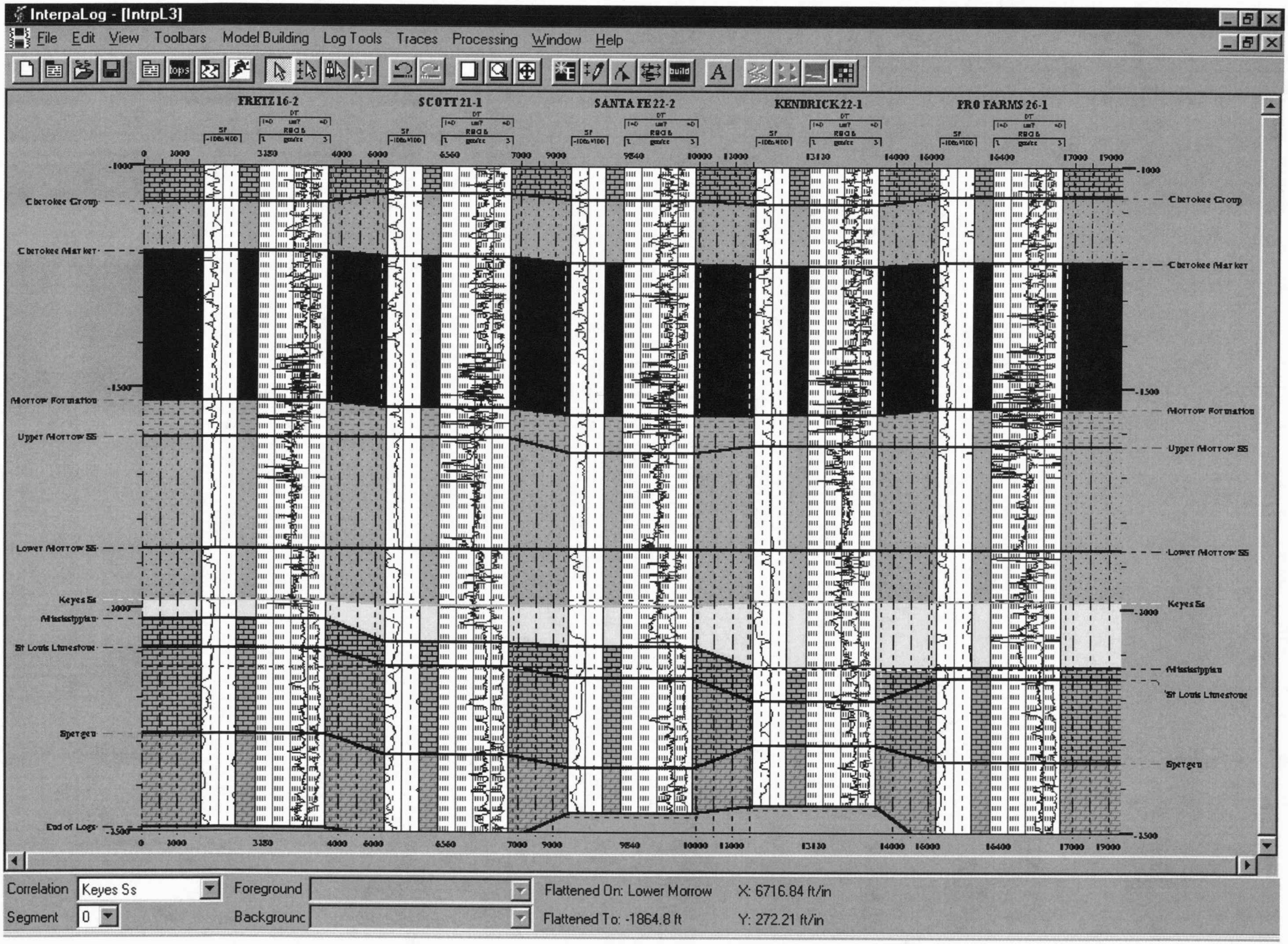

InterpaLog - [IntrpL3]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
FRETZ 16-2
SCOTT 21-1
SANTA FE 22-2
KENDRICK 22-1
PRO FARMS 26-1
Cherokee Group
Cherokee Marker
Morrow Formation
Upper Morrow SS
Lower Morrow SS
Mississippian
St Louis Limestone
Spergen
End of Logs
New Event
General
Notes
Defaults
Name
Keyes Ss
What type of surface is this
Horizon
Fault
Display Properties
Pattern Color
Pattern
Background
OK
Cancel
Help
Pick Keyes Sandstone
Use Extend Correlations to Edge Command Under Log Tools
Correlation
Lower Morrow SS
Segment
0
Foreground
Background
Flattened On: Lower Morrow
Flattened To: -1864.8 ft
X: 6803.62 ft/in
Y: 272.21 ft/in



Select All Wells

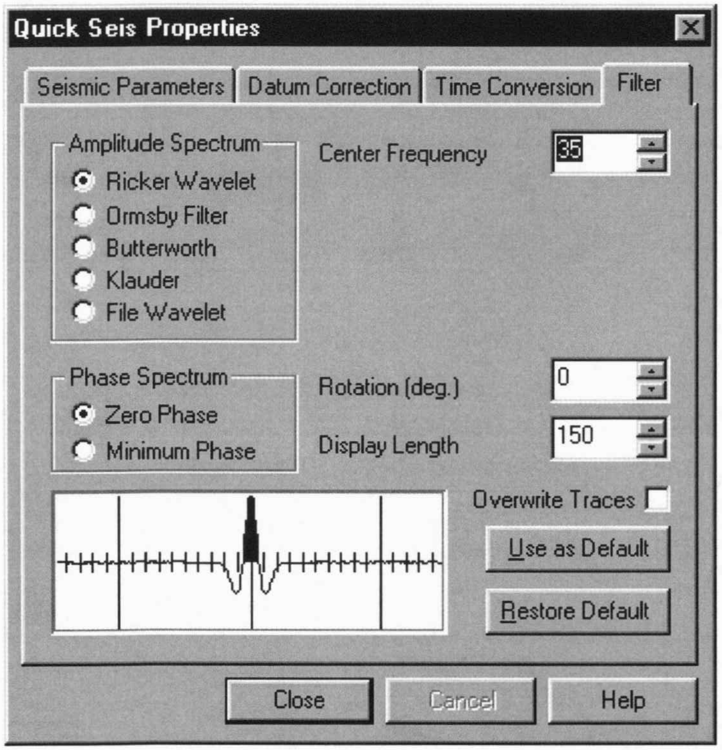
Use Fill Missing Data Command to Extend RhoB Under Log Tools

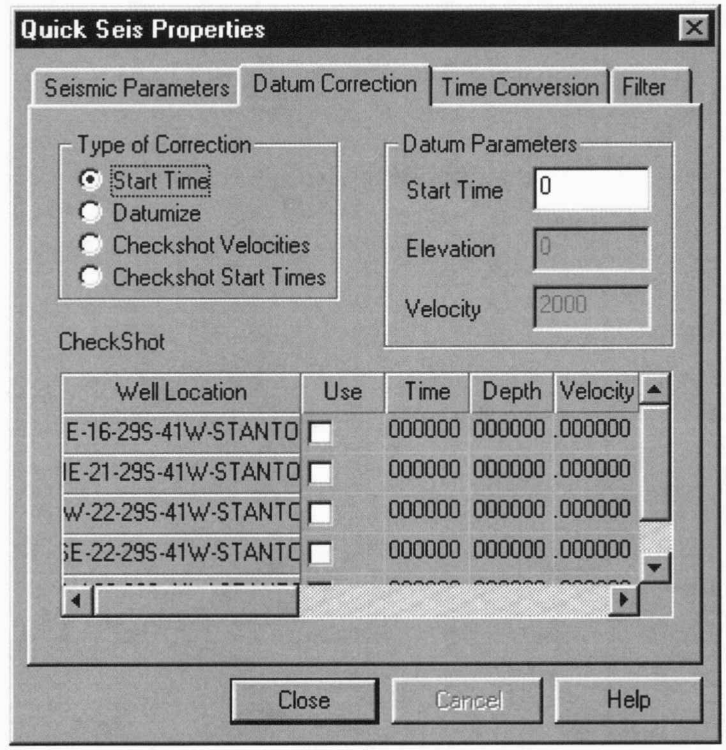
Use Gardner's Equation



InterpaLog - [IntrpL3]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
FRETZ 16-2
SCOTT 21-1
SANTA FE 22-2
KENDRICK 22-1
PRO FARMS 26-1
Cherokee Group
Cherokee Marker
Morrow Formation
Upper Morrow SS
Lower Morrow SS
Keyes Ss
Mississippian
St Louis Limestone
Spergen
End of Logs
Correlation Keyes Ss
Segment 0
Foreground
Background
Flattened On: Lower Morrow
Flattened To: -1864.8 ft
X: 6716.84 ft/in
Y: 272.21 ft/in

Seismic Modeling: Properties



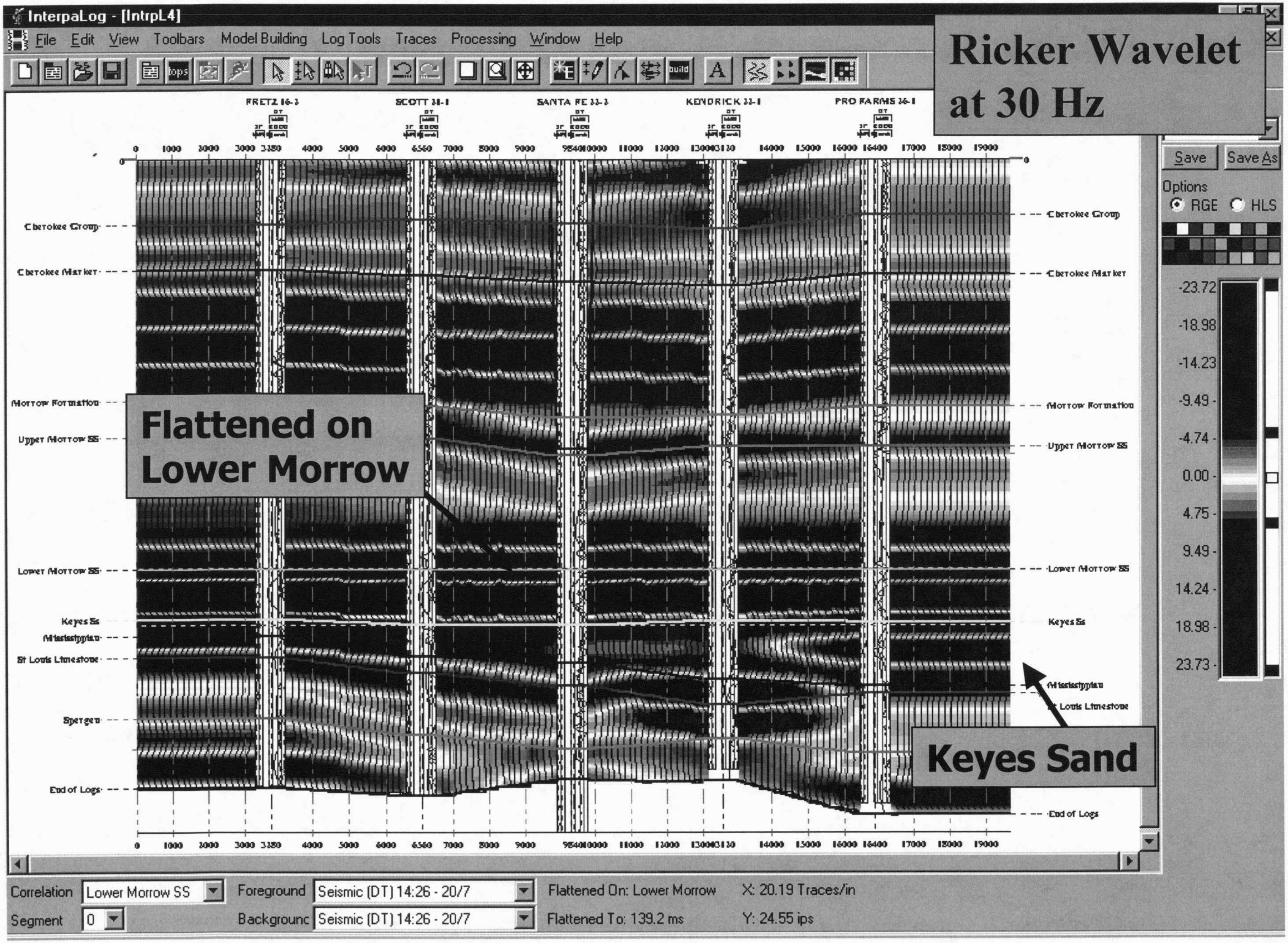


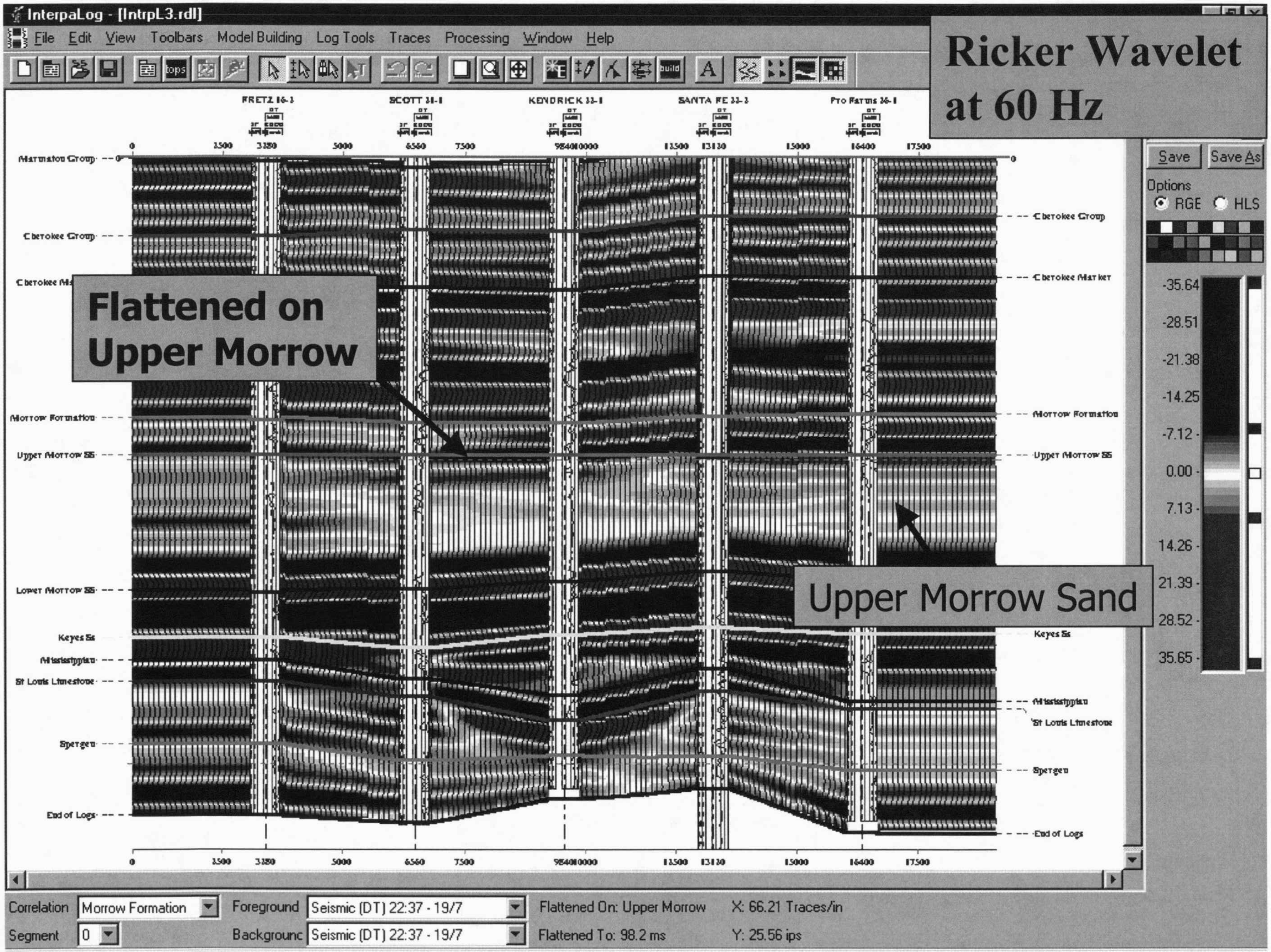
Deselect Tops Above Zone of Interest

Tops Button

Select Seismic Parameters

Quick Seis Config Button


InterpaLog - [IntrpL4]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
Ricker Wavelet at 30 Hz
FRETZ 16-2
SCOTT 31-1
SANTA FE 33-3
KENDRICK 33-1
PRO FARMS 36-1
Cherokee Group
Cherokee Marker
Morrow Formation
Upper Morrow SS
Lower Morrow SS
Keyes Ss
Mississippian
St Louis Limestone
Spergen
End of Logs
Flattened on Lower Morrow
Keyes Sand
Save
Save As
Options
RGE
HLS
-23.72
-18.98
-14.23
-9.49
-4.74
0.00
4.75
9.49
14.24
18.98
23.73
Correlation
Lower Morrow SS
Segment
0
Foreground
Seismic (DT) 14:26 - 20/7
Background
Seismic (DT) 14:26 - 20/7
Flattened On: Lower Morrow
Flattened To: 139.2 ms
X: 20.19 Traces/in
Y: 24.55 ips



InterpaLog - [IntrpL3.rdl]
File Edit View Toolbars Model Building Log Tools Traces Processing Window Help
Ricker Wavelet at 60 Hz
FRETZ 16-1
SCOTT 31-1
KENDRICK 33-1
SANTA FE 33-1
Pro Farms 36-1
Flattened on Upper Morrow
Upper Morrow Sand
Marmaton Group
Cherokee Group
Cherokee Marker
Morrow Formation
Upper Morrow SS
Lower Morrow SS
Keyes Ss
Mississippian
St Louis Limestone
Spergen
End of Logs
Save
Save As
Options
RGE
HLS
-35.64
-28.51
-21.38
-14.25
-7.12
0.00
7.13
14.26
21.39
28.52
35.65
Correlation Morrow Formation
Segment 0
Foreground Seismic (DT) 22:37 - 19/7
Background Seismic (DT) 22:37 - 19/7
Flattened On: Upper Morrow
Flattened To: 98.2 ms
X: 66.21 Traces/in
Y: 25.56 ips

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Seismic Modeling: Results

- Recognition of Lower Morrow Keyes Sands
  - Onlap onto Mississippian Erosional Surface
  - Incised Valley Fill
- Recognition of Upper Morrow Sands
  - Toplap below Upper Morrow
  - Initial Development on East Side

Workshop Project 7.0

- Use InterpaLog to Create Synthetic Seismic Section
  - Wells are located in C:\Logs
- Import Wells into Program
- Follow Outline to Create Seismic Model
- Experiment
  - Wavelet
  - Frequency
  - Datums

Seismic Modeling

A seismic model, either a forward model (sometimes referred to as direct or normal model) or an inverse model, can improve the interpretation of the subsurface geology. The forward seismic model works with a configuration of physical properties usually obtained from a wellbore (e.g., velocity, density and stratigraphy), and attempts to compute the effects (i.e., expected seismic data in one or more dimensions). A 1D forward seismic model would be a zero offset synthetic seismogram. An inverse seismic model attempts to use the seismic data (the effects) to derive a configuration of the physical properties. The inverse approach has received recent attention in reservoir geology. Seismic attributes derived from 3D data are used to make an inverse model and predictions about reservoir properties away from boreholes (e.g., porosity and fluid type). In most approaches an iterative process of forward and inverse modeling is used to condition aspects of seismic data to wellbore data.

The objectives of seismic modeling are:

1. To identify problems associated with acquisition, and assist in determination of the limits to resolution that can be achieved.
2. To test design solutions (acquisition, processing, etc.) that can improve resolution.
3. To identify the geologic basis for the seismic response.
4. To help guide an interpretation in complex geologic areas.
5. To provide an accurate velocity/depth model of the geological section.

An important goal in seismic modeling is to determine the geological parameters that can be observed seismic response (i.e., the maximum resolution). This objective is particularly critical in addressing questions in highly structured areas, thin stratigraphic intervals, small faults and subtle changes in reservoir properties. Modeling can provide the interpreter insight into how far the seismic data can be pushed. Anything beyond the resolving power as indicated by an accurate seismic model is not interpretation but speculation (There is nothing wrong with geologic speculation, but one should be cognizant of limits in your data).

Another objective of modeling is to identify problems associated with acquisition and to help design solutions. Time migration can collapse diffractions, unravel bow ties and generally clean up the reflections, making them easier to visualize and understand. However, time migration can introduce errors. Even with the best velocity field data, time migration will not account for severe raypath bending. Reflections are more interpretable but are often in the wrong place. To interpret a time migrated section; the interpreter should understand the errors inherent in time migration, how they are affected by the geology in the survey area and how to correct for them in the interpretation process. Depth migration, especially pre-stack, can account for severe raypath effects and can correctly image even the most complex sections. However, for depth migration to be effective, the input must equal the output. The critical input to depth migration must be an accurate picture of the subsurface geology, which, unfortunately we don't see until the depth migration itself is complete. Once again then, in order to depth migrate we must understand the zero offset section and we must use it either directly or through the intermediate step of time migration to produce an accurate picture of the geological section. In both time and depth migration an accurate seismic model of the subsurface geology is critical to an improved seismic interpretation.

The process of seismic interpretation can be thought of as analyzing and constraining geophysical errors in order to generate a geologic model of the subsurface. A seismic model can assist in this process. We will concentrate on forward modeling, using sonic and density logs to model the expected seismic response based on a possible interpretation of the subsurface geology. Knowledge of the expected seismic response can constrain interpretation of seismic sections or volumes.

Making a 2D Seismic Model

Several computer packages are available with two-dimensional seismic modeling from log data. These programs simplify the creation of synthetic seismic sections from sonic and density log data.

The following example generates a 2D synthetic seismic model using ***InterpaLog*** from Digi-Rule Inc. The ***InterpaLog*** program is designed to perform two-dimensional seismic modeling from log data. Additional information and evaluation software can be obtained by contacting Digi-Rule Inc. at http://www.digirule.com. The digital well log used in this example is available from the Kansas Geological Survey through an online search at http://magellan.kgs.ukans.edu/Logs/index.html. The wells are from the Arroyo Field, a Lower Morrow (Keyes Sandstone) reservoir in Stanton County, Kansas. Since its discovery in 1990, the Arroyo Field has produced nearly 30 BCF of gas and slightly less than 1 MMBO from 29 wells. The Lower Morrow sandstone reservoir occurs as a incised valley fill ranging from 0 to 60 feet. The synthetic seismic section consists of five wells (Table 1). The section crosses the reservoir from northwest to southeast (Figure 1). You can search the KGS online database of digital logs and select the wells by township-range or by field. Well data including formation tops can be obtained from the Kansas Digital Petroleum Atlas at http://www.kgs.ukans.edu/DPA/Arroyo/Wells/drlgcomp.zip. (Remember that all digital well log files and well data have been compressed to improve online transfer efficiency and must be uncompressed). Formation tops used in the model are shown in Table 2.

API Number	*Well Name*	*Location*
15-187-20636	J. M. Huber Pro Farms 26-1	T29S-R41W, Sec. 26
15-187-20639	J. M. Huber Kendrick 22-1	T29S-R41W, Sec. 22
15-187-20650	J. M. Huber Santa Fe 22-2	T29S-R41W, Sec. 22
15-187-20667	J. M. Huber Scott 21-1	T29S-R41W, Sec. 1
15-187-20668	J. M. Huber Fretz 16-2	T29S-R41W, Sec. 2

Table 1 Listing of five wells from Arroyo Field (T29S-R41W) that will be used to construct the synthetic seismic section shown in Figure 1.

Formation	Pro Farms 26-1	Kendrick 22-1	Scott 21-1	Santa Fe 22-2	Fretz 16-2
Chase Group	2154	2205	2203	2200	2214
Council Grove	2462	2510	2503	2503	2510
Neva	2676	2734	2729	2724	2736
Waubansee	2853	2900	2895	2895	2903
Heebner	3585	3650	3642	3640	3669
Lansing Grp.	3678	3793	3780	3784	3810
Marmaton	4240	4307	4295	4294	4335
Cherokee	4442	4495	4483	4484	4550
Cherokee Mk.	4587	4635	4625	4625	4660
Morrow	4917	4970	4965	4967	5000
U. Morrow	5003	5274	5034	5052	5080
L. Morrow	5236	5040	5285	5270	5332
Mississippian	5502	5541	5496	5491	5491
St Louis	5526	5616	5550	5561	5558
Spergen	5715	5715	5750	5761	5750

Table 2 Stratigraphic markers used in the five-well seismic model across Arroyo Field. Data is available online at http://www.kgs.ukans.edu/DPA/Arroyo/Wells/drlgcomp.zip.

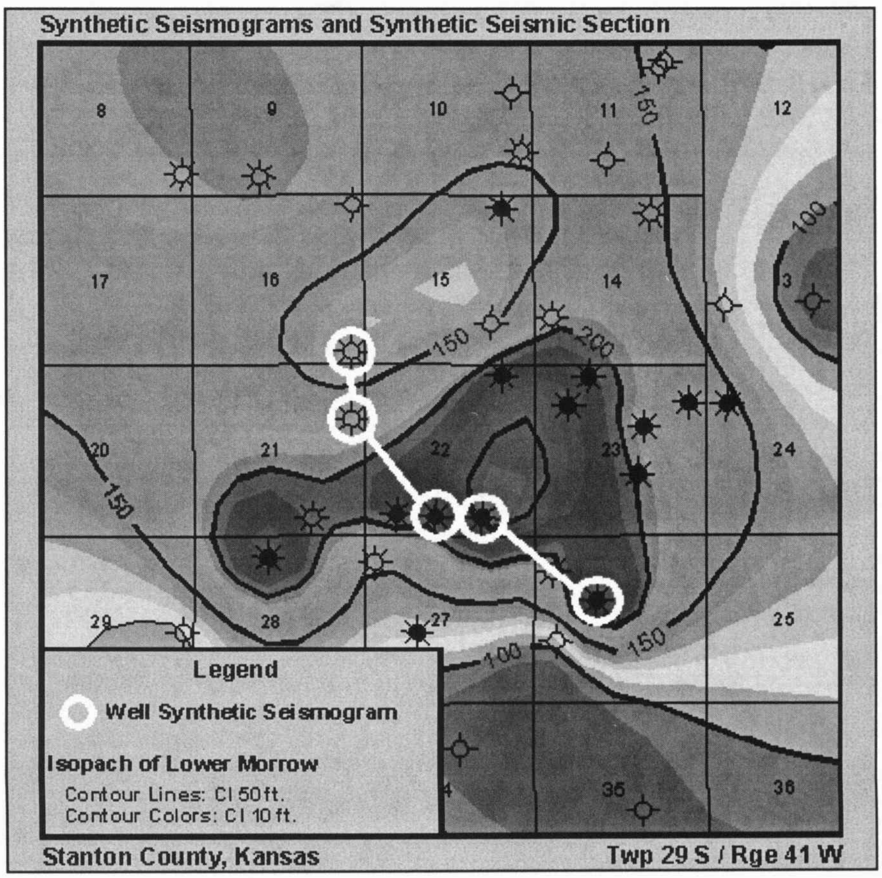

Figure 1 An isopach map of the Lower Morrow reservoir at the Arroyo Field (Stanton County, Kansas). The location of a synthetic seismic cross-section constructed from five wells listed in Table 1.

Editing Logs.- The first step is to edit all geologic logs using a program such as ***Log Editing*** from Digi-Rule Inc. Import the unzipped LAS logs using the **Import Logs**[1] command under **File**. Examine all the density and especially the sonic logs. One should be alert to cycle skips and other data artifacts that can be introduced by extreme wellbore conditions and operational procedures (i.e., pulling the tool at an overly fast rate). Under **Edit** select **Set Active Curve** and repair any obvious artifacts using interactive tools (Figure 2). One could also use the **Curve Clipping** function in the **Utilities** menu, and this would be another way to clip the data over a range limit to a certain value. The formational tops (Table 2) can be imported from a spreadsheet or entered by interactively using the editing tools under **Tops**. Also multiple wells can be opened and "slipped" to select and modify tops between wells. The final edited log with stratigraphic markers is save to file (.log format), and is ready to import into the modeling package.

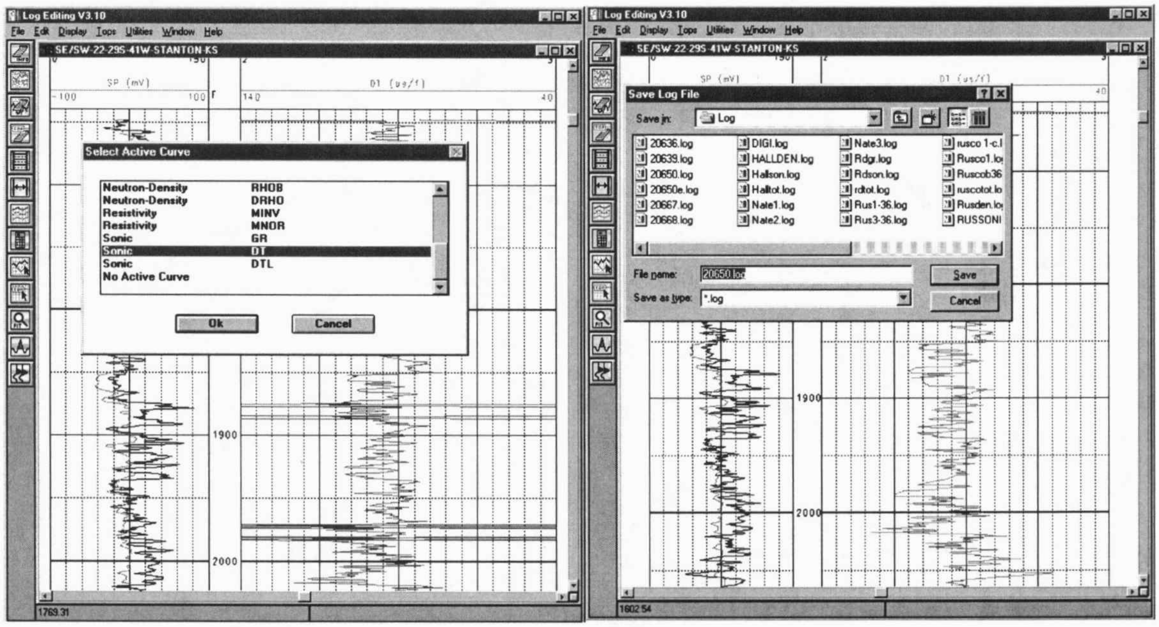

Figure 2 Left side shows the election of the sonic log (DT) with cycle skips. The same sonic curve on the right side of the figure is edited using the interactive tools. The final edited log along with formational tops is save to file (.log format) for importing into the modeling package.

Constructing the Seismic Model.- InterpaLog from Digi-Rule Inc. is a flexible modeling package. One can select any number of wells and position them in the section either with offset or shotpoint values, or graphically with the mouse. Tops can be imported from log files or created and picked graphically. Tops do not need to be continuous through the section, but can onlap or subcrop. The well logs can be displayed in depth or in seismic time. Missing well log data can be computed using standard formulas or interpolated between wells.

[1] Words in underlined bold correspond to commands, menus or pull-down options in the programs.

The first step is to **Set Model Parameters** (e.g., units, length, height) and to import the well logs using the **Import Logs** command. Wells can be repositioned through dialog boxes or graphically. New stratigraphic and structural events can be added using the **Add New Event** command (Figure 3). Missing well logs can be interpolated using standard equations (e.g., Gardner's Equation) and empirical relationships (Figure 4).

Using various wavelets and frequencies, a seismic trace model can be created from the geologic model (Figure 5). With an understanding of the seismic data the interpreter can understand limits imposed by standard seismic processing. In addition to generating a synthetic seismic model the program can:

- Flatten on any horizon;
- View multiple interpolated log models and trace models simultaneously;
- View traces in wiggle, variable area and/or color amplitude modes;
- Output models in SEG-Y format.

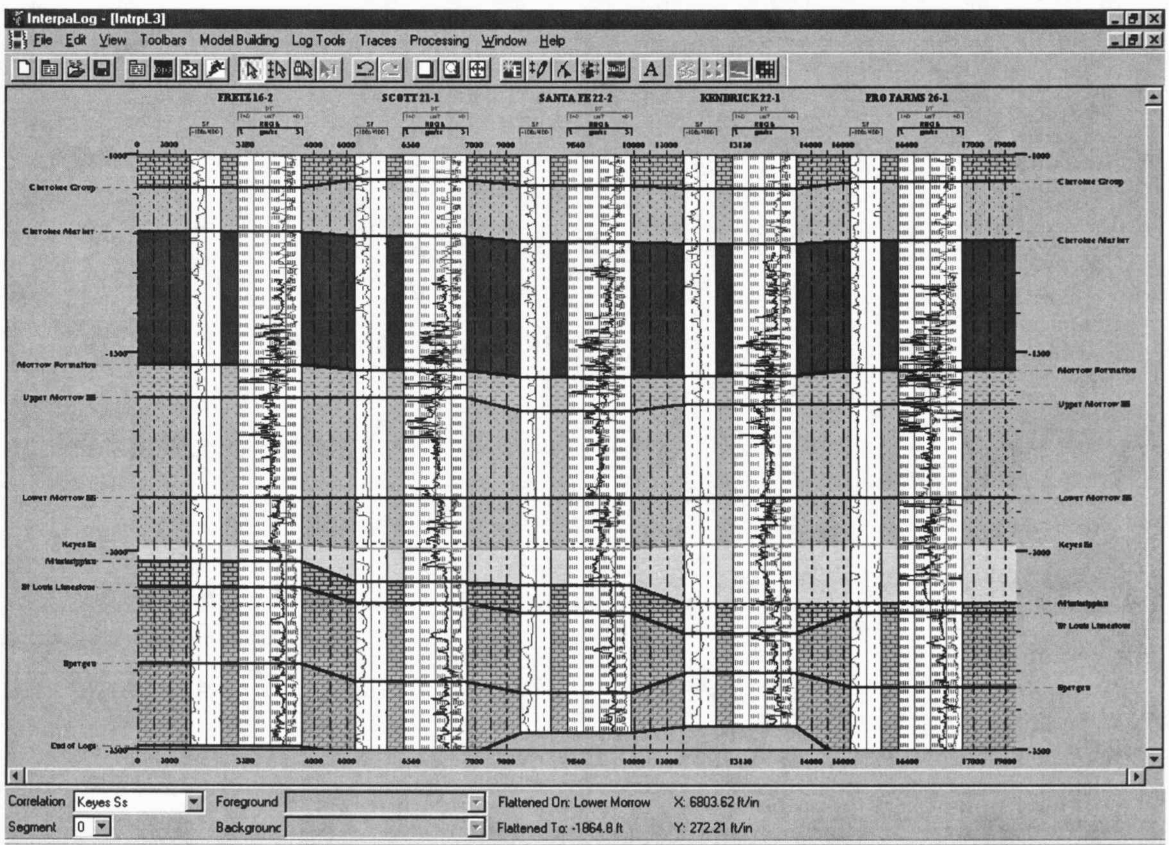

Figure 3 Geologic model across Arroyo Field showing the addition of the Keyes Sandstone. The section is flattened on the top of the Lower Morrow Sandstone. Note that density logs are incomplete and do not extend to the top of the section. Applying Gardner's equations to the sonic log can extend the missing data (Figure 4).

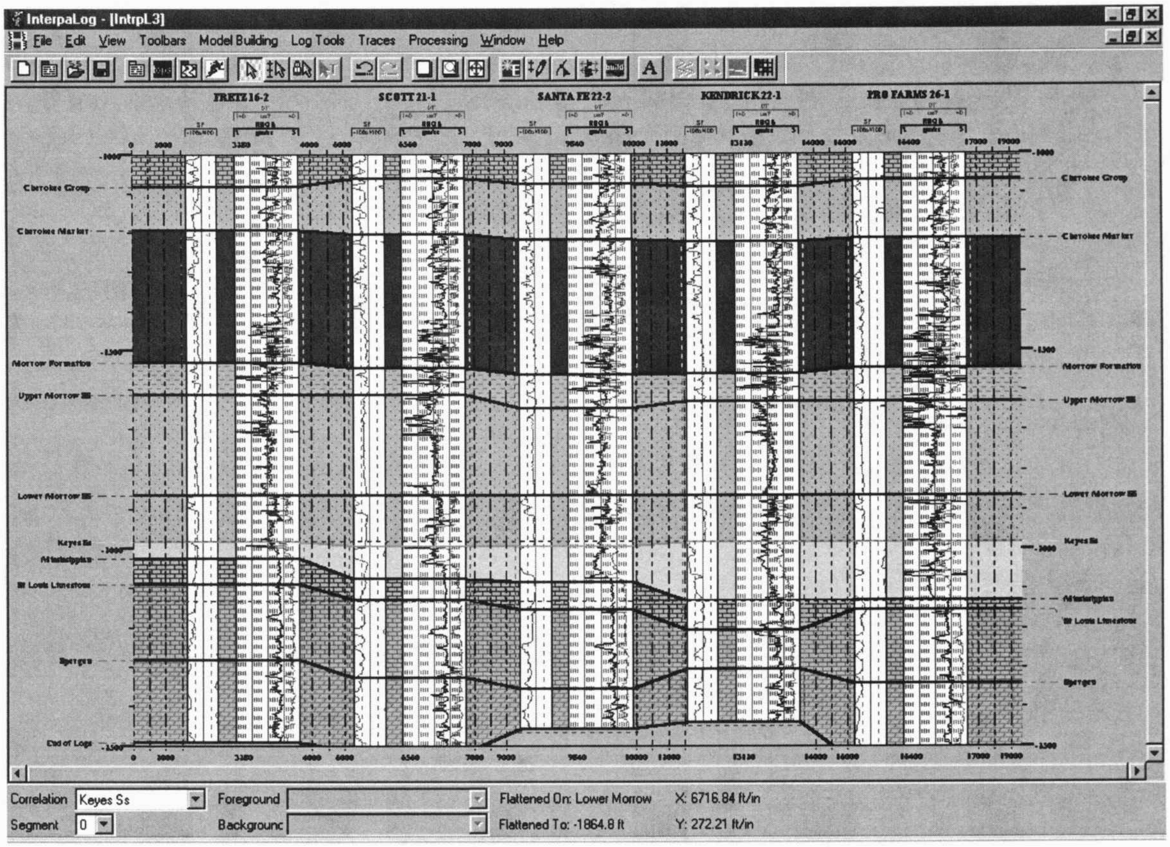

Figure 4 Geologic model across Arroyo Field showing the estimated density curves. Gardner's equations were applied to the sonic log to generate the missing data.

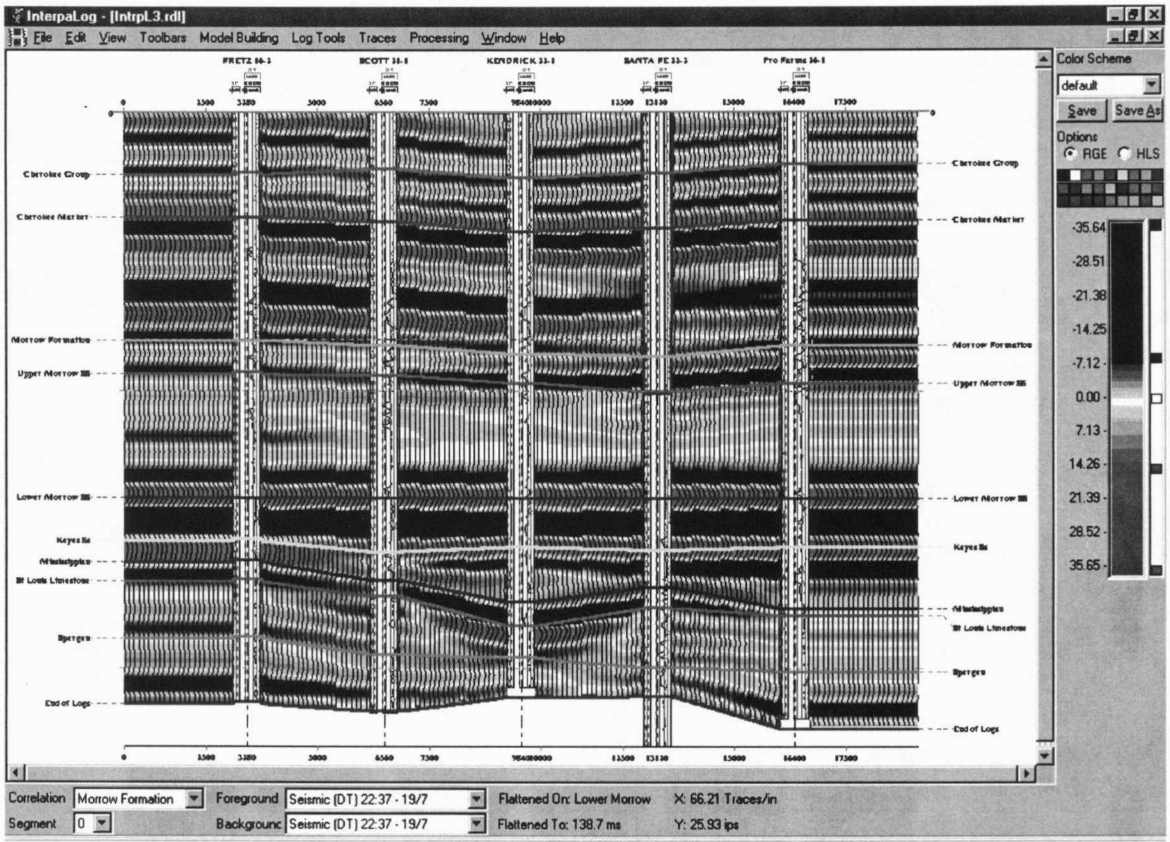

Figure 5 Synthetic seismic model across Arroyo Field showing the seismic response of the Keyes Sandstone incised into the Mississippian. The section is flattened on the top of the Lower Morrow Sandstone. Section also shows the response as Upper Morrow Sandstone is developed on the right hand side of the synthetic seismic section. Model was built using a zero phase Ricker wavelet (35 Hz).