Recent Developments in 3-D Survey Design and Analysis

Norm Cooper
and Yajaira Herrera
MUSTAGH RESOURCES LTD.

and Michael Cooper
DIREC+AID


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3


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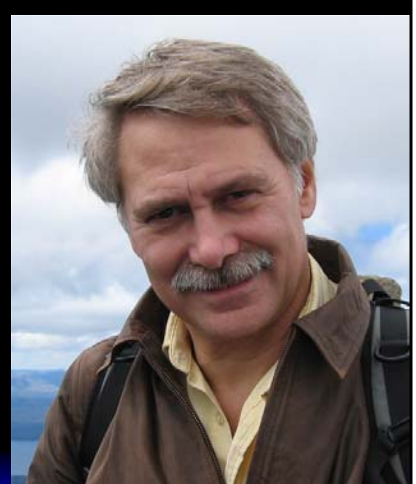
4

Norm Cooper

- Graduated from UBC in 1977
- BSc with a major in Geophysics
- Amoco Canada 1977 to 1981
- Voyager Petroleums Ltd. 1981 to 1983
- Mustagh Resources Ltd. Founded in 1983



Yajaira Herrera

- Graduated from University of Zulia, Venezuela in 1994
- BSc in Industrial Engineering
- PDVSA 1992-1994
- Lubvenca 1994-1995
- MSc in Mechanical Engineering from U of C in 1999
- MSc in Geophysics from U of C in 2006
- Mustagh 1998 to present

7

Mustagh Resources Ltd.

Since 1983 we have specialized in all types of Geophysical Consulting:

Design and Management of 2D and 3D seismic programs.

Quality Assurance and Parameter Optimization on program start ups.

8

Mustagh Resources Ltd.

We provide training programs in:

Application of Seismic Methods,

Land Seismic Acquisition,

Array Theory, Instrumentation

3D design, Vibroseis Theory,

and Basic Processing

Mustagh Resources Ltd.

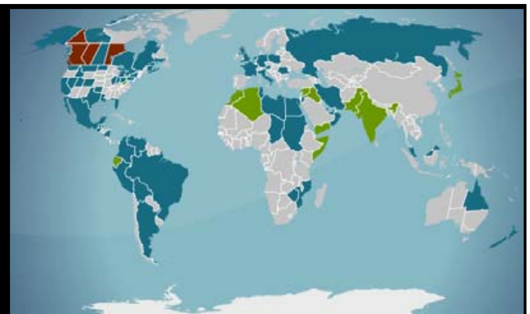
We have worked extensively throughout onshore Canadian basins.

We design and implement 100 - 200 programs each year.

We visit about 20 seismic crews per year.

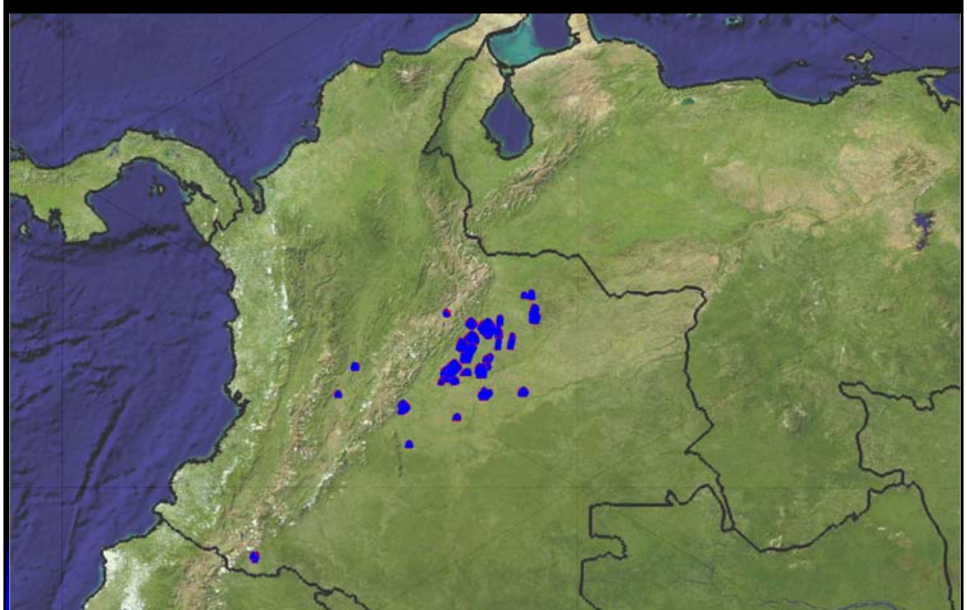
Mustagh
Resources Ltd.

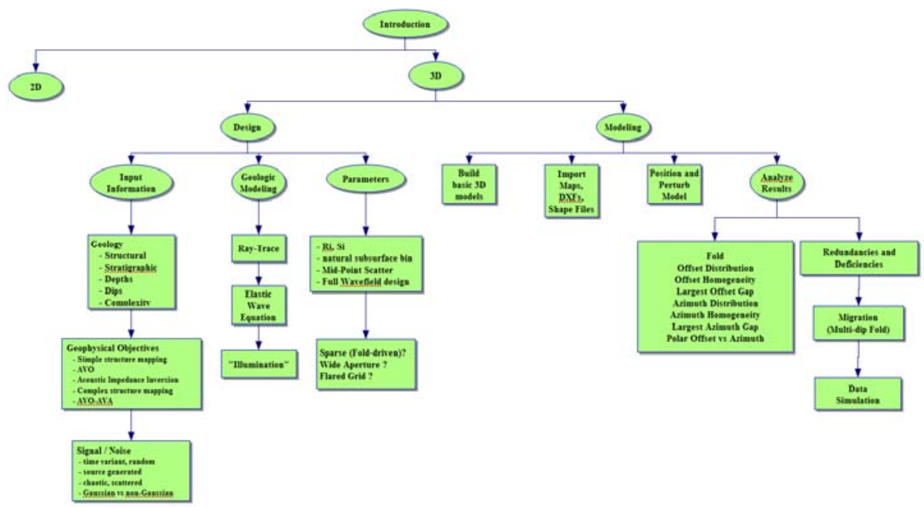
We have worked in over 40 countries across 6 continents



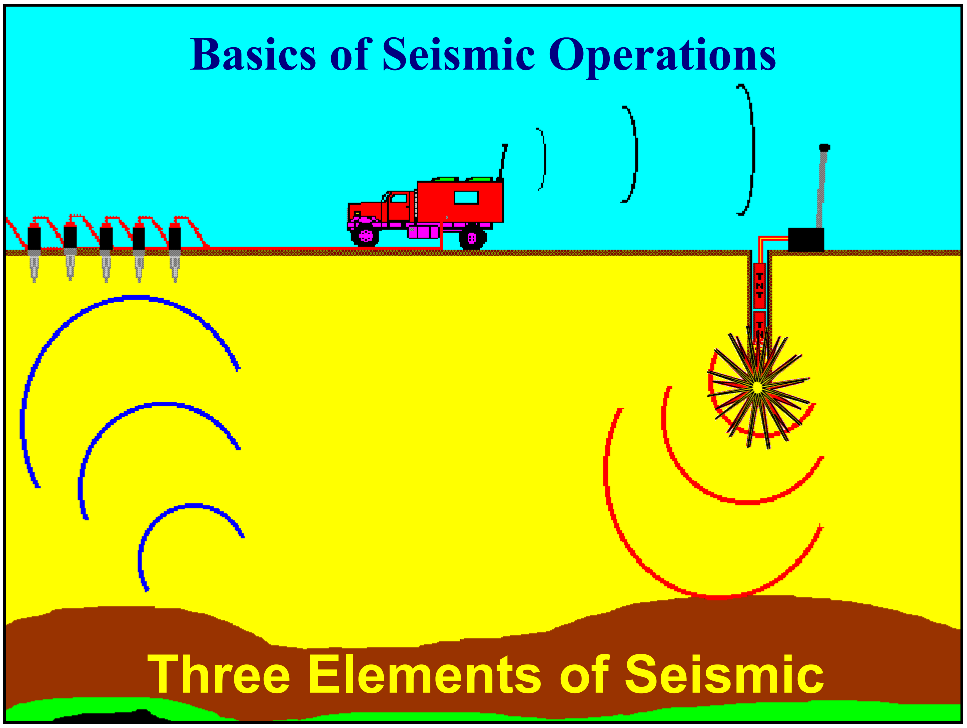
Canada, USA, Mexico, Guatemala, Nicaragua, Trinidad,
Argentina, Brazil, Bolivia, Venezuela, Colombia, Ecuador, Peru,
England, North Ireland, Poland, Romania, France, Germany
Algeria, Tunisia, Libya, Egypt, Sudan, Chad, Mozambique, Somalia
Russia, Iran, Oman, Yemen, Qatar, Syria, Jordan, Iraq, UAE,
Malaysia, Japan, New Zealand, Australia, Pakistan, India

- more than 40 3-D designs in Colombia




Introduction
2D
3D
Design
Modeling
Input Information
Geologic Modeling
Parameters
Build basic 3D models
Import Maps, DXFs, Shape Files
Position and Perturb Model
Analyze Results
Geology
- Structural
- Stratigraphic
- Depths
- Dips
- Complexity
Ray-Trace
Elastic Wave Equation
"Illumination"
- Ri, Si
- natural subsurface bin
- Mid-Point Scatter
- Full Wavefield design
Sparse (Fold-driven)?
Wide Aperture ?
Flared Grid ?
Geophysical Objectives
- Simple structure mapping
- AVO
- Acoustic Impedance Inversion
- Complex structure mapping
- AVO-AVA
Signal / Noise
- time variant, random
- source generated
- chaotic, scattered
- Gaussian vs non-Gaussian
Fold
Offset Distribution
Offset Homogeneity
Largest Offset Gap
Azimuth Distribution
Azimuth Homogeneity
Largest Azimuth Gap
Polar Offset vs Azimuth
Redundancies and Deficiencies
Migration (Multi-dip Fold)
Data Simulation


SI NO SABE PREGUNTE



2-D versus 3-D

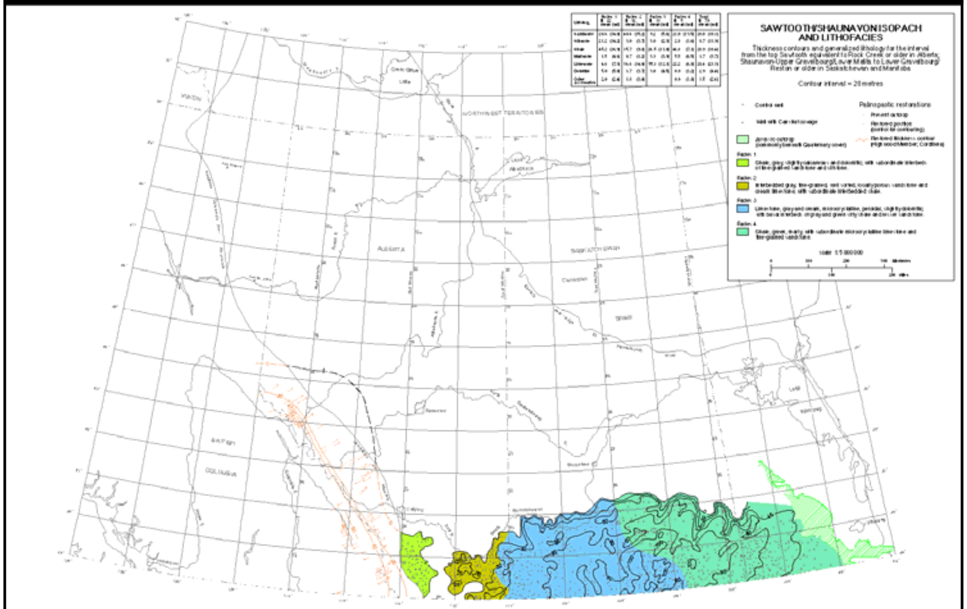
3-D Seismic Diffractions and Out-of-Plane Resolution

A Case History From The Vauxhall Area, Alberta

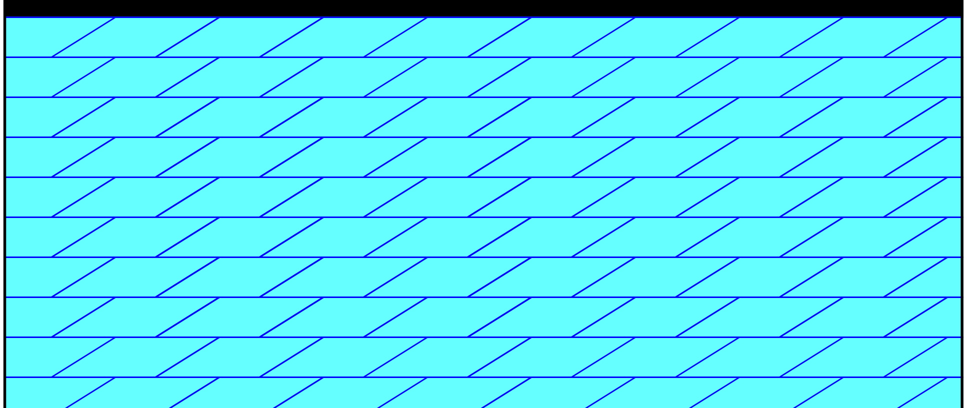
Jim Bruce (Rozsa Petroleums)
Norm Cooper (Mustagh Resources)

Western Canada Today

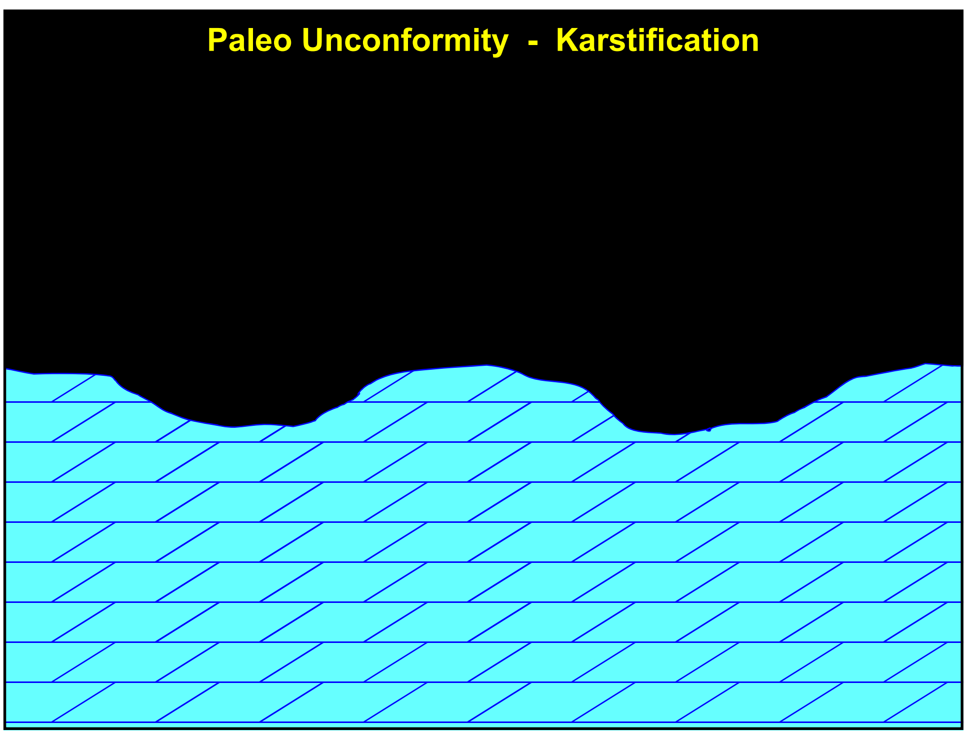
Jurassic: Sawtooth and Shaunovon Distribution

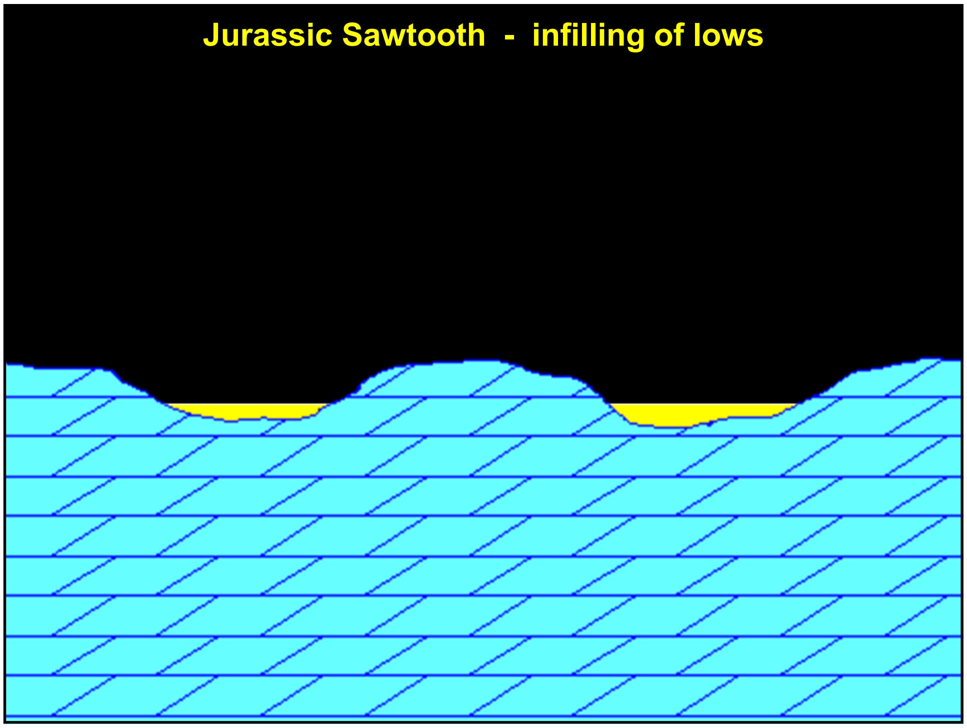


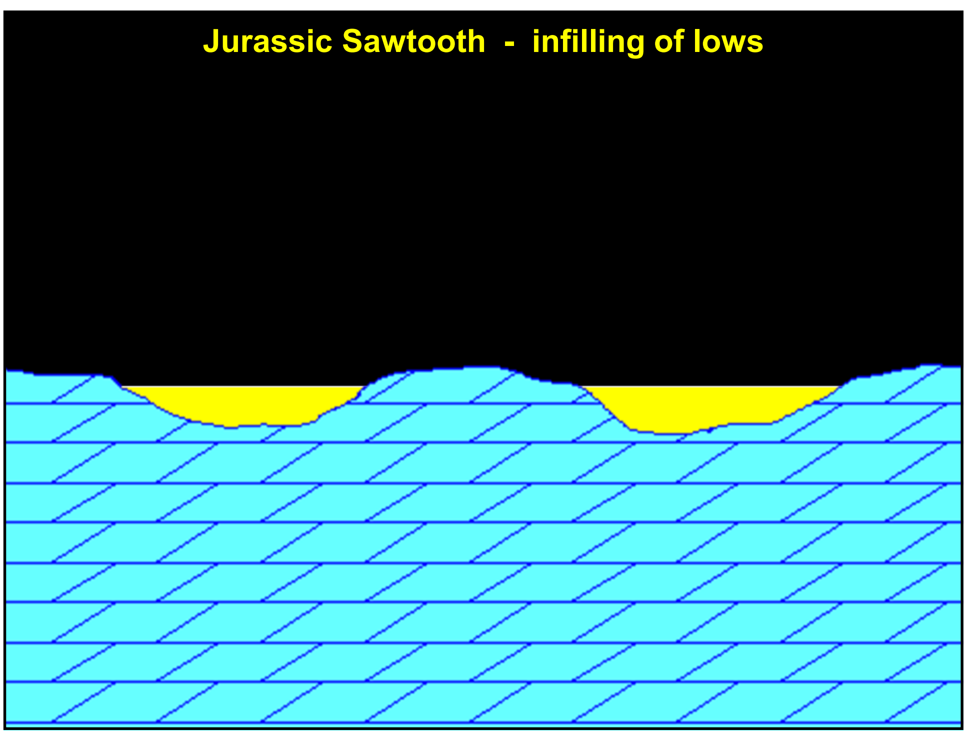
Carboniferous / Mississippian - Carbonate deposition

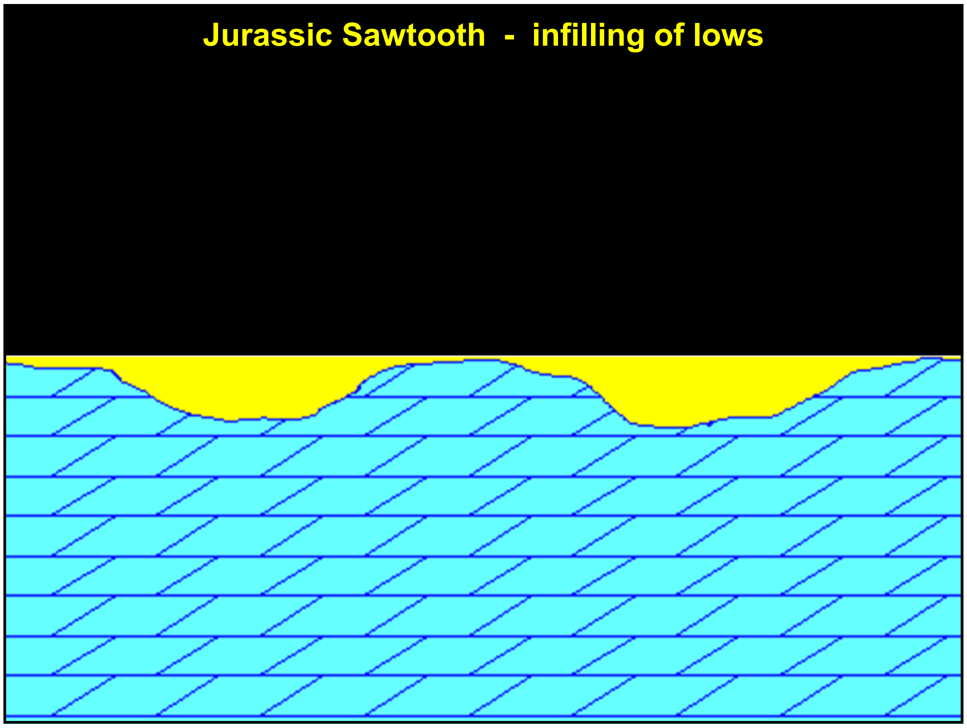


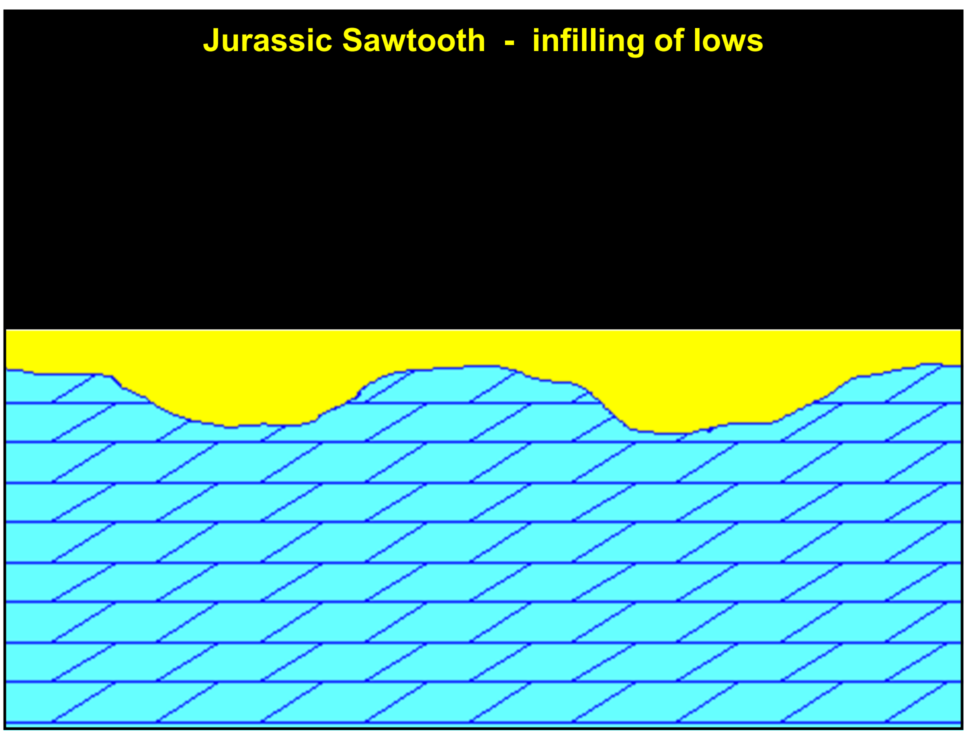

Carboniferous / Mississippian - start of Karstification

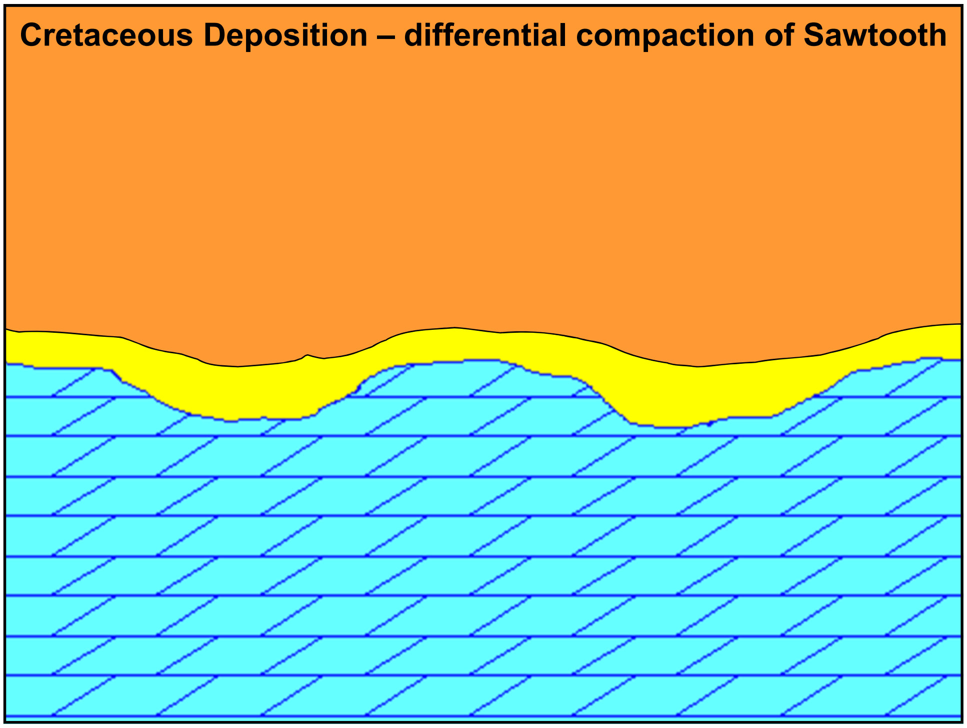

Paleo Unconformity - Karstification

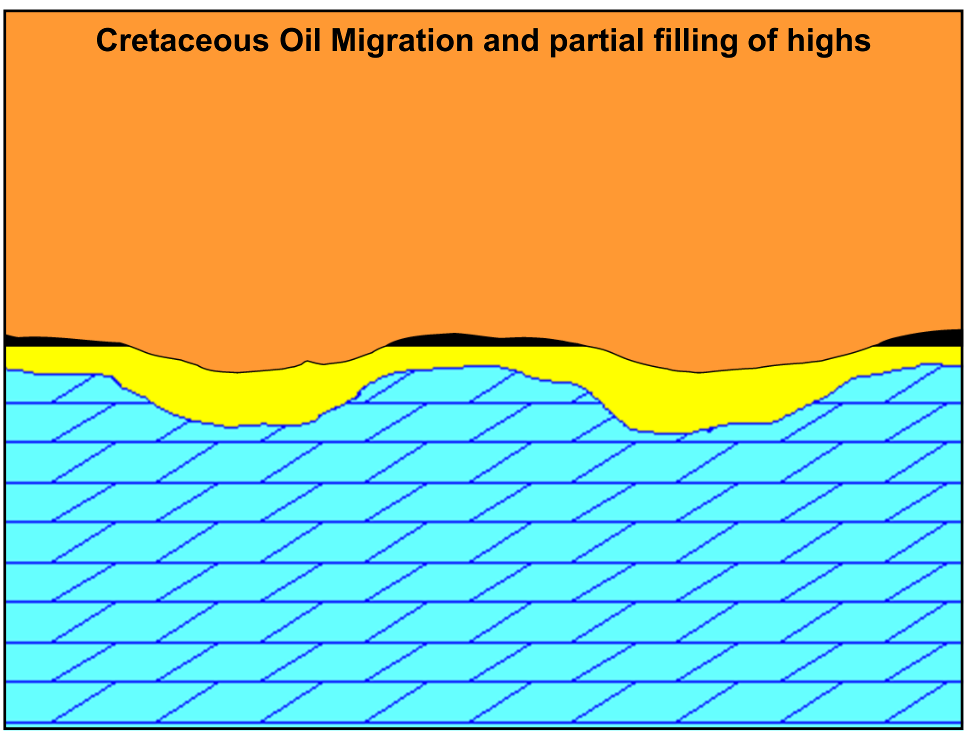

Jurassic Sawtooth - infilling of lows

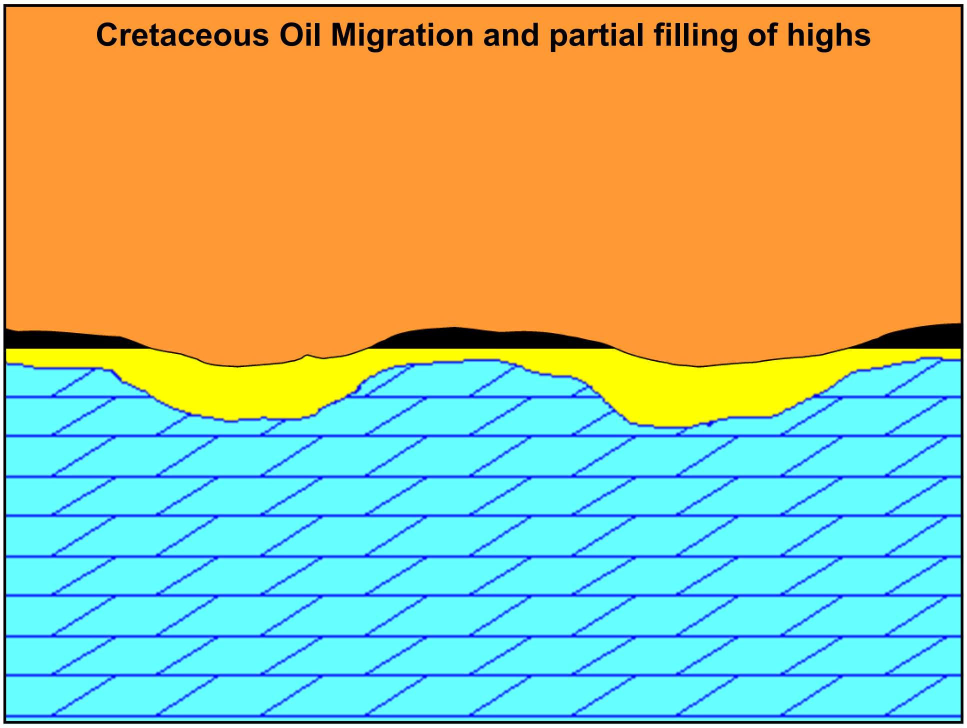

Jurassic Sawtooth - infilling of lows

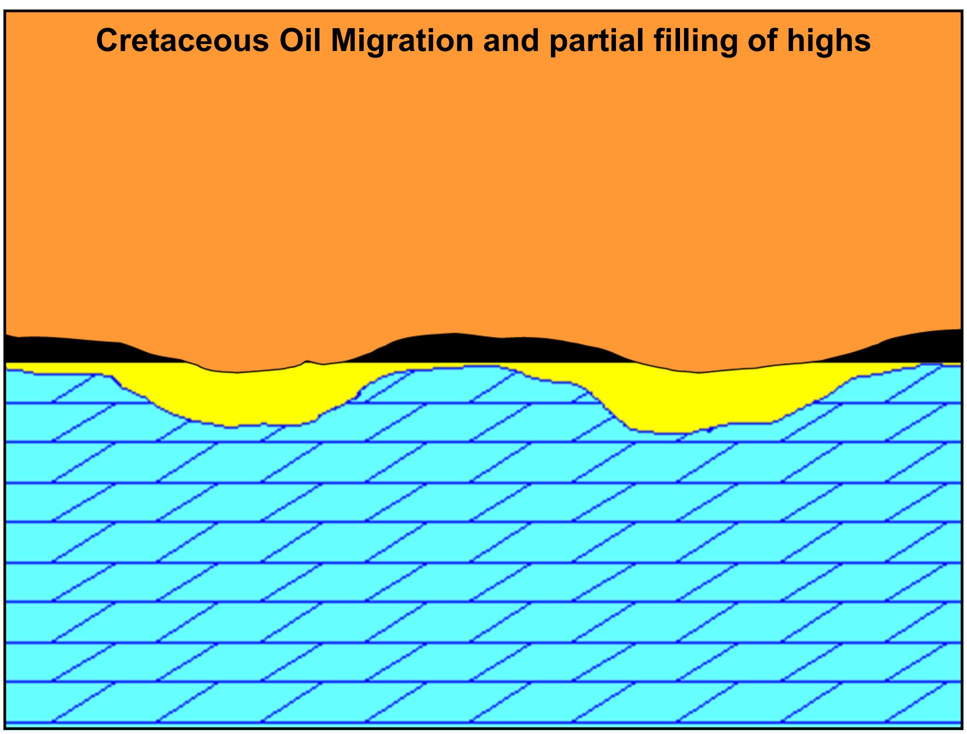

Jurassic Sawtooth - infilling of lows

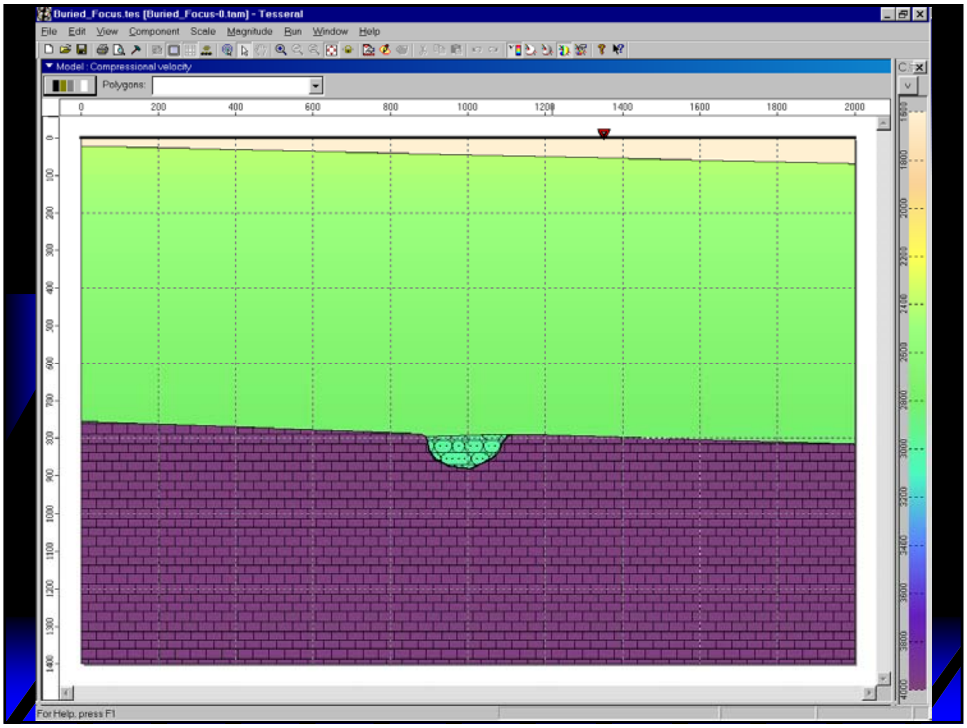

Jurassic Sawtooth - infilling of lows

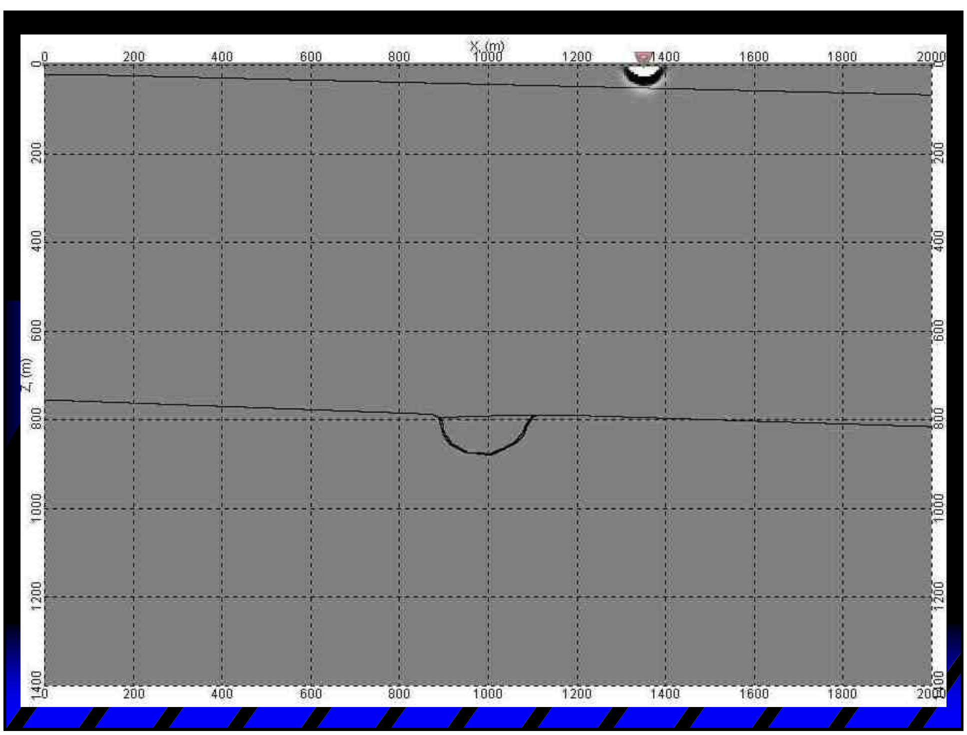

Cretaceous Deposition – differential compaction of Sawtooth


Cretaceous Oil Migration and partial filling of highs


Cretaceous Oil Migration and partial filling of highs


Cretaceous Oil Migration and partial filling of highs


Buried_Focus.tes [Buried_Focus-0.tam] - Tesseral
File Edit View Component Scale Magnitude Run Window Help
Model : Compressional velocity
Polygons:
0 200 400 600 800 1000 1200 1400 1600 1800 2000
For Help, press F1


X (m)
Z (m)
0 200 400 600 800 1000 1200 1400 1600 1800 2000
0 200 400 600 800 1000 1200 1400

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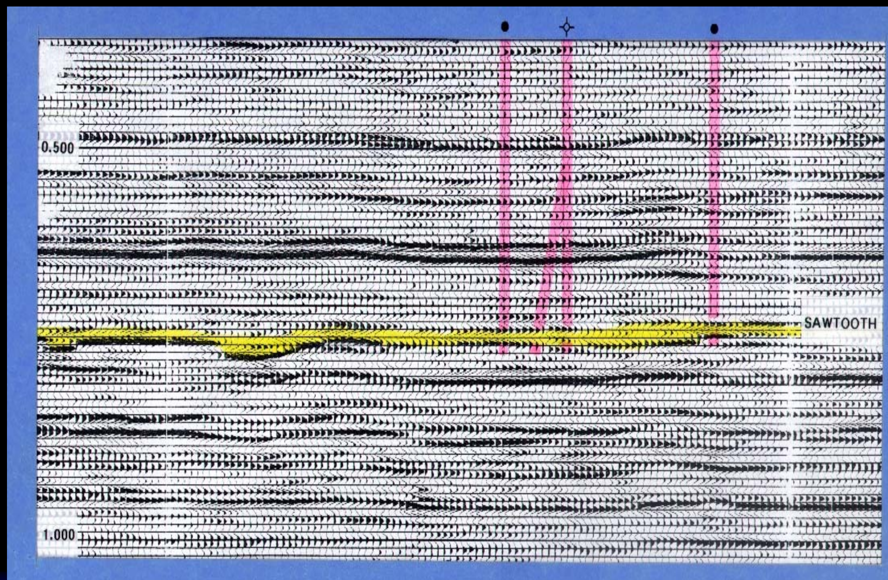
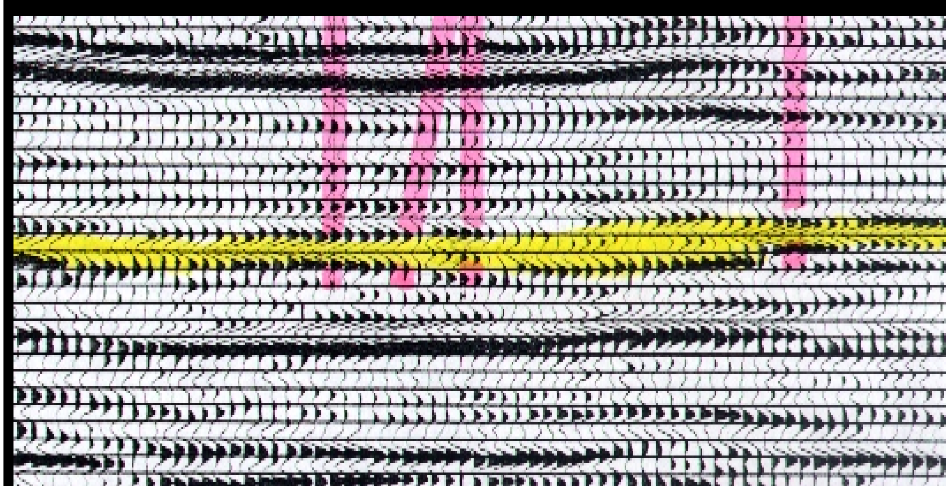
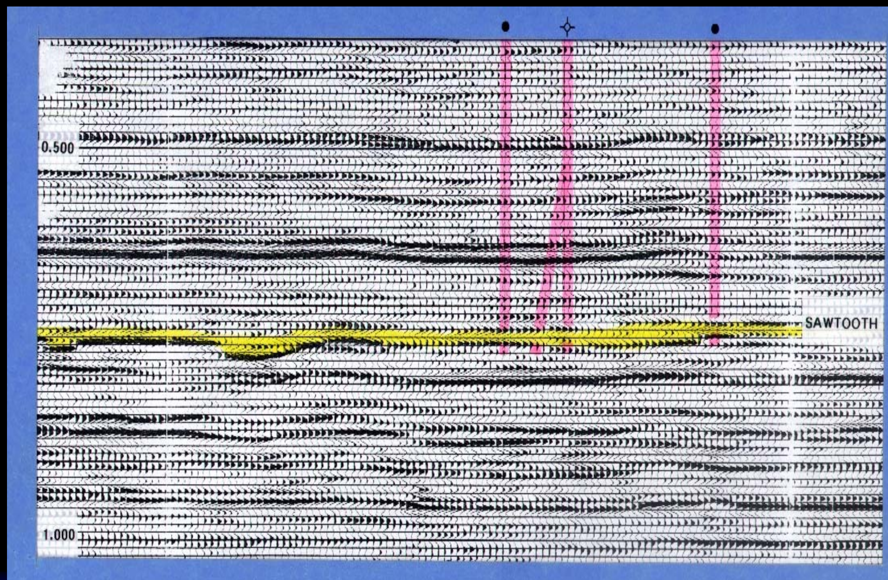
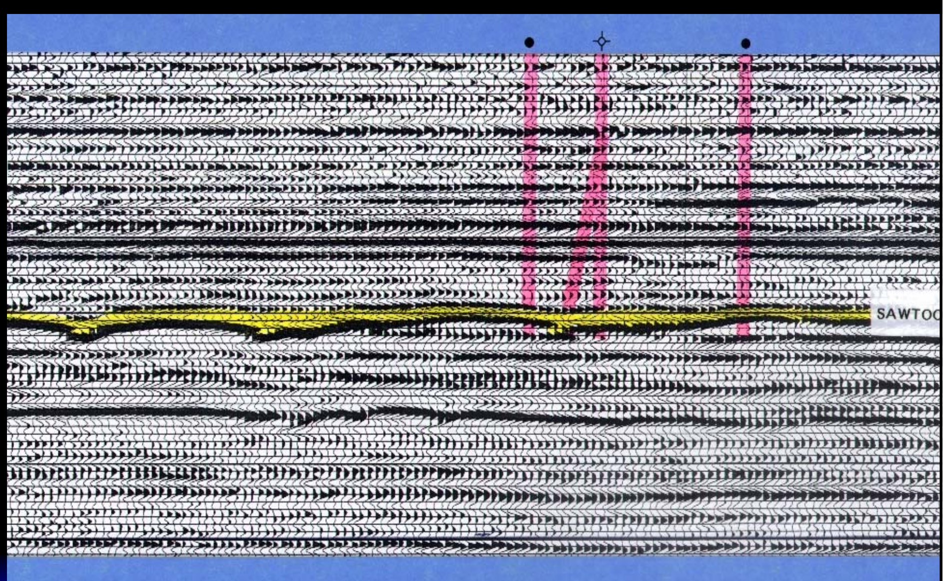
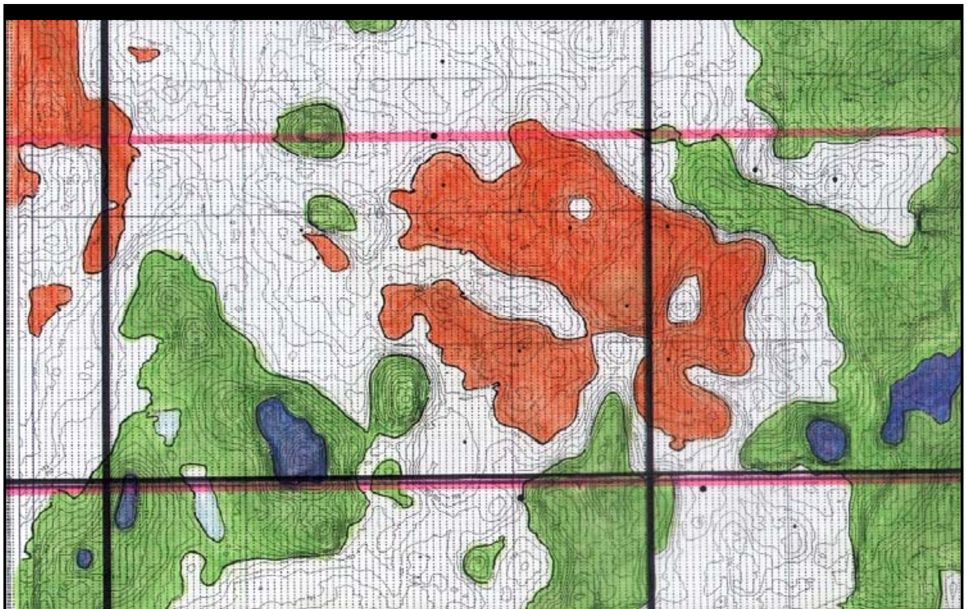


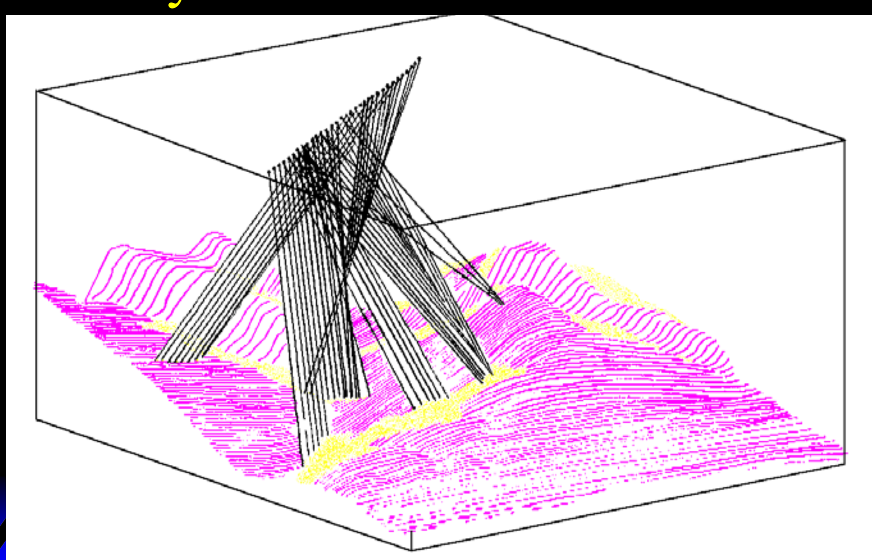


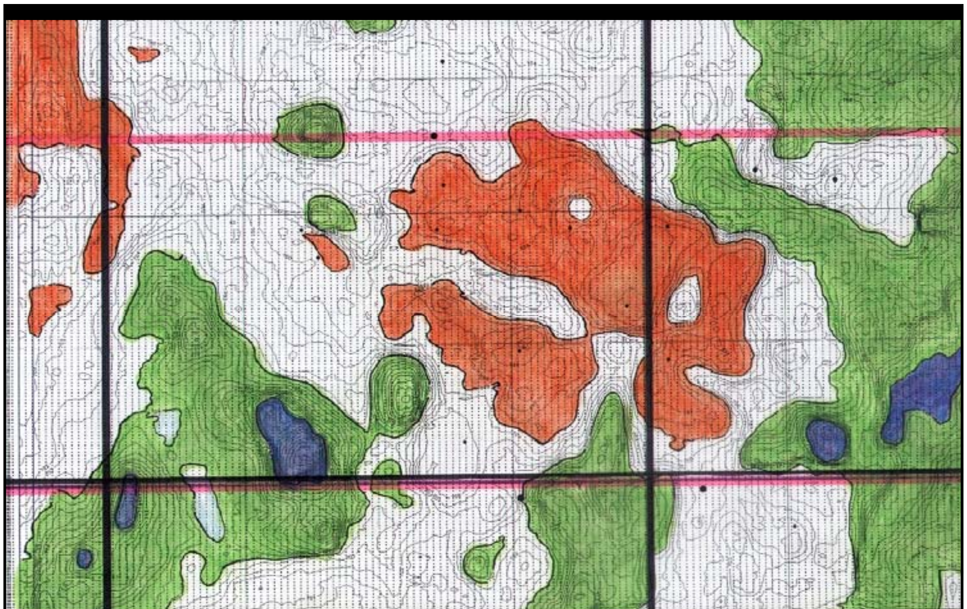

0.500
SAWTOOTH
1.000

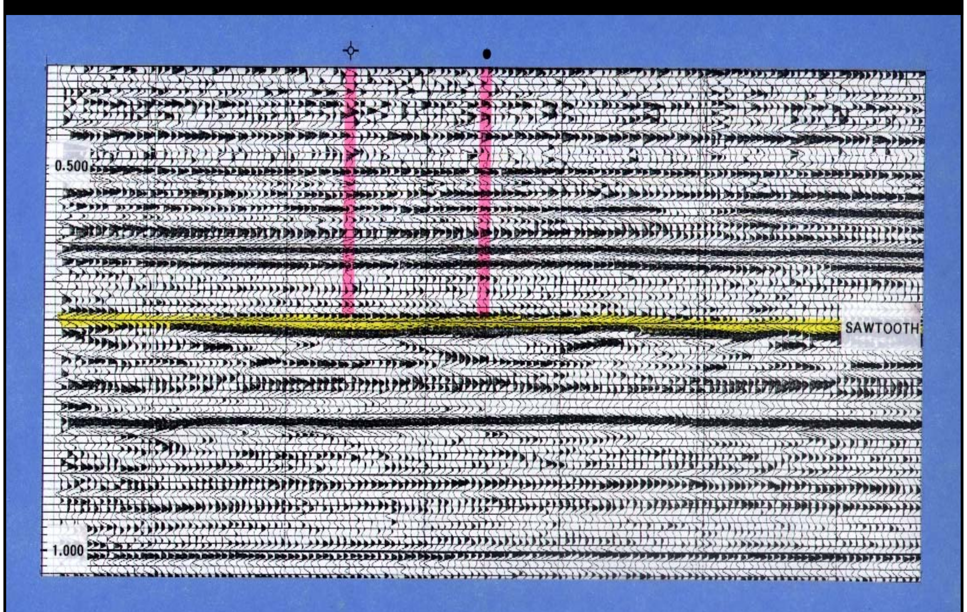

SAWTOO



2-D Seismic can be confused by "Out-of-Plane" effects



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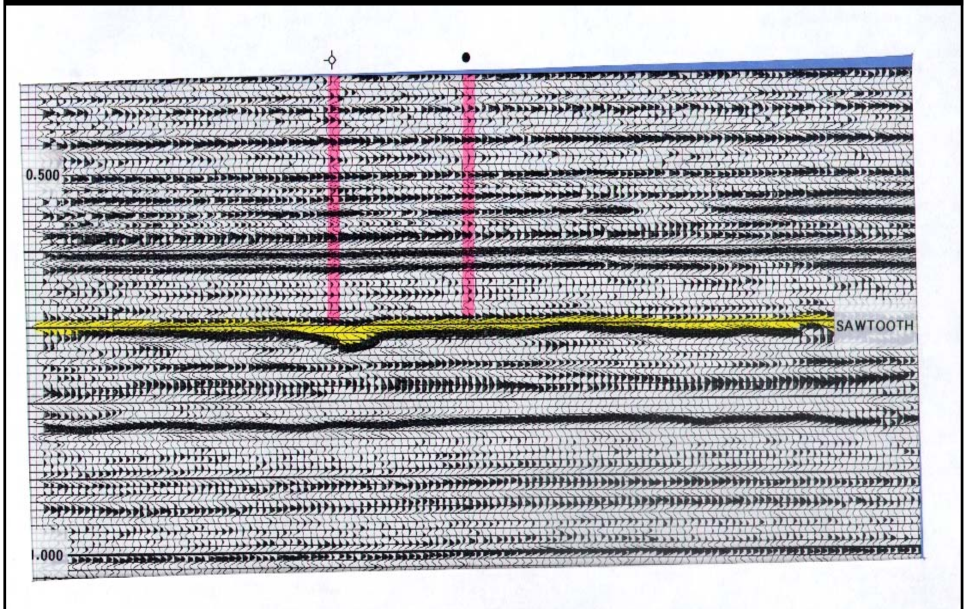
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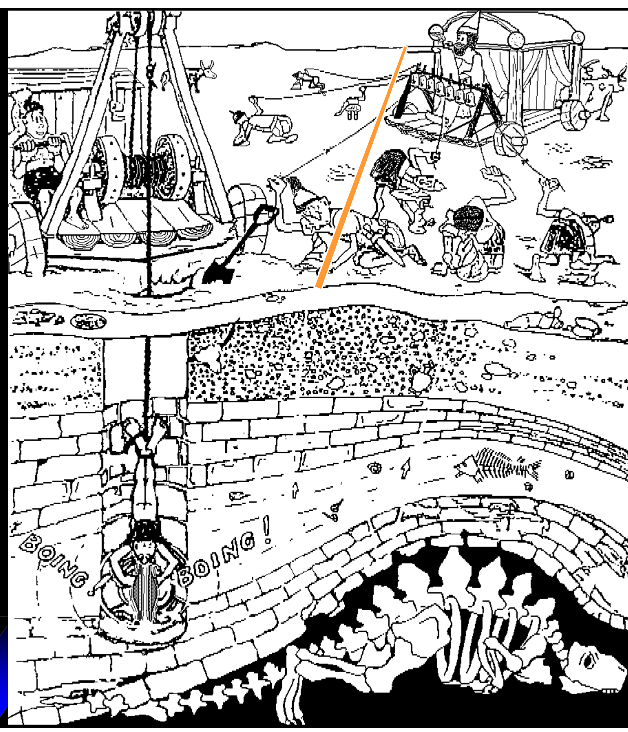

BOING
BOING!

Summary of Design Objectives

Clear Images
– broad bandwidth temporal and lateral

Accurate in Depth and Space
– 3-D migration, velocities, spatial sampling

Efficient and Cost-Effective
- available recording equipment, regulations, topography and culture

Robust under Perturbation
- variations in geologic model, topography, culture

DESIGN versus MODELING

Design versus Modeling

Design

Analyze exploration objectives

Study Geological attributes

Review existing data and study Signal and Noise attributes

Incorporate operational limitations

Determine appropriate basic model parameters

The designer will also recommend source types, receiver types, array configurations, etc.

The designer will generally establish basic skid and offset guidelines.

Program "Design" requires in-depth knowledge and experience in geology, geophysics, and seismic field operations.

Modeling

Use parameters of the designer

Fit them to known cultural, topographic, environmental and regulatory restrictions using background air photos, DEMs, satellite images and other information maps

Perturb the model and analyze the impact using various statistics (hopefully not just fold!)

Modeling is also used as part of the quality control process when additional changes are required during program implementation

The role of "Modeling" contains some professional skills, but may be suited to a more technical level

Design versus Modeling

The inputs to the “Design” phase are project objectives, geological models, geographic information and available equipment.

The tools used are calculators (often Excel spreadsheets), fundamental calculations and application of extensive experience.

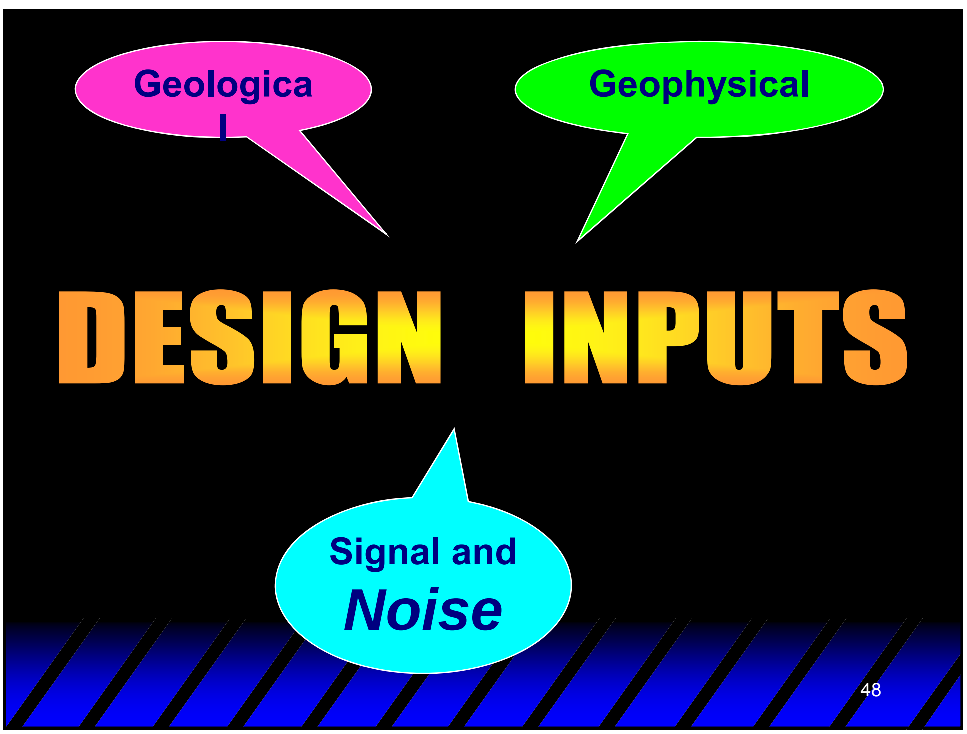
The output is a parameter sheet and perhaps a basic model on geographic maps.

The inputs to “Modeling” are parameters, perhaps a basic model.

The tools used are modeling software such as DirectAid, Omni, Mesa or various in-house programs.

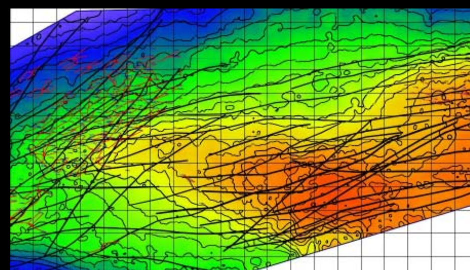
The outputs are statistical analyses such as fold, offset homogeneity, offset-azimuth polar plots, migration imaging plots.

47



Design Inputs - Geological

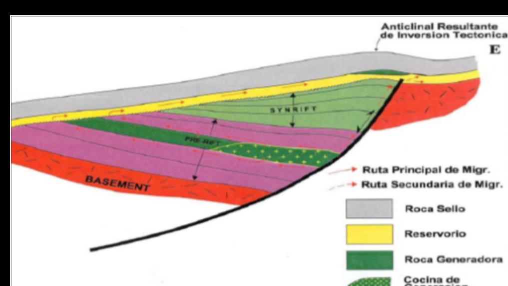
- Structure Maps
- Stratigraphic Information
- Velocities
- Depths
- Dips (geological and diffractions)
- Complexity



Existing seismic interpretations, geologic mapping,
residual gravity maps,
magnetic and EM surveys

Design Inputs - Geological

- Structure Maps
- Stratigraphic Information
- Velocities
- Depths
- Dips (geological and diffractions)
- Complexity



Geologic models,
Stratigraphic Charts,
Communication with Client

Design Inputs - Geological

Structure Maps

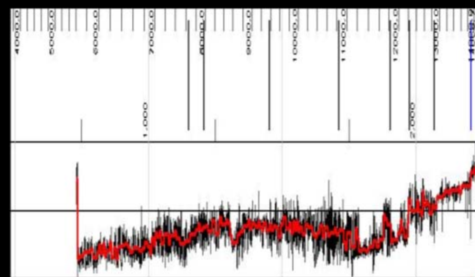
Stratigraphic Information

Velocities

Depths

Dips (geological and diffractions)

Complexity



Well logs (LAS), VSPs,
Synthetic Seismograms
Seismic Processor Velocity Functions

Design Inputs - Geological

Structure Maps

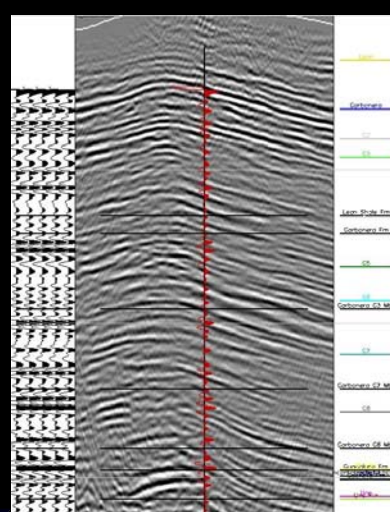
Stratigraphic Information

Velocities

Depths and TWT

Dips (geological and diffractions)

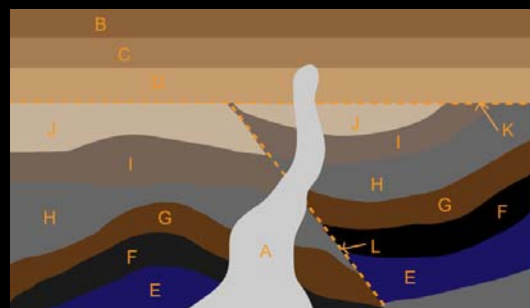
Complexity



Well logs, VSPs,
Existing seismic interpretations

Design Inputs - Geological

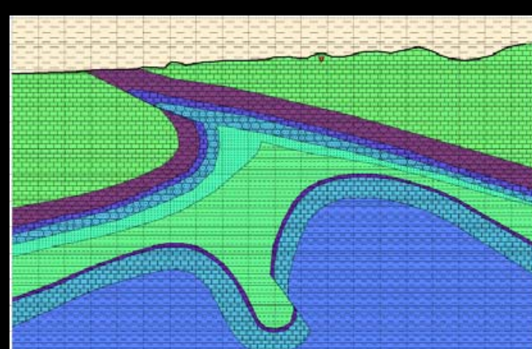
- Structure Maps
- Stratigraphic Information
- Velocities
- Depths
- Dips (geological and diffractions)
- Complexity



Geologic Cross-Sections,
un-migrated seismic sections
Calculations and models

Design Inputs - Geological

- Structure Maps
- Stratigraphic Information
- Velocities
- Depths
- Dips (geological and diffractions)
- Complexity

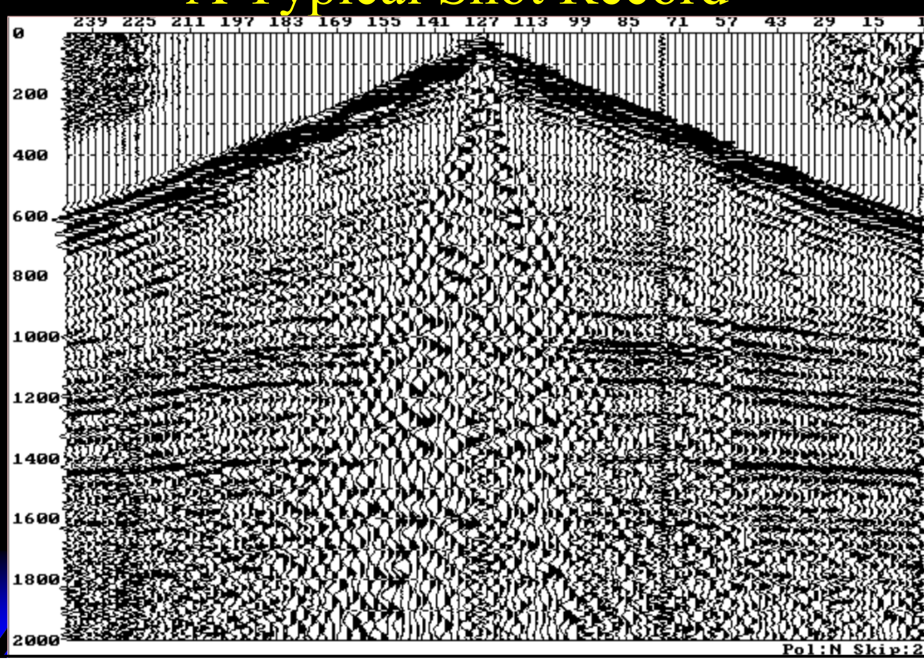


Geologic Cross-Sections,
Existing seismic interpretations

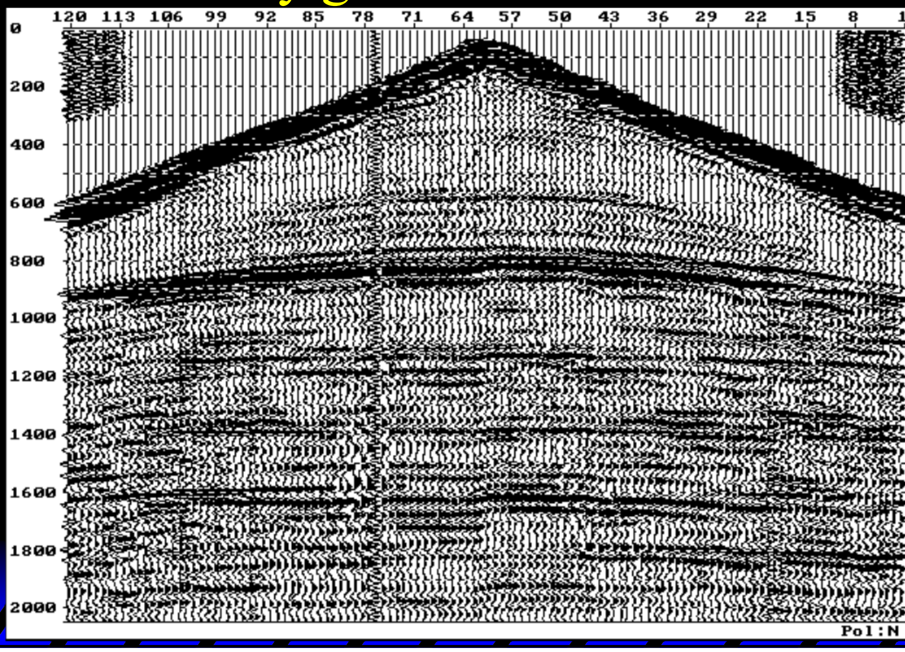
Fold and Geophysical Objectives

Simple Structure	> 8-10
Complex Structure ??	> 20
AVO (2D)	> 20
AVO (3D)	> 40
AI (acoustic impedance) inversions	> 50
AVA / AVO	> 80

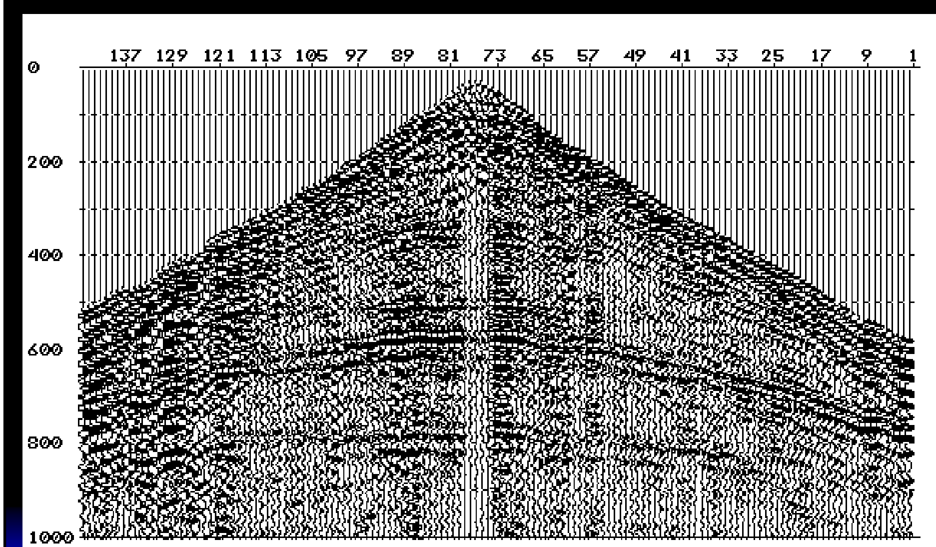
A Typical Shot Record



A very good Shot Record



Poorer Quality Shot Record

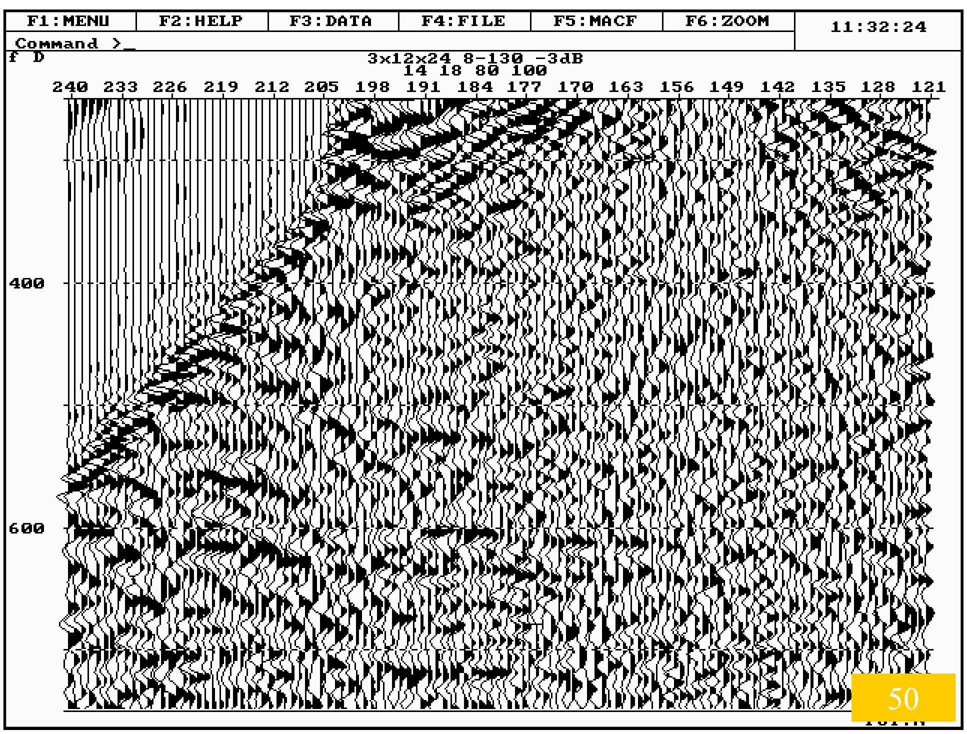


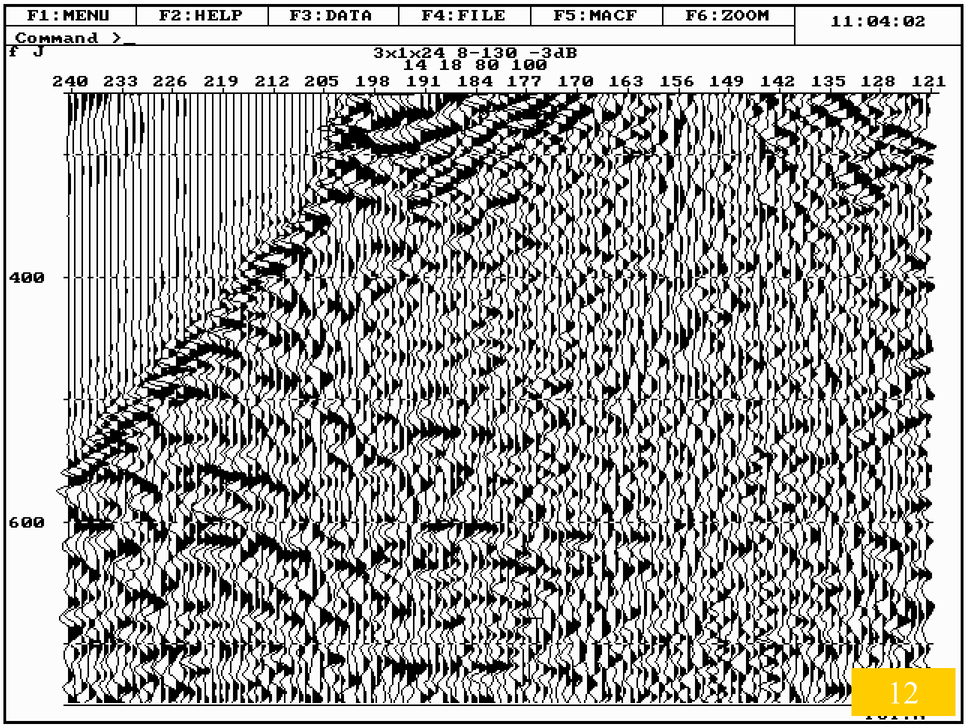
Types of Noise

Noise is

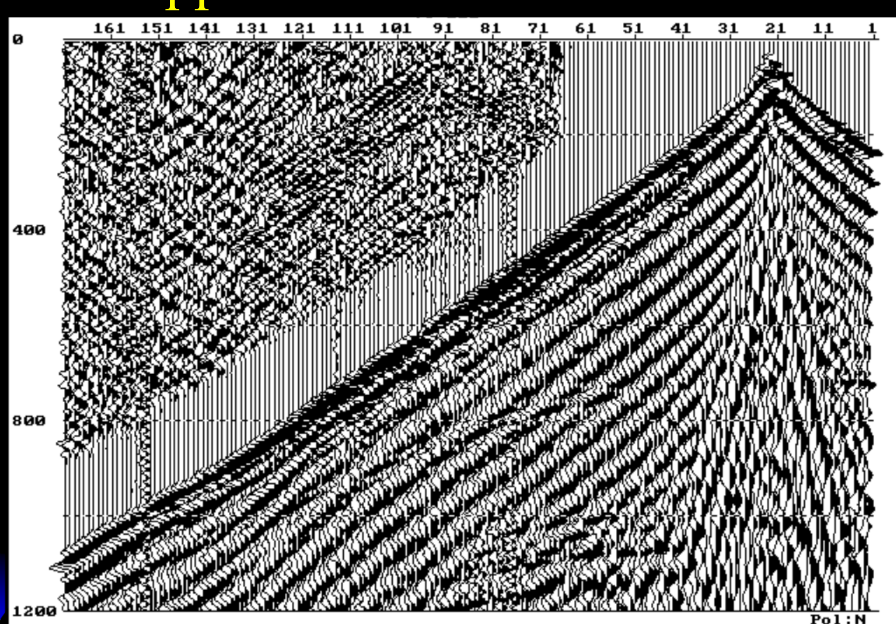
RANDOM

??

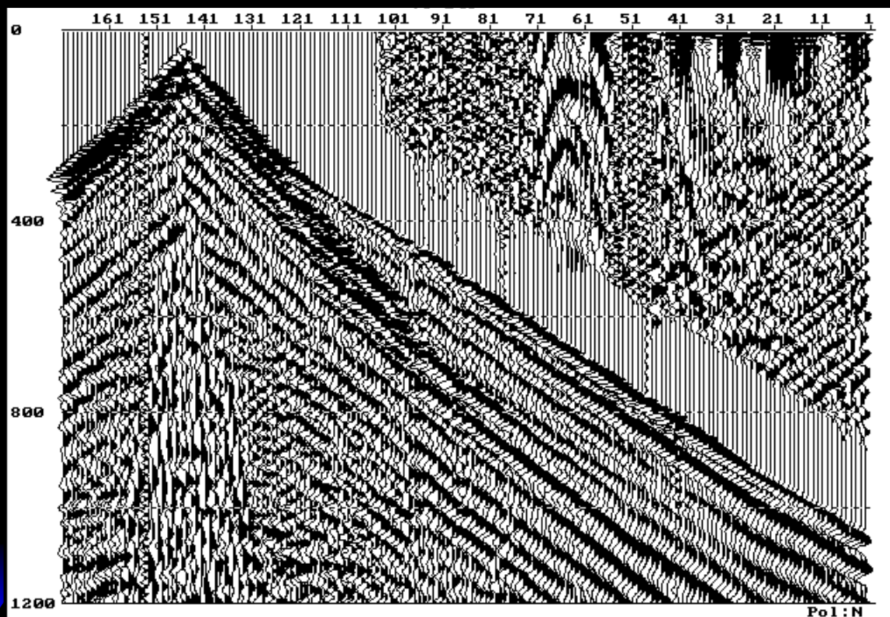




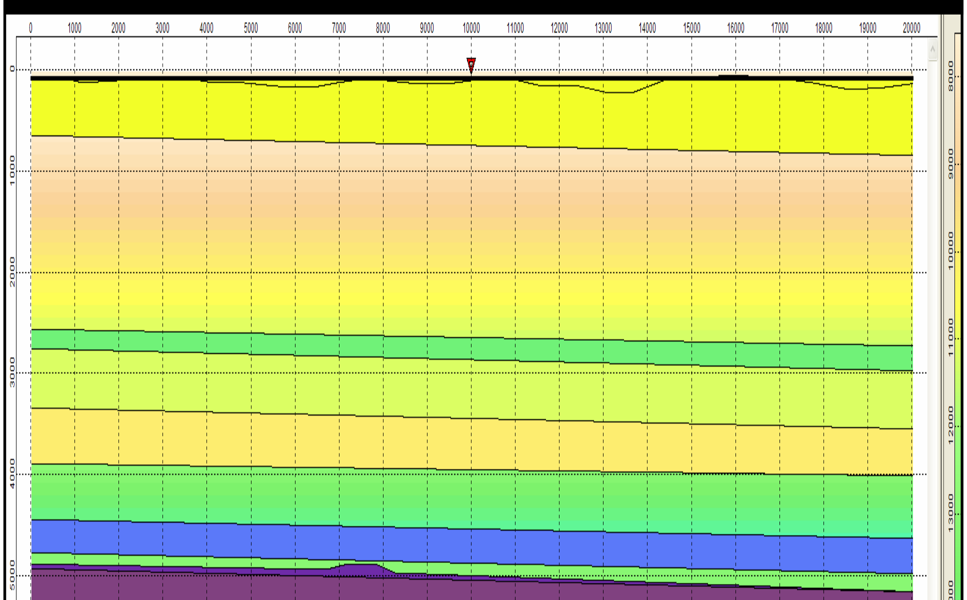
Trapped Mode Reverberations



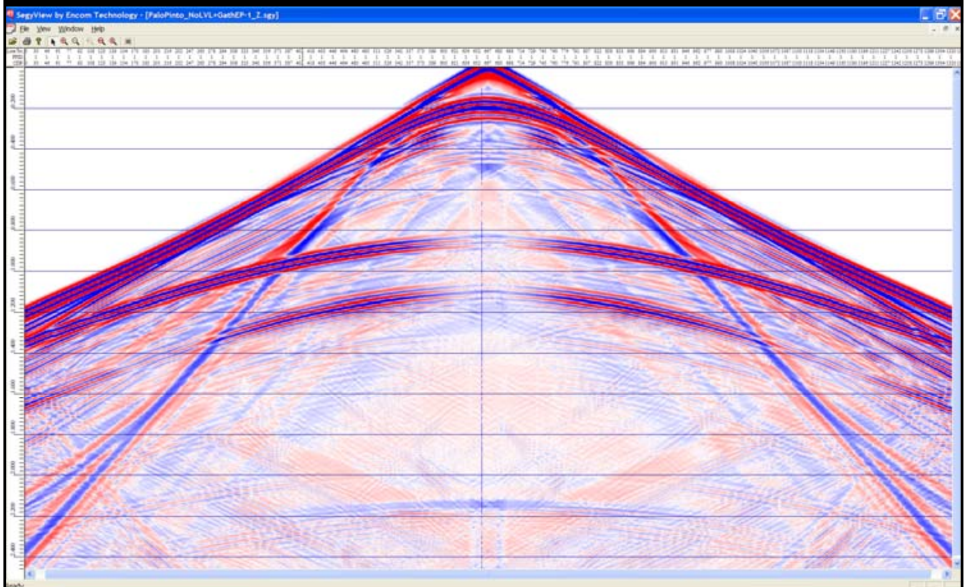
Tuned Guided Waves and Harmonics



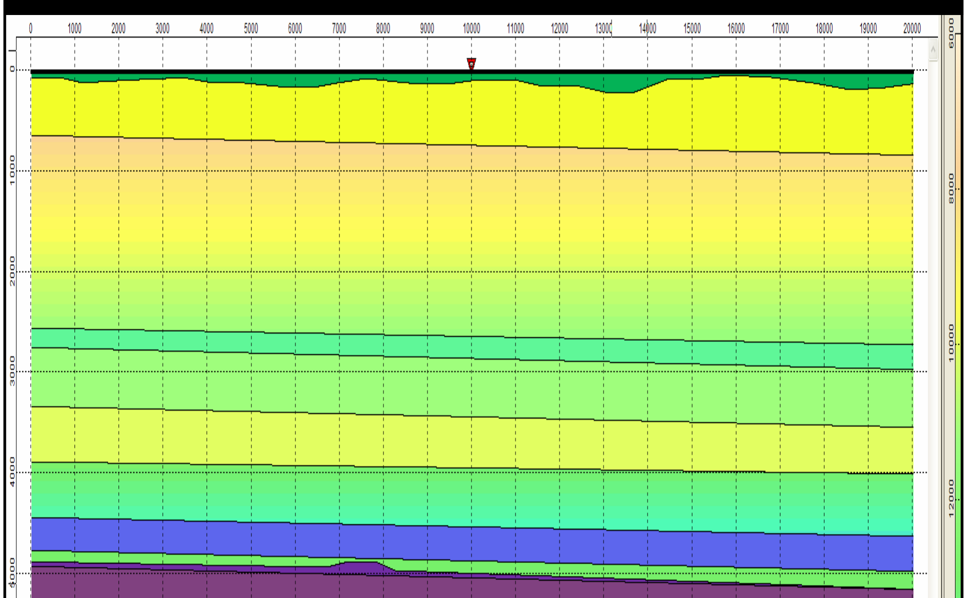
Model with no LVL

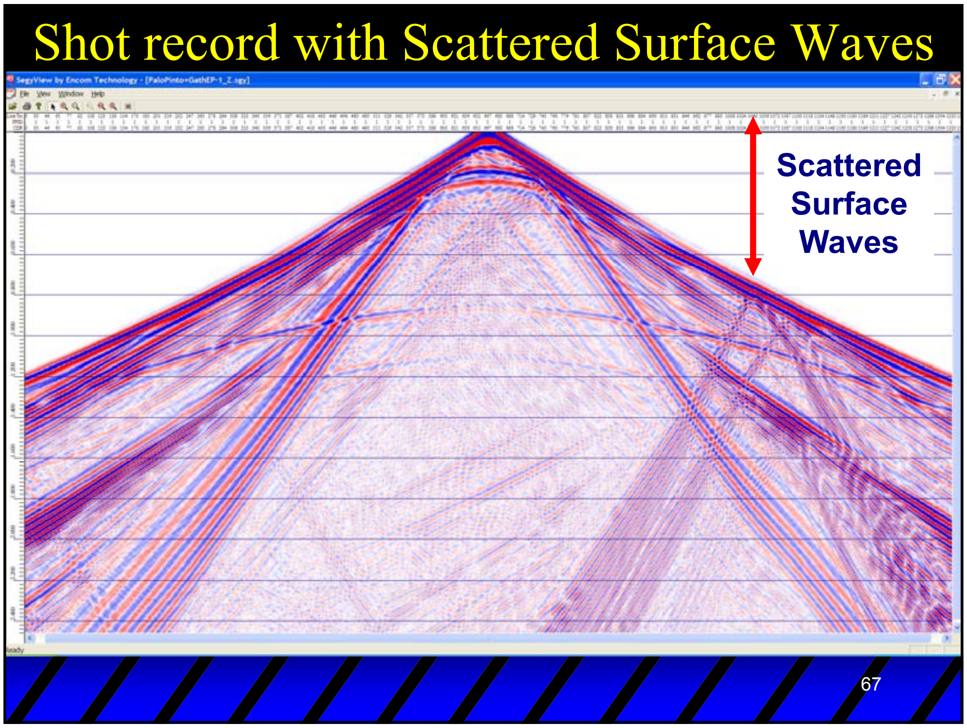


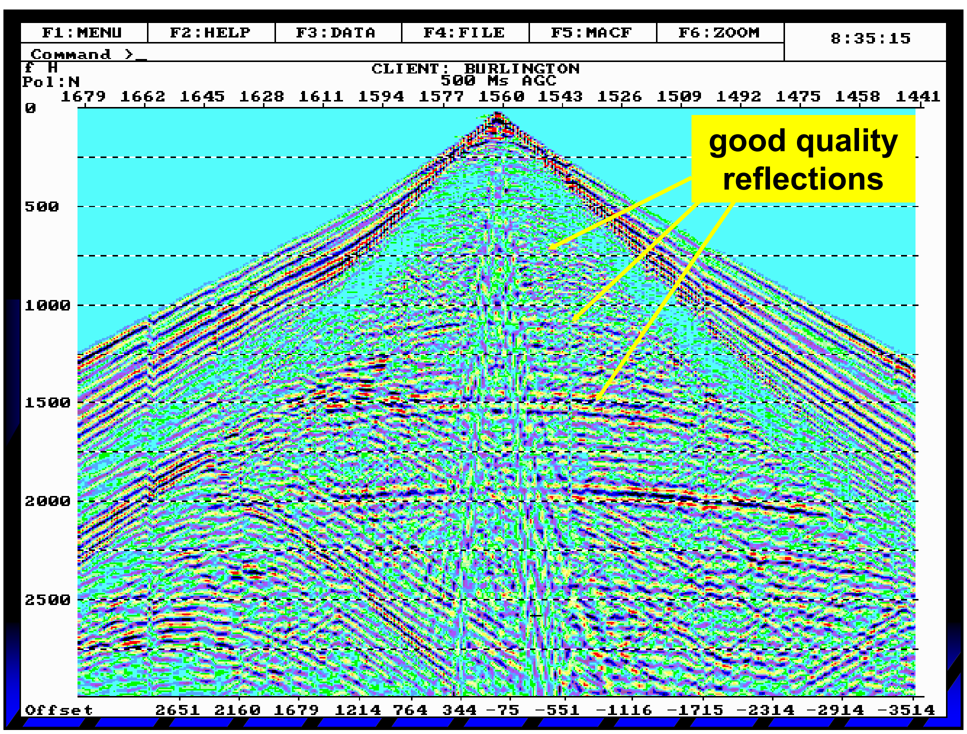
Shot record with no LVL

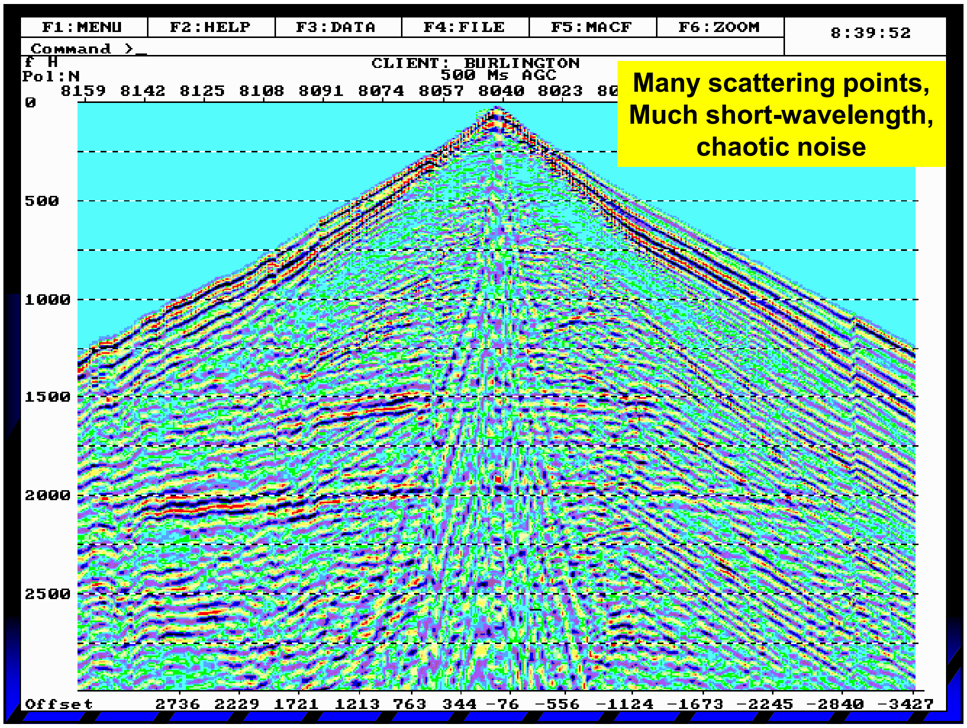


Model with LVL inhomogeneity




Shot record with Scattered Surface Waves
Scattered Surface Waves
67


F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
8:35:15
Command >_
CLIENT: BURLINGTON
500 Ms AGC
Pol:N
1679 1662 1645 1628 1611 1594 1577 1560 1543 1526 1509 1492 1475 1458 1441
0
500
1000
1500
2000
2500
good quality reflections
Offset 2651 2160 1679 1214 764 344 -75 -551 -1116 -1715 -2314 -2914 -3514


F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
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f H
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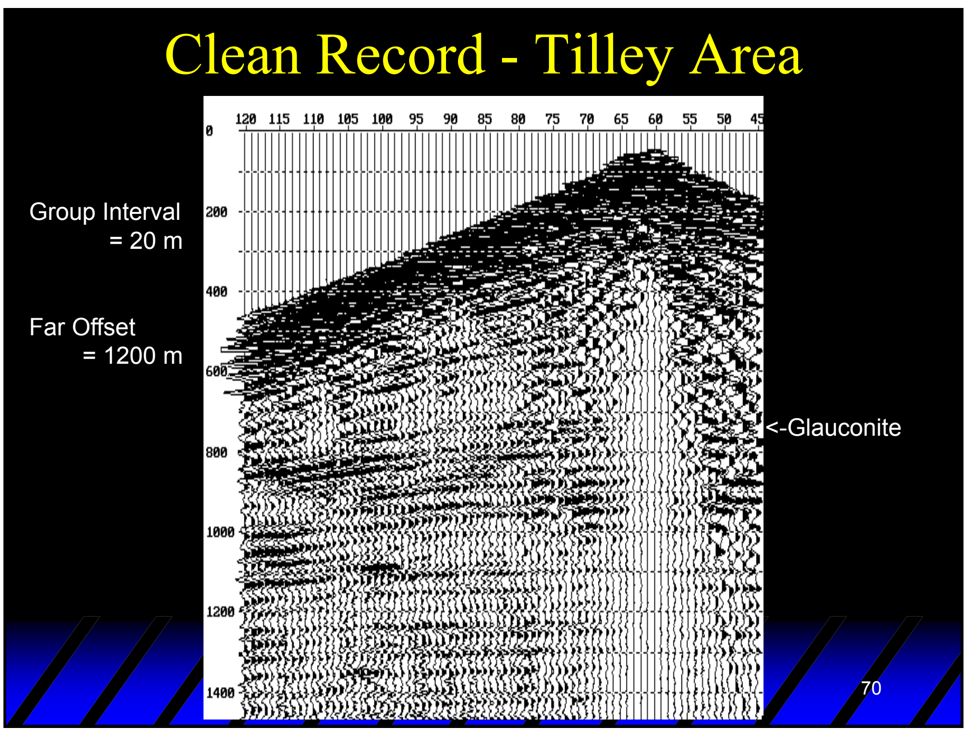
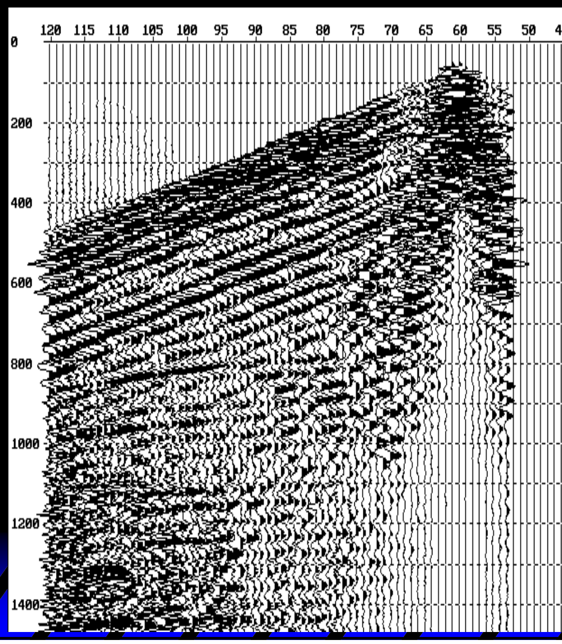
CLIENT: BURLINGTON
500 Ms AGC
8159 8142 8125 8108 8091 8074 8057 8040 8023
0
500
1000
1500
2000
2500
Offset 2736 2229 1721 1213 763 344 -76 -556 -1124 -1673 -2245 -2840 -3427
Many scattering points,
Much short-wavelength,
chaotic noise


Clean Record - Tilley Area
120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45
0
200
400
600
800
1000
1200
1400
Group Interval
= 20 m
Far Offset
= 1200 m
<-Glauconite
70

Noisy Record - Guided Wave



Just 136 m away from previous record

Types of Noise

- Time variant
- Offset variant (Source-generated)
- Source variant
- Receiver variant
- Azimuth variant

$$\text{Noise} = f_{(t,x,s,r,\phi)}$$

Types of Noise

- Time variant
- **Offset variant (Source-generated)**
- Source variant
- Receiver variant
- **Azimuth variant**

$$\text{Noise} = f_{(t,\ X,\ s,\ r,\ \phi)}$$

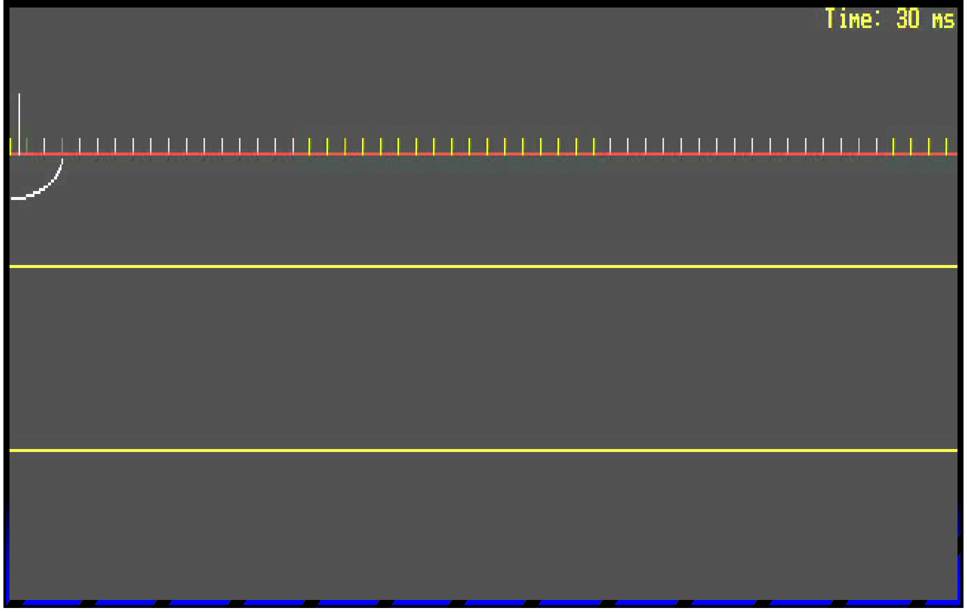
Ray Tracing

Wave Equation

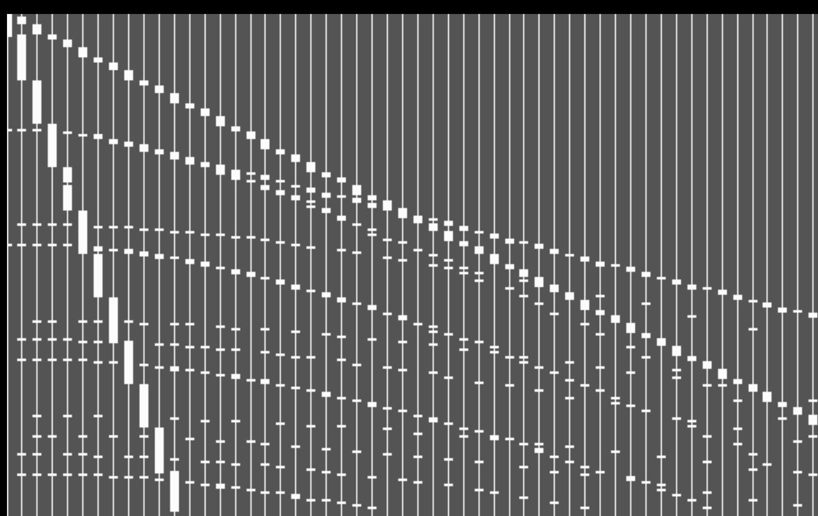
Geologic Modeling

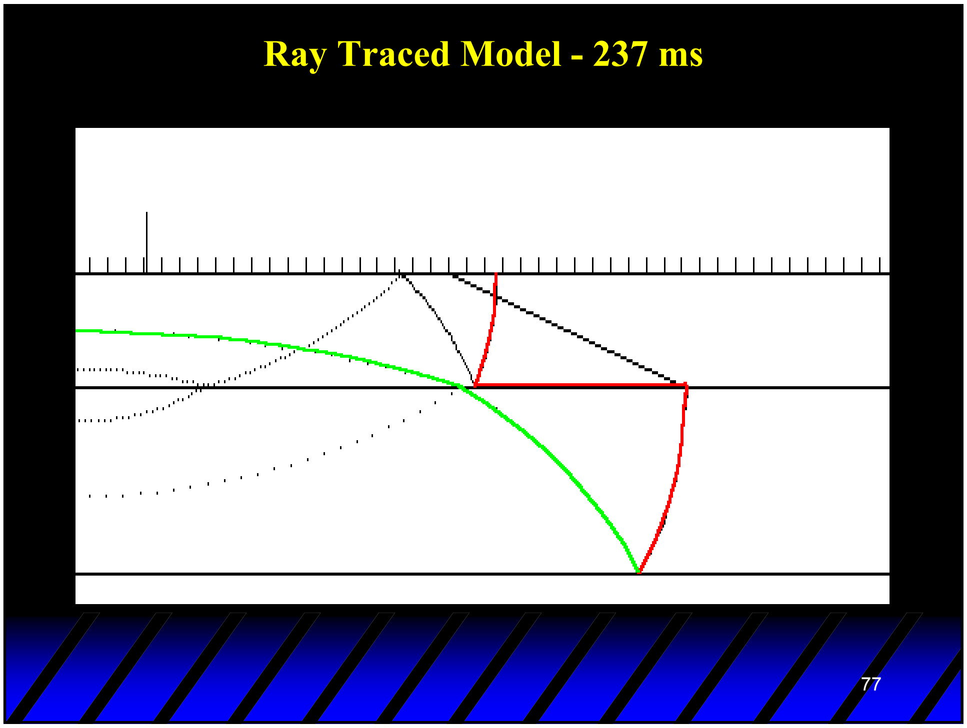
"illumination" Studies

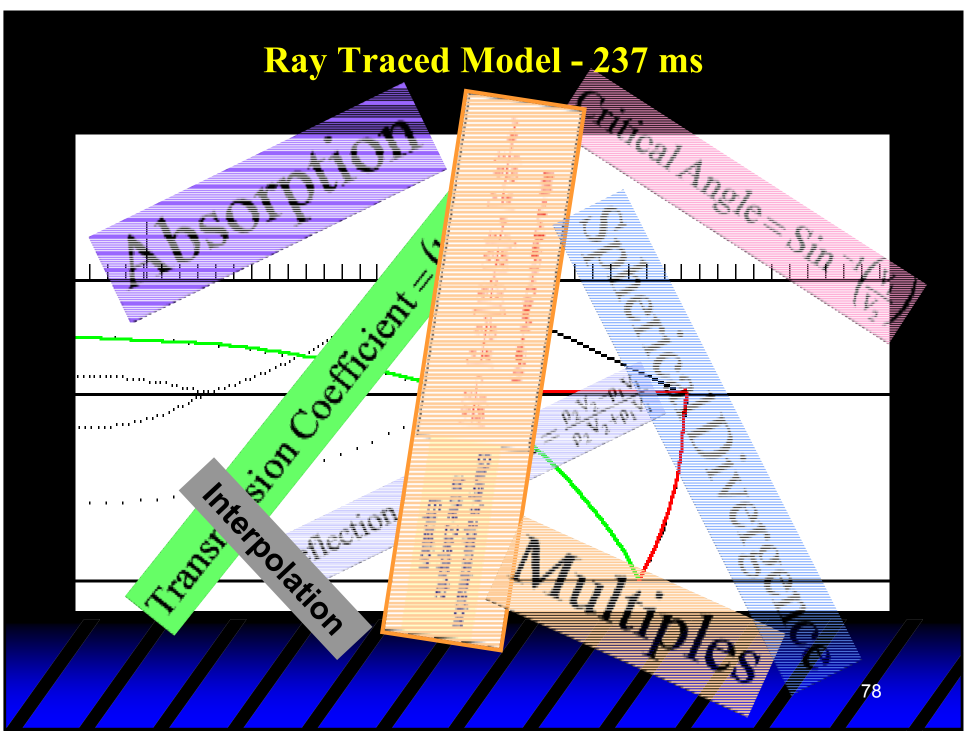
Ray Traced Model – in X-Z Space

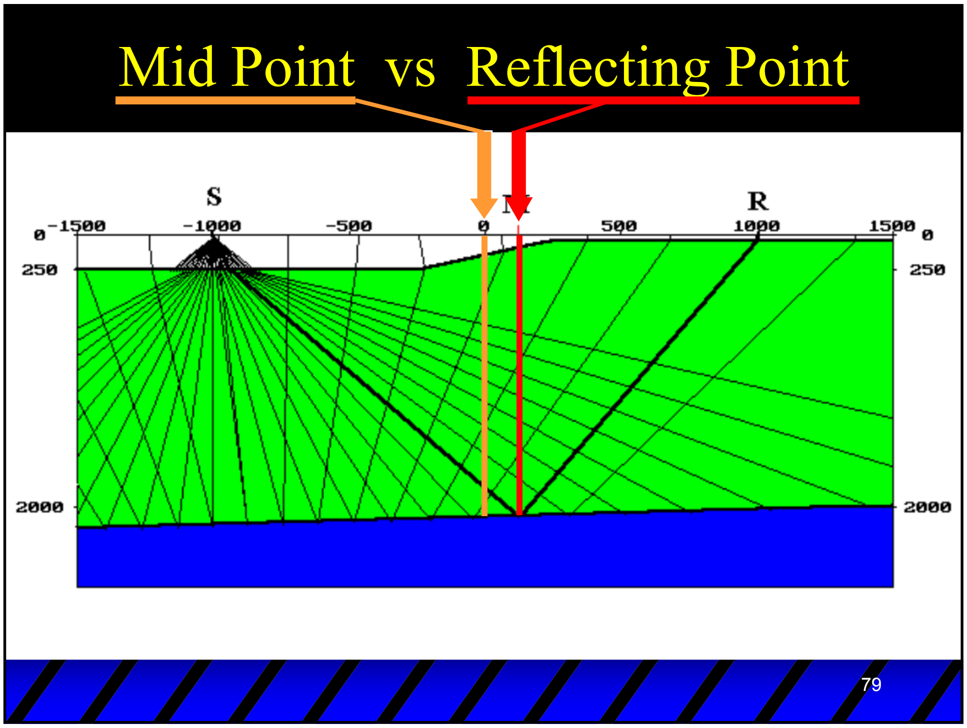


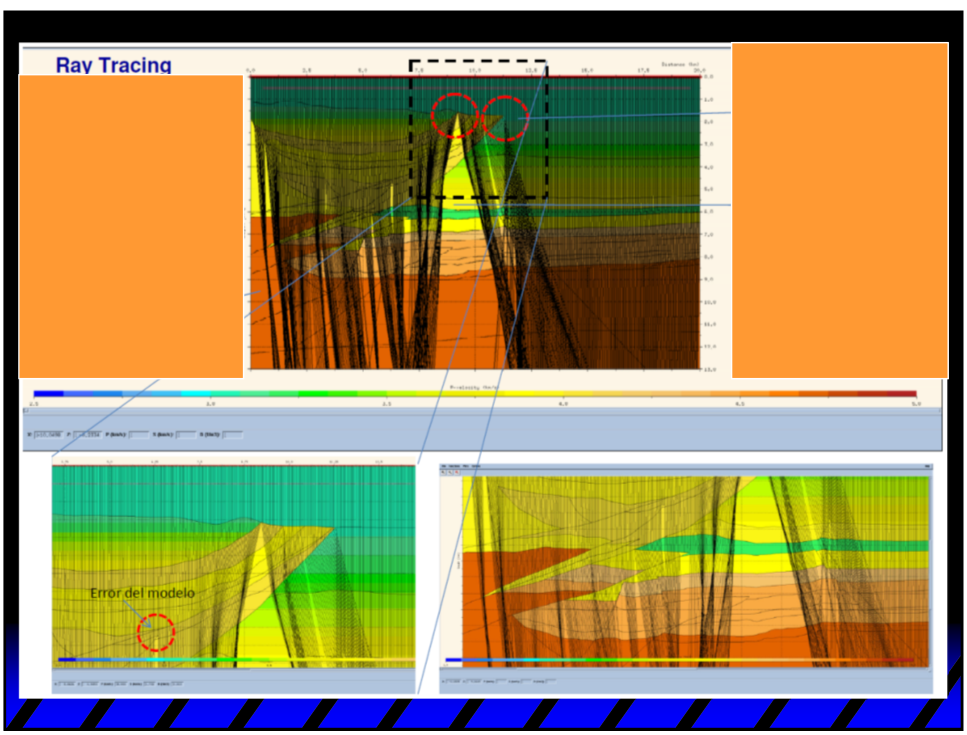
Ray Traced Model – in X-T Space

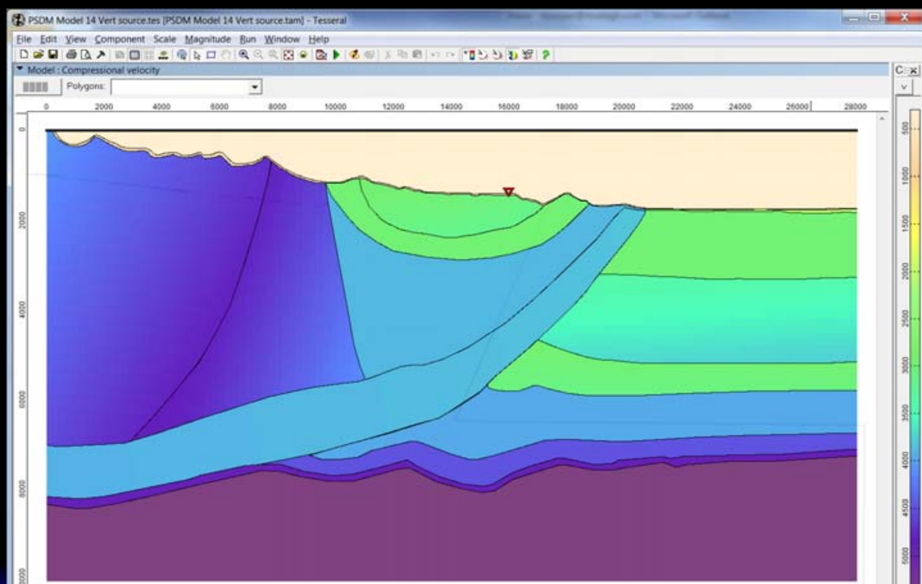



Ray Traced Model - 237 ms
77

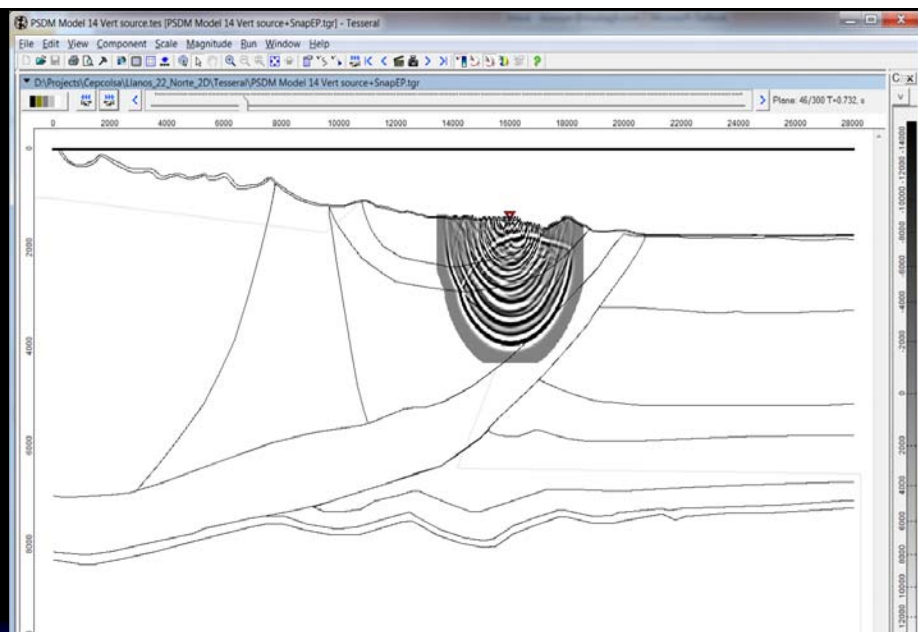

Ray Traced Model - 237 ms
Absorption
Critical Angle = Sin
Spherical Divergence
Transmission Coefficient =
Interpolation
Multiples
78


Mid Point vs Reflecting Point
S
R
-1500
-1000
-500
0
500
1000
1500
0
250
2000
0
250
2000
79

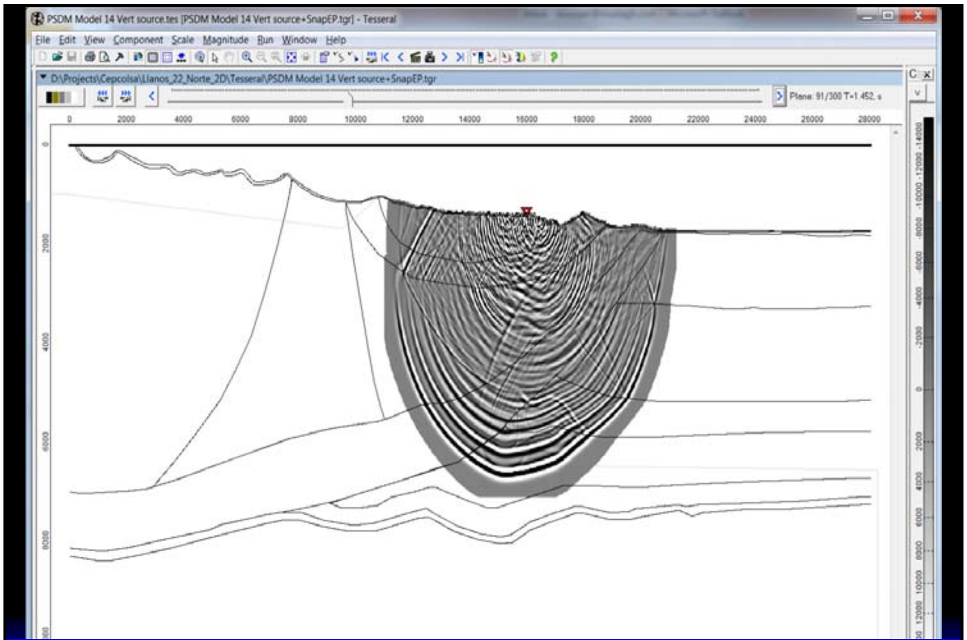

Ray Tracing
Error del modelo



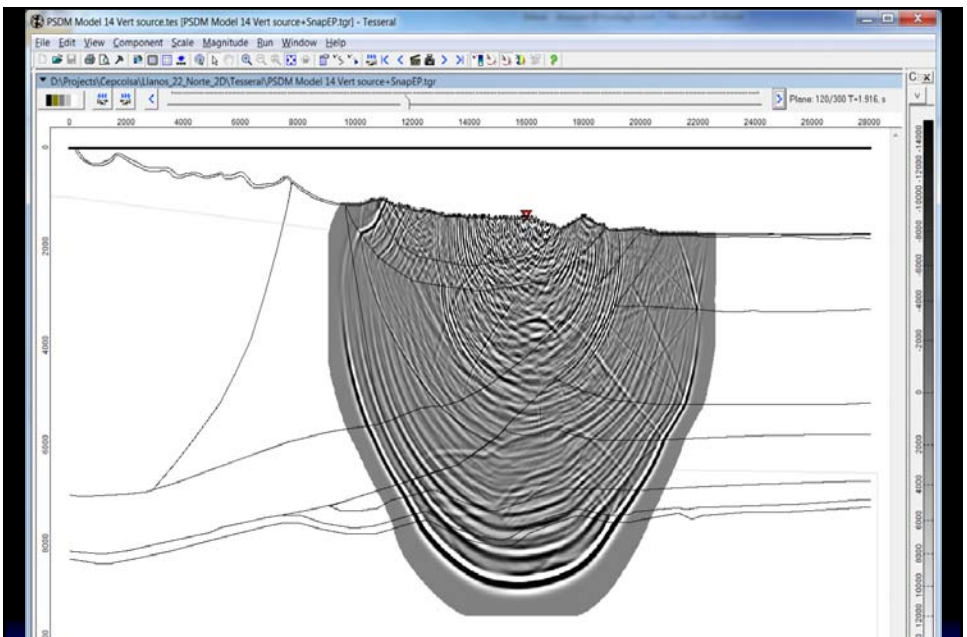
Input Model for Tesseral Wave Equation Modeling



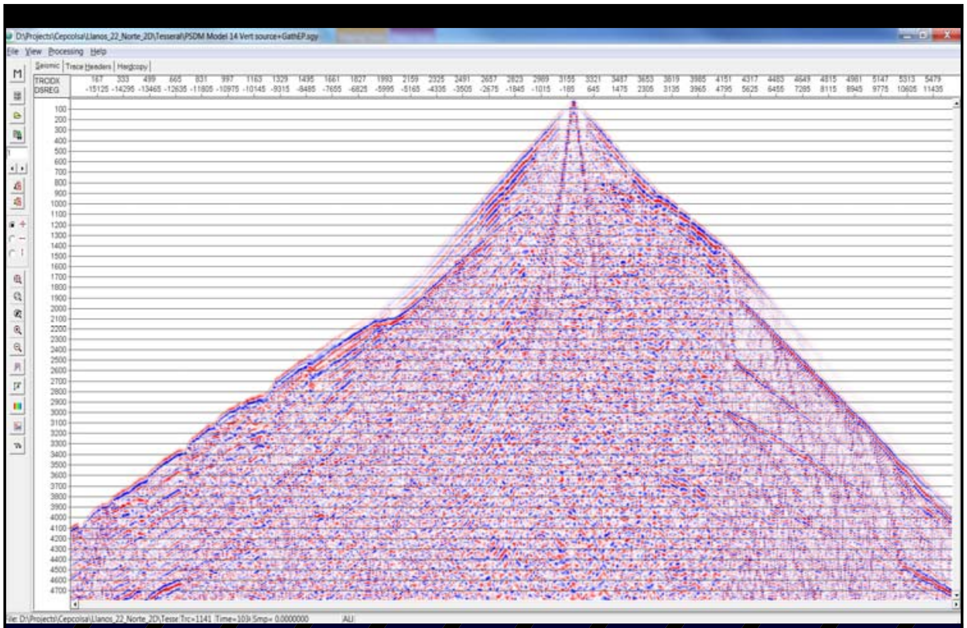
Snapshot of Wavefield 0.732 seconds after shot



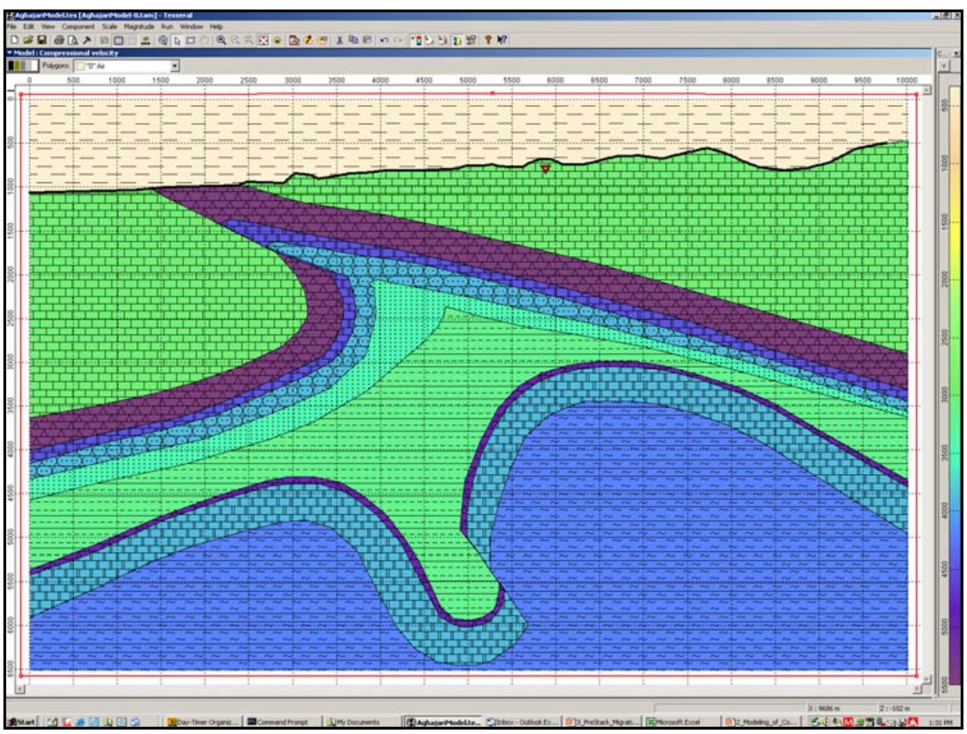
Snapshot of Wavefield 1.452 seconds after shot

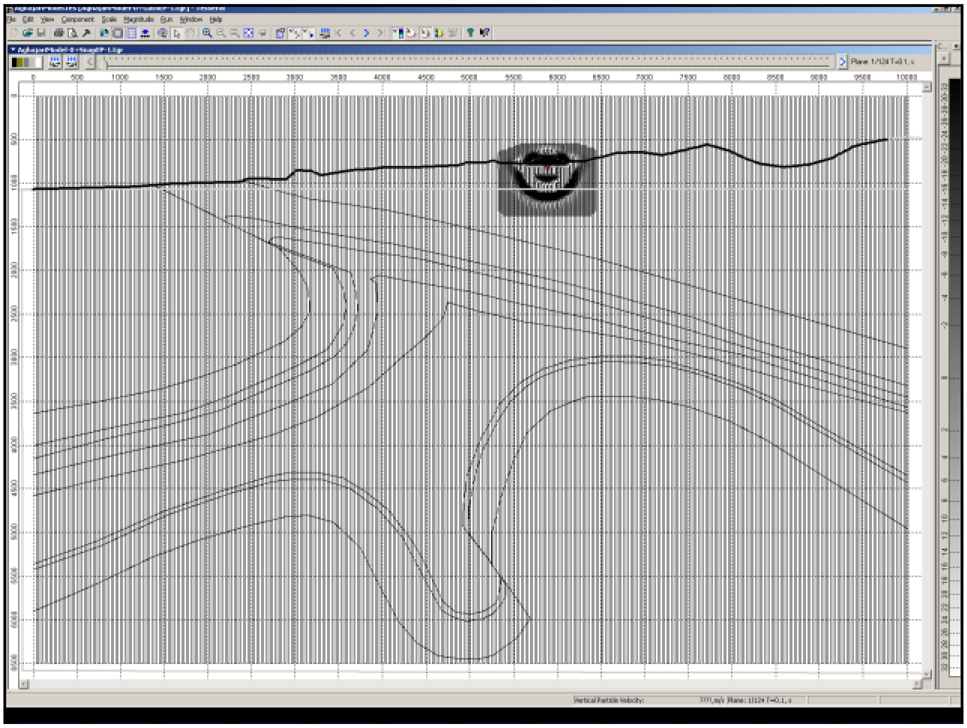


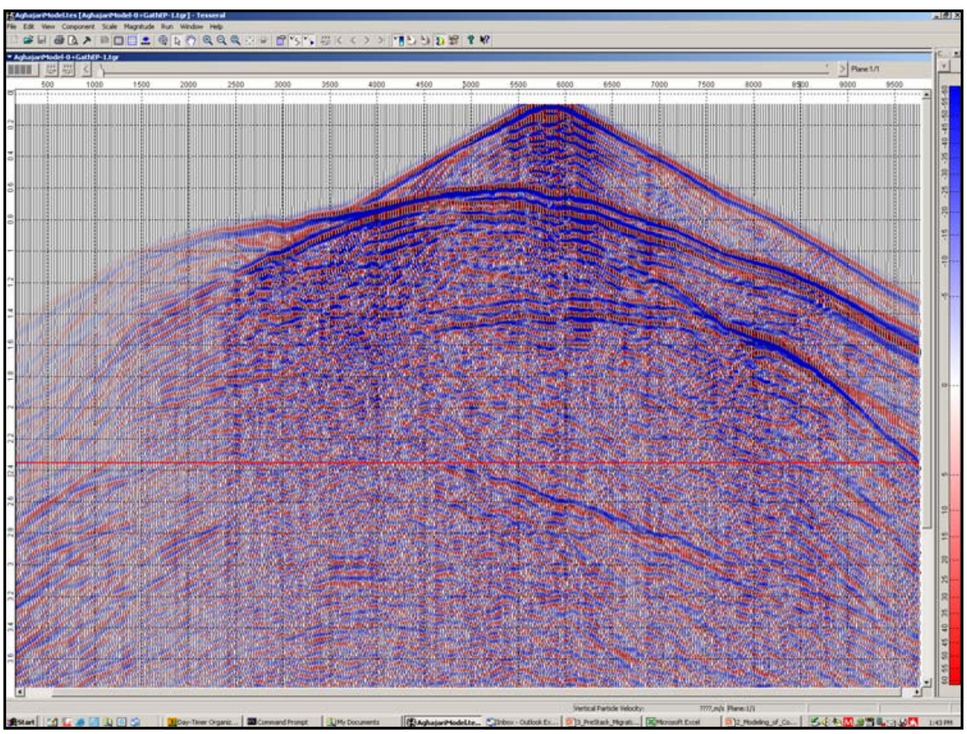
Snapshot of Wavefield 1.916 seconds after shot

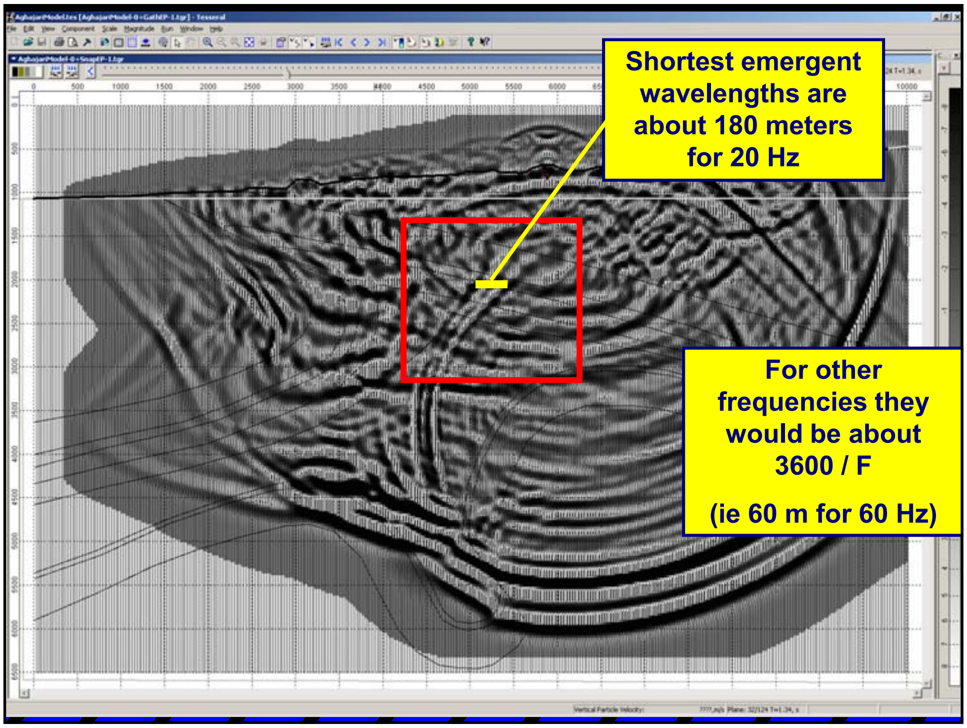


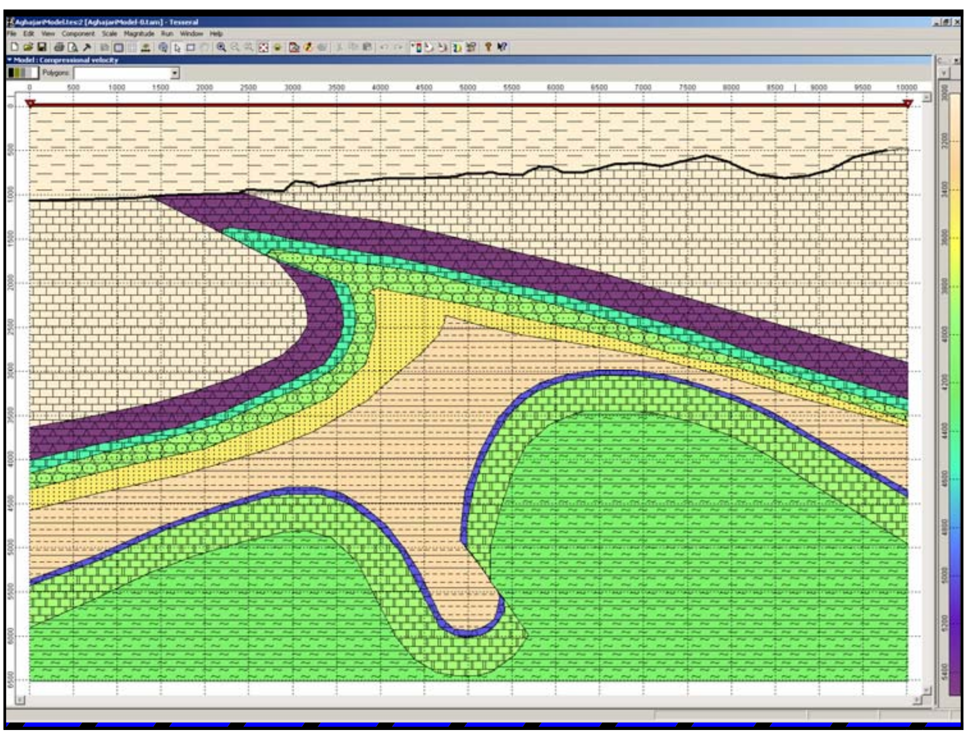
Modeled Shot Record with 5-meter trace

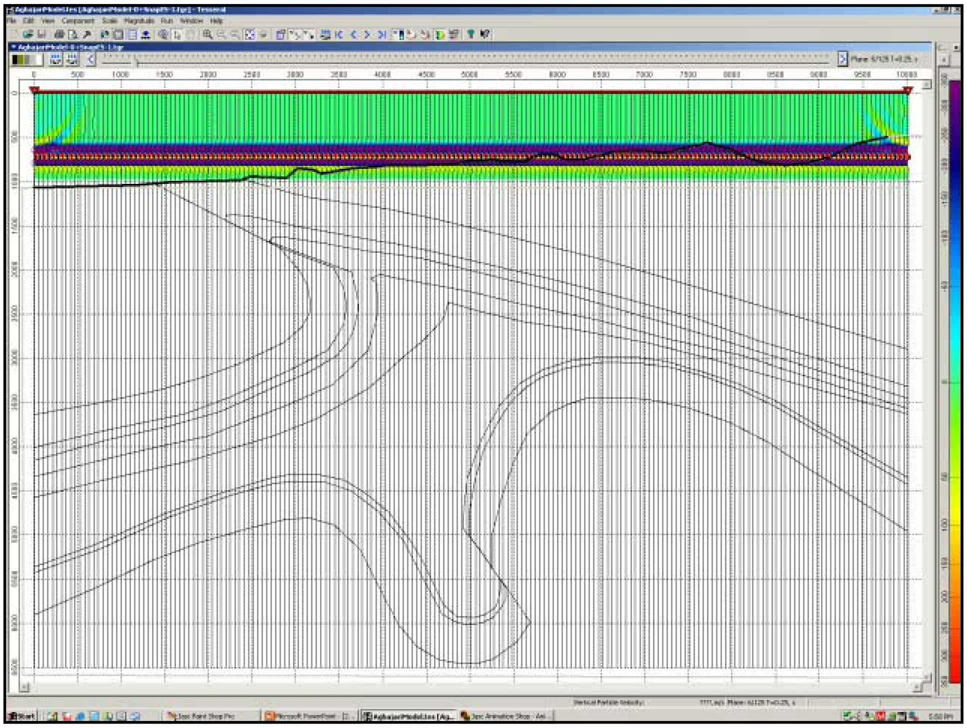


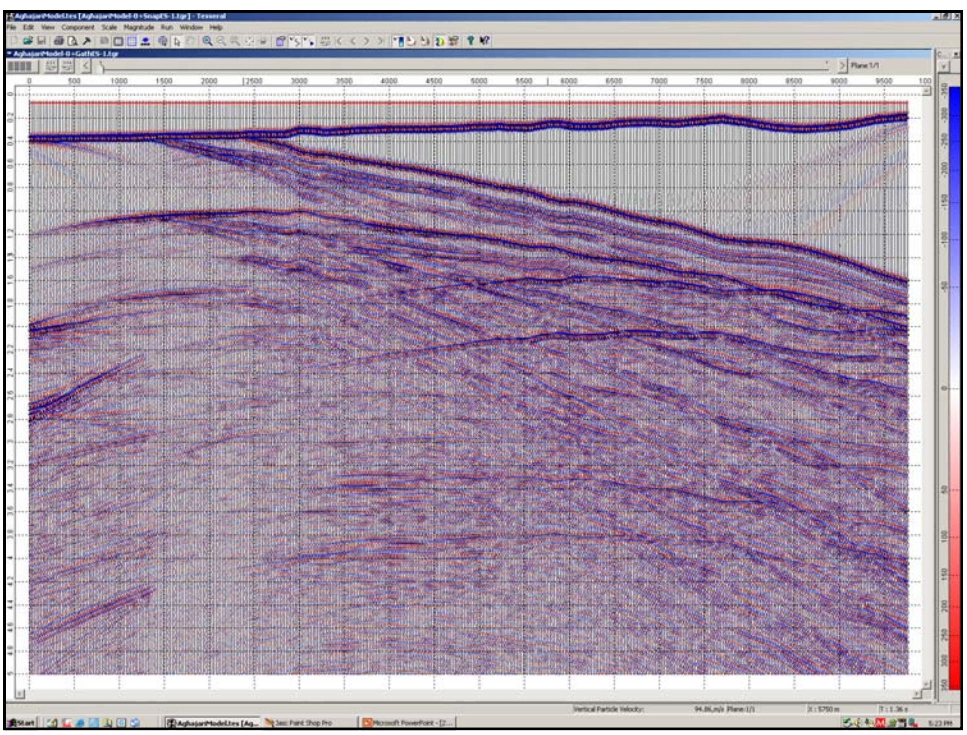





Shortest emergent wavelengths are about 180 meters for 20 Hz
For other frequencies they would be about 3600 / F
(ie 60 m for 60 Hz)







Receiver Interval

Source Interval

Line Spacings

Parameter Determination

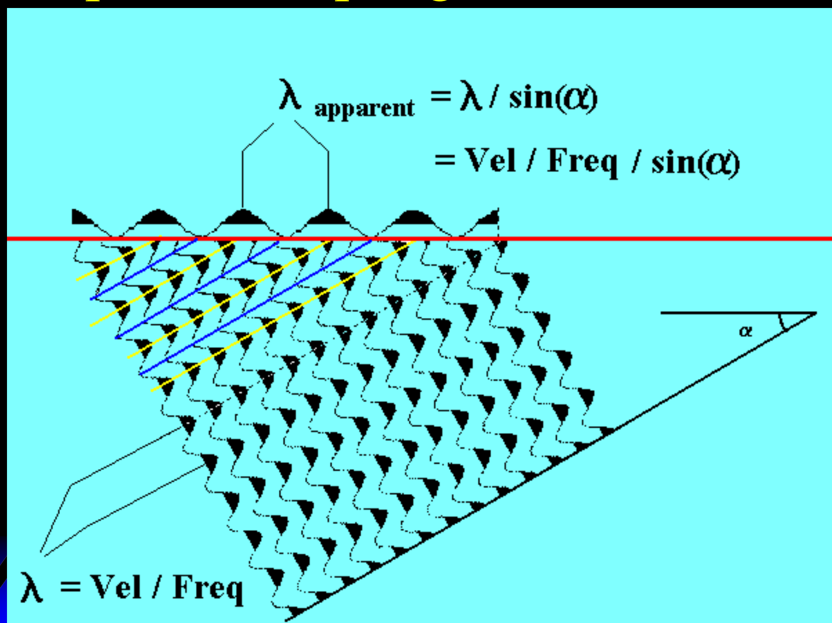
Bin Size

Mid-Point Scatter ?

Receiver and Source Intervals

Ri & Si

Spatial Sampling at the Surface



Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq x Sin } \alpha}$$

Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq} \times \text{Sin}\,\alpha}$$

a = *1* for sub-surface bin size

a = *2* for surface bin size

Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq} \times \text{Sin}\,\alpha}$$

Use:

Stacking for NMO-consistent result

RMS if deriving from well-log intervals

Average for slightly conservative results

Do NOT use Interval Velocities !

Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq x Sin}\ \alpha}$$

Migrated or Geologic dips
for migration output trace spacing
(NOT necessarily "natural" bin size)

Unmigrated dips (max 45°) for surface intervals

30° for stratigraphic plays in gently dipping geology in order to properly measure diffraction limbs from lateral velocity changes

Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq x Sin}\ \alpha}$$

Using $F_{dominant}$ will only provide correct sampling of data before deconvolution

We should use F_{max} in order to protect all recoverable frequencies through deconvolution and migration

Working backwards from anticipated Stacked Data …

$$\text{Surface Interval} = \frac{a \times \text{Velocity}}{b \times \text{Freq x Sin}\,\alpha}$$

b = *4* for basic Nyquist and plane wave theory (two-way time)

b = *2* for basic Nyquist and estimate of curved-ray theory

b = *3* for over-sampling Nyquist and estimate of curved-ray theory

Many variations for Ri or Si …

$$\text{Surface Interval} = \frac{2 \times \text{Velocity}_{\text{average}}}{3 \times \text{Freq}_{\text{maximum}} \text{ x Sin}(30^\circ)}$$

Many variations for Ri or Si …

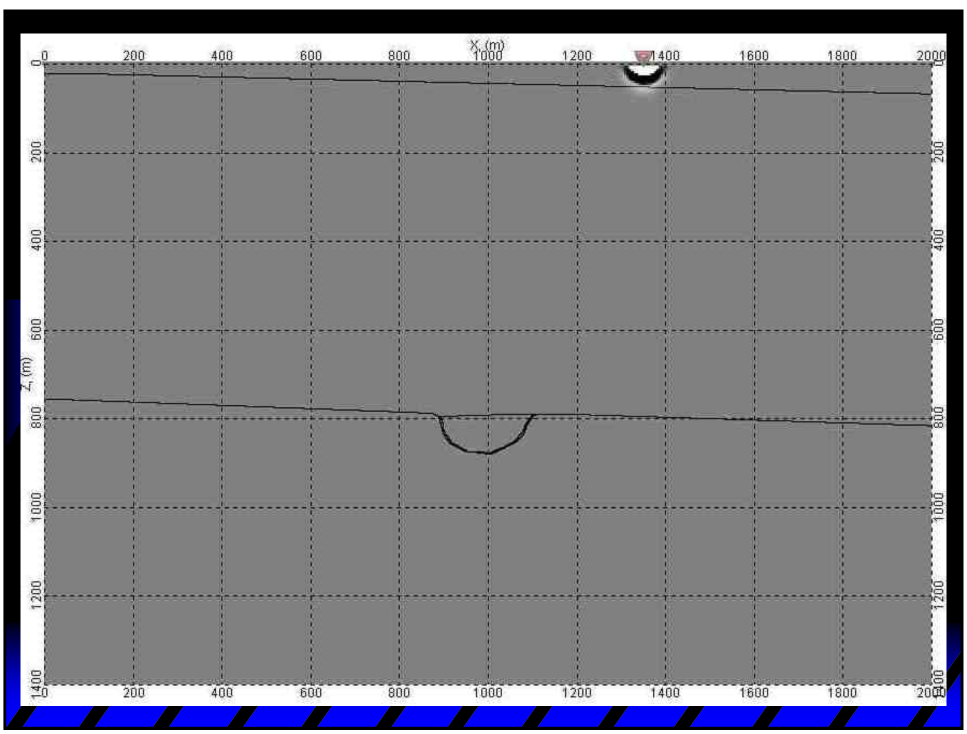
$$\text{Surface Interval} = \frac{2 \times \text{Velocity}_{\text{average}}}{3 \times \text{Freq}_{\text{maximum}} \ \text{x} \ \text{Sin}\,(30^{\circ})}$$

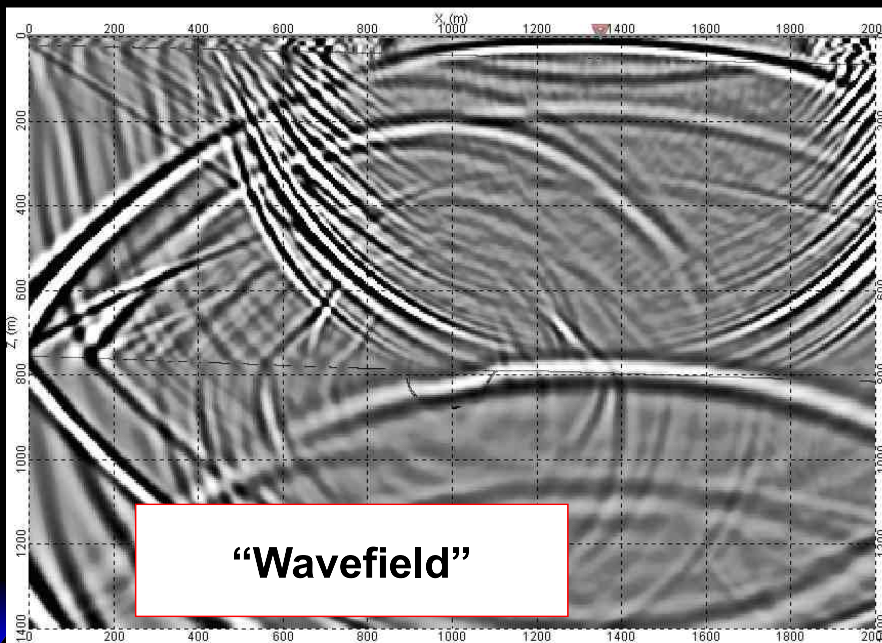
$$\text{Surface Interval} = \frac{\text{Velocity}_{\text{average}}}{\text{Freq}_{\text{maximum}}}$$

From sampling of emerging apparent wavelengths

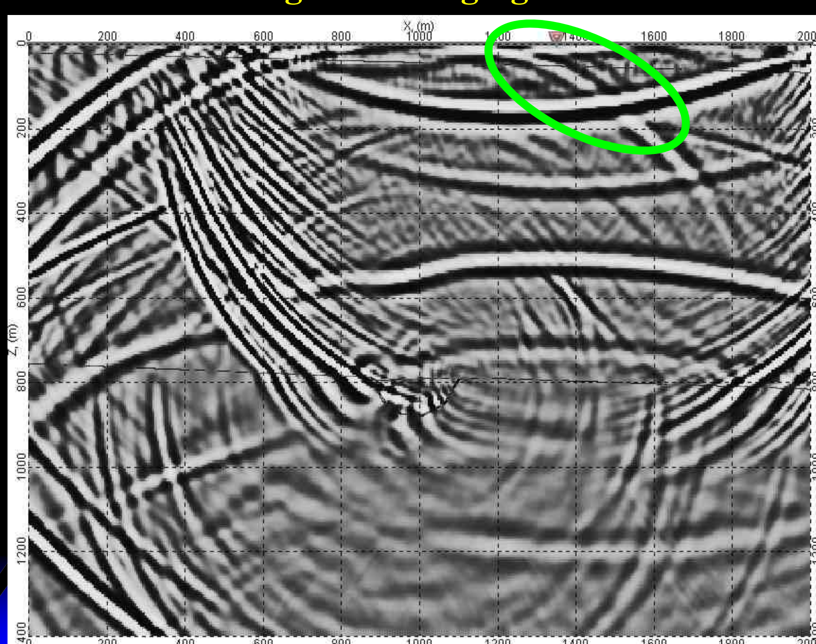
$$\text{Surface Interval} = \frac{\text{Depth}}{50}$$

From Frequency limits after 100 cycles of absorption

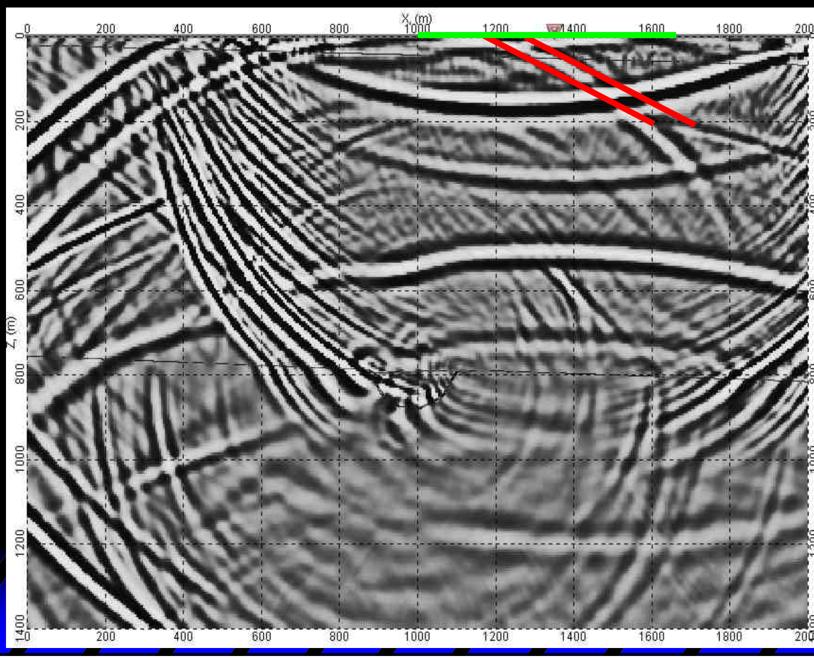




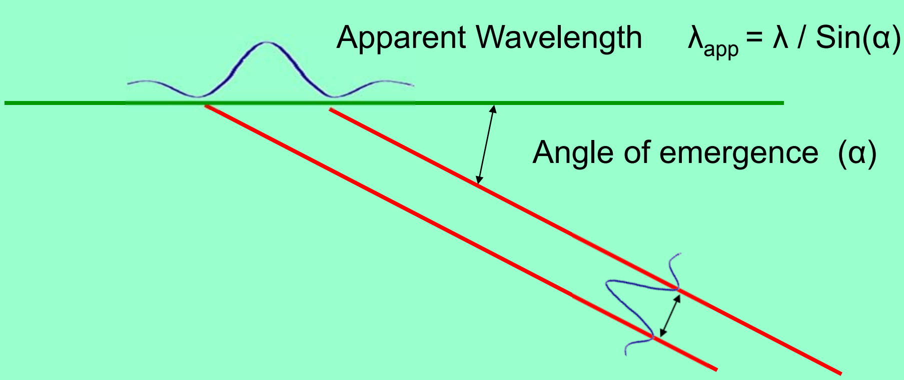
Measuring the Emerging Wavefield

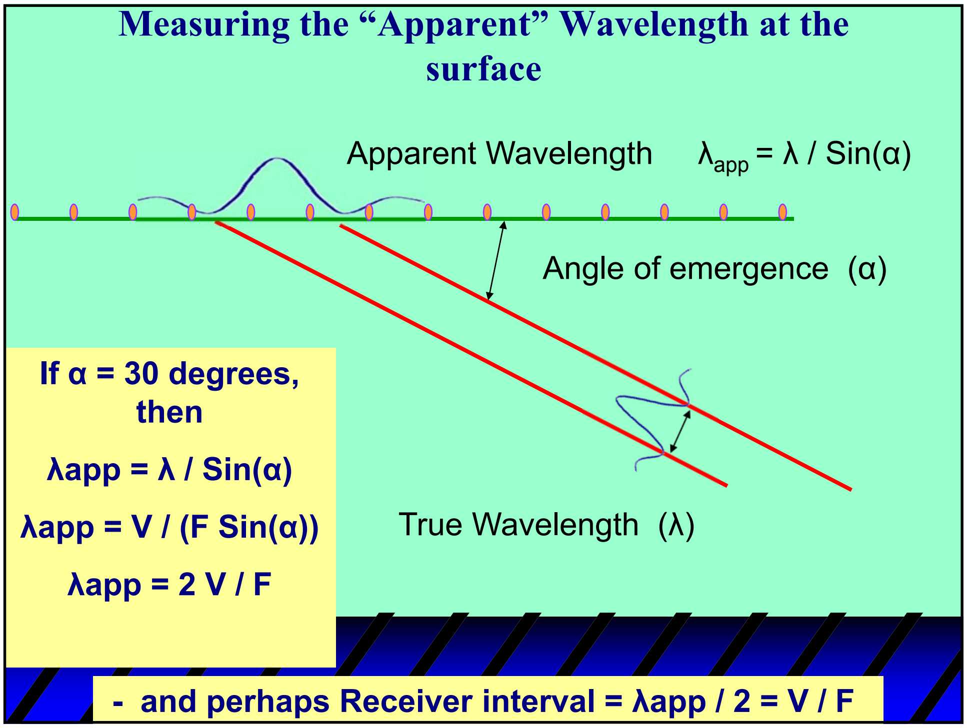


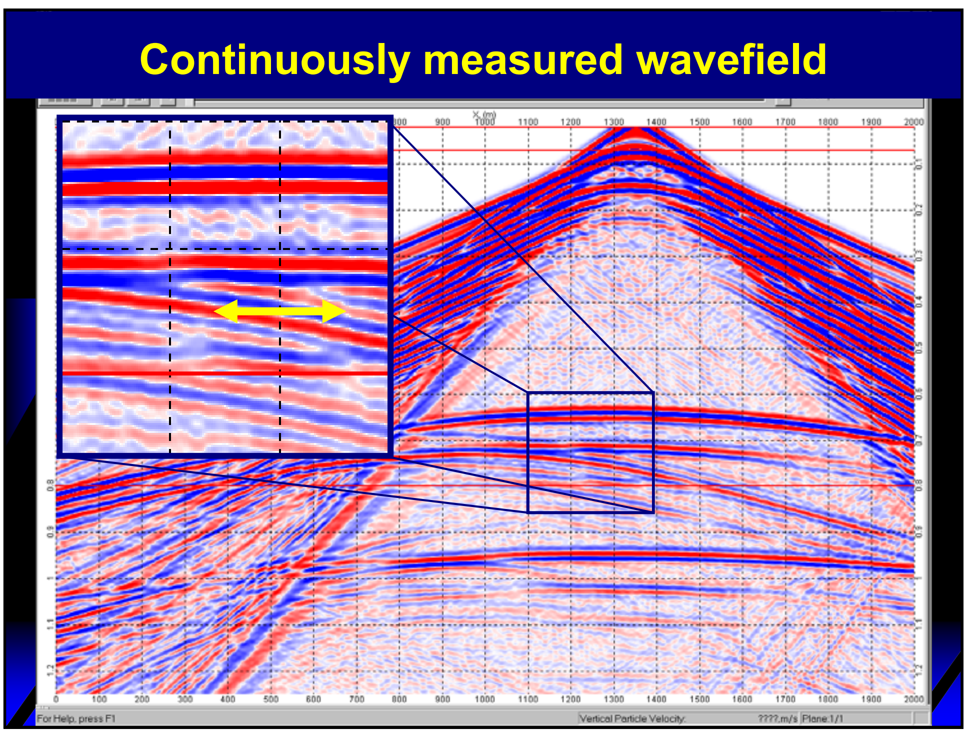
Measuring the Emerging Wavefield



"Apparent" Wavelength at the surface




Measuring the "Apparent" Wavelength at the surface
Apparent Wavelength
$\lambda_{app} = \lambda / \mathrm{Sin}(\alpha)$
Angle of emergence (α)
If α = 30 degrees, then
λapp = λ / Sin(α)
λapp = V / (F Sin(α))
λapp = 2 V / F
True Wavelength (λ)
- and perhaps Receiver interval = λapp / 2 = V / F


Continuously measured wavefield
For Help, press F1
Vertical Particle Velocity

Many variations for Ri or Si …

$$\text{Surface Interval} = \frac{2 \times \text{Velocity}_{\text{average}}}{3 \times \text{Freq}_{\text{maximum}} \times \text{Sin}(30^{\circ})}$$

$$\text{Surface Interval} = \frac{\text{Velocity}_{\text{average}}}{\text{Freq}_{\text{maximum}}}$$

From sampling of emerging apparent wavelengths

$$\text{Surface Interval} = \frac{\text{Depth}}{50}$$

From Frequency limits after 100 cycles of absorption

Bin Size

Ri / 2 x Si / 2

Many variations for Ri or Si …

$$\text{Natural Sub-Surface Bin Size} = \frac{Ri}{2} \times \frac{Si}{2}$$

BUT …

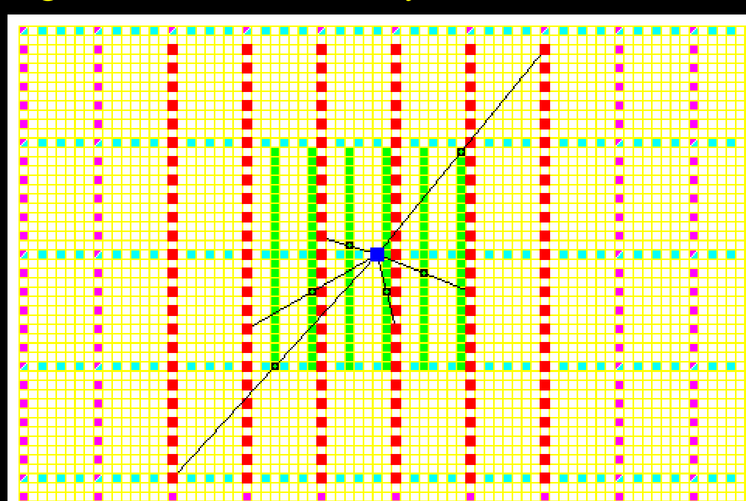
Trace spacing of final Migrated data volume does not necessarily have to be natural bins !!

Jump to slide 152
To skip bin size

Then use Midpoint scatter seminar to talk about this

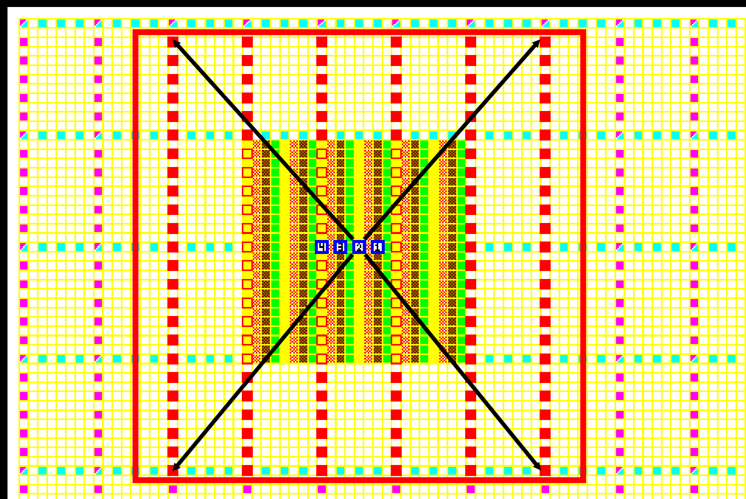
Use DA20 to show
offset orthogonal versus triple staggered
with and without perturbation

Trace out the mid-points illuminated by a single source recorded by a Patch of receivers

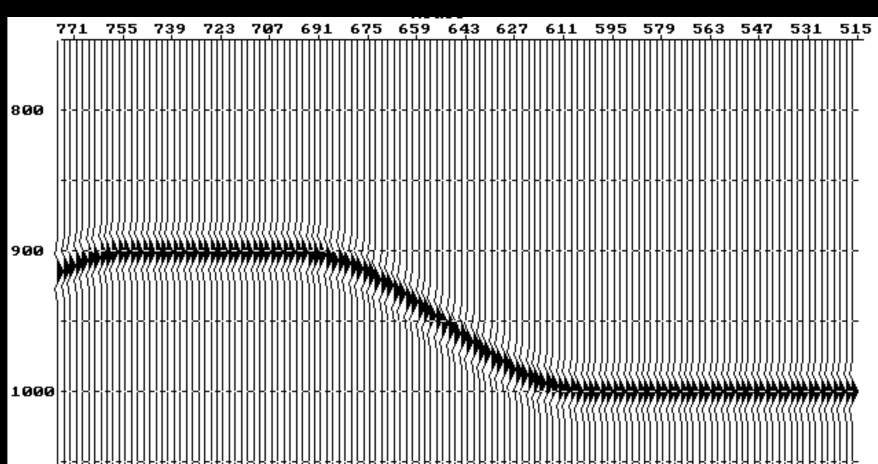


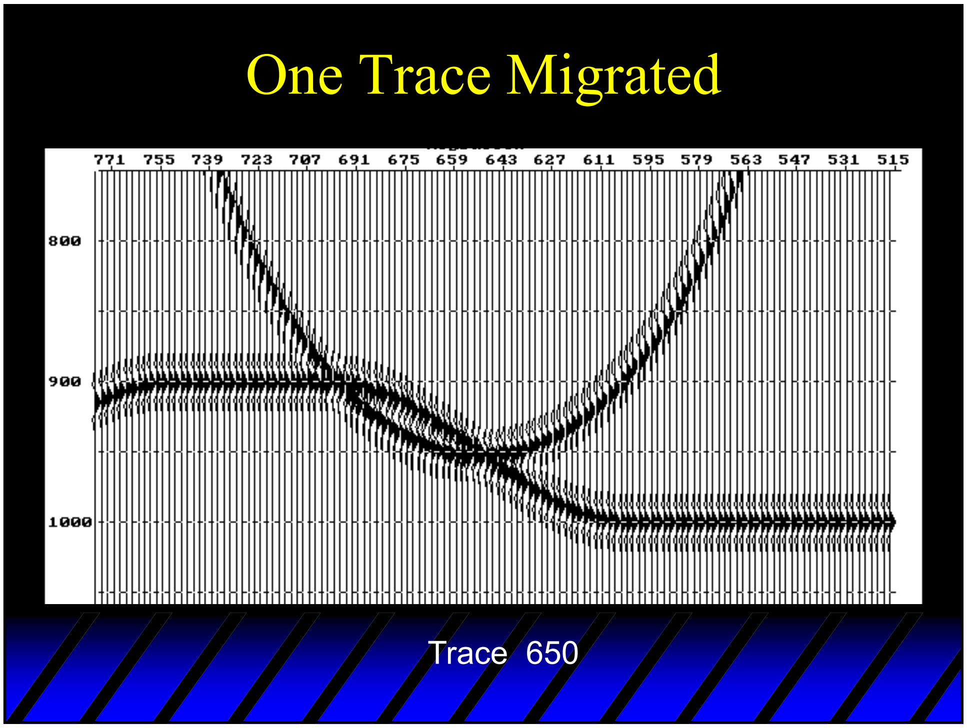
"Columns" of bins are imaged - one column for each receiver line (each half the length)

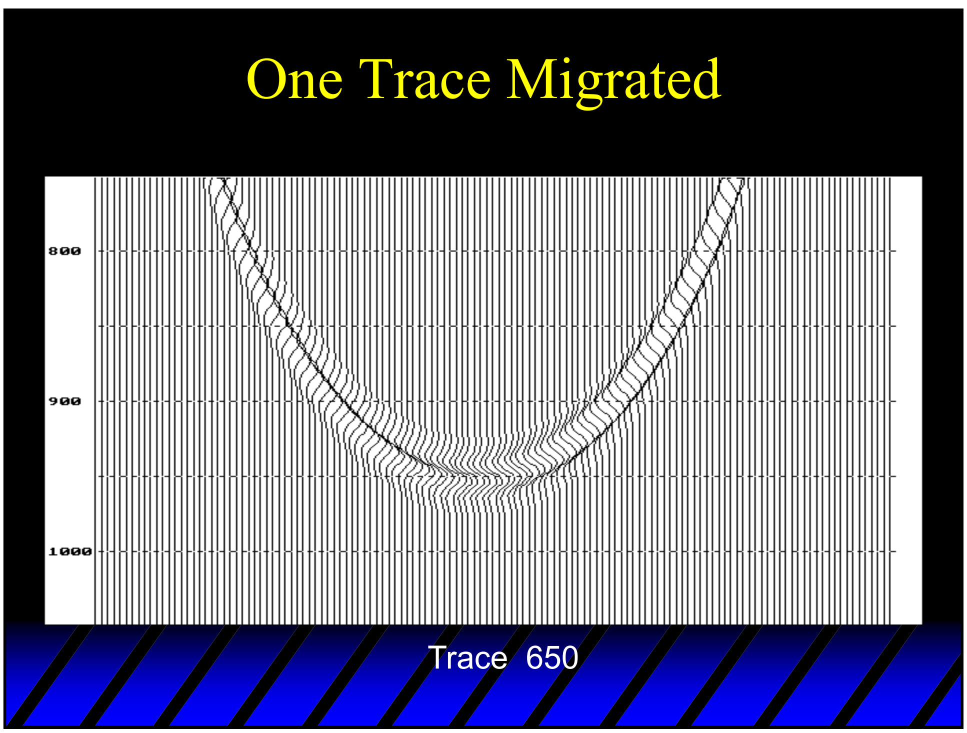
Shot 2 in normal position



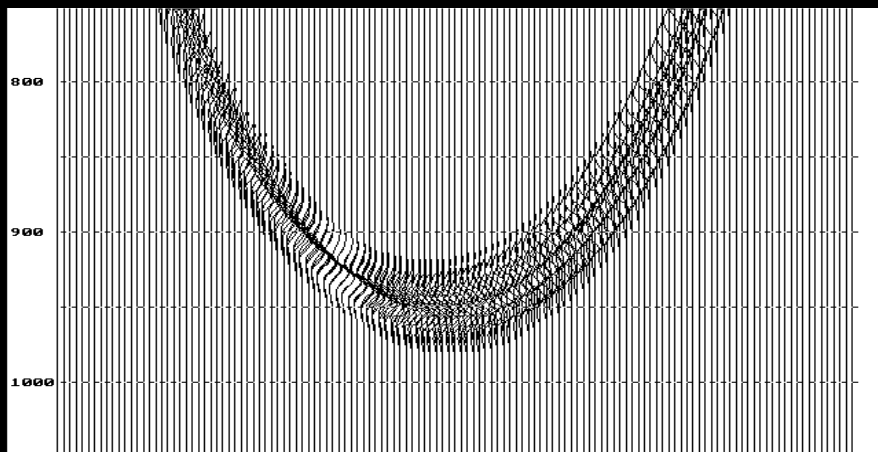
Detail of Model Before Migration




One Trace Migrated
771 755 739 723 707 691 675 659 643 627 611 595 579 563 547 531 515
800
900
1000
Trace 650

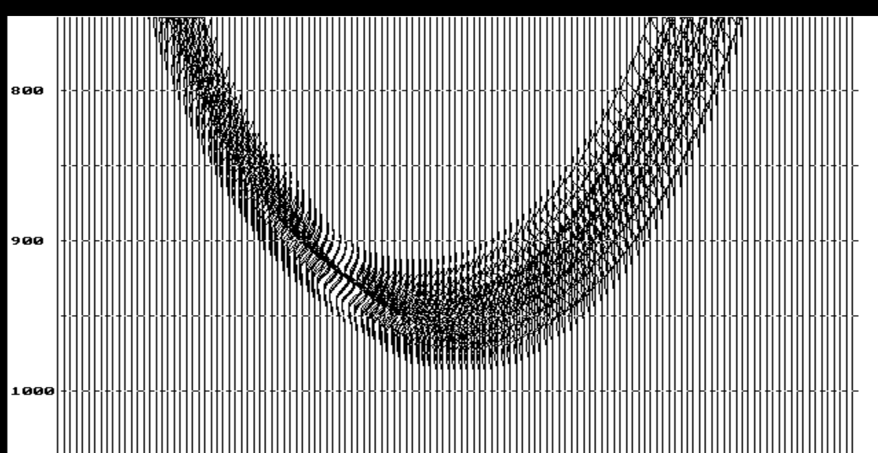

One Trace Migrated
800
900
1000
Trace 650

Three Traces Migrated



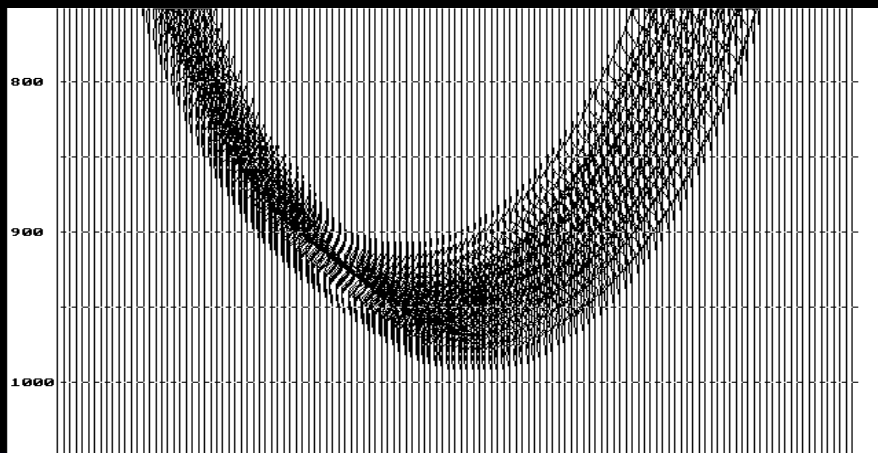
Trace 646 to 654 (ever 4th)

Five Traces Migrated



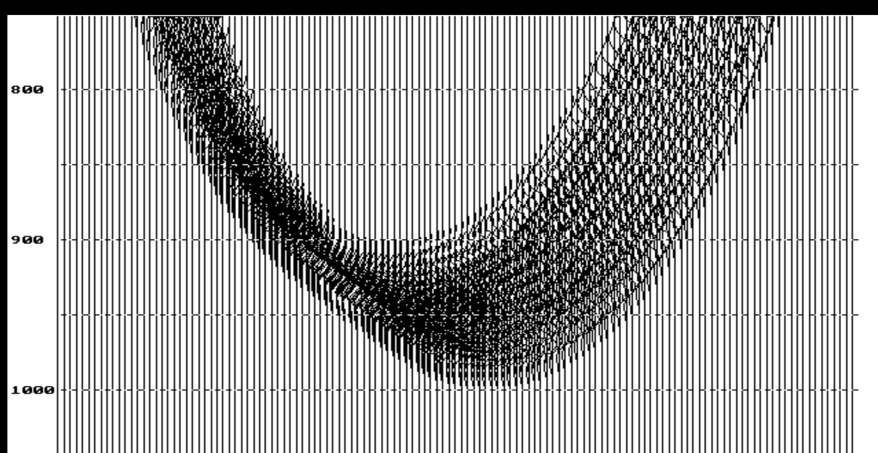
Trace 642 to 658 (ever 4th)

Seven Traces Migrated



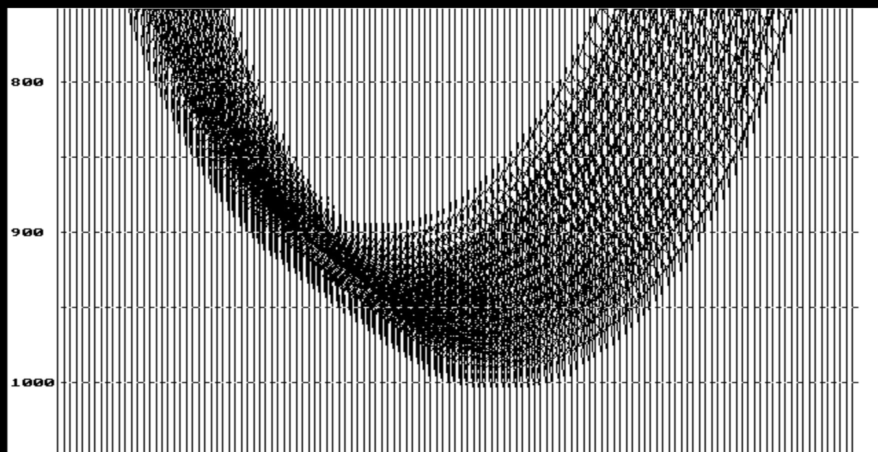
Trace 638 to 662 (ever 4th)

Nine Traces Migrated



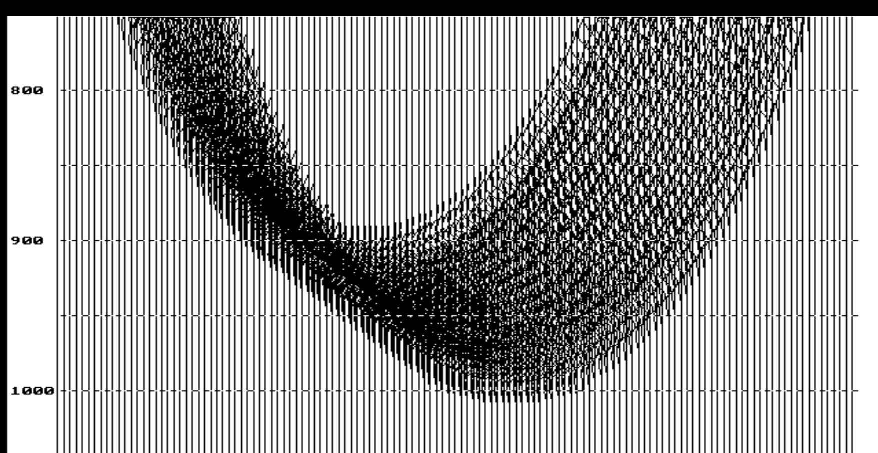
Trace 634 to 666 (ever 4th)

Eleven Traces Migrated



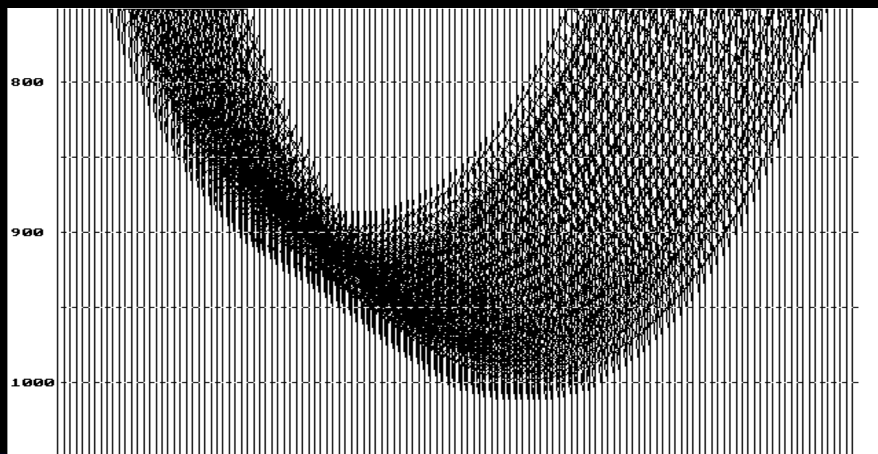
Trace 630 to 670 (ever 4th)

Thirteen Traces Migrated



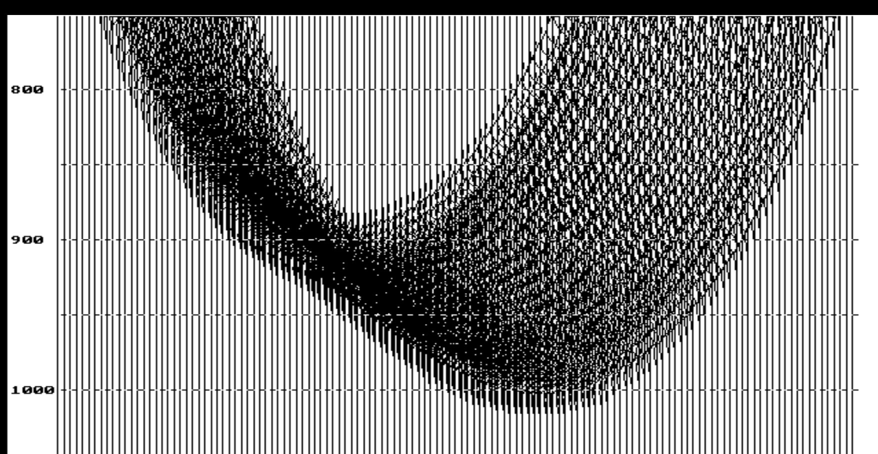
Trace 626 to 674 (ever 4th)

Fifteen Traces Migrated



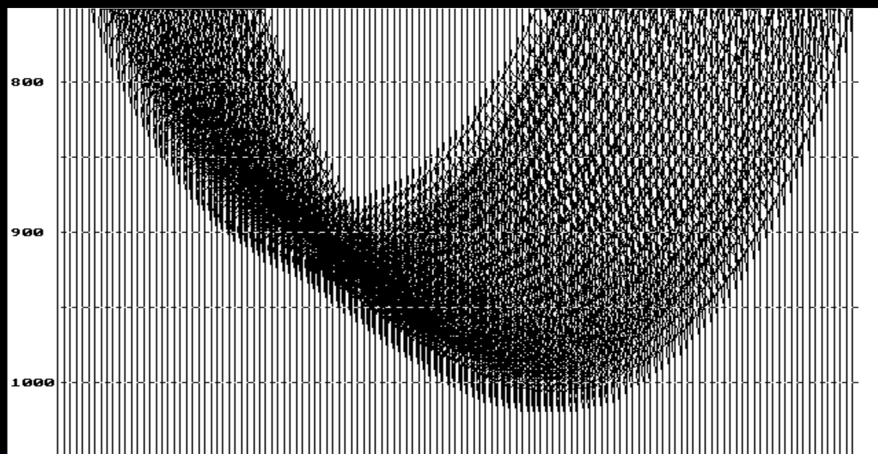
Trace 622 to 678 (ever 4th)

Seventeen Traces Migrated



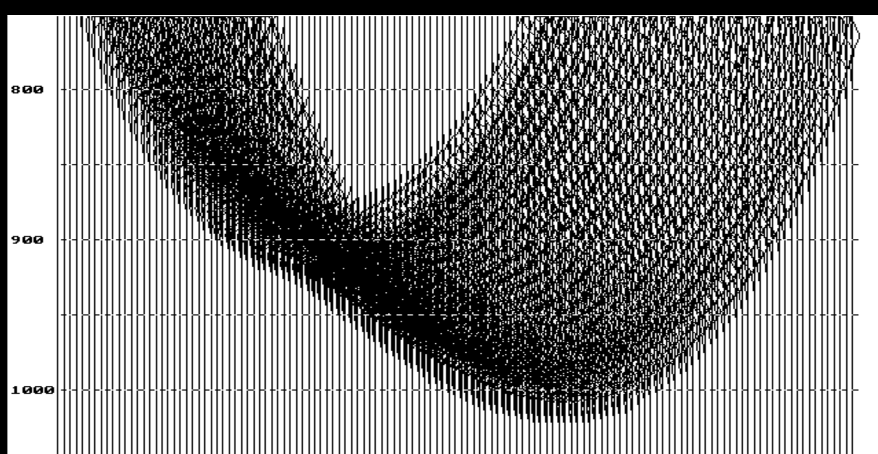
Trace 618 to 682 (ever 4th)

Nineteen Traces Migrated



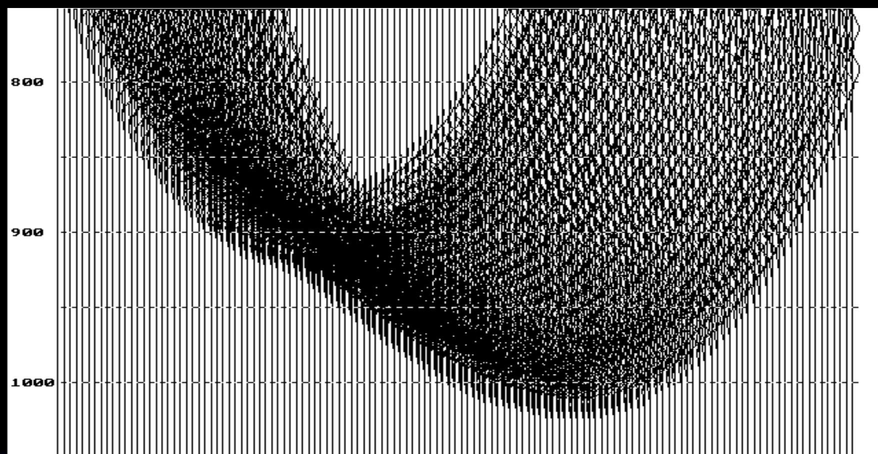
Trace 614 to 686 (ever 4th)

Twentyone Traces Migrated



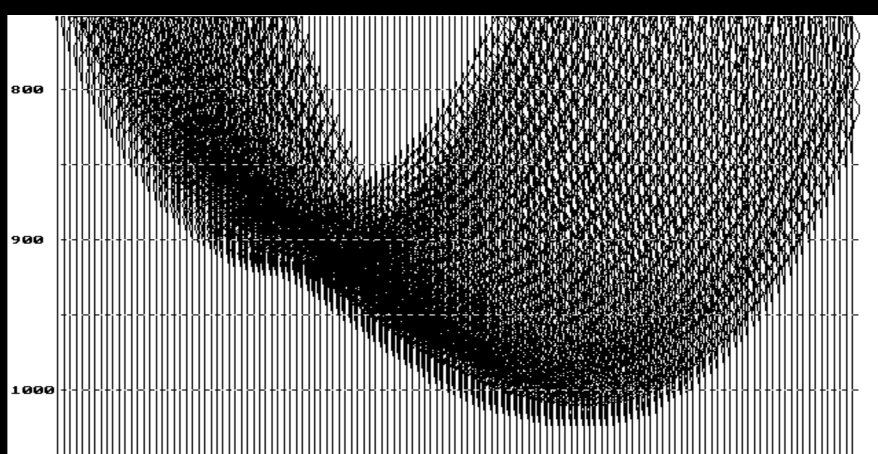
Trace 610 to 690 (ever 4th)

Twentythree Traces Migrated

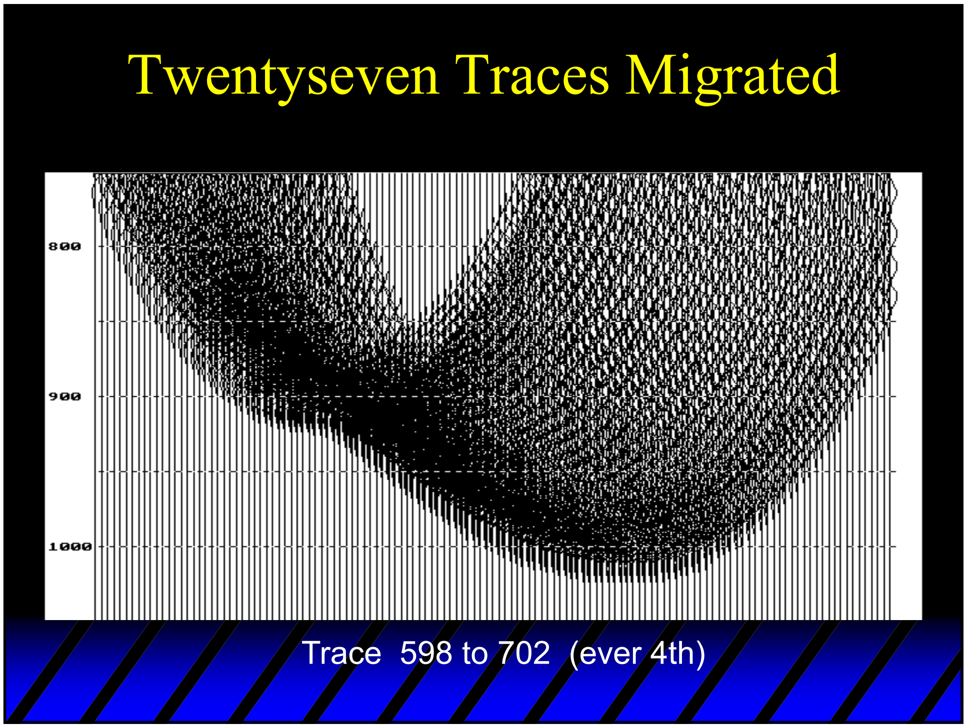


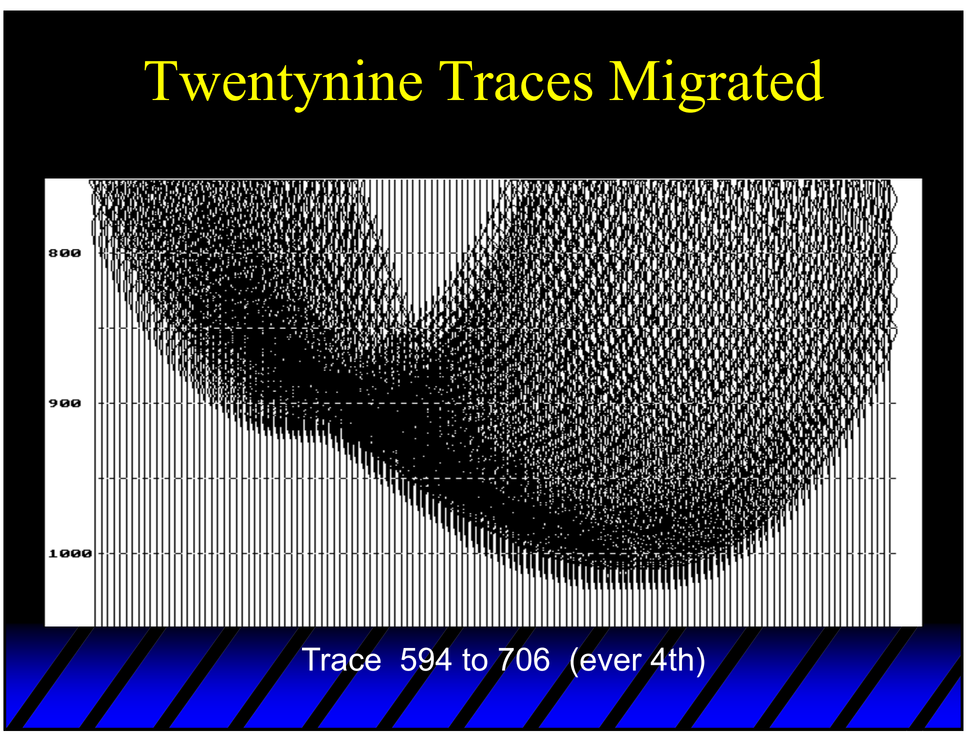
Trace 606 to 694 (ever 4th)

Twentyfive Traces Migrated

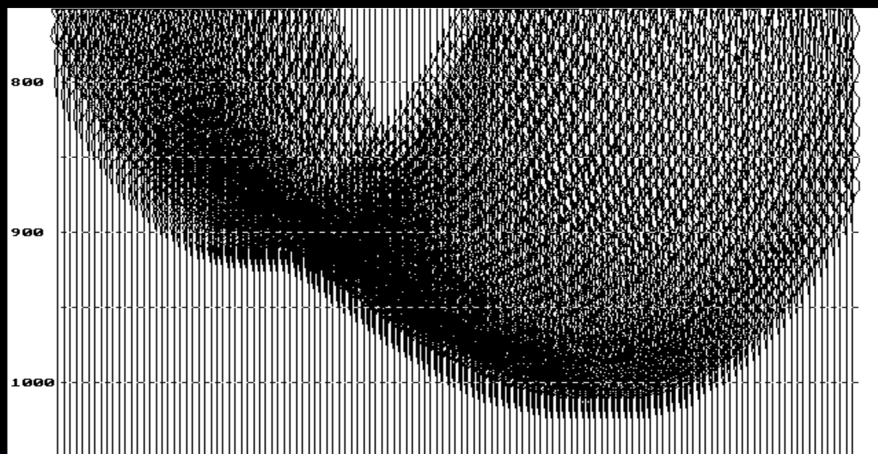


Trace 602 to 698 (ever 4th)


Twentyseven Traces Migrated
800
900
1000
Trace 598 to 702 (ever 4th)

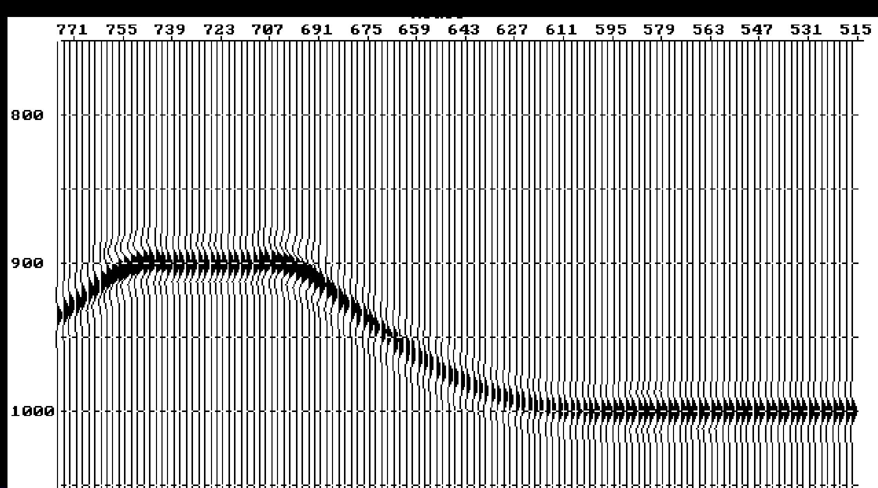

Twentynine Traces Migrated
800
900
1000
Trace 594 to 706 (ever 4th)

Thirtyone Traces Migrated

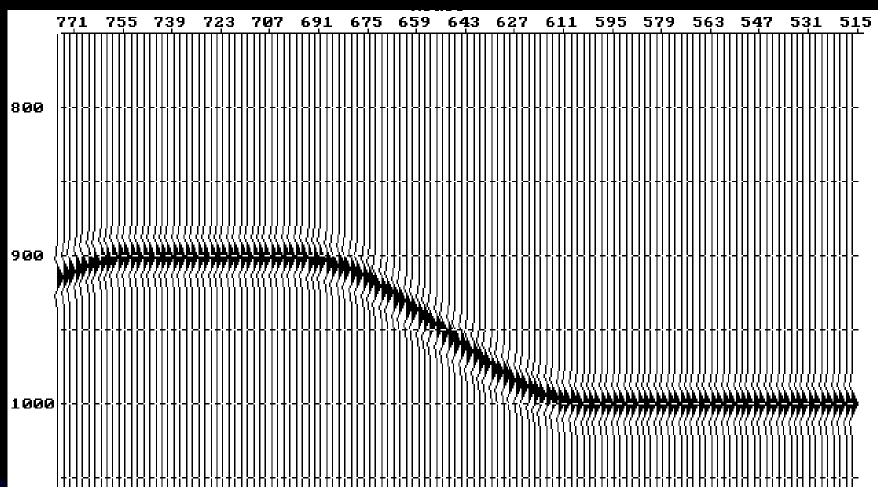


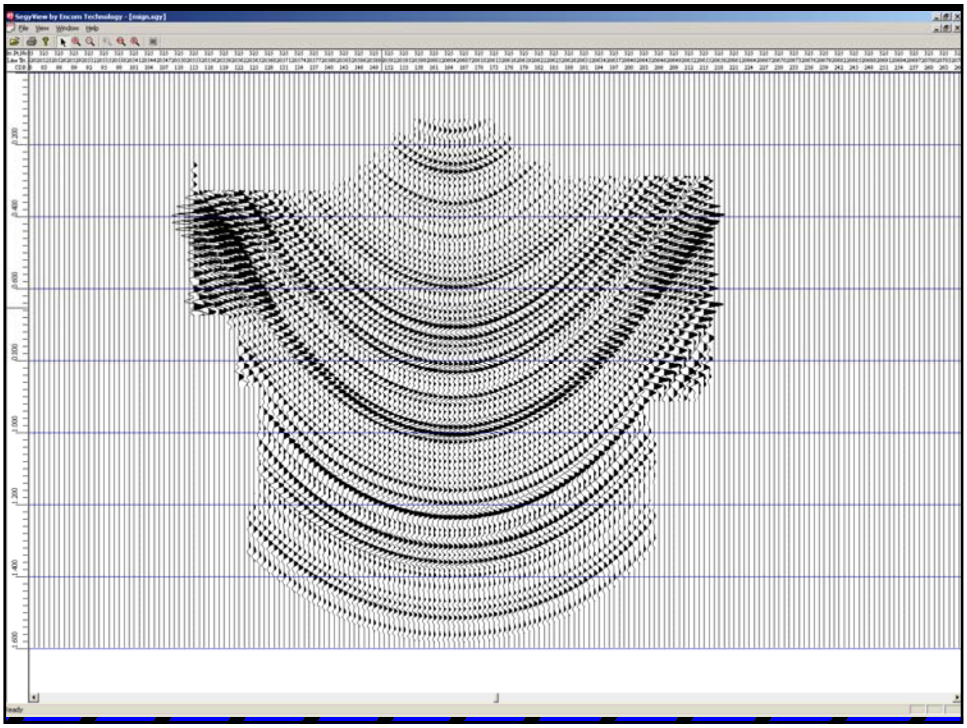
Trace 590 to 710 (ever 4th)

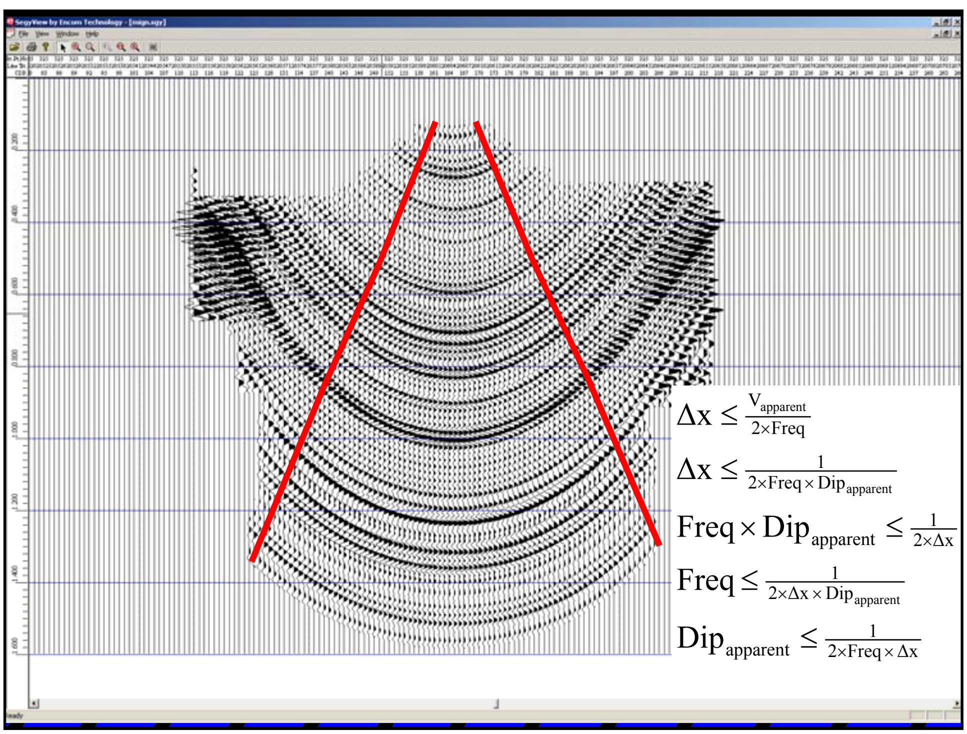
Detail of Model After Migration

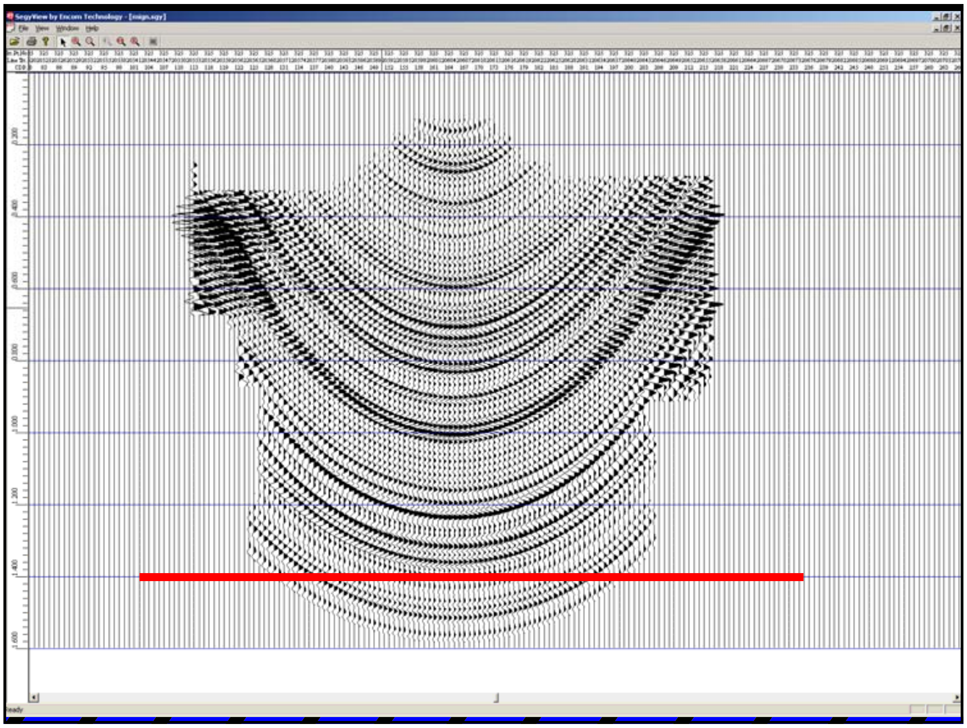


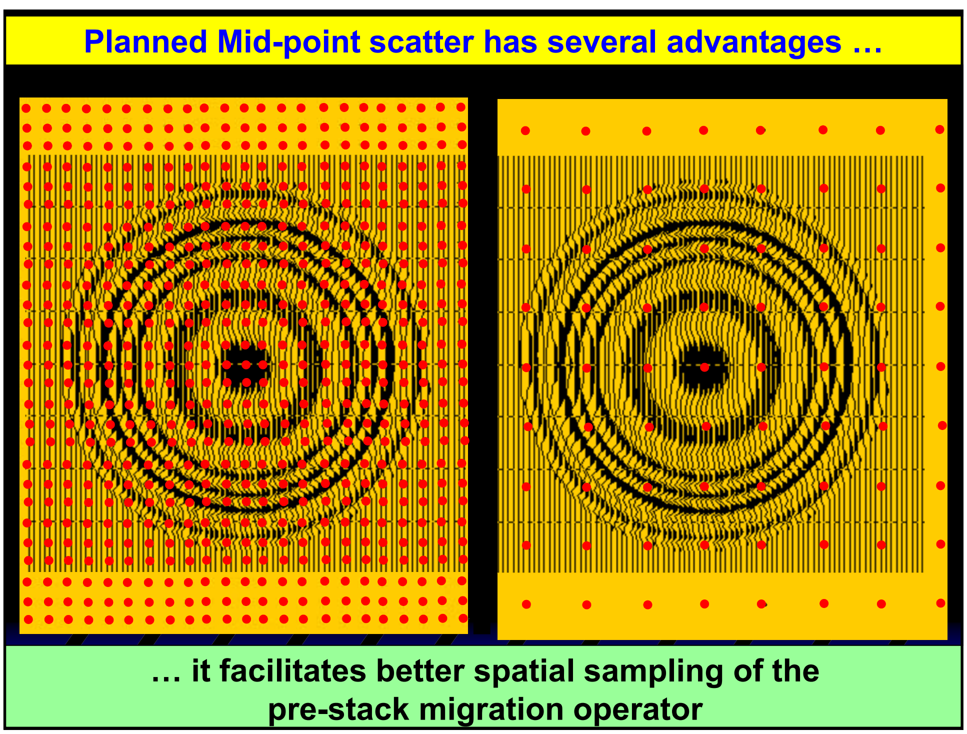
Detail of Model Before Migration





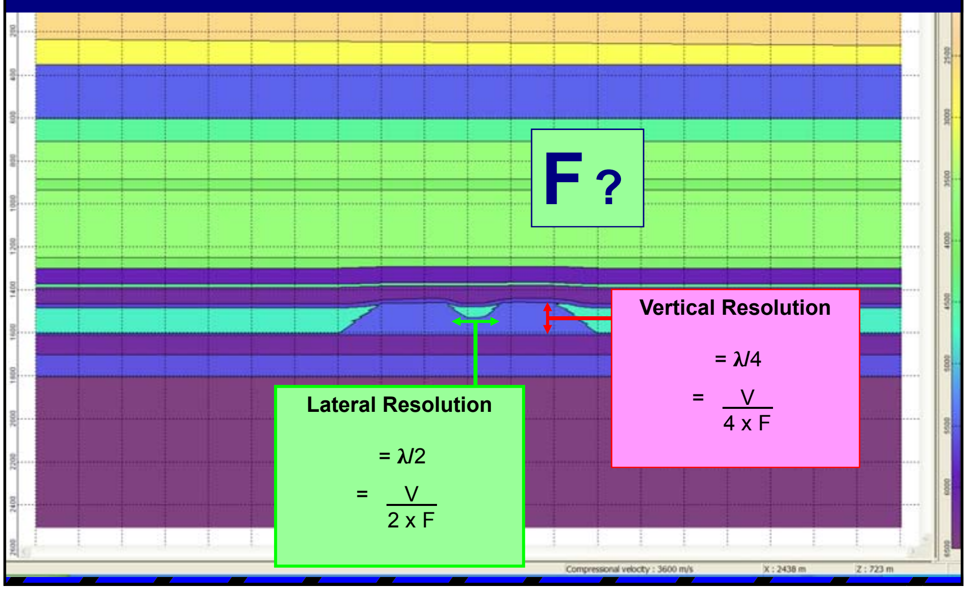

$\Delta x \le \frac{V_{apparent}}{2 \times Freq}$
$\Delta x \le \frac{1}{2 \times Freq \times Dip_{apparent}}$
$Freq \times Dip_{apparent} \le \frac{1}{2 \times \Delta x}$
$Freq \le \frac{1}{2 \times \Delta x \times Dip_{apparent}}$
$Dip_{apparent} \le \frac{1}{2 \times Freq \times \Delta x}$




Planned Mid-point scatter has several advantages …
… it facilitates better spatial sampling of the
pre-stack migration operator

Use DA20 to show
migration circle with and without
midpoint scatter

How Small can we see??
… What is the smallest Bin Size needed?

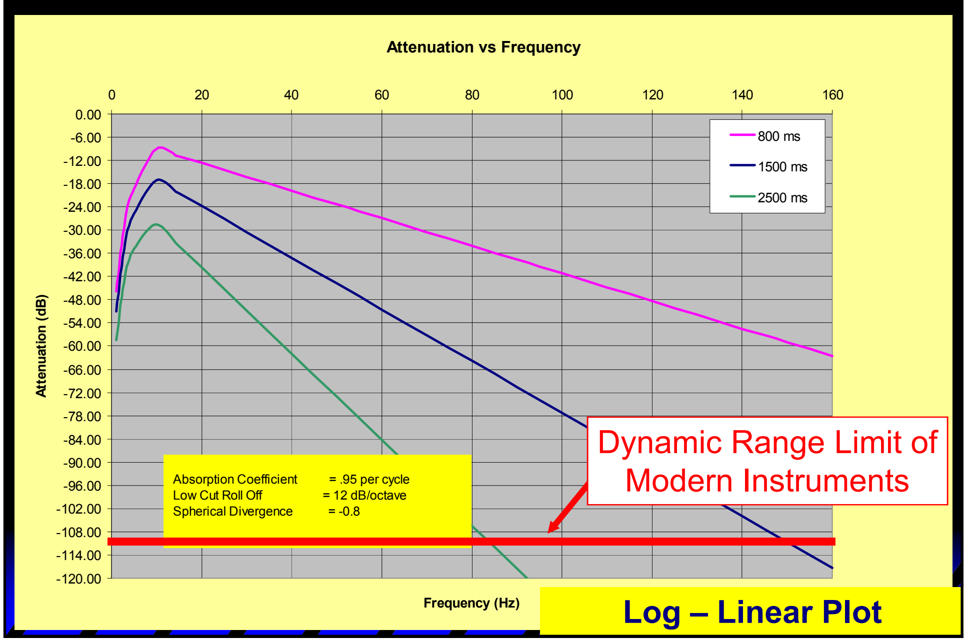


Energy Loss Mechanisms

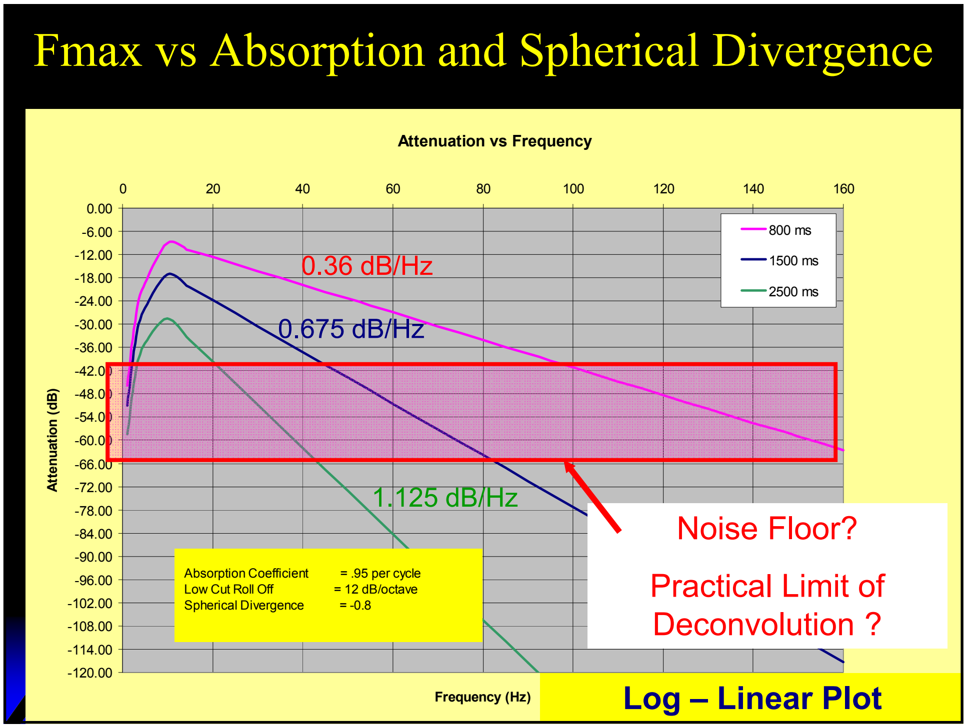
- Reflection Coefficients and Transmission Losses
- Mode Conversion and Energy Partition
- Spherical Divergence
- **Absorption**

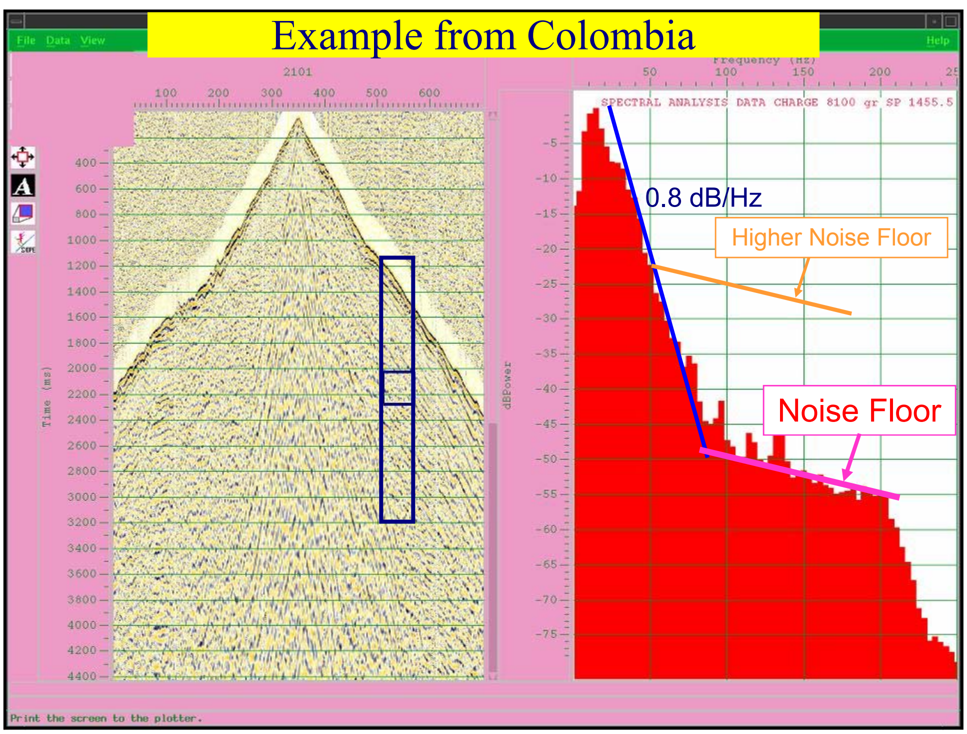
$$A_{(f,\, t)} = A_0 \times \boxed{e^{-bt}} \times \boxed{C^{(t \times f)}}$$

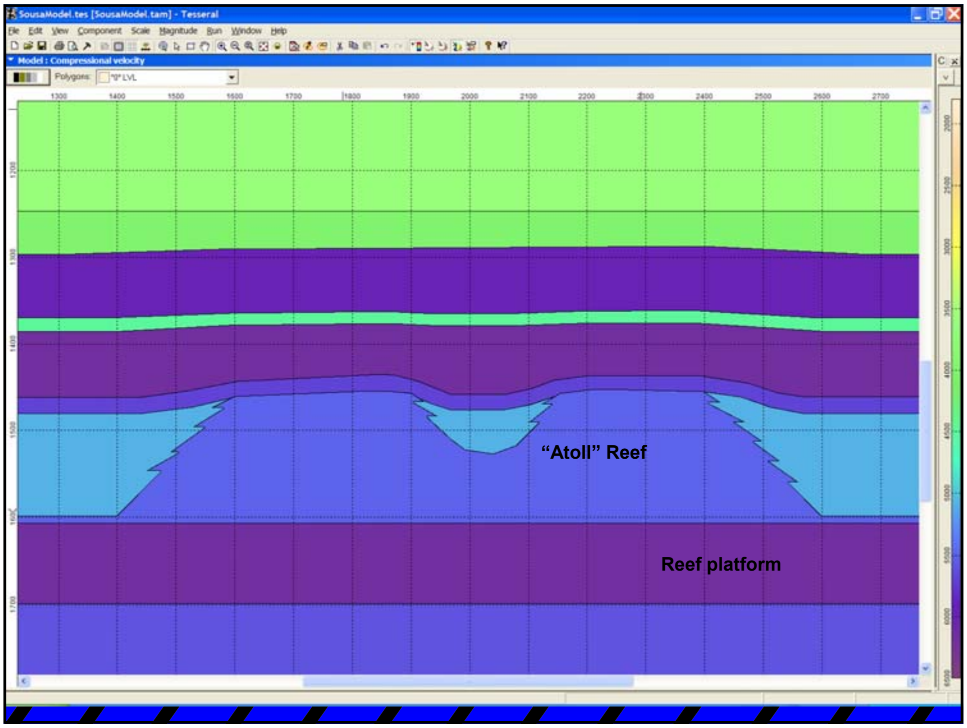
Fmax vs Absorption and Spherical Divergence



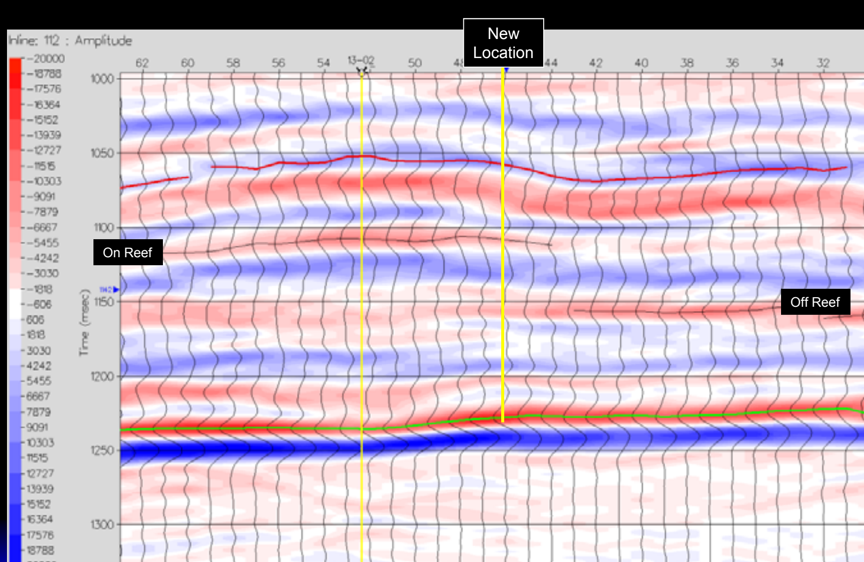
MUSTAGH RESOURCES LTD.



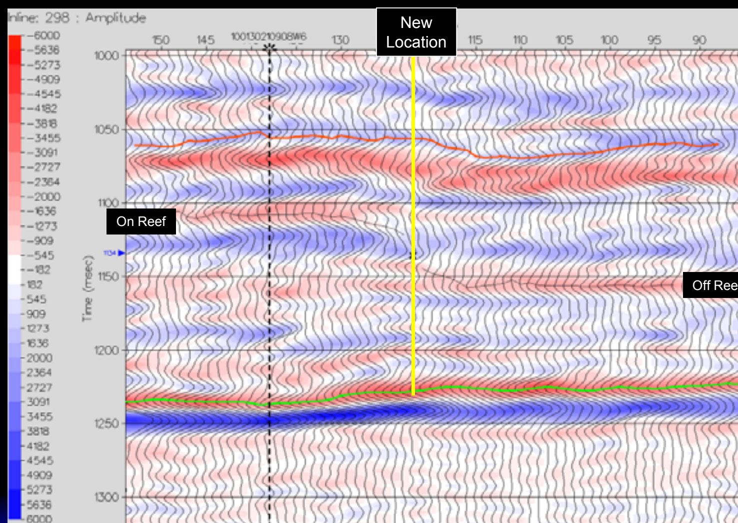




Pre-Stack Time Migration, 40 m bin size



Pre-Stack Time Migration, 15 m bin size

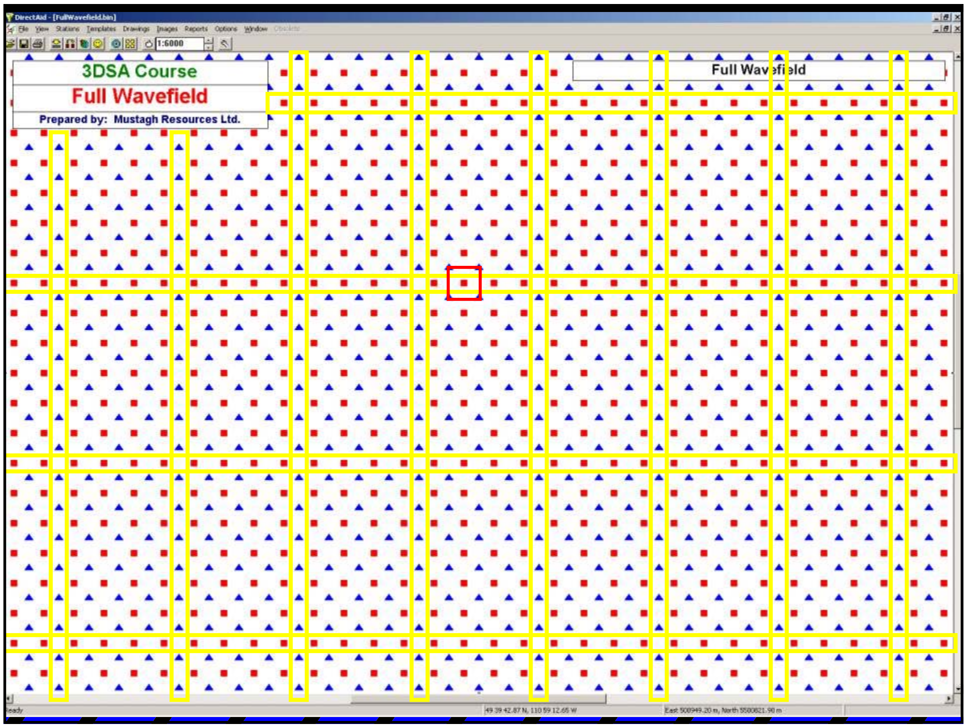


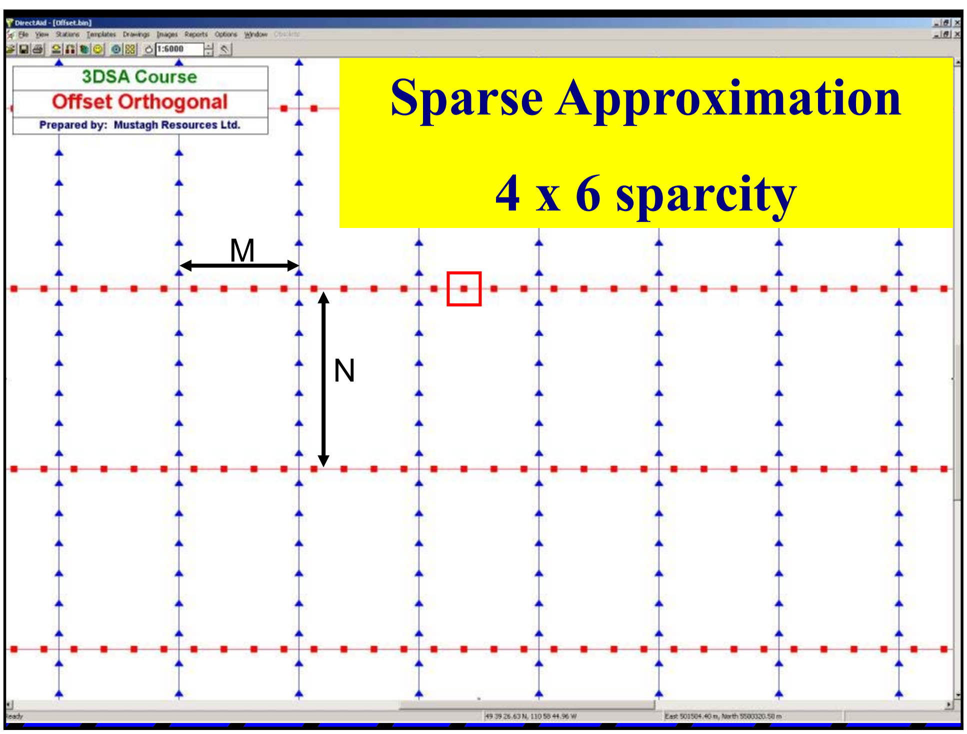
151

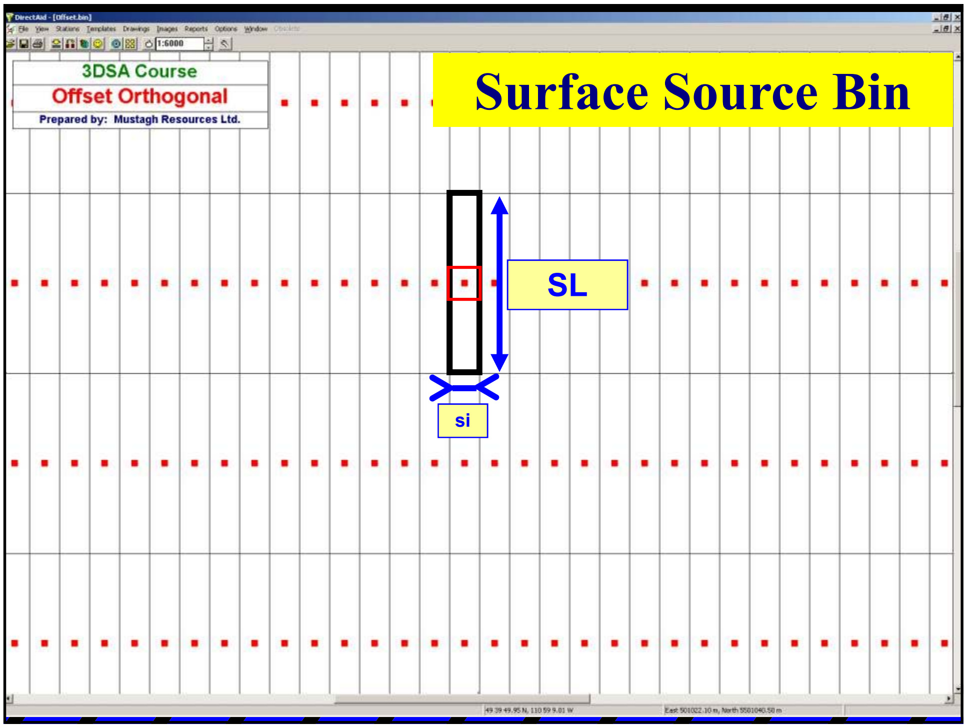
Receiver and Source line spacings

RL & SL

152


DirectAid - [FullWavefield.bin]
File View Stations Templates Drawings Images Reports Options Window
1:6000
3DSA Course
Full Wavefield
Prepared by: Mustagh Resources Ltd.
Full Wavefield
Ready


DirectAid - [Offset.bin]
File View Stations Templates Drawings Images Reports Options Window
1:6000
3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
Sparse Approximation
4 x 6 sparcity
M
N
Ready



Calculation of 3-D Fold

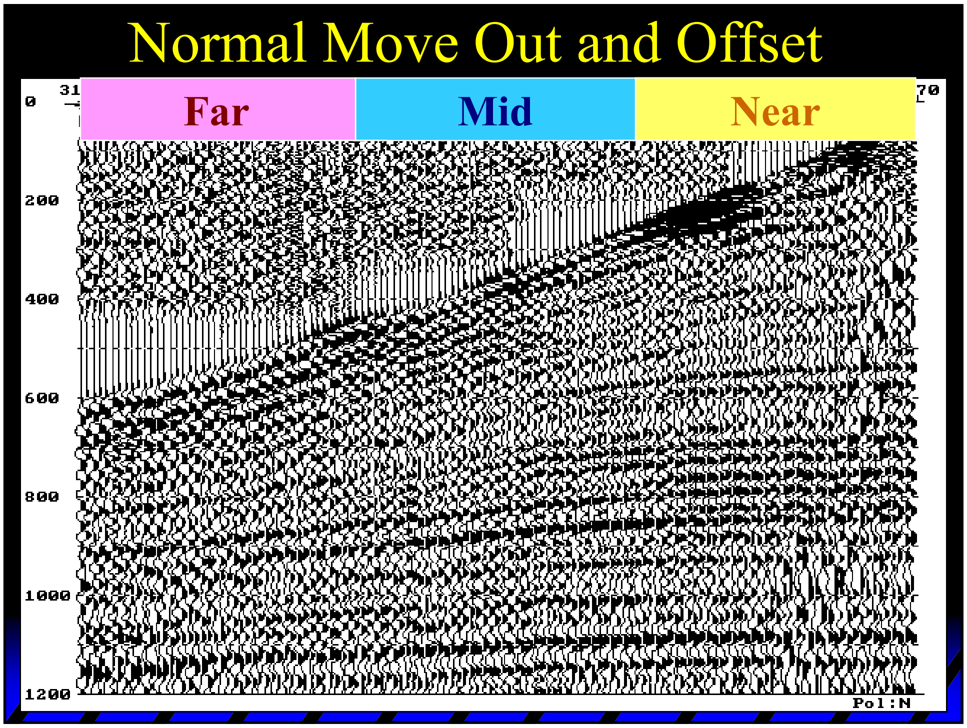
- The rectangular fold will be:

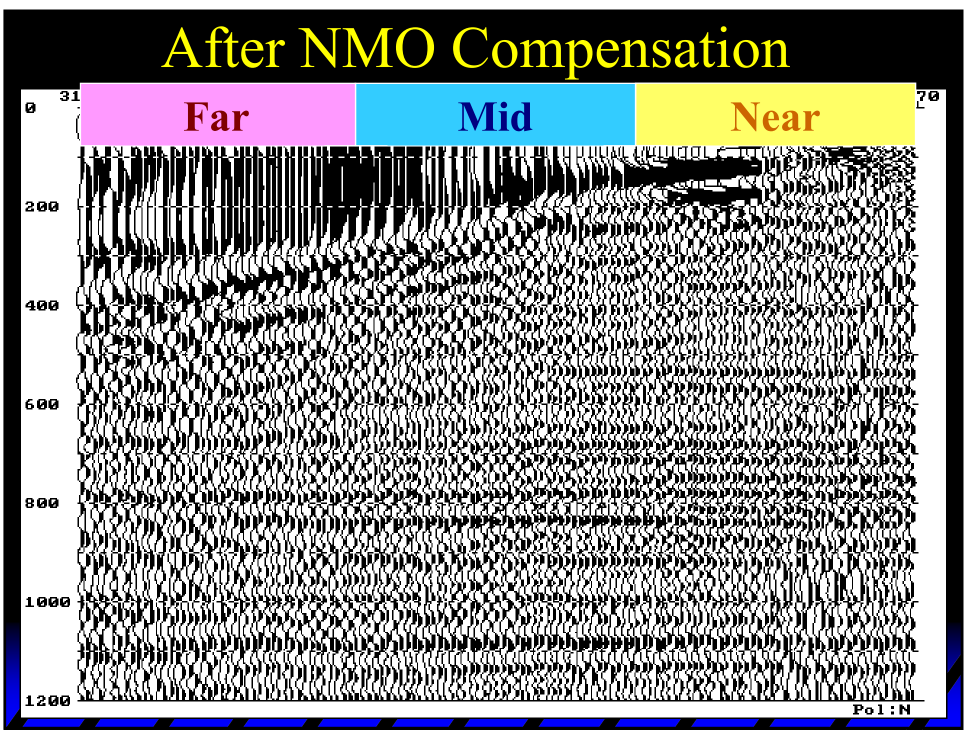
$$\frac{\text{Surface Patch Area}}{4 \times \text{Source Line Spacing} \times \text{Receiver Line Spacing}}$$

- And the offset limited (circular) fold will be :

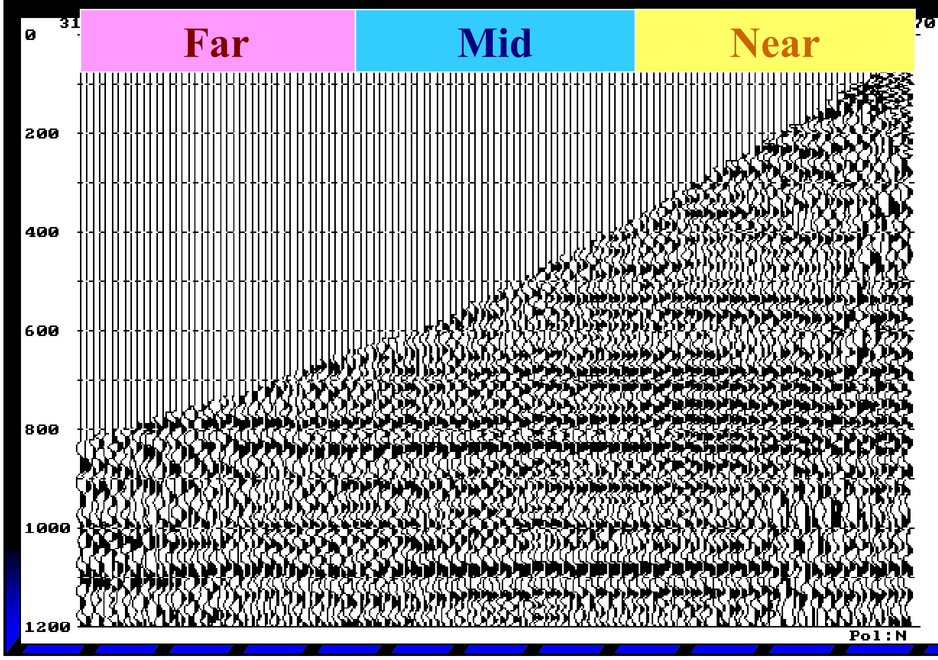
$$\frac{\pi \ \text{Xmax}^2}{4 \times \text{SL} \times \text{RL}}$$

Assuming a patch encompassing all useable offsets


Normal Move Out and Offset
Far
Mid
Near
31
70
0
200
400
600
800
1000
1200
Pol:N


After NMO Compensation
Far
Mid
Near
31
70
0
200
400
600
800
1000
1200
Pol:N

After Mute



How Sparse can we go??
… Line Spacing

$$SL \times RL = \frac{\pi \times \text{Offset}_{\text{Max}}^{2}}{4 \times \text{Desired Fold}}$$

Avoid:

SL / RL = 1.0

SL / RL > 3/2

SL / RL < 2/3

… but really, we mean:

$$Ri \times Si \le SL \times RL \le \frac{\pi \times Offset_{Max}^2}{4 \times Desired\ Fold}$$

Avoid: SL / RL = 1.0

SL / RL > 3/2

SL / RL < 2/3

Parameters versus Noise

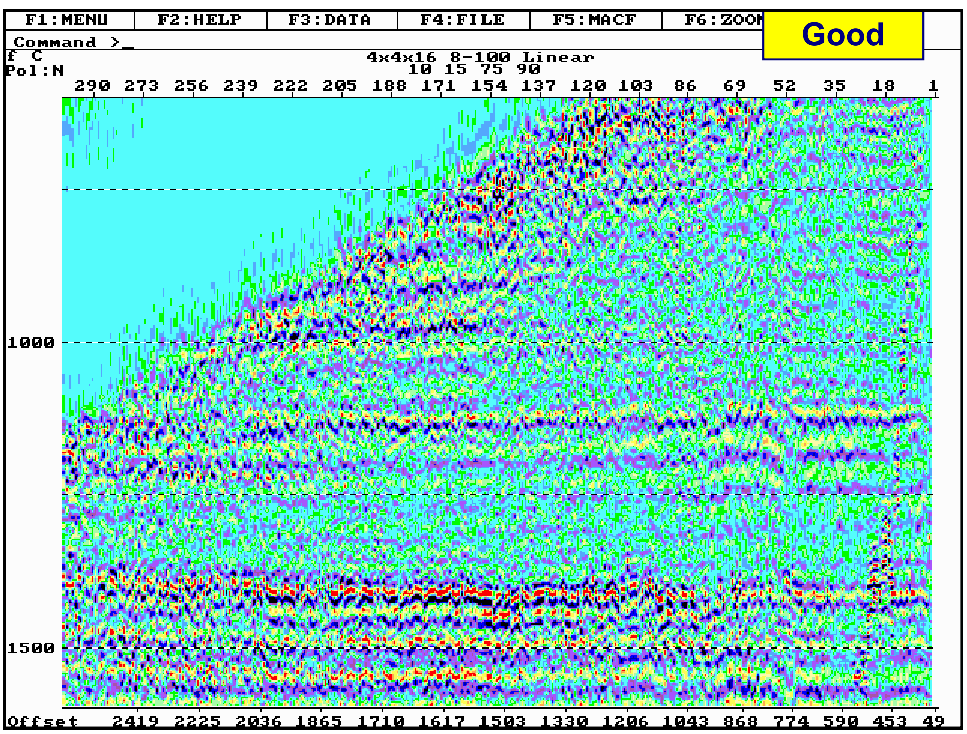
$$Ri \le Source\ Interval \le \frac{Offset_{max}}{Desired\ Fold}$$

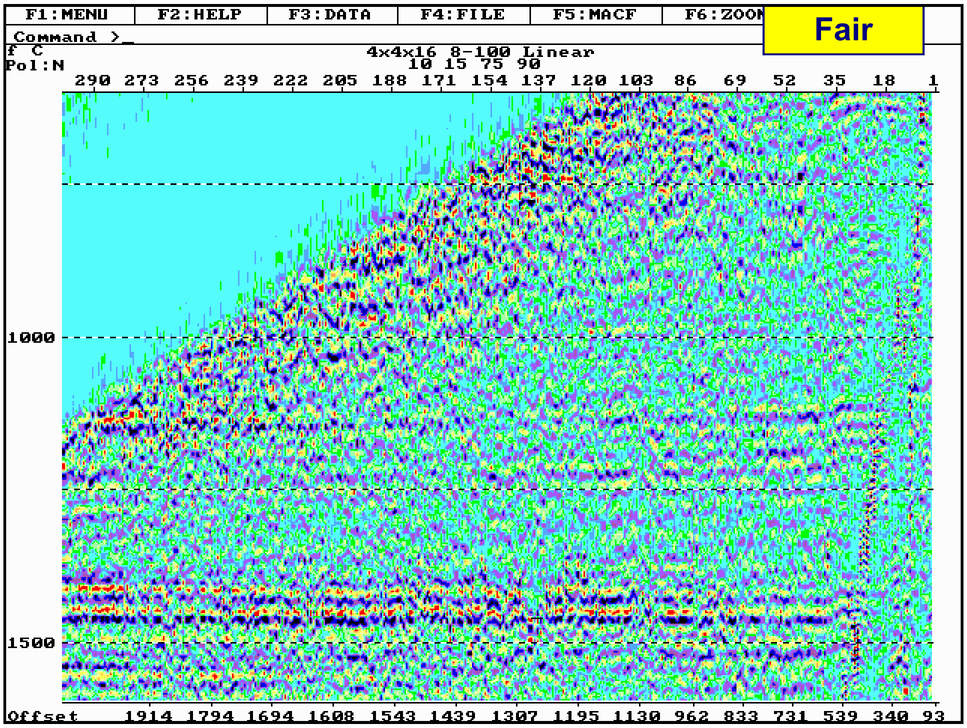
NOISE

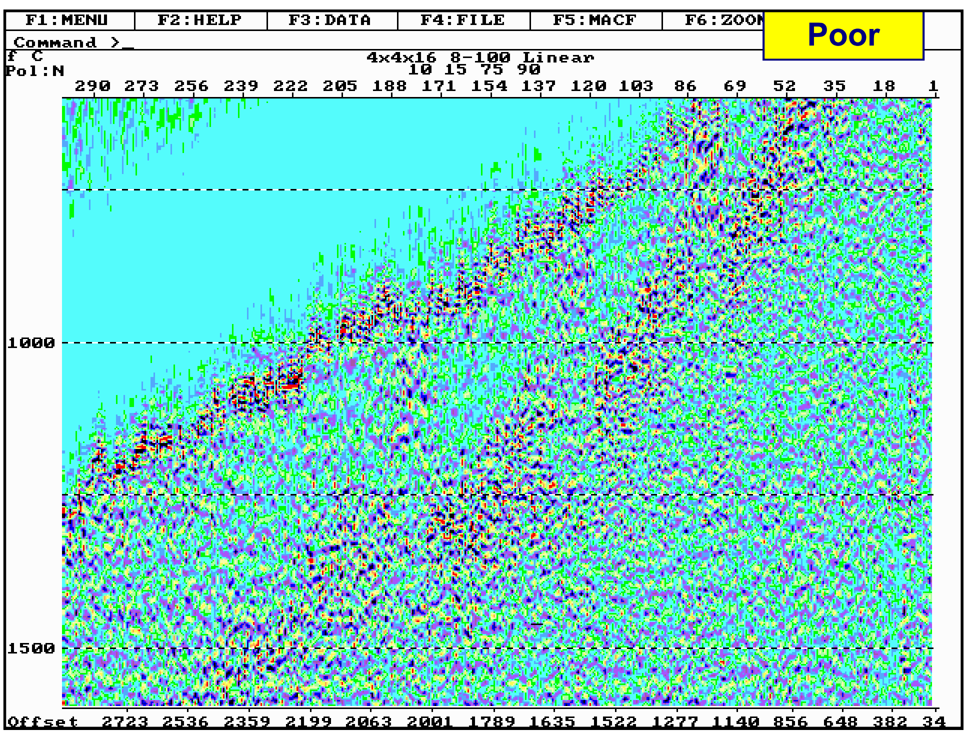
$$Ri \times Si \le SL \times RL \le \frac{\pi\, Offset_{max}^2}{4 \times Desired\ Fold}$$

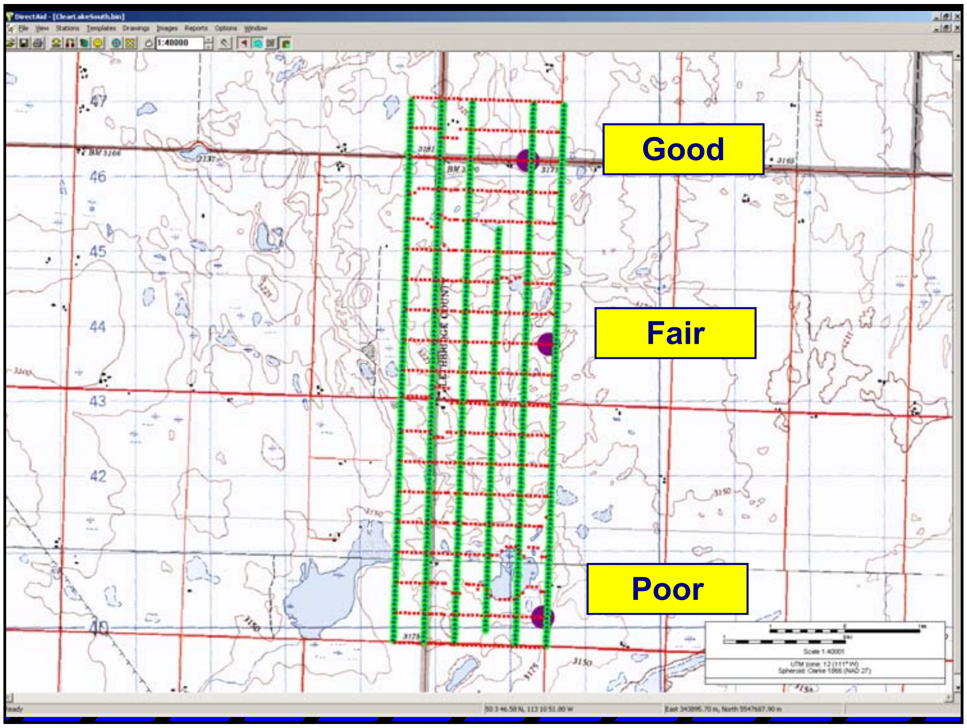
$$Costs \propto Noise$$

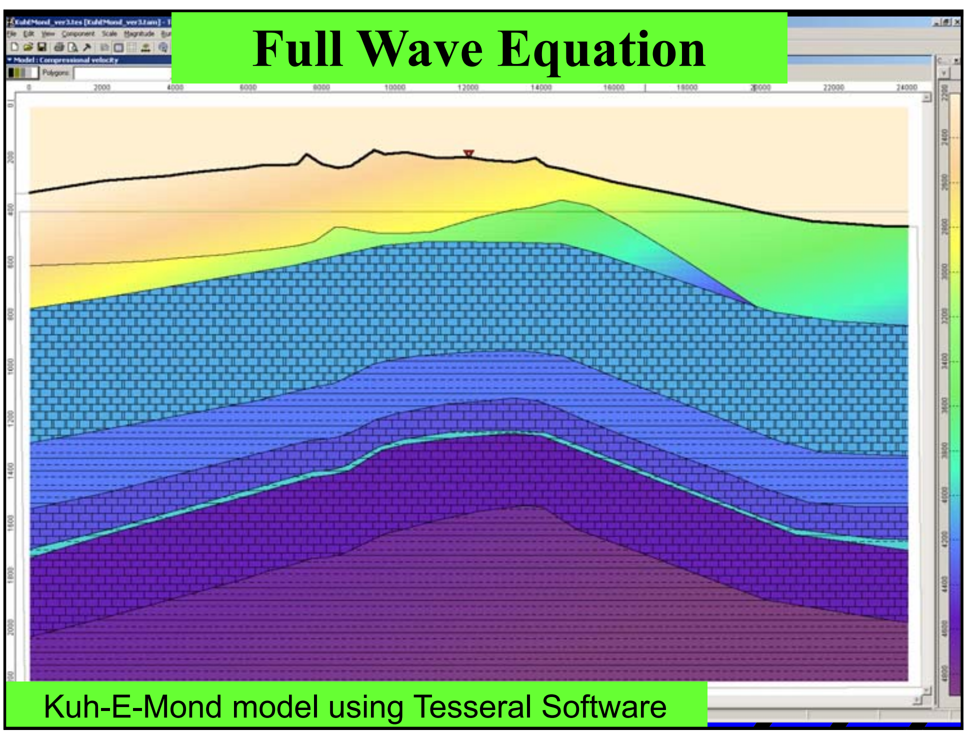
Flared Grids



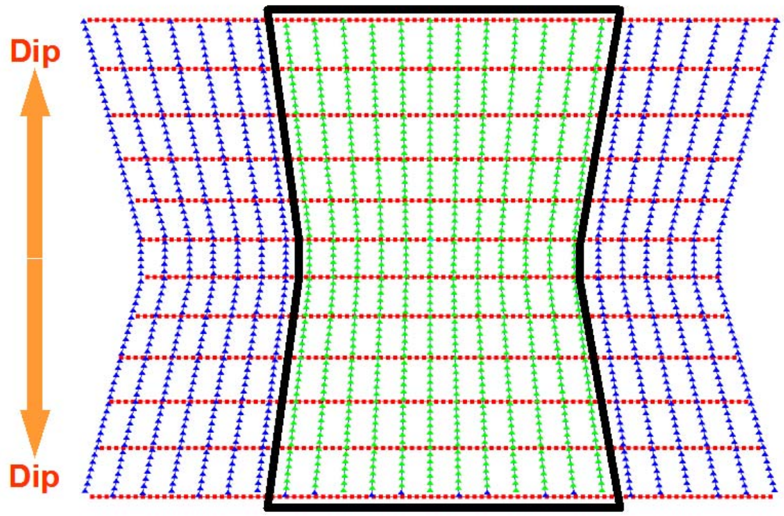

F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
Fair
Command >_
f C
Pol:N
4x4x16 8-100 Linear
10 15 75 90
290 273 256 239 222 205 188 171 154 137 120 103 86 69 52 35 18 1
1000
1500
Offset 1914 1794 1694 1608 1543 1439 1307 1195 1130 962 833 731 539 340 93


F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
Poor
Command >_
f C
Pol:N
4x4x16 8-100 Linear
10 15 75 90
290 273 256 239 222 205 188 171 154 137 120 103 86 69 52 35 18 1
1000
1500
Offset 2723 2536 2359 2199 2063 2001 1789 1635 1522 1277 1140 856 648 382 34


Good
Fair
Poor


Full Wave Equation
Kuh-E-Mond model using Tesseral Software

“Flared” Grid Designs



Use DA20 to show
Flared Grid program and statistics

Patch Analysis

Use DA10 to demonstrate patch analysis
and BOLEOL on As Built survey

3-D

Design for

Trace Density and

Statistical Diversity

But Also :

Minimize Costs

Optimize Operational Efficiency

Minimize Environmental Impact

173

3-D Seismic Design on Land
- a juggling act

MUSTAGH RESOURCES LTD.

If you desire more information or would like a copy of this tutorial, please contact Norm Cooper or Yajaira Herrera

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web page http://www.mustagh.com

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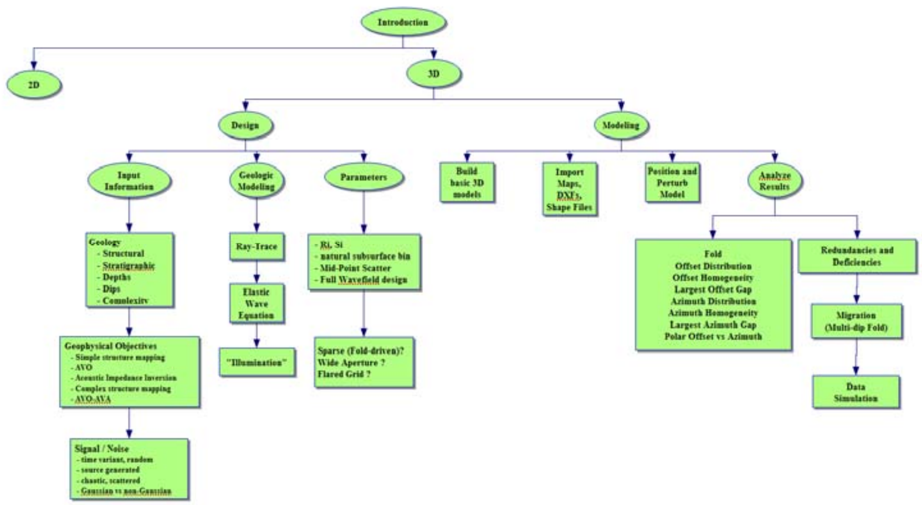
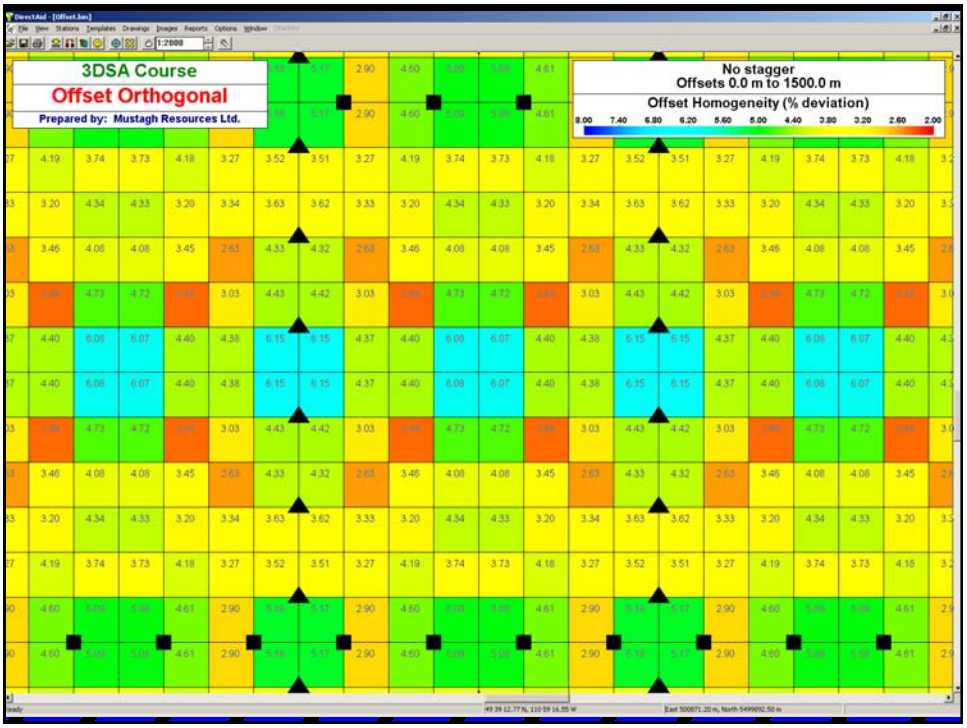
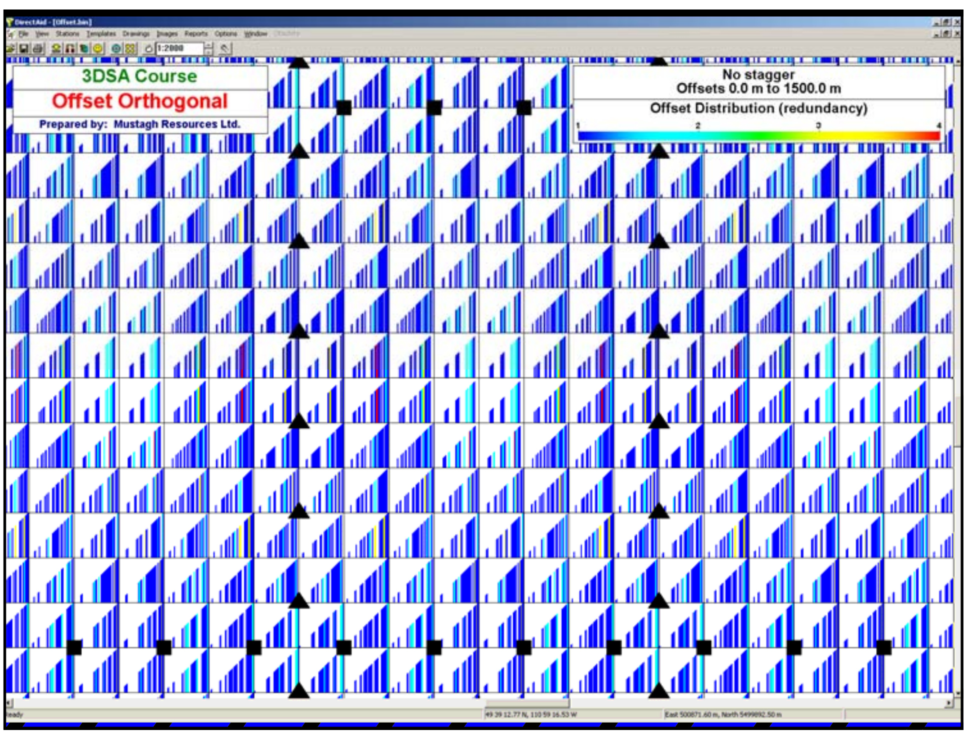
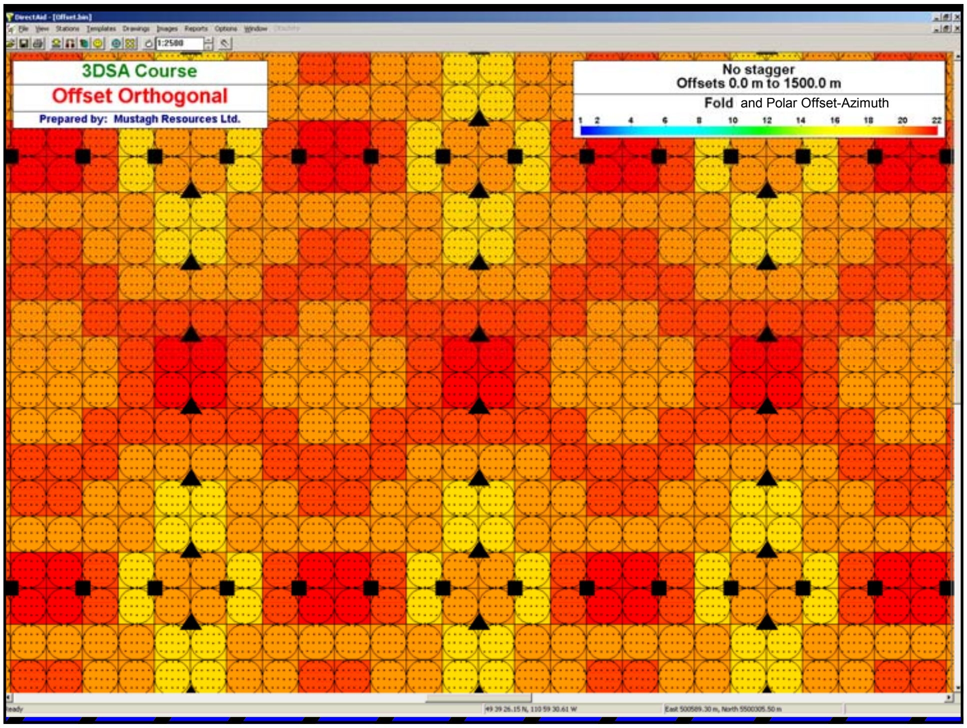


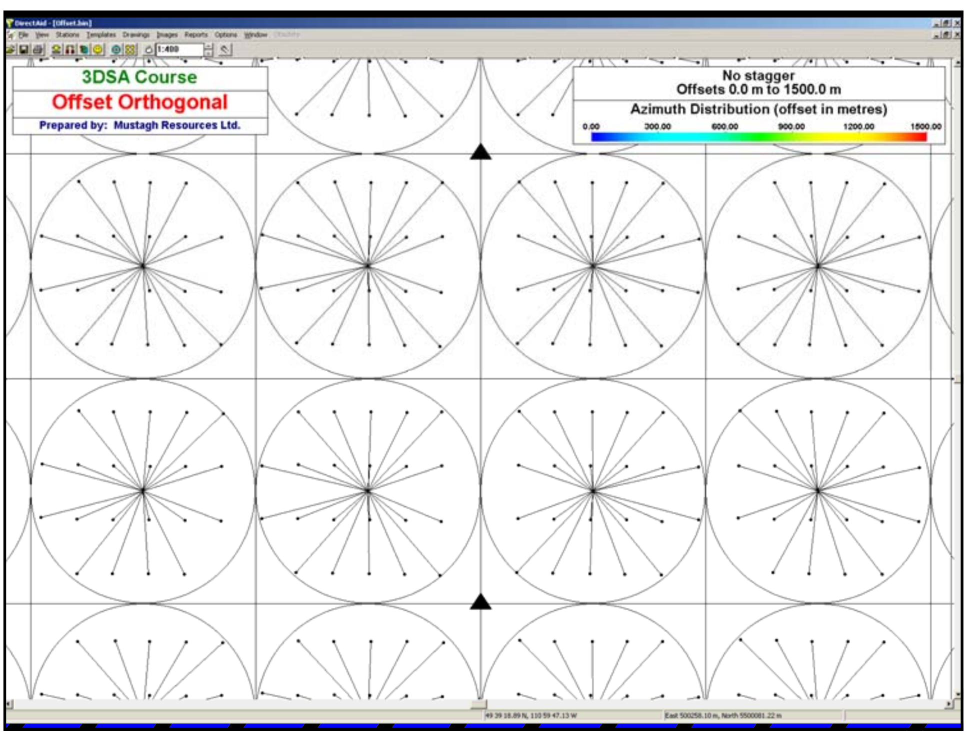
Introduction
2D
3D
Design
Modeling
Input Information
Geologic Modeling
Parameters
Build basic 3D models
Import Maps, DXFs, Shape Files
Position and Perturb Model
Analyze Results
Geology
- Structural
- Stratigraphic
- Depths
- Dips
- Complexity
Ray-Trace
- Ri, Si
- natural subsurface bin
- Mid-Point Scatter
- Full Wavefield design
Fold
Offset Distribution
Offset Homogeneity
Largest Offset Gap
Azimuth Distribution
Azimuth Homogeneity
Largest Azimuth Gap
Polar Offset vs Azimuth
Redundancies and Deficiencies
Elastic Wave Equation
Geophysical Objectives
- Simple structure mapping
- AVO
- Acoustic Impedance Inversion
- Complex structure mapping
- AVO-AVA
"Illumination"
Sparse (Fold-driven)?
Wide Aperture ?
Flared Grid ?
Migration (Multi-dip Fold)
Data Simulation
Signal / Noise
- time variant, random
- source generated
- chaotic, scattered
- Gaussian vs non-Gaussian

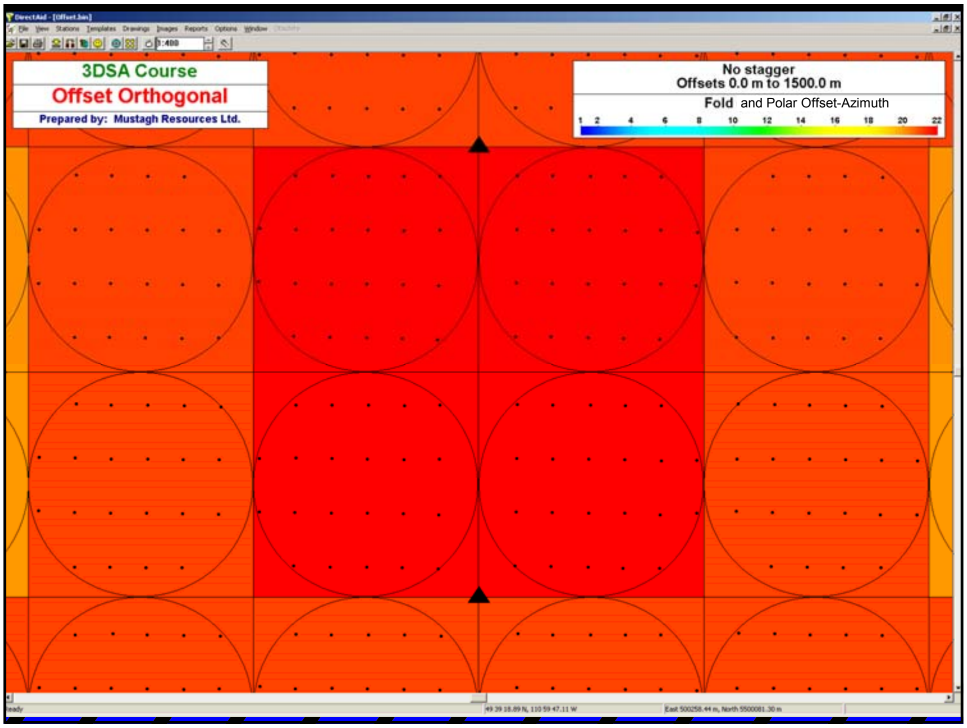

3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Offset Homogeneity (% deviation)

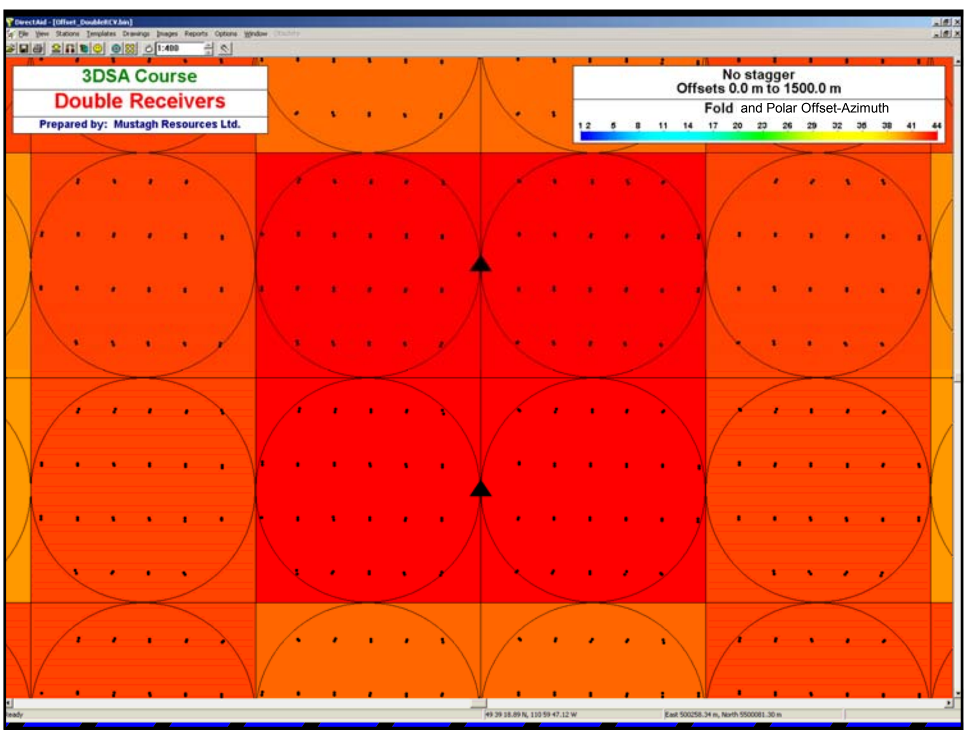

3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Offset Distribution (redundancy)

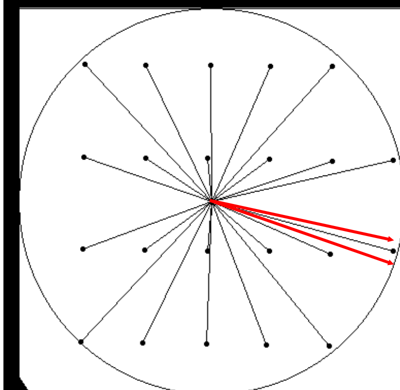
The 3D Case


3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Fold and Polar Offset-Azimuth
1 2 4 6 8 10 12 14 16 18 20 22

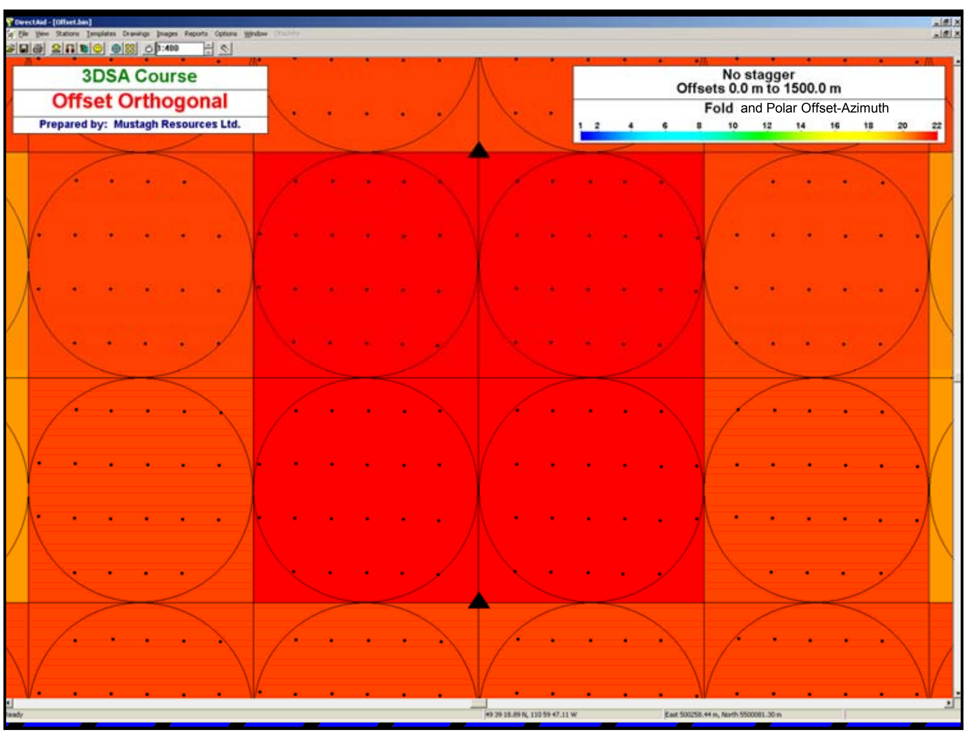

3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Azimuth Distribution (offset in metres)
0.00 300.00 600.00 900.00 1200.00 1500.00

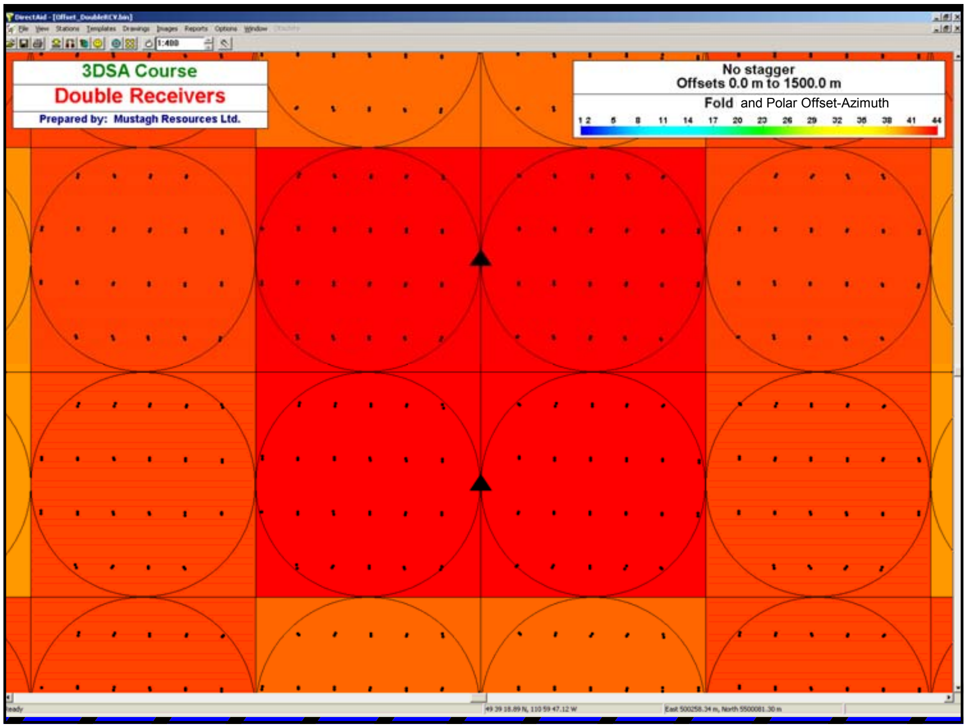

3DSA Course
Offset Orthogonal
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Fold and Polar Offset-Azimuth
1 2 4 6 8 10 12 14 16 18 20 22


3DSA Course
Double Receivers
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Fold and Polar Offset-Azimuth

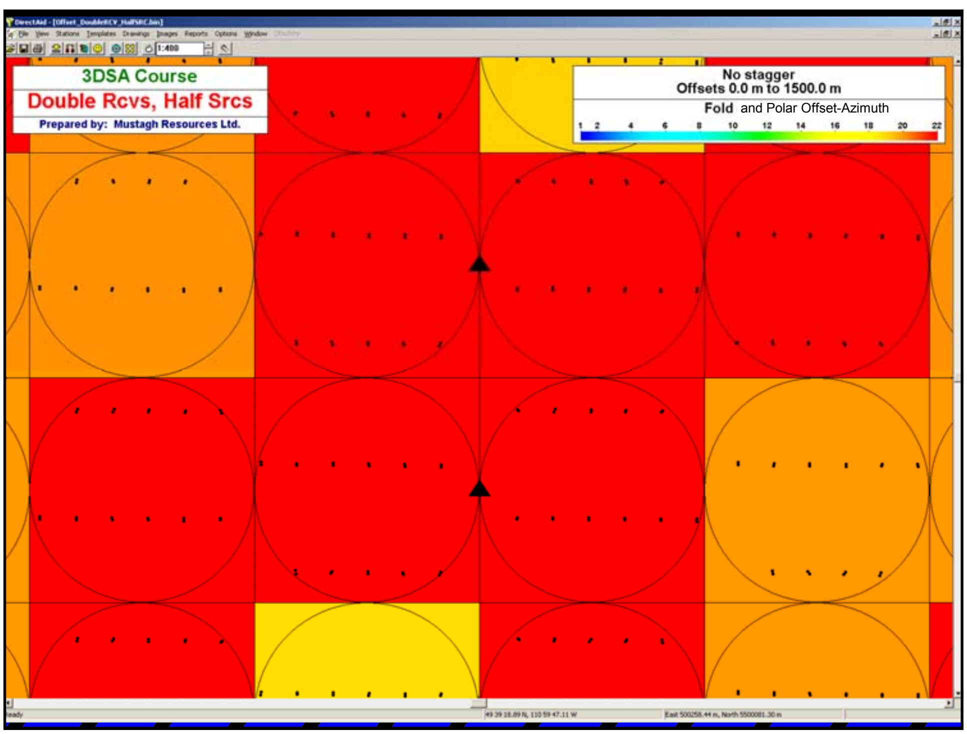


SL =	360	RL =	240		
Si =	60	Ri =	60		
N =	6	M =	1		
	N x RL - Si/2	M x SL - Ri/2			
	dx	dy		dist	azimuth
Normal pt	1410	330		1448.1	13.2
1/2 stn N	1410	315		1444.8	12.6
1/2 stn S	1410	345		1451.6	13.7

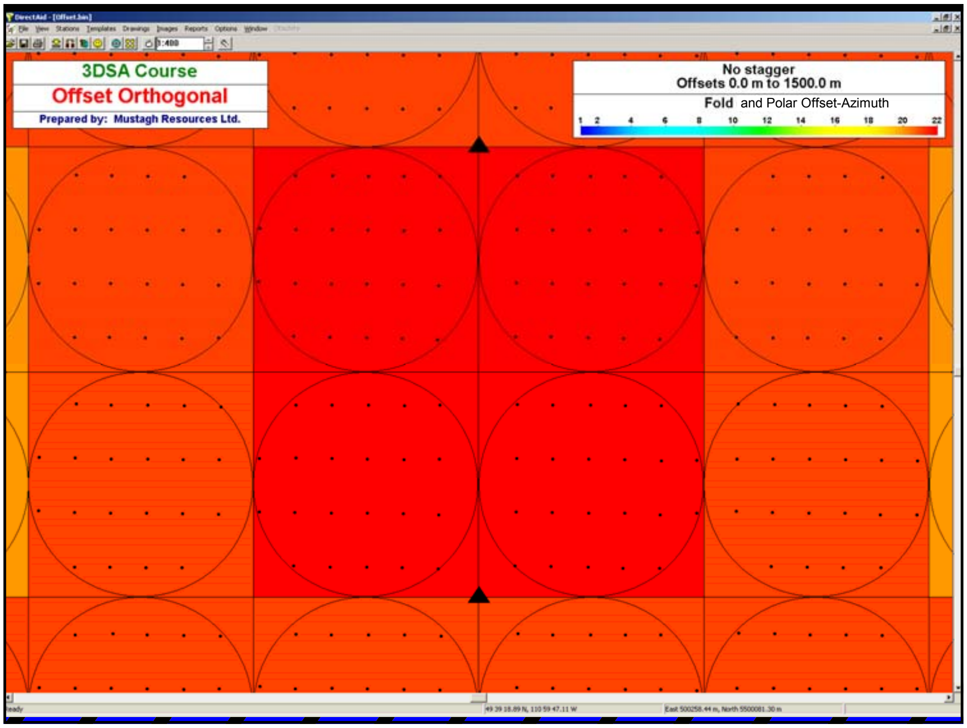




3DSA Course
Double Receivers
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Fold and Polar Offset-Azimuth
1 2 5 8 11 14 17 20 23 26 29 32 35 38 41 44

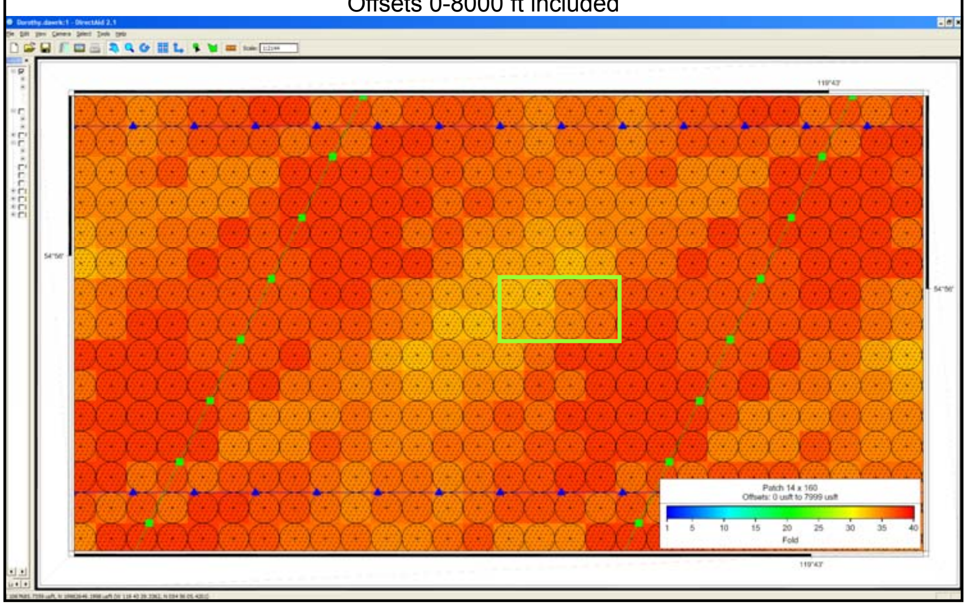


3DSA Course
Double Rcvs, Half Srcs
Prepared by: Mustagh Resources Ltd.
No stagger
Offsets 0.0 m to 1500.0 m
Fold and Polar Offset-Azimuth
1 2 4 6 8 10 12 14 16 18 20 22



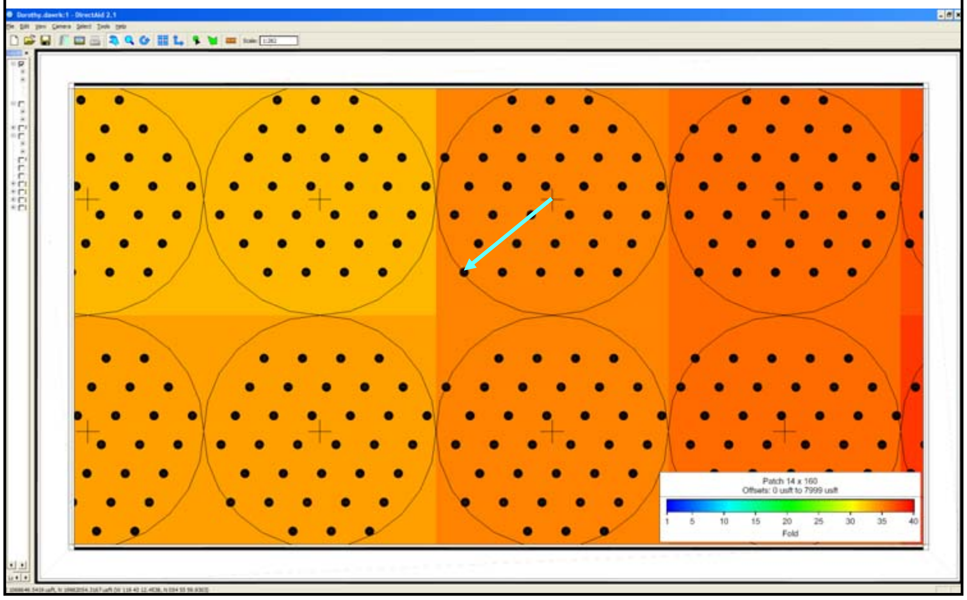
Basic diagonal grid 6 x 8 sparcity, 14 x 160 patch.
Detail for each bin showing fold in color and polar plot of offsets vs azimuths
(equivalent to "spider" plot – just the "feet")

Offsets 0-8000 ft included



Detail from previous plot (detail are shown in green box)

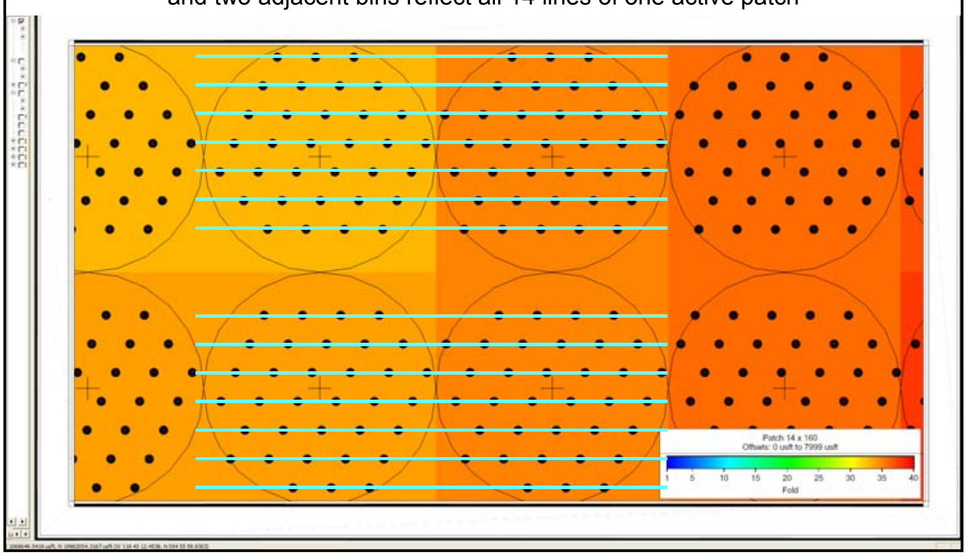
Polar plot where center of circle (+ sign) is zero offset
and distance along any radial increases to outer edge of circle (8000 ft)



Detail from previous plot (detail are shown in green box)

The apparent horizontal alignments of statistics are due to receiver line grid

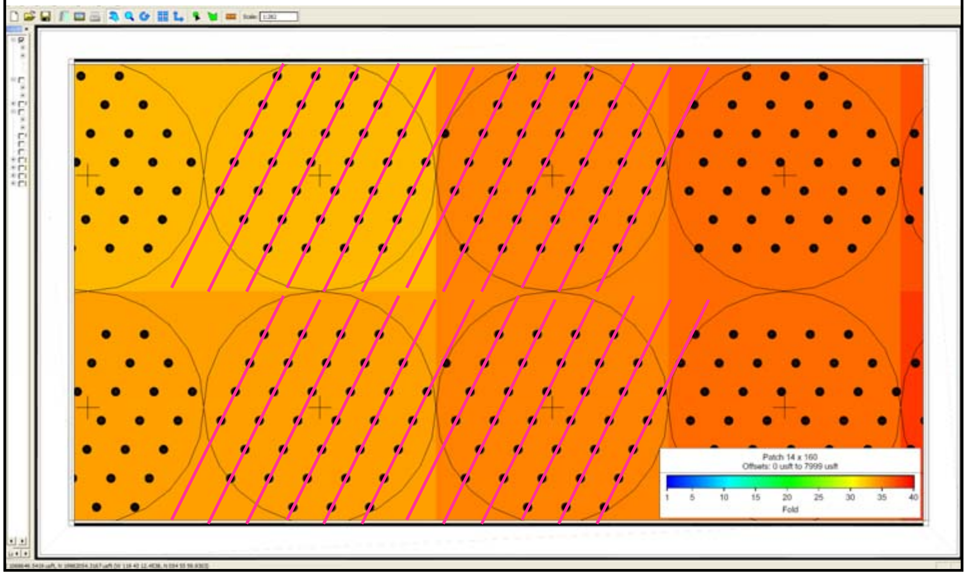
Cross-line separation between horizontal blue lines
equates to two times receiver line spacing
and two adjacent bins reflect all 14 lines of one active patch



Detail from previous plot (detail are shown in green box)

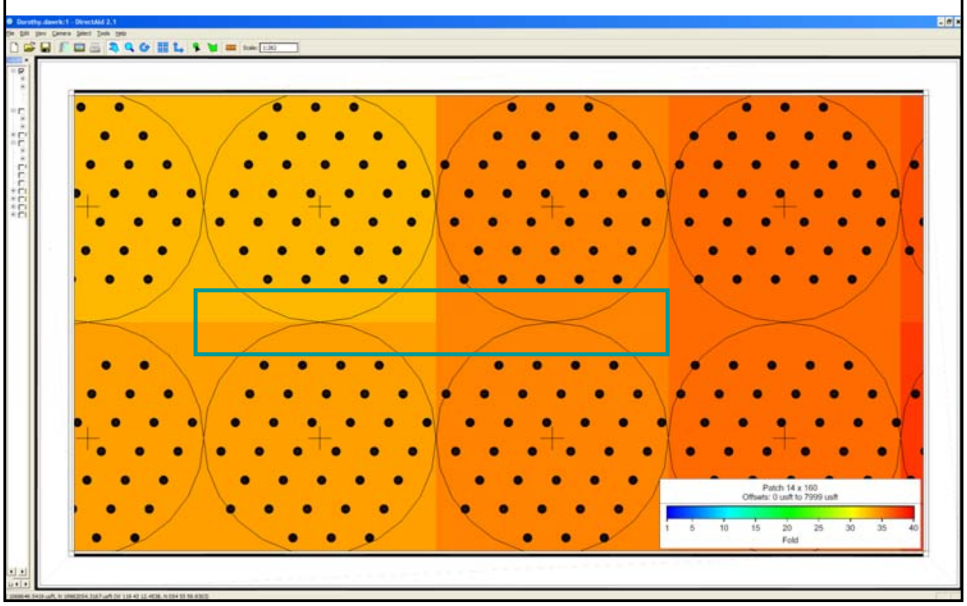
The apparent diagonal alignments of statistics are due to source line grid

Cross-line separation between diagonal pink lines
equates to two times source line spacing



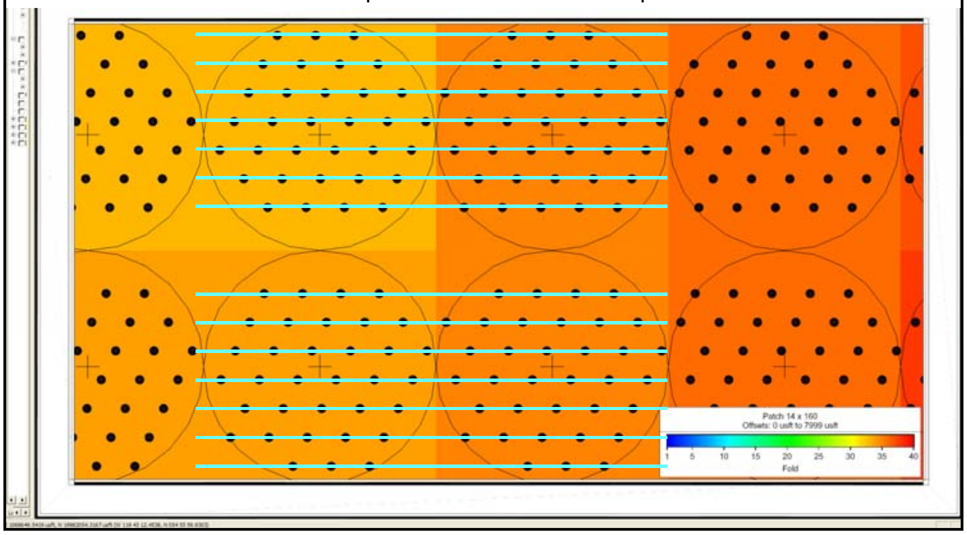
Offsets and azimuths in highlighted area are limited by 14 line patch.
A 16 line patch would have added more fold and more statistics in this area.

However, this is only useful for offsets extending to 8000 meters.

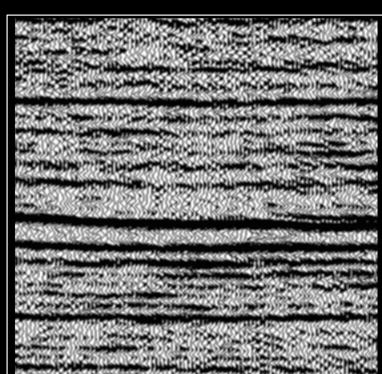


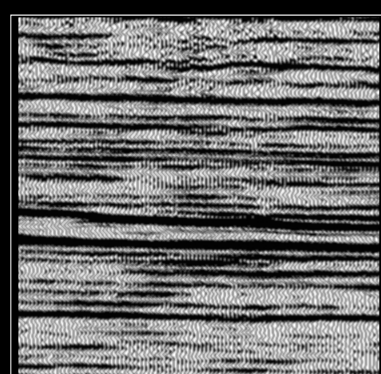
With this insight, it is easy to see that reducing receiver line spacing will bring the offset-azimuth statistics in closer proximity to each other and will provide better statistical sampling of source generated noise modes and of pre-stack migration operators.

BUT – if long offsets are important, sufficient lines must be recorded in order to preserve total cross-line aperture



Geometric Noise – remember importance of statistical diversity !!





4 vibs x 4 swps x 1000 / 80

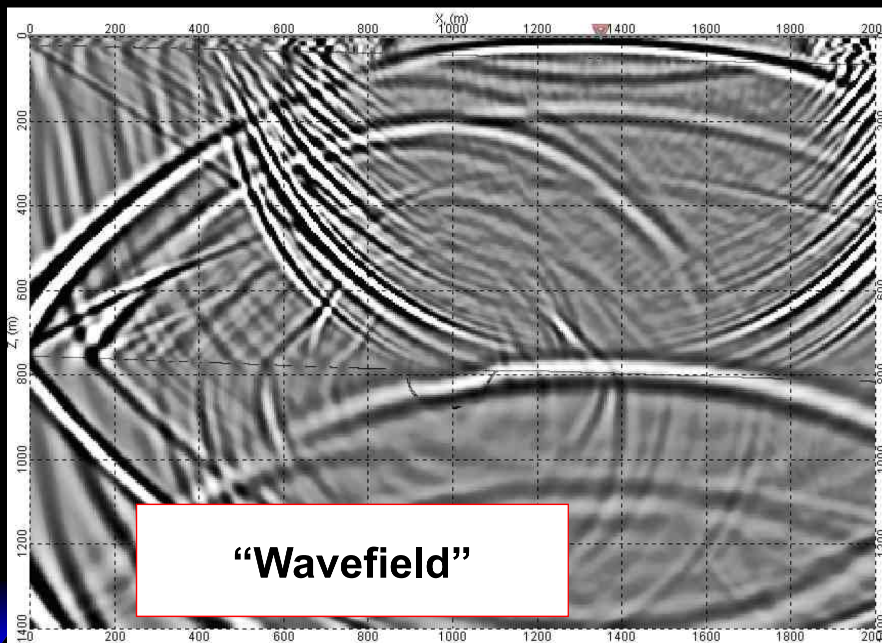
= 200 vib-swps/km

S. I. = 4 x R. I.

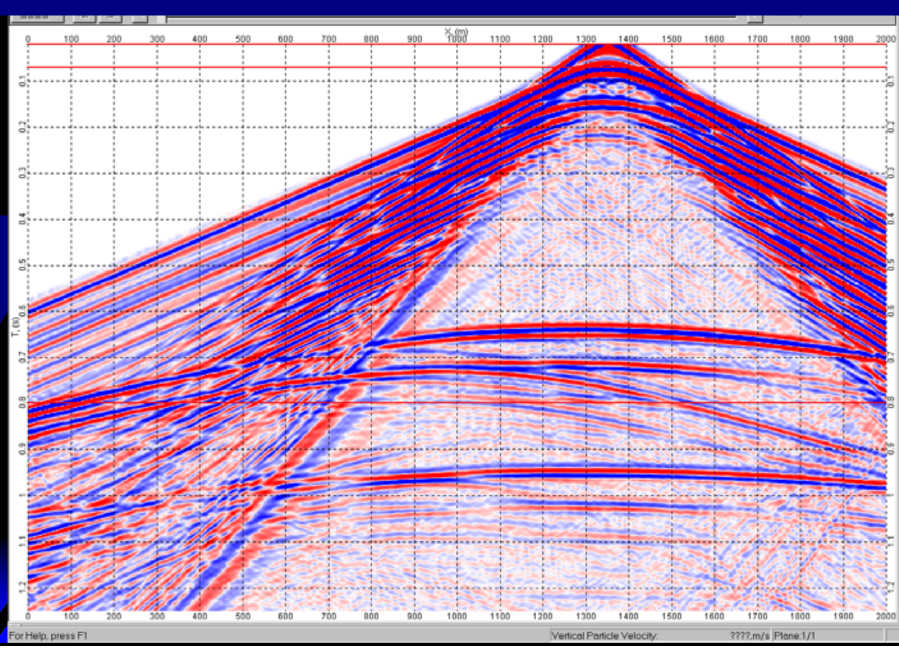
1 vib x 2 swps x 1000 / 20

= 100 vib-swps/km

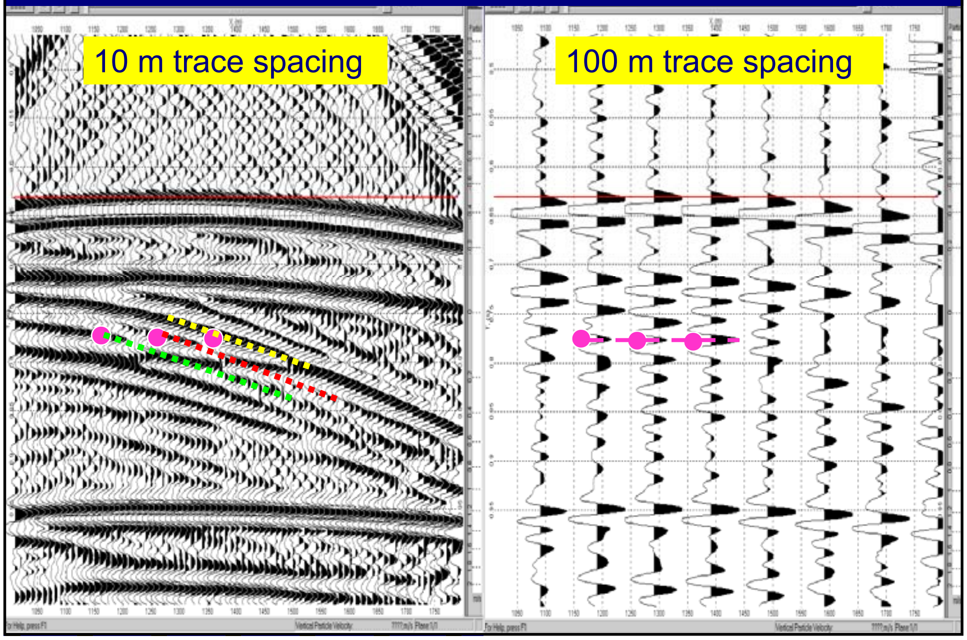
S. I. = R. I.



Continuously measured wavefield



… discretely measured with geophone groups



Recommendations – 2D

Ensure Source Interval is less than or equal to maximum useable offset divided by desired fold

Where affordable, allow source interval to more closely approach receiver interval

A geophone array should be used distributed over the receiver interval

There is little value in recording receiver intervals smaller than two times the desired CDP interval

Recommendations – 3D

Ensure source and receiver line spacings are sufficiently small to deliver the desired fold within the maximum useable offsets

Where affordable, allow grid density tighter than the minimum predicted necessary density

A combination of midpoint scatter and arrays of about 1/3 of the source or receiver interval should be considered

There is little value in recording receiver intervals smaller than two times the desired subsurface bin size