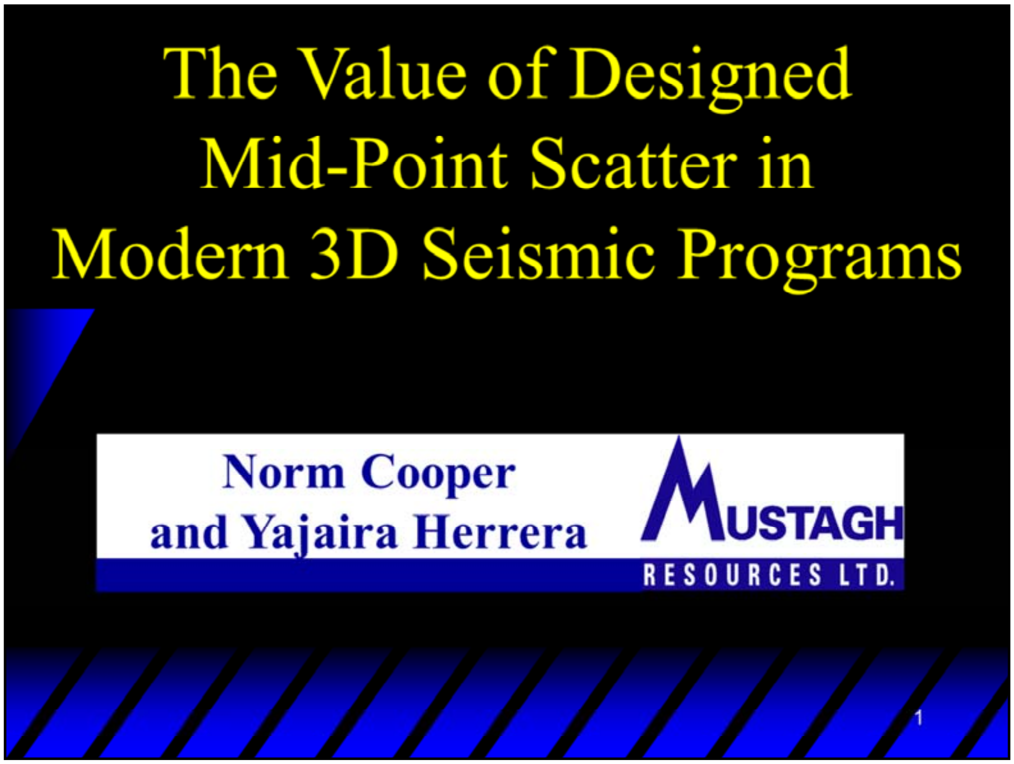
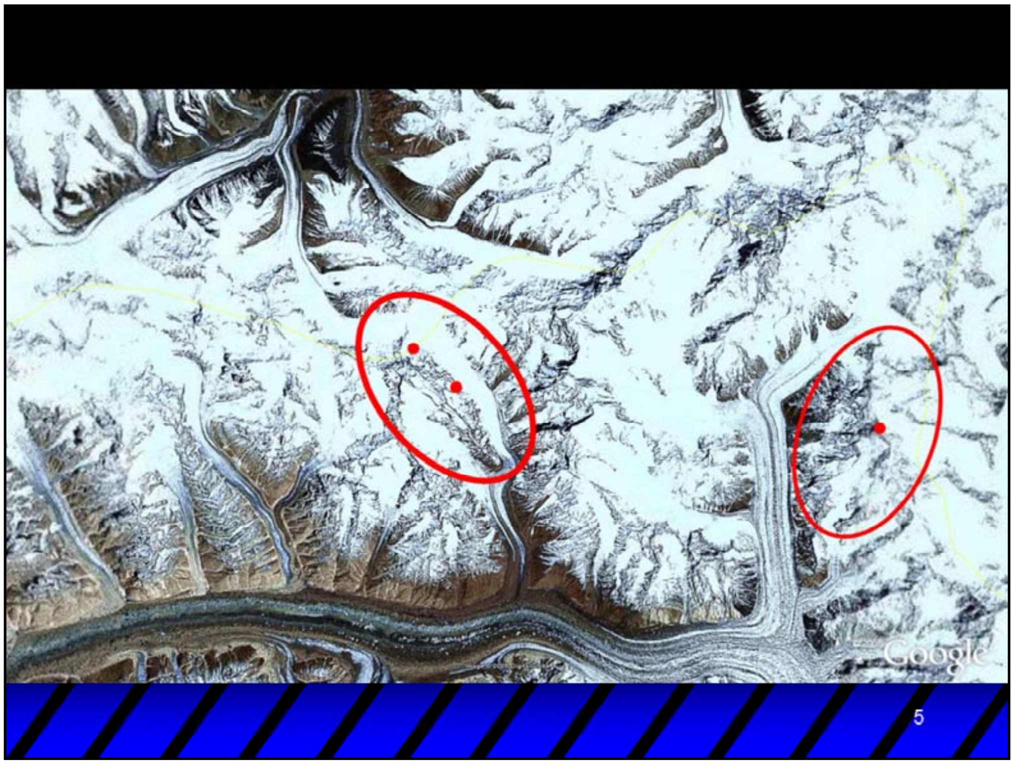
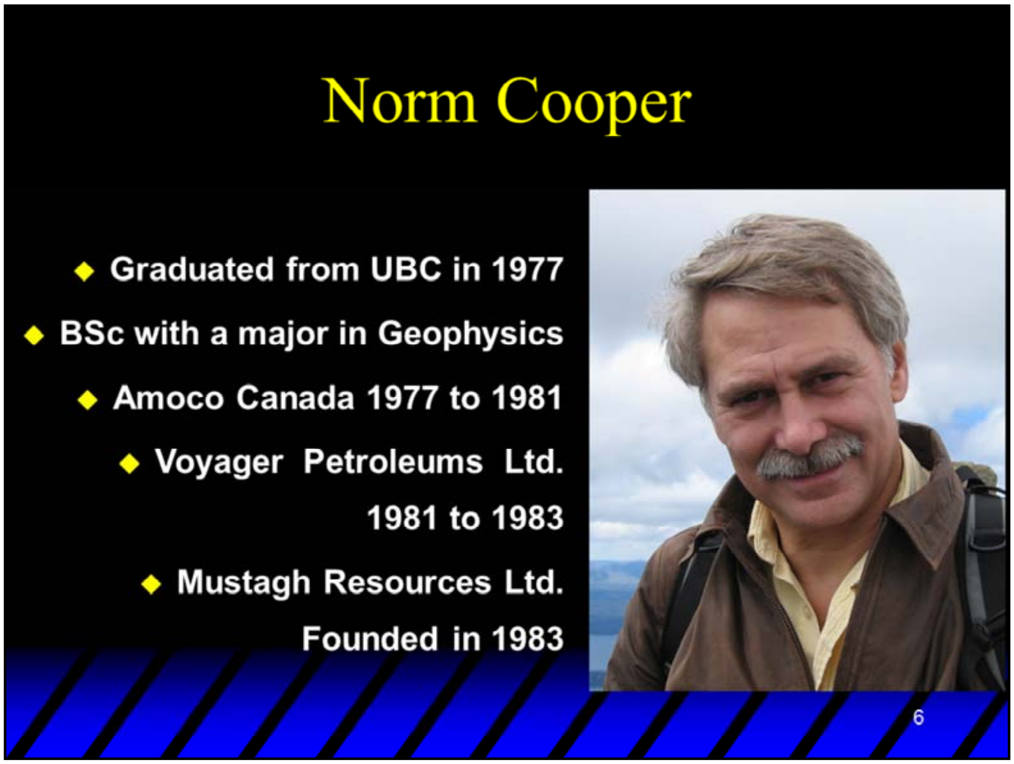

The Value of Designed
Mid-Point Scatter in
Modern 3D Seismic Programs
Norm Cooper
and Yajaira Herrera
MUSTAGH
RESOURCES LTD.
1


MUSTAGH
RESOURCES LTD.


©2005 Google
3


Google
4


Google
5


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
6

MUSTAGH RESOURCES LTD.

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

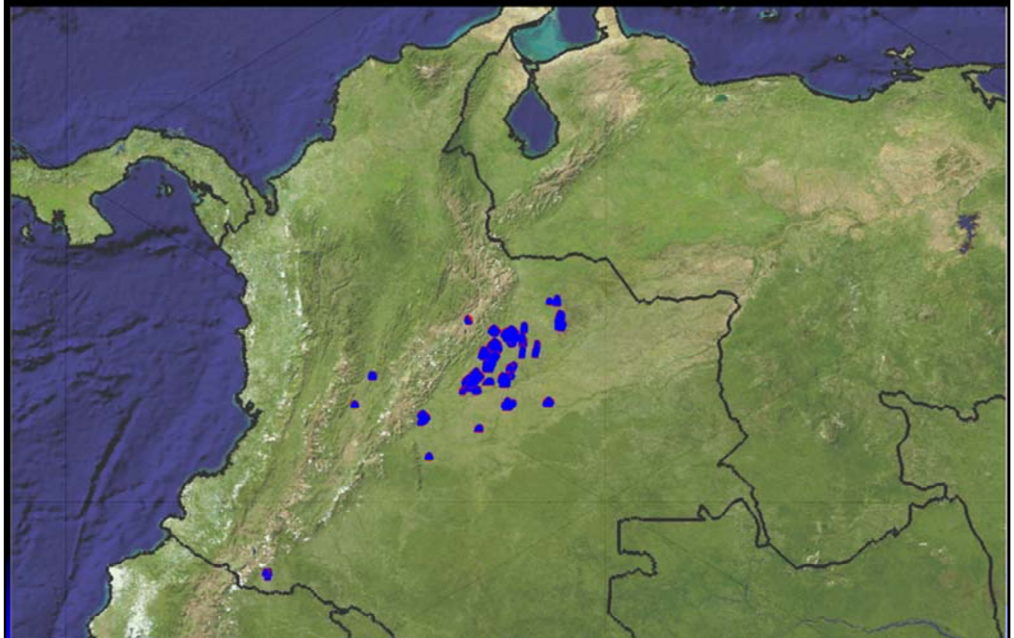

Mustagh Resources Ltd.
Since 1983 we have specialized in all types of Geophysical Consulting:
Design and Management of 2D and 3D seismic programs.
Quality Assurance and Parameter Optimization on program start ups.
8


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
9

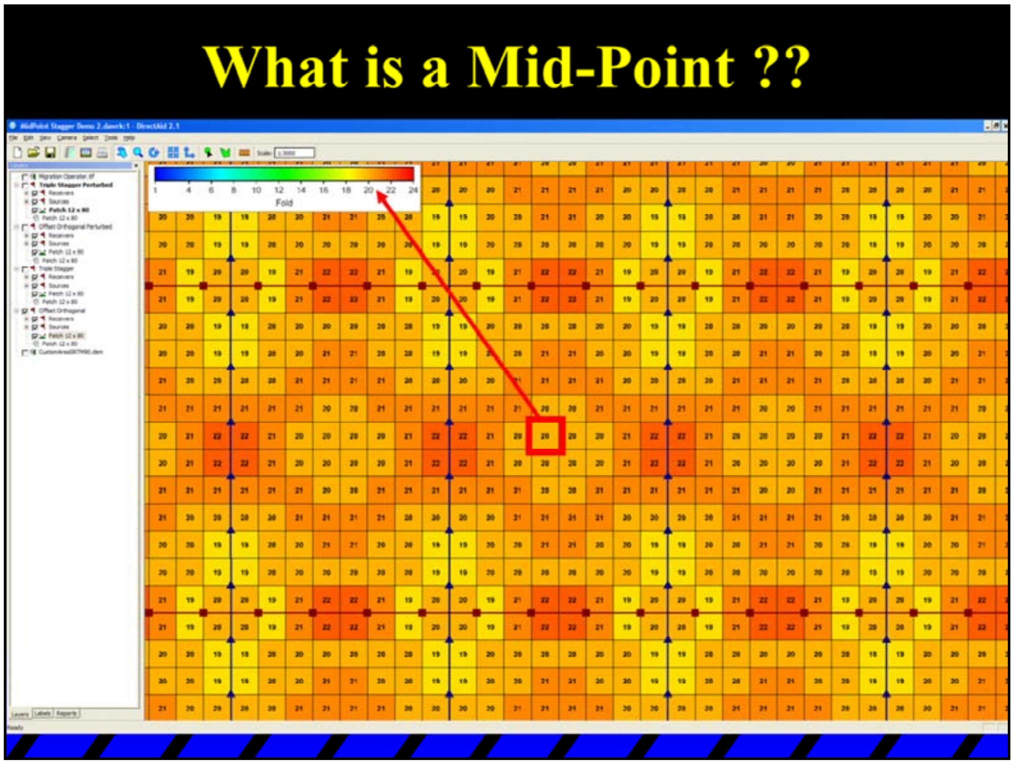

Mustagh Resources Ltd.
We have worked extensively throughout onshore Canadian basins.
We design and implement 100 - 200 programs each year.
We visit about 20 seismic crews per year.
10


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
11

- more than 40 3-D designs in Colombia

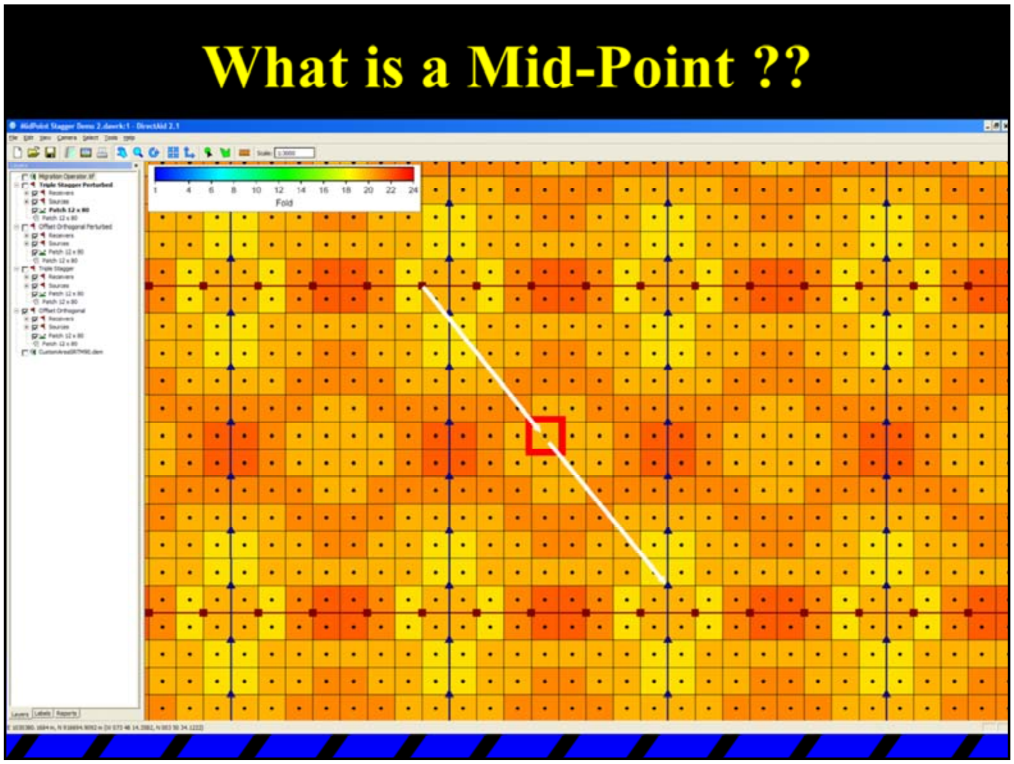


Let’s start with a simple review of what we mean by a Mid-Point.



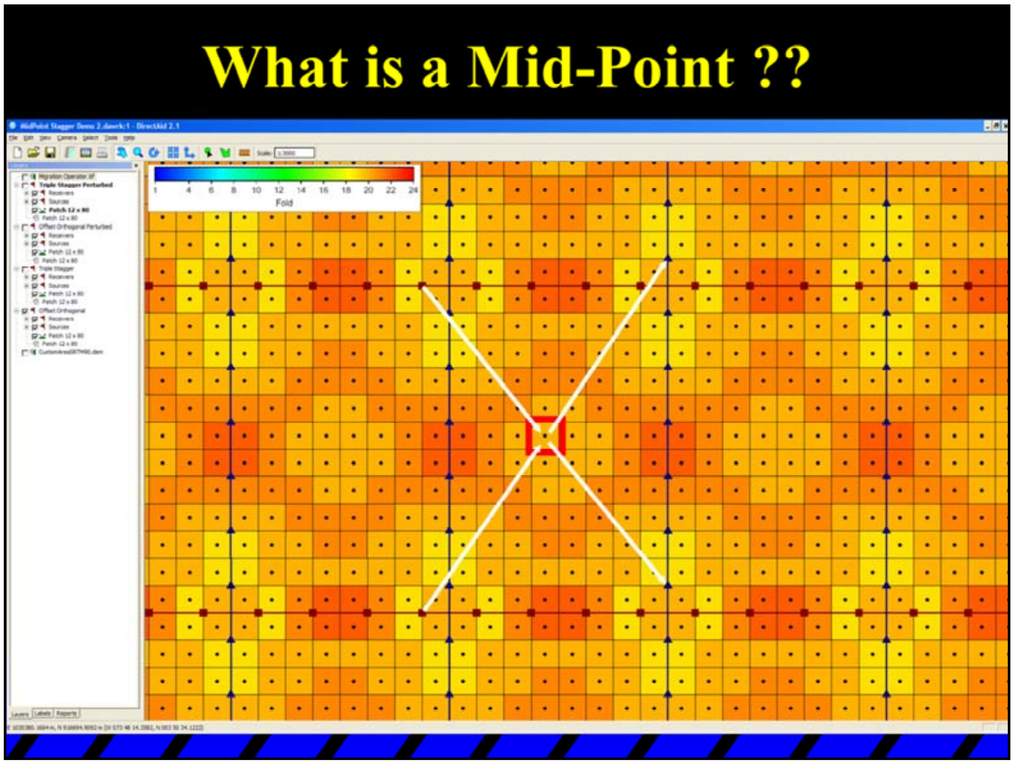
The fold plot indicates that the bin highlighted in the red box is 20 fold.

This means that there are 20 source-receiver pairs whose mid-points fall within this bin.

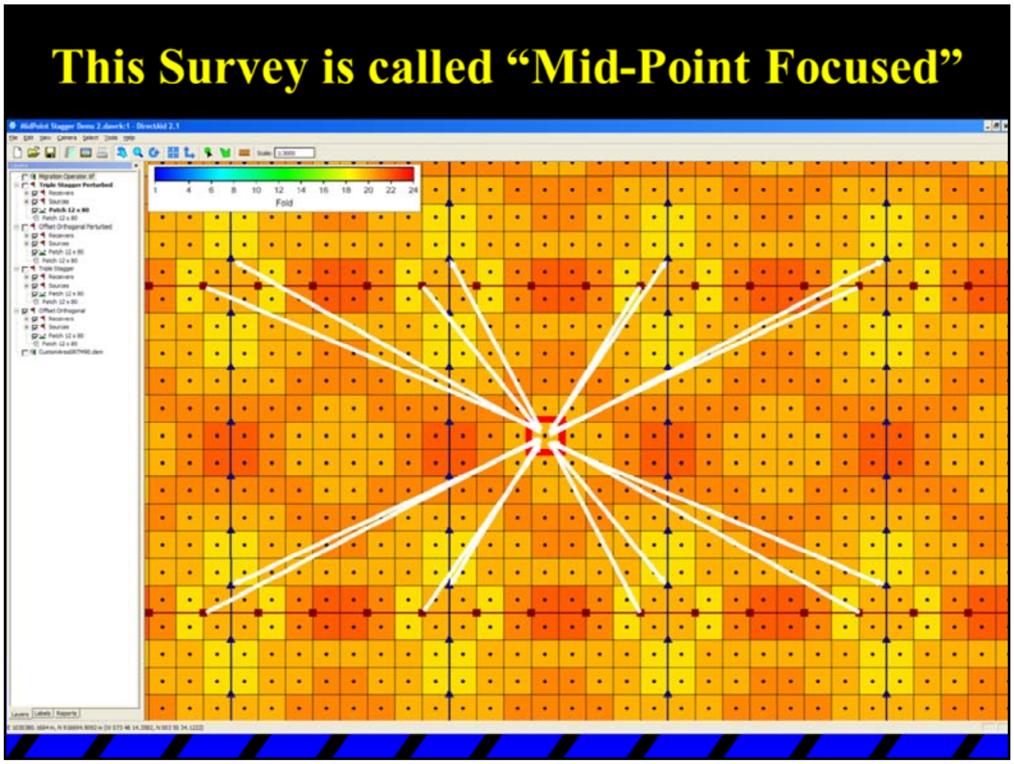


The white arrows show the down-going and up-going waves leaving one source and arriving at one receiver.

The geometric mid-point of this source receiver pair falls at the center of the high-lighted bin. The Mid-Point is an index for this trace whose coordinates are the geometric average of the source and receiver surface coordinates.

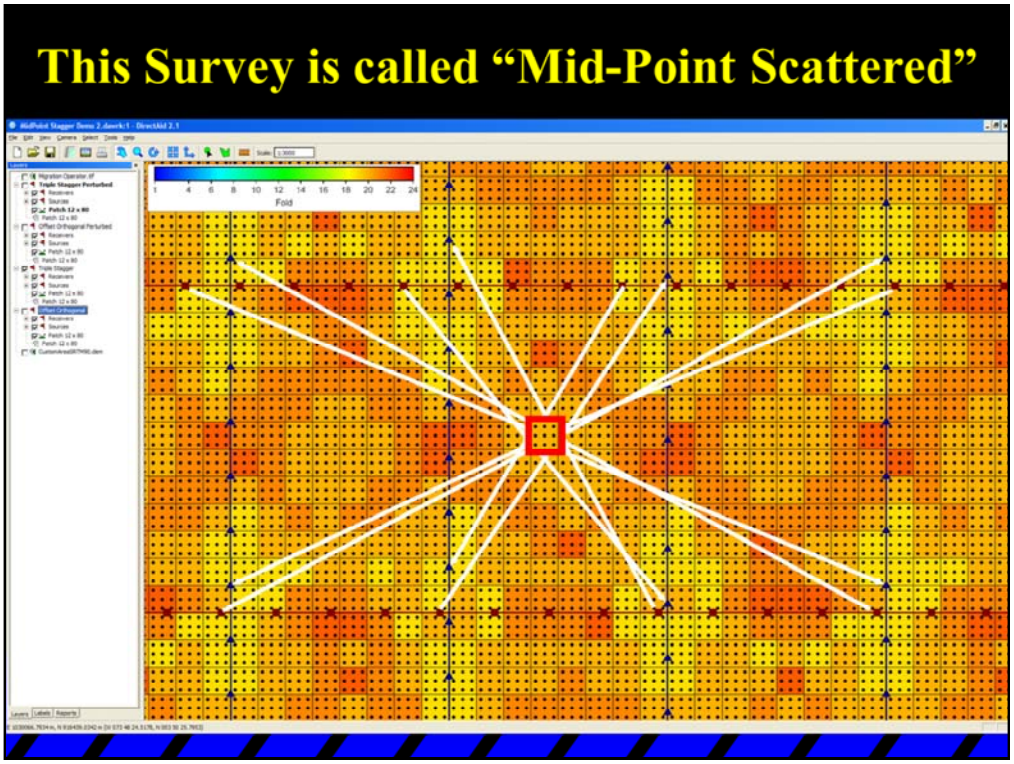


Now there are two sets of arrows showing two source-receiver pairs whose mid-points are coincident at the center of the high-lighted bin.



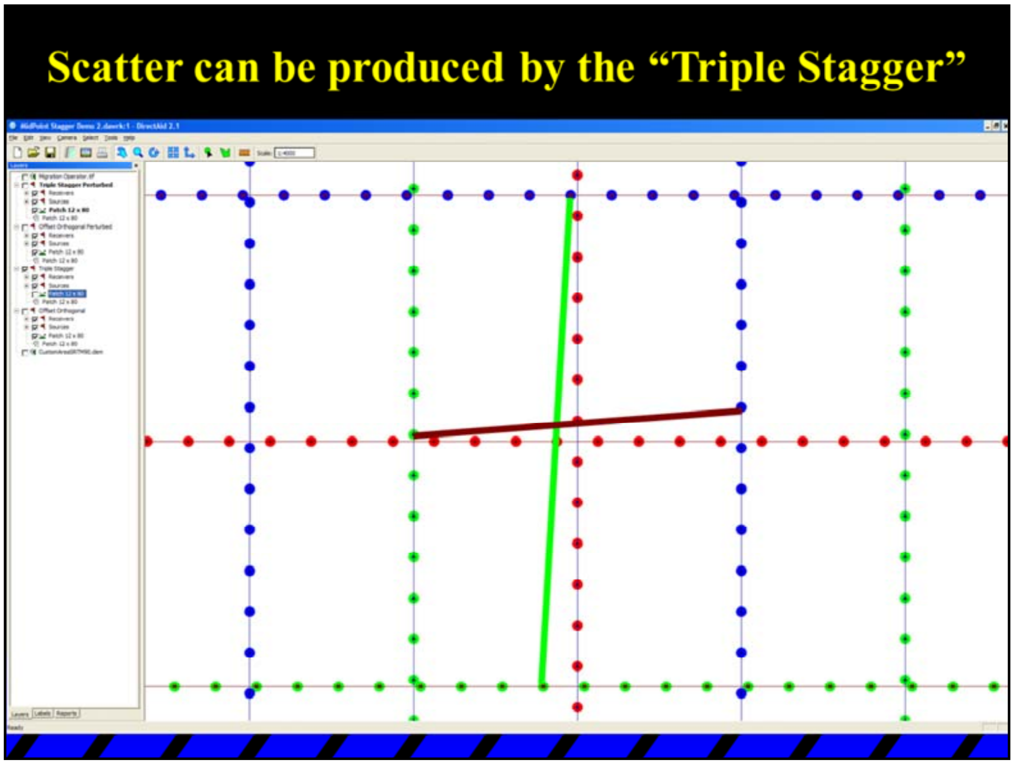
Here are eight of the 20 source-receiver pairs whose mid-points fall within the high-lighted bin.

Note that all eight midpoints fall exactly at the same location within the center of the bin. This type of survey is called "Mid-Point Focused"

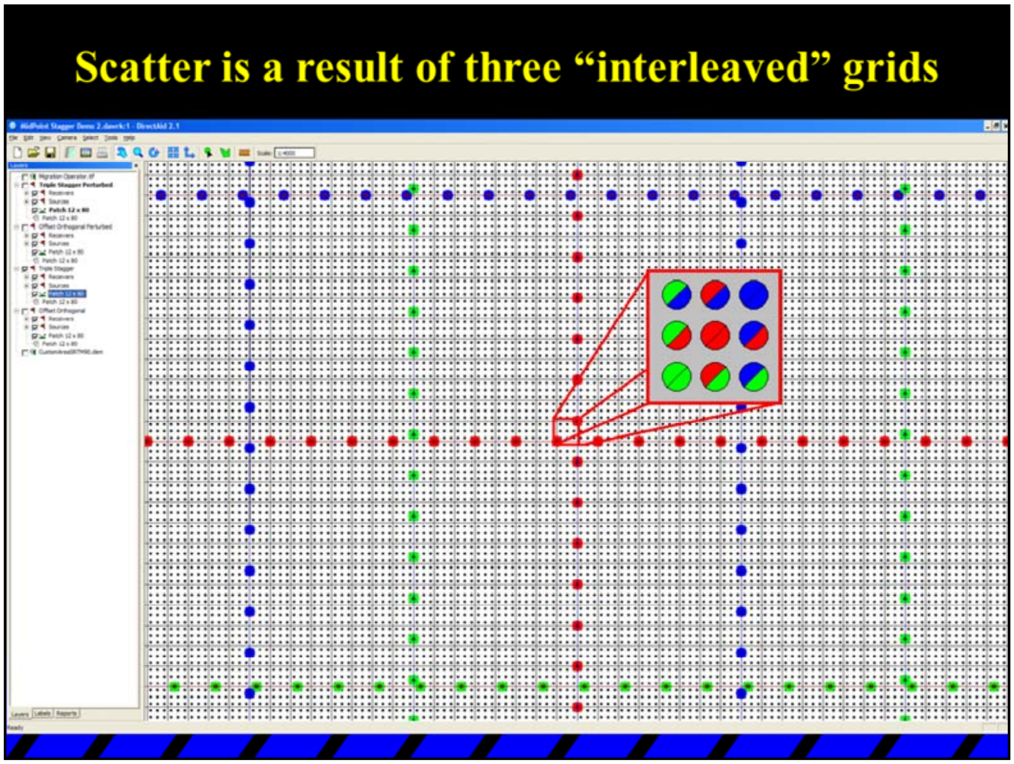


Here are eight of the 20 source-receiver pairs whose mid-points fall within the high-lighted bin using a "Triple Stagger" design.

Note that all mid-points fall in different locations within the bin and that offsets and azimuths are a bit more diverse.



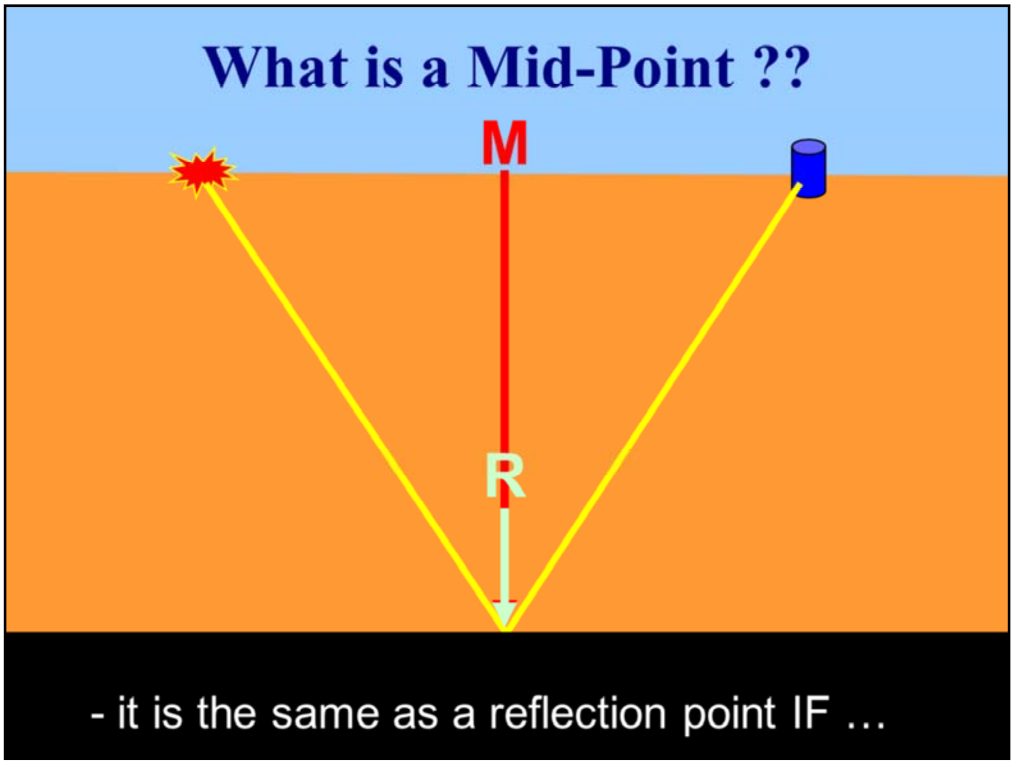
Forced midpoint scatter can be easily produced by relative shifts of point positions along adjacent lines of sources or receivers.
For a triple stagger that produces 9 midpoint centers per bin (3 x 3), the relative shift from line to line should be 1/3 of an interval.
We usually ensure that no intersections produce coincident sources and receivers by using relative point shifts of 1/6, 3/6 and 5/6 of a source or receiver interval.



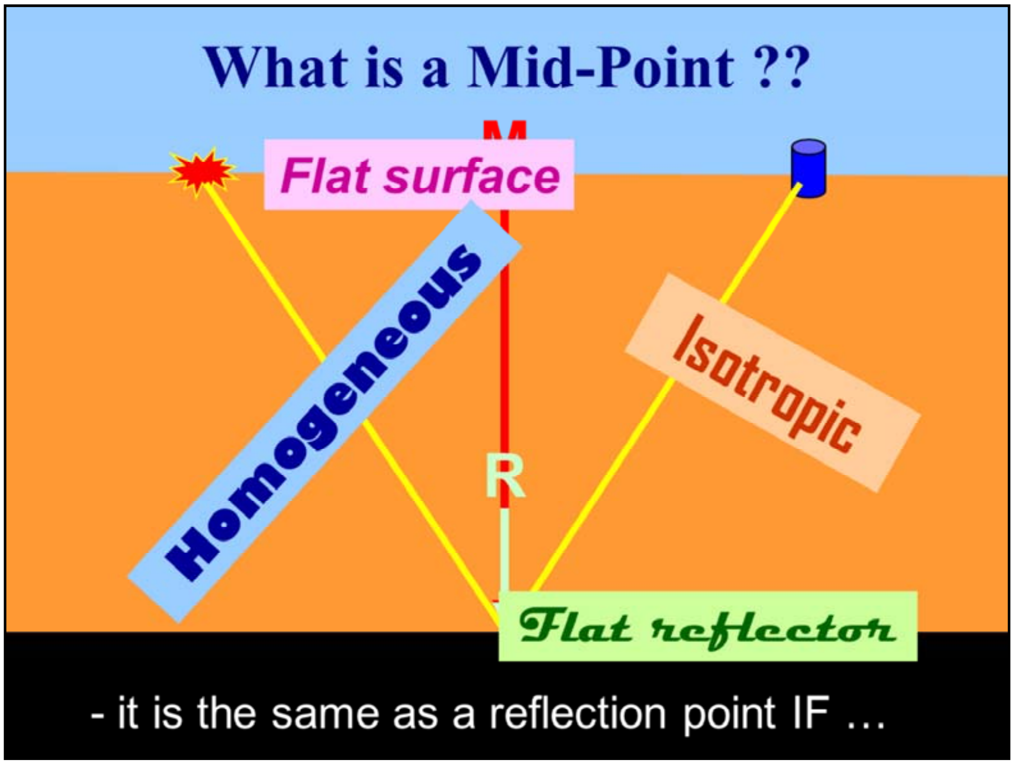
This, in effect, produces three interleaved grids that together produce the desired midpoint scatter.

We have observed many advantages to midpoint scatter. The greatest advantage that will be described in terms of improved spatial sampling of pre-stack migration operators.

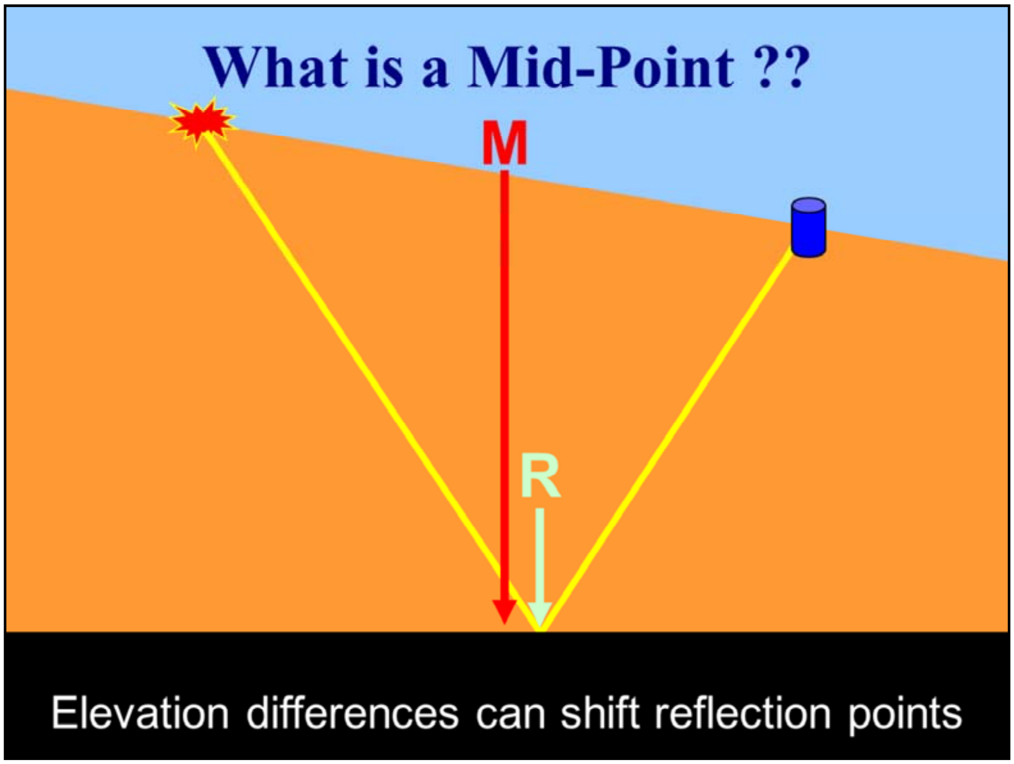
Some people have stated that mid-point scatter is bad for data because it causes "smearing" of reflection points within a CDP gather. It is important NOT to confuse geometric mid-points with theoretical reflection points.



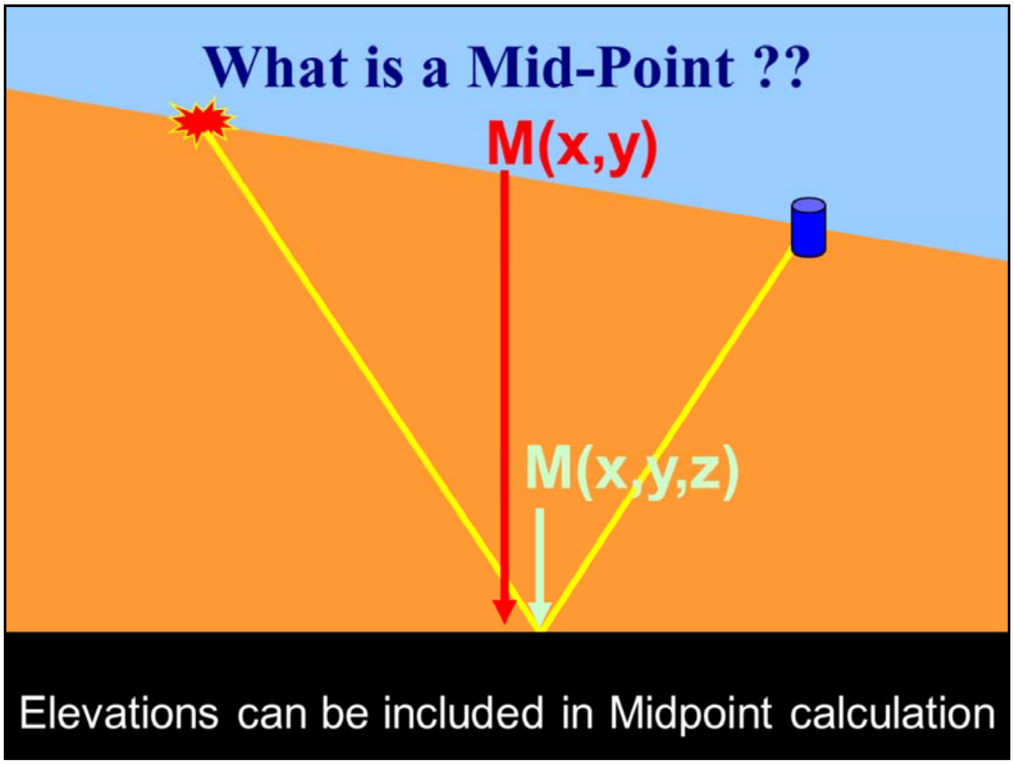
Many people confuse the geometric MID-POINT with the physical REFLECTION POINT



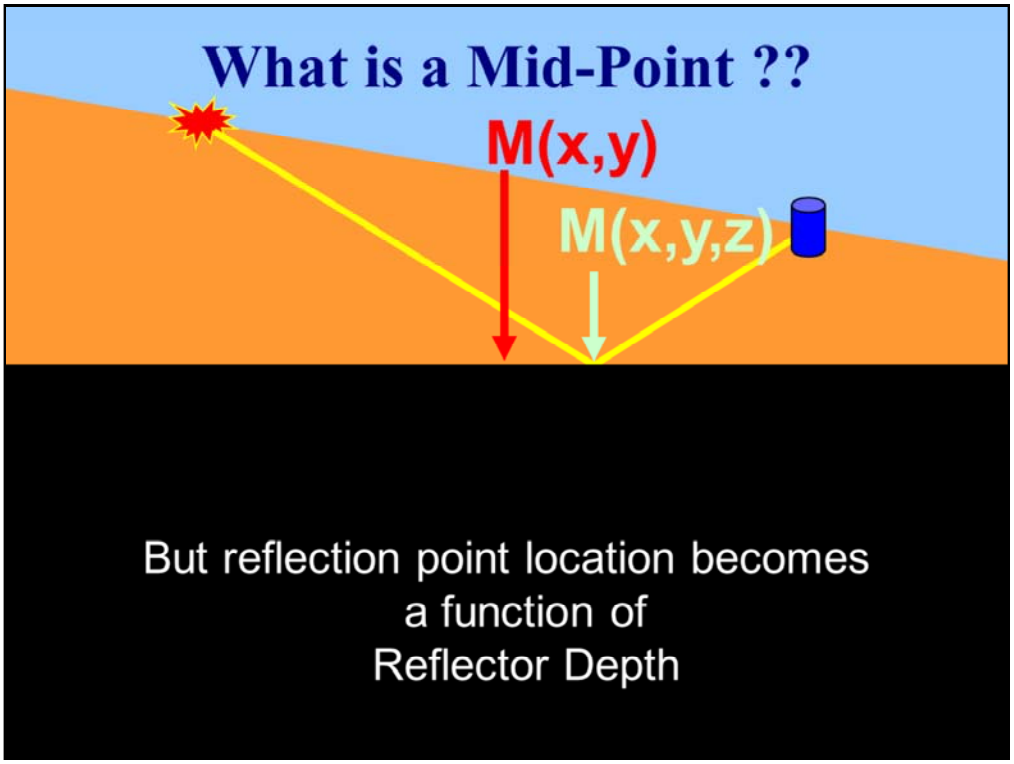
But Mid-Points are only coincident with Reflection Points if the source and receiver are at the same elevation,
AND the reflector is flat, AND the intervening material is homogeneous in all acoustic properties,
AND, the material is isotropic, AND ????



When the source and receiver are not at the same elevation, the reflection point is NOT vertically below the surface midpoint.

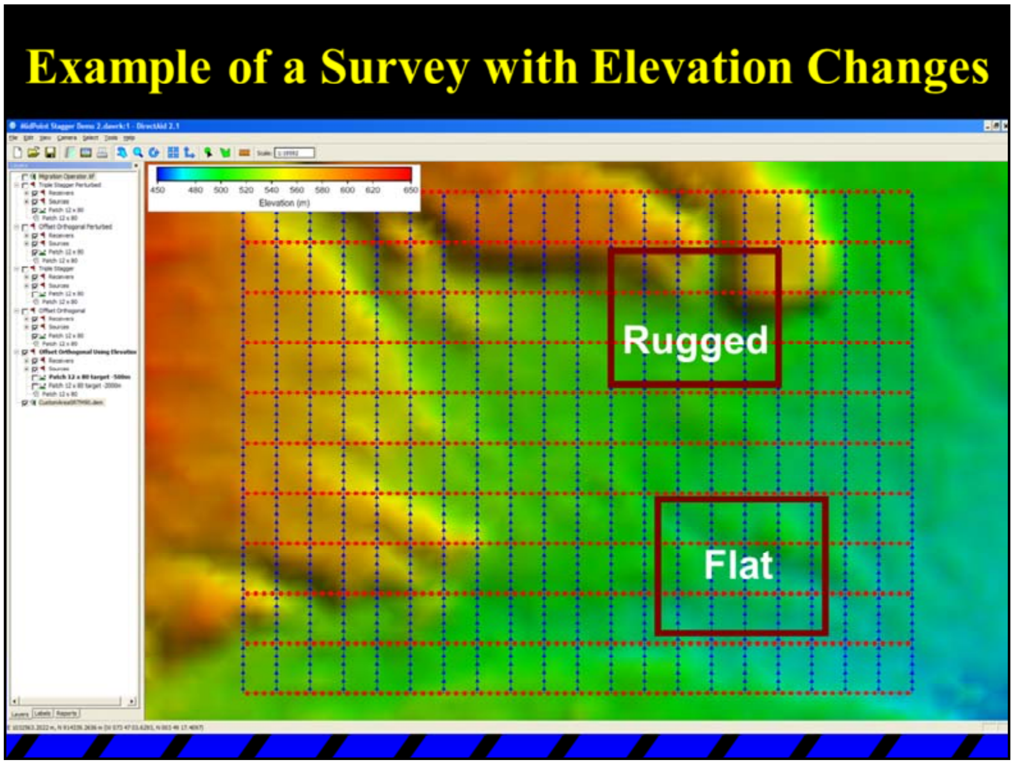


Midpoint calculations can include elevations. However, the midpoint coordinate then becomes a function of reflector depth.

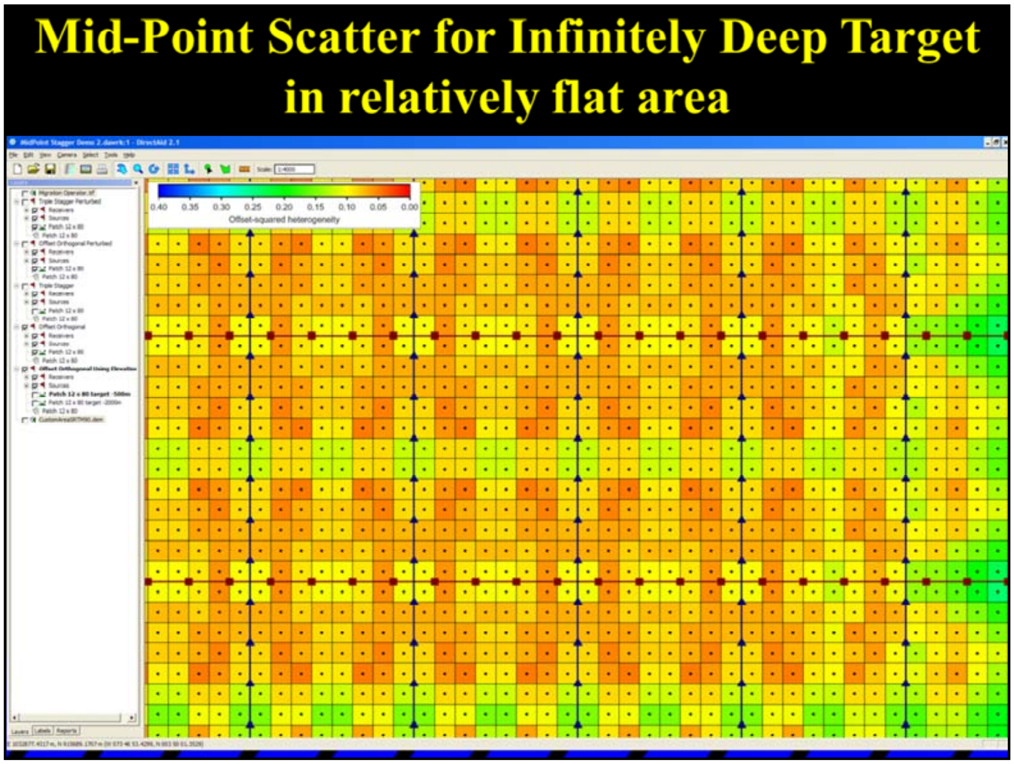


Midpoint calculations can include elevations. However, the midpoint coordinate then becomes a function of reflector depth.

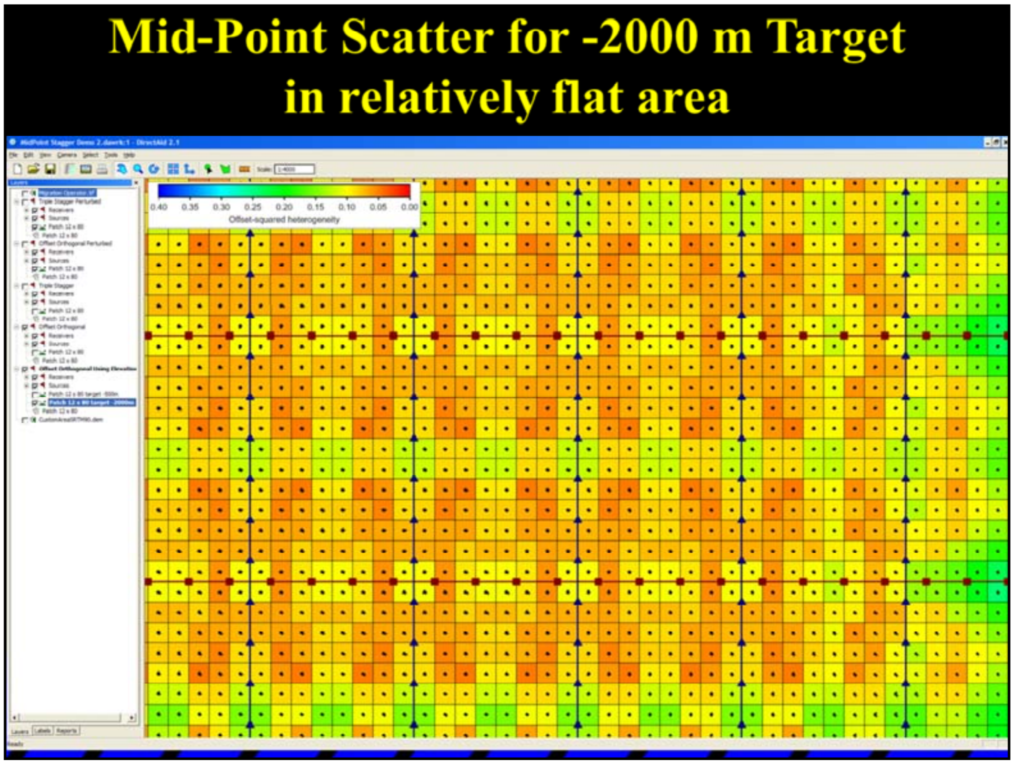
For shallow reflections, the reflection point moves closer to the lower element.



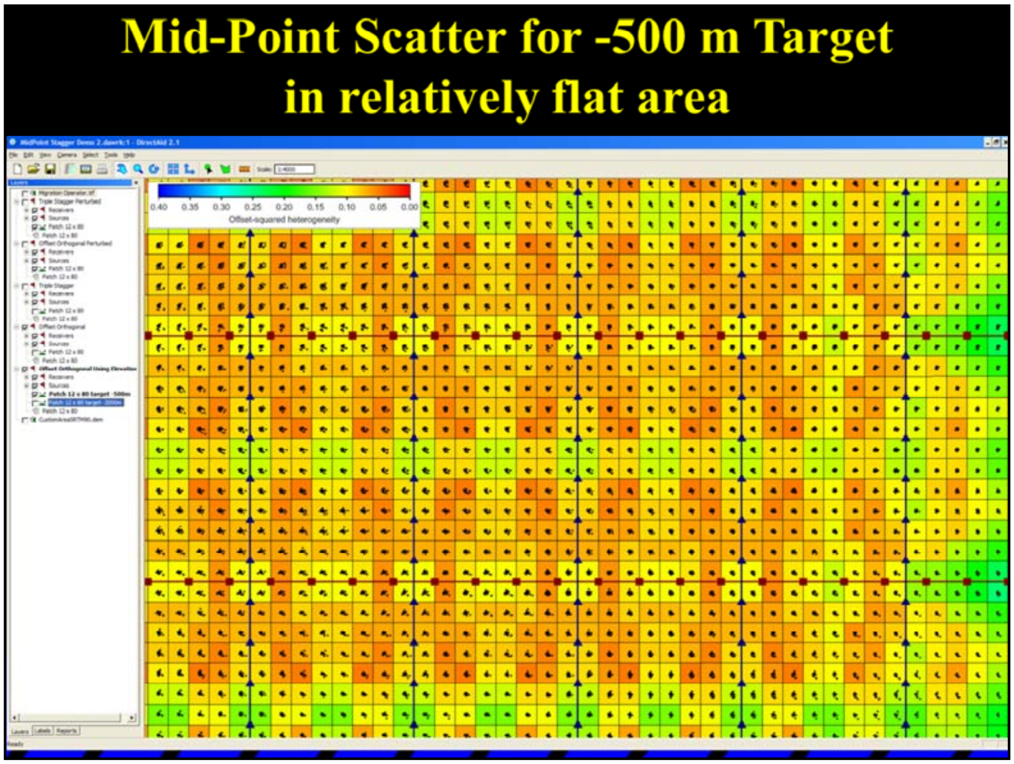
This survey has some elevation changes across its area. The south-east is relatively flat while the north-east is moderately rugged.



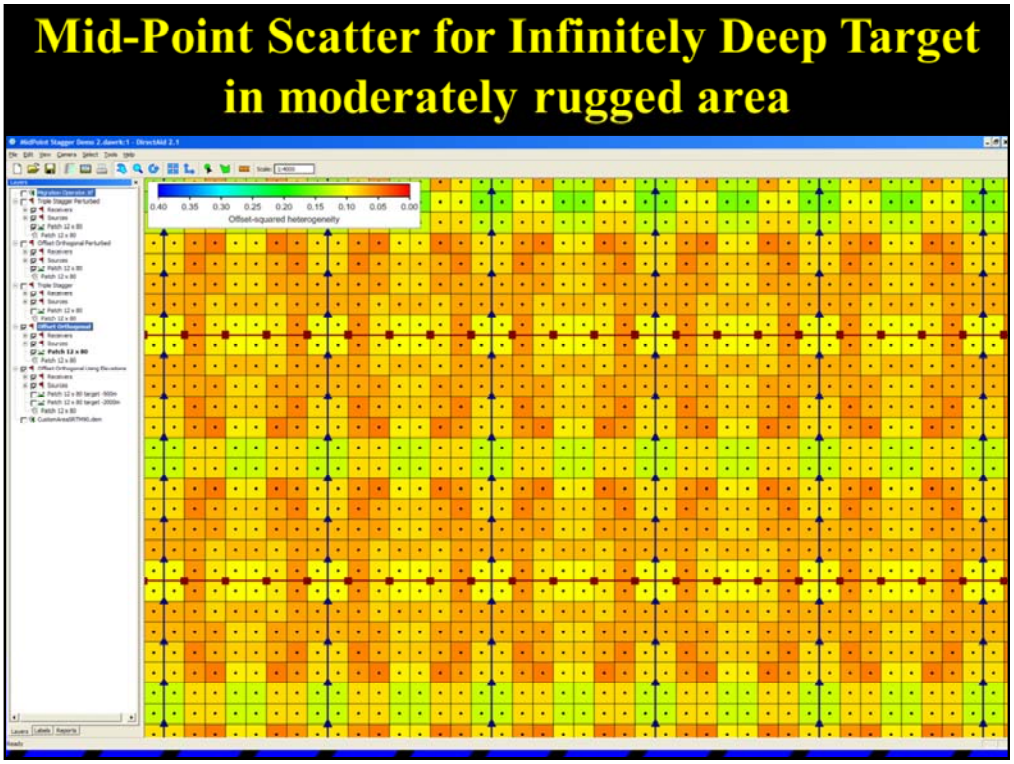
We normally calculate mid-point locations as simple averages of X and Y coordinates for the contributing source-receiver pair.
In areas of homogeneous and isotropic materials and flat reflectors, this coincides with the reflection point only for very deep reflection points.



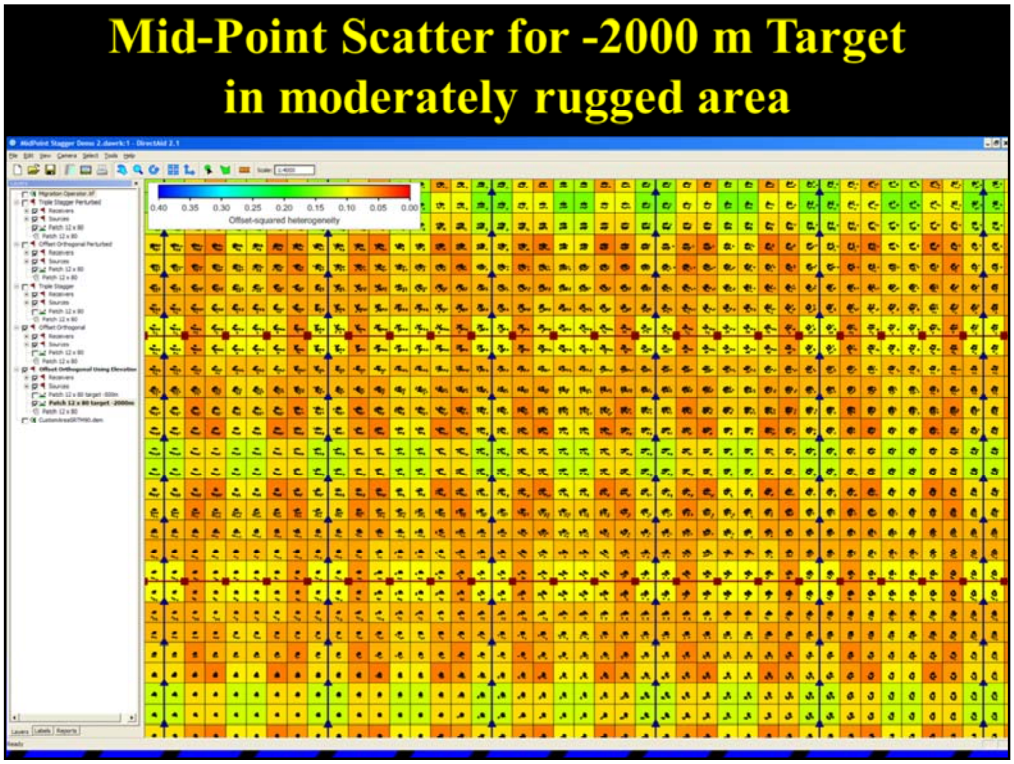
For medium-depth reflectors, we begin to see a scattering of reflection points due only to minor elevation changes between sources and receivers.



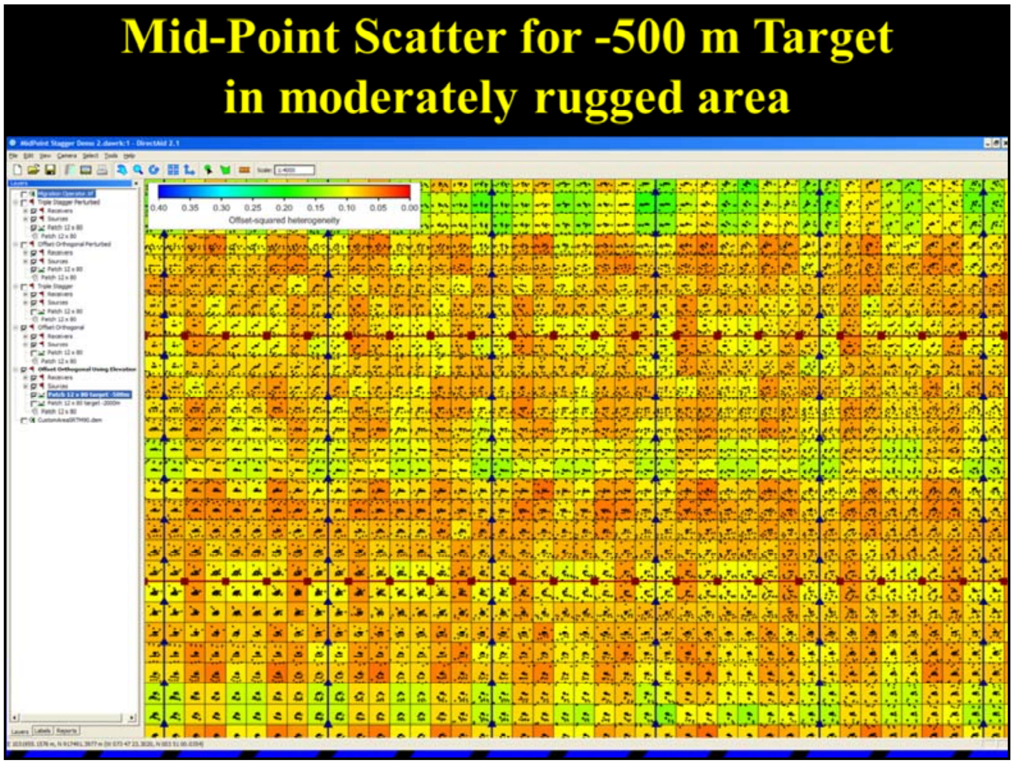
For shallow reflectors, we see more scattering of reflection points due only to minor elevation changes between sources and receivers.



Even where there are more substantial elevation changes, the theoretical mid-point or very deep reflections are focused.



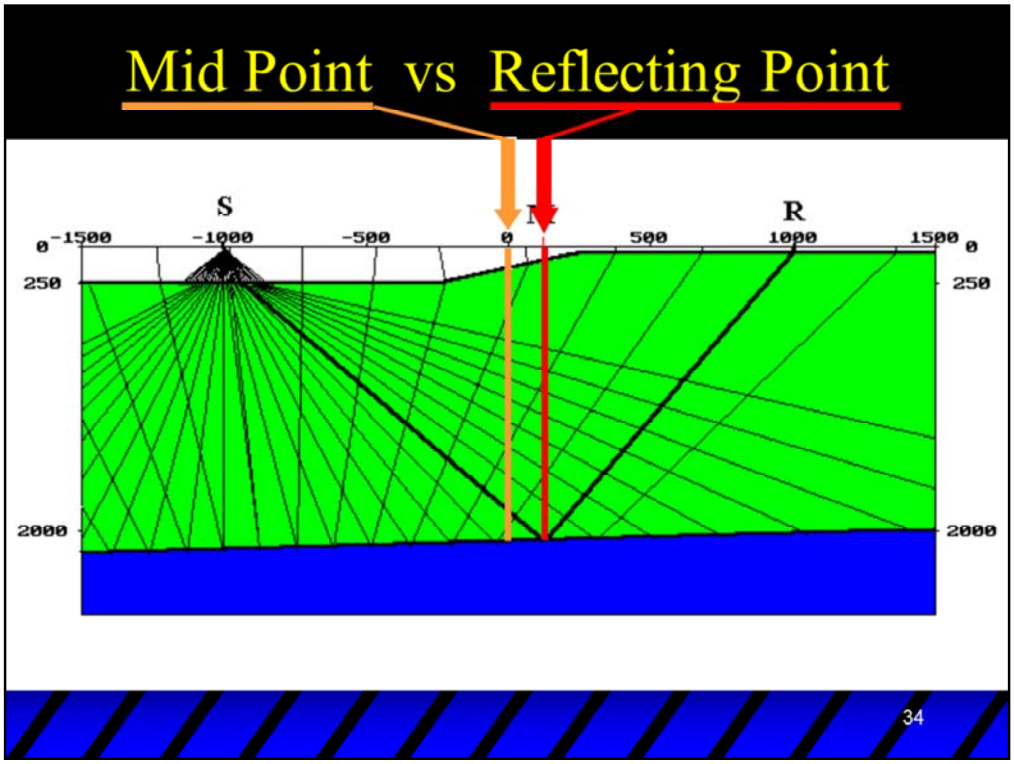
For medium-depth reflectors, we see noticeably more scattering of reflection points due only to more significant elevation changes between sources and receivers within our active patch dimension.



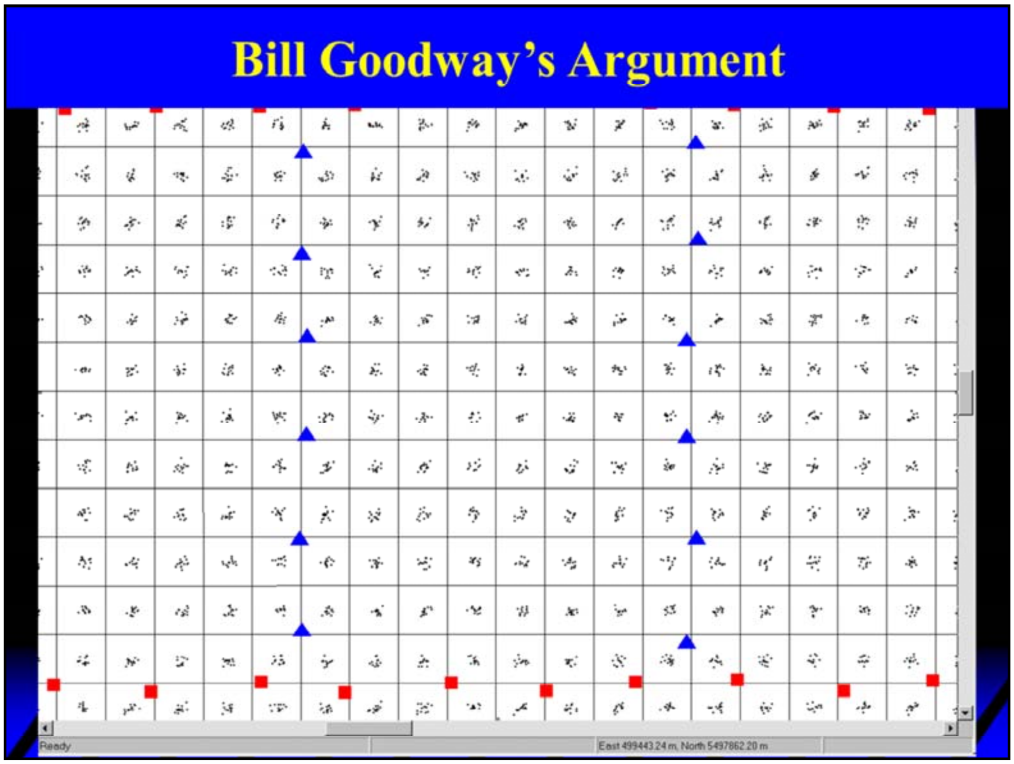
For shallow reflectors in rugged areas, we see considerable scattering of reflection points.

The scattering is severe enough to send some reflection points into adjacent bins and the apparent statistics of the survey have changed.

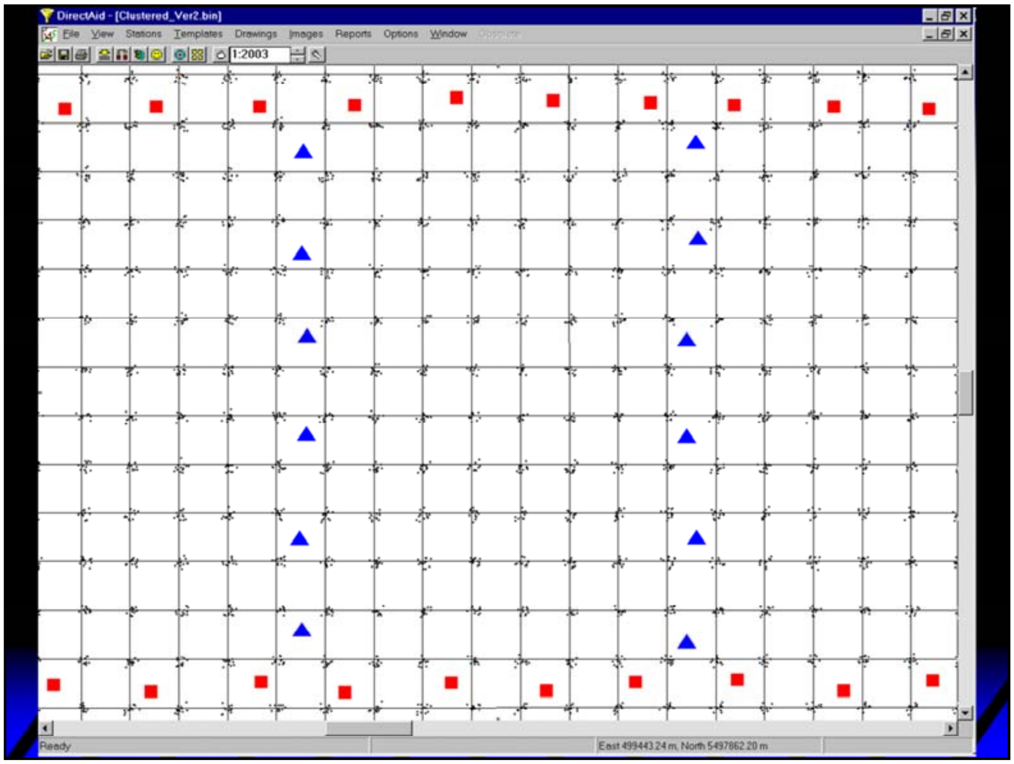
Note that the statistical distribution is more diverse now.



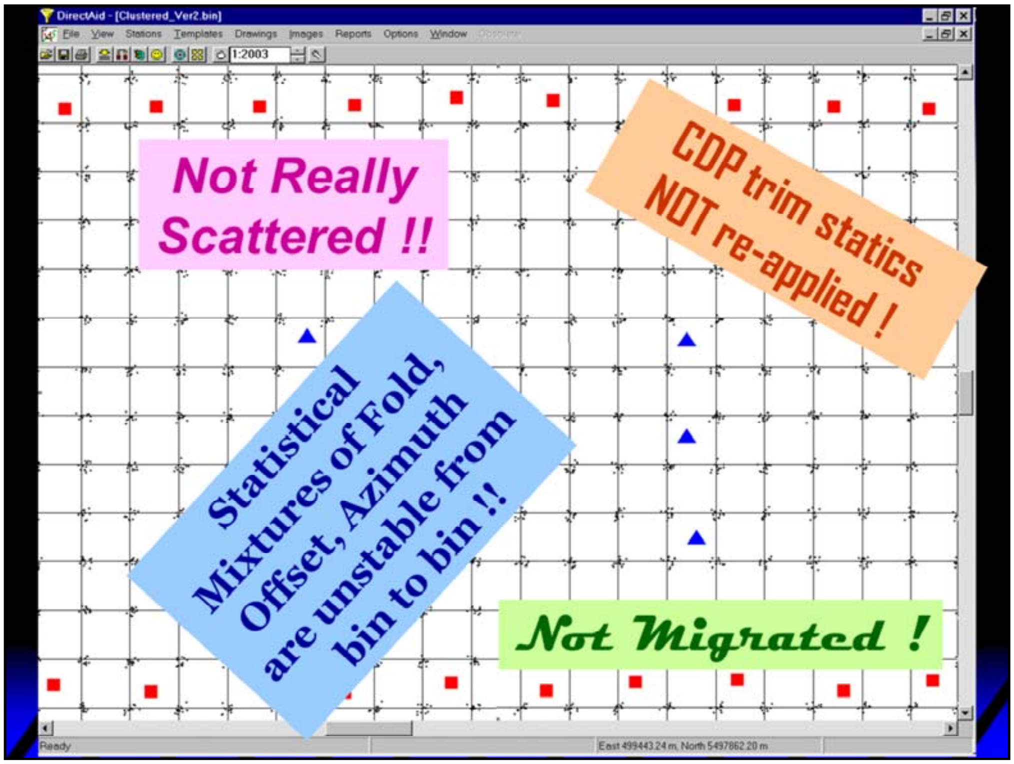
Simple Ray-Trace models of very simple geologic situations demonstrate that geometric midpoints and theoretical reflection points can easily be separated by 80 meters or more (several bins of a normal 3-D program).



Bill Goodway once experimented with a survey that had minor mid-point scatter such as the example above.



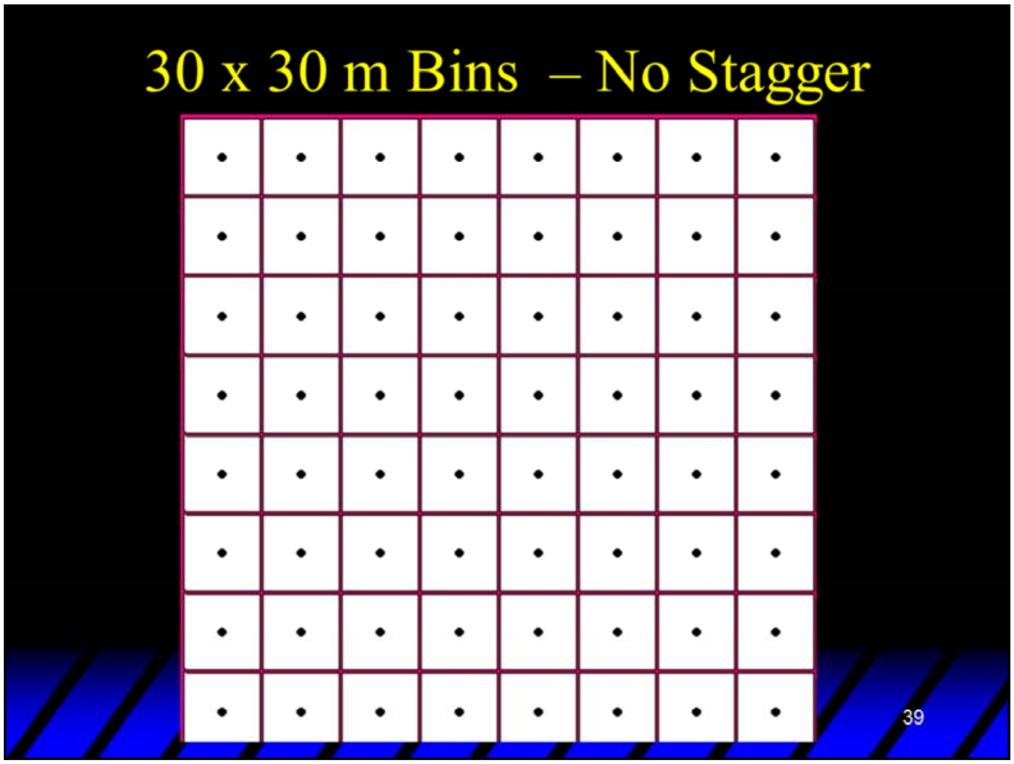
Bill then re-binned the same data and compared the stack of this bin grid to the stack of the previous bin grid. He claimed that this binning simulated Maximum Mid-Point Scatter. He observed that the stack quality of this configuration was not as good as the more "focused" configuration in the previous slide. Bill never presented this study in public for peer review.



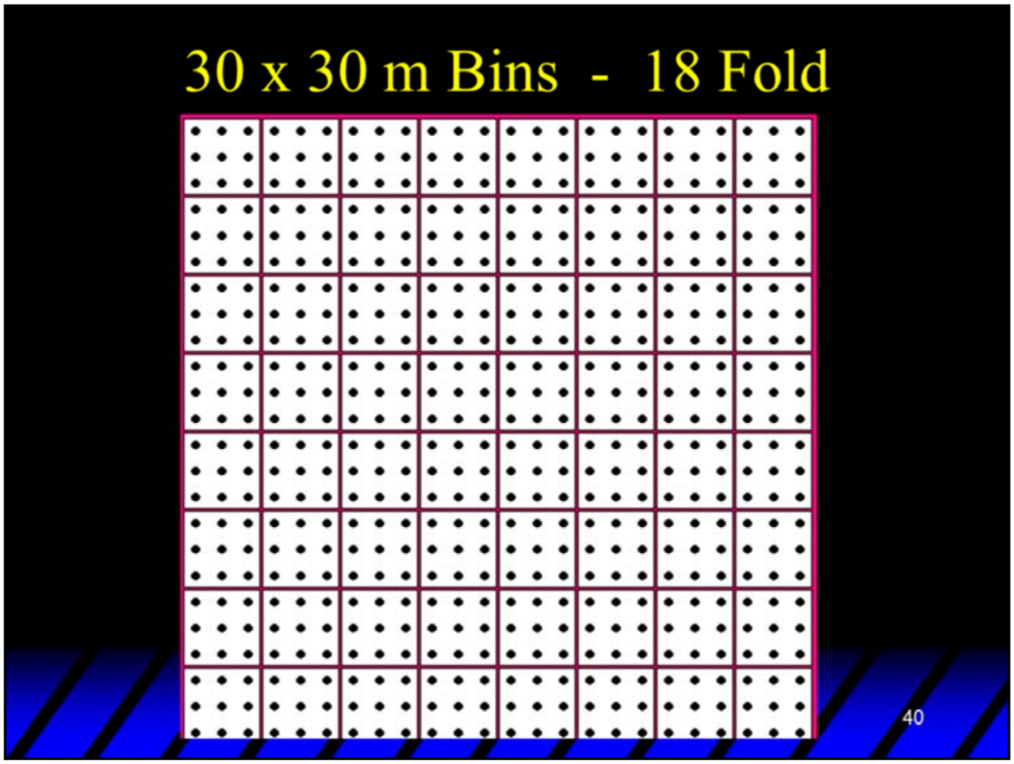
We feel this is a poor experiment. First, this configuration is NOT well scattered as the spatial sampling of the clusters of midpoints is still sparse. Second, the statistical mixtures of fold, offsets and azimuths are unstable from bin to bin. Third, we do not believe that the CDP gathers had correlation TRIM statics re-applied in the re-gathered data set. Fourth, neither data set was ever migrated, and at this time Pre-Stack migration was not an option.

Scattering of mid-points is NOT necessarily equivalent to scattering of reflection points !!

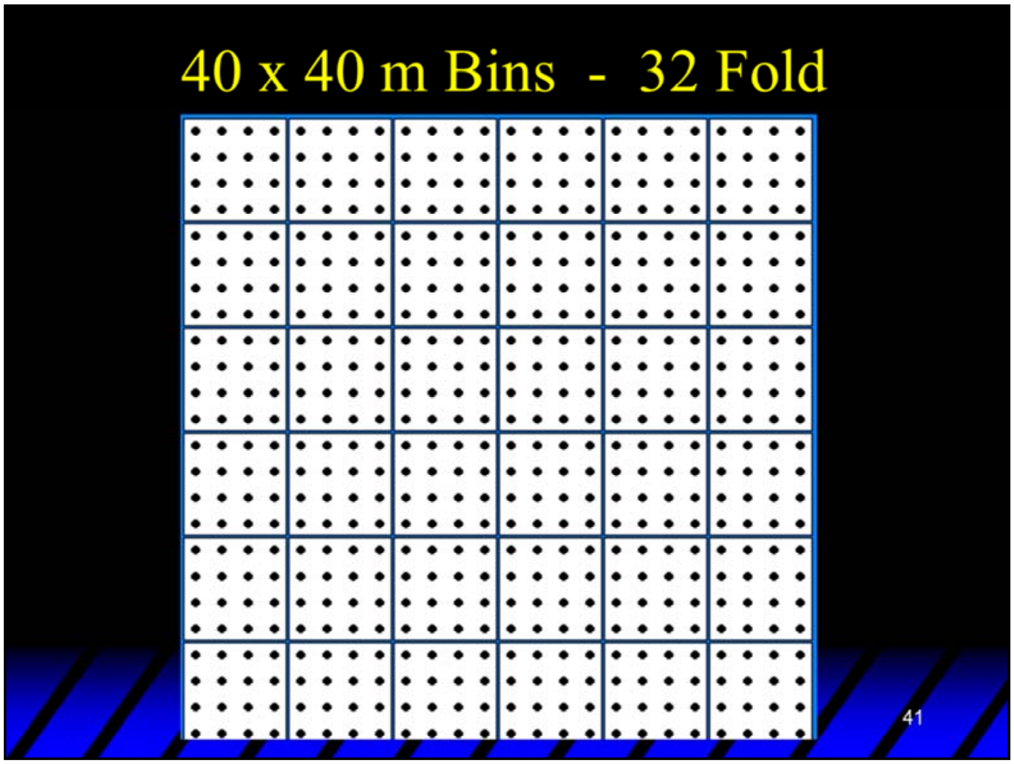
Andreas Cordsen and others (including Mustagh in years long past) have promoted the idea of re-binning data in non-natural bins. A Natural Subsurface Bin is one half a surface receiver interval by one half a surface source interval. It is used by most processors when gathering CDP gathers for stacking and post-stack migration. With Mid-Point scatter, other options are available.



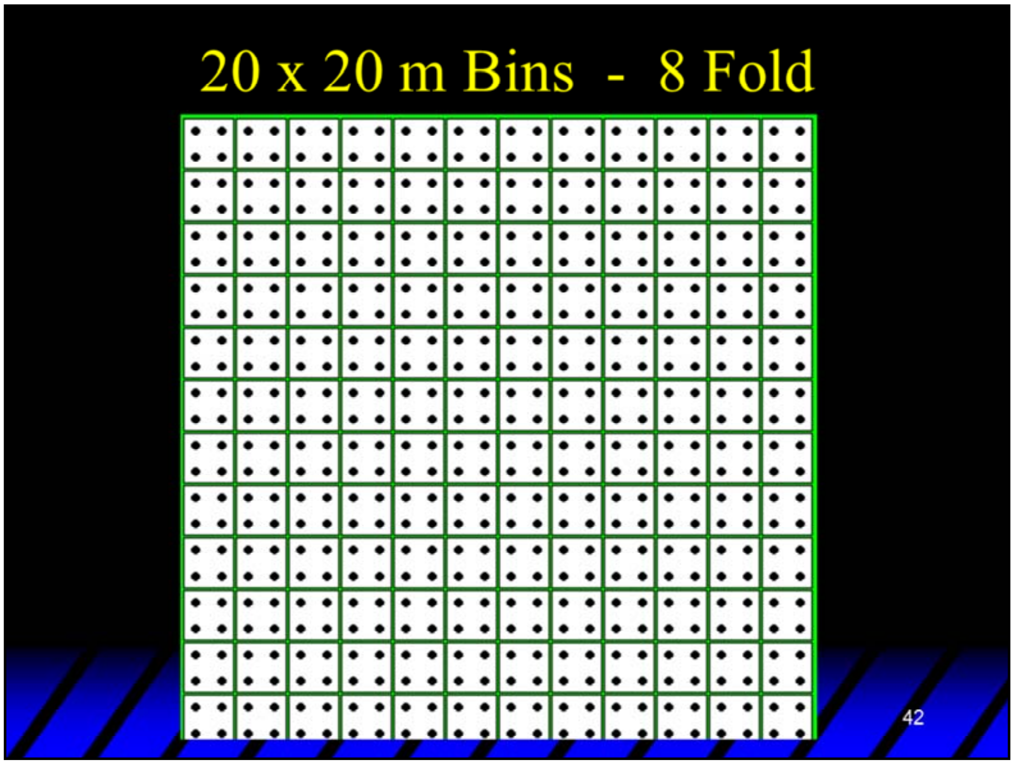
Let's use a simple model with Natural bins of 30 m x 30 m. In a Mid-Point Focused design we have collections of traces sampled every 30 m x 30 m.



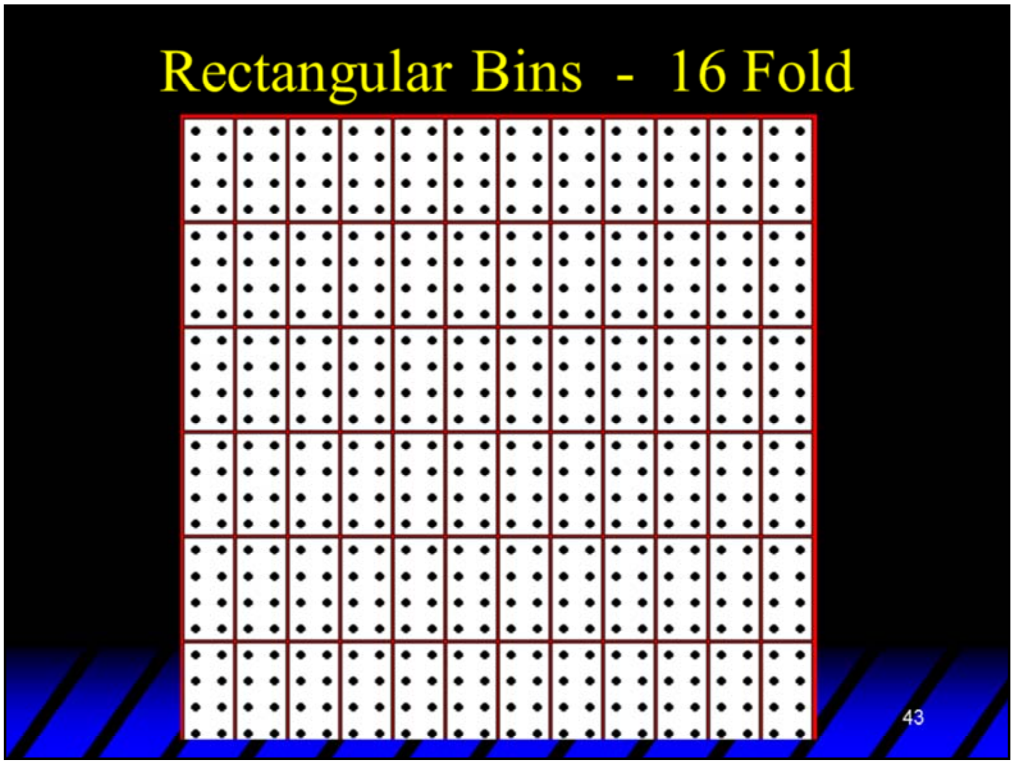
In a Mid-Point Scattered design we have collections of traces sampled every 10 m x 10 m (in this case, 2 traces per mid-point, 18 fold per bin)



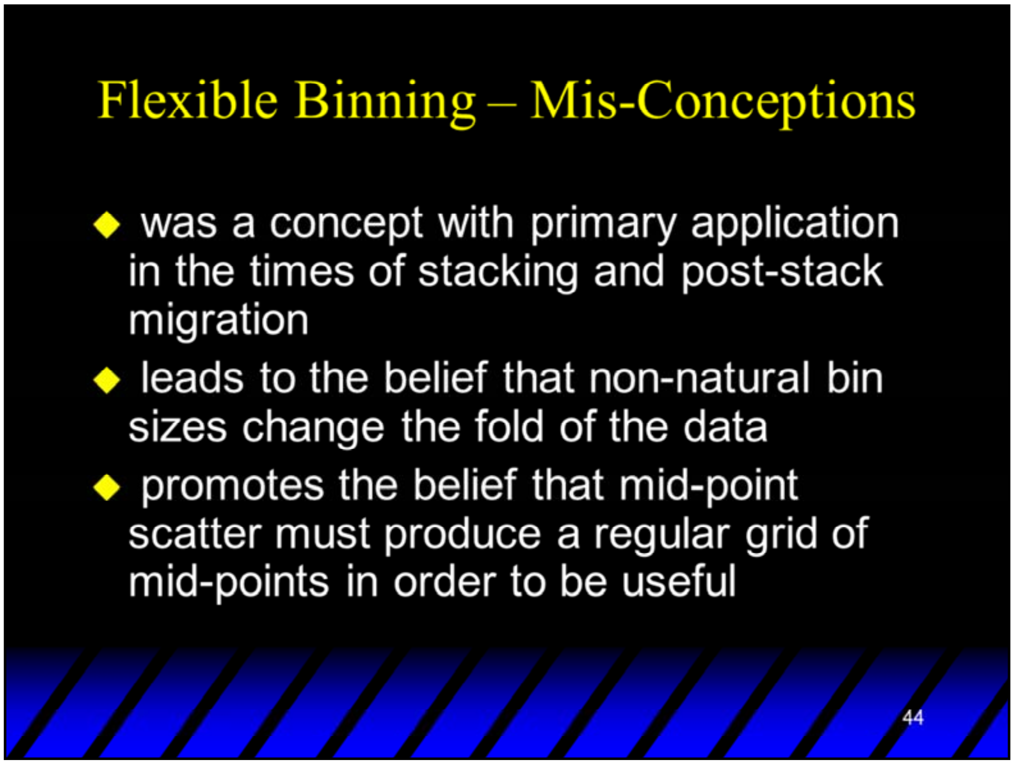
If our stacked data is poor and we wish to increase fold, we can easily collect the same data in non-natural bins of 40 m x 40 m and increase the stack fold from 18 to 32.



If the data is very good, and we desire improved post-stack spatial resolution, we can gather and stack the data in 20 m x 20 m bins, although the stack fold will drop to 8 traces per bin.

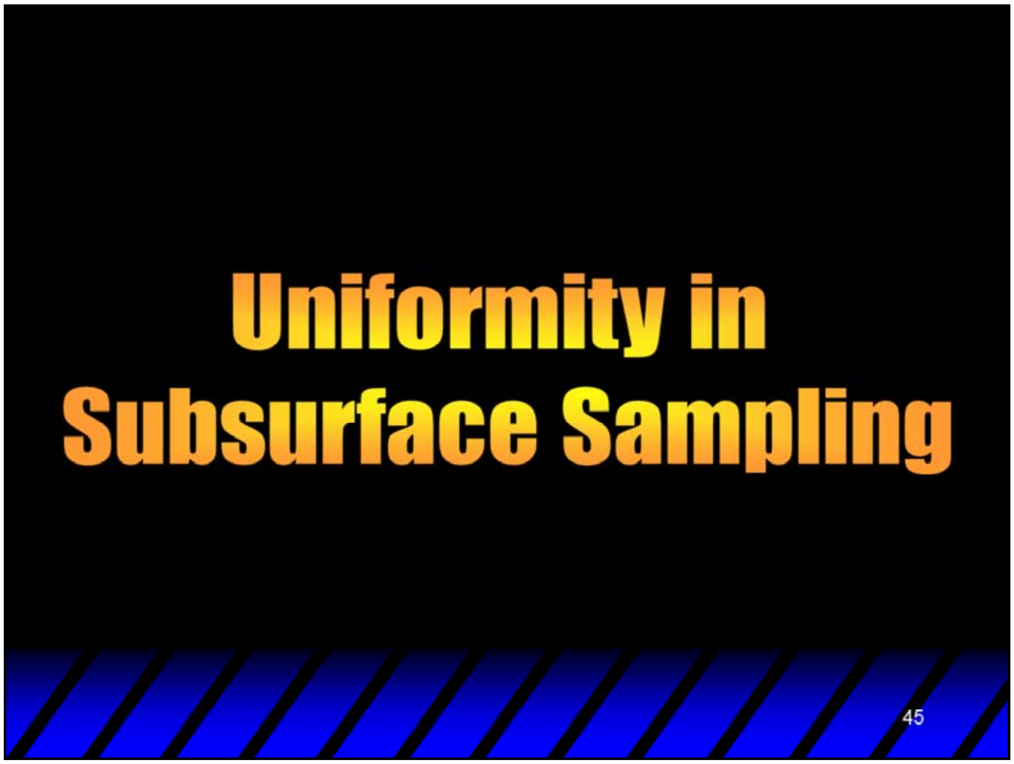


If our geology is dominantly 2-dimensional (roll-overs along thrust faults for example), then we can gather our data in asymmetric bins.

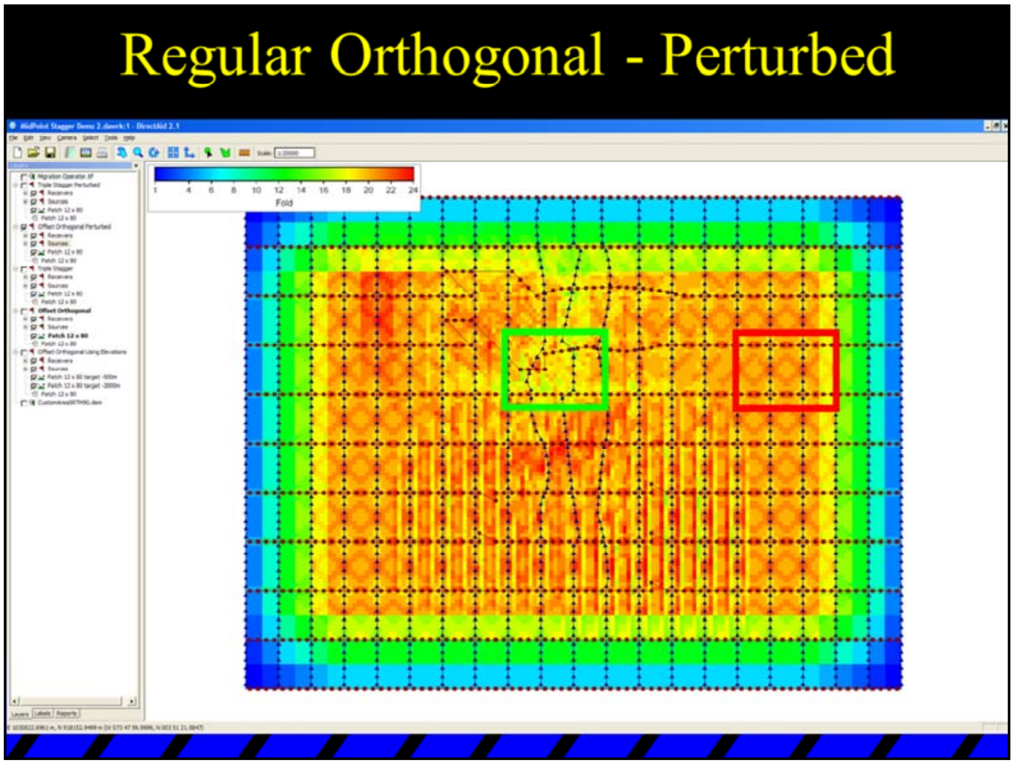


The wide-spread promotion of the concept of flexible binning during the 1990's led to many mis-understandings and mis-conceptions about the benefits of mid-point scatter.

Many of these mis-conceptions prevail today.

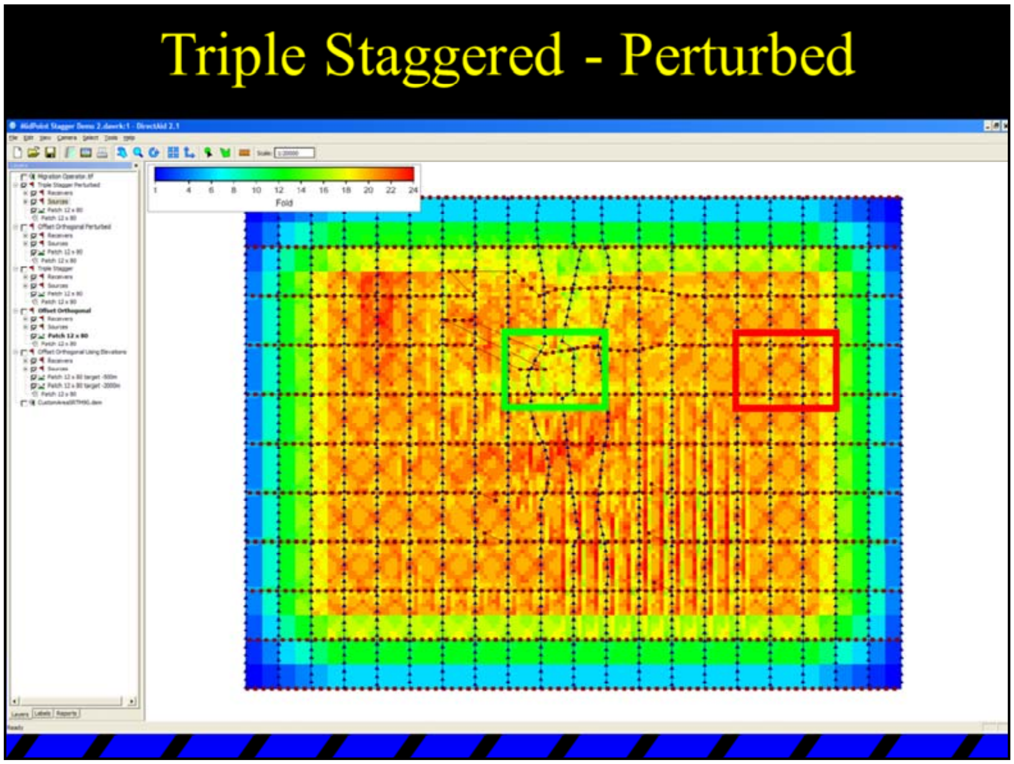


Do we ever have Mid-Point Focused surveys in reality? What happens when designs become perturbed during implementation?



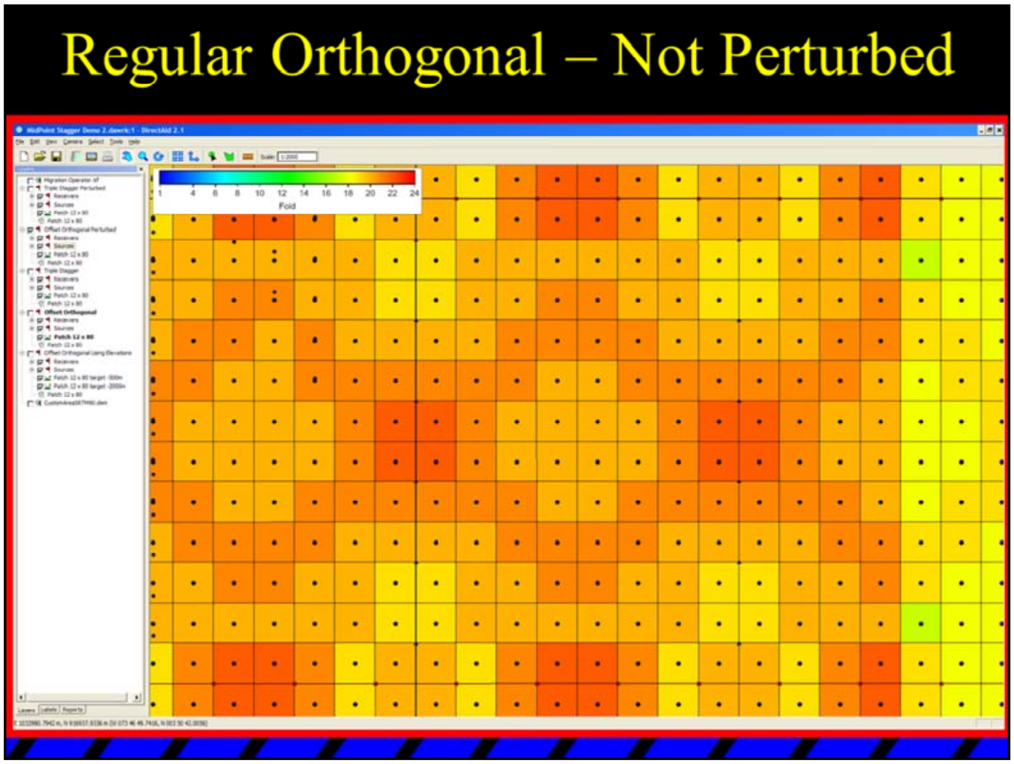
Here is a Regular Orthogonal design (mid-point focused) showing a fairly regular area (red square) and an area where sources and receivers have been moved (perturbed – green square).

Notice that regular fold patterns (and patterns of other more important statistics) are disrupted by perturbation.

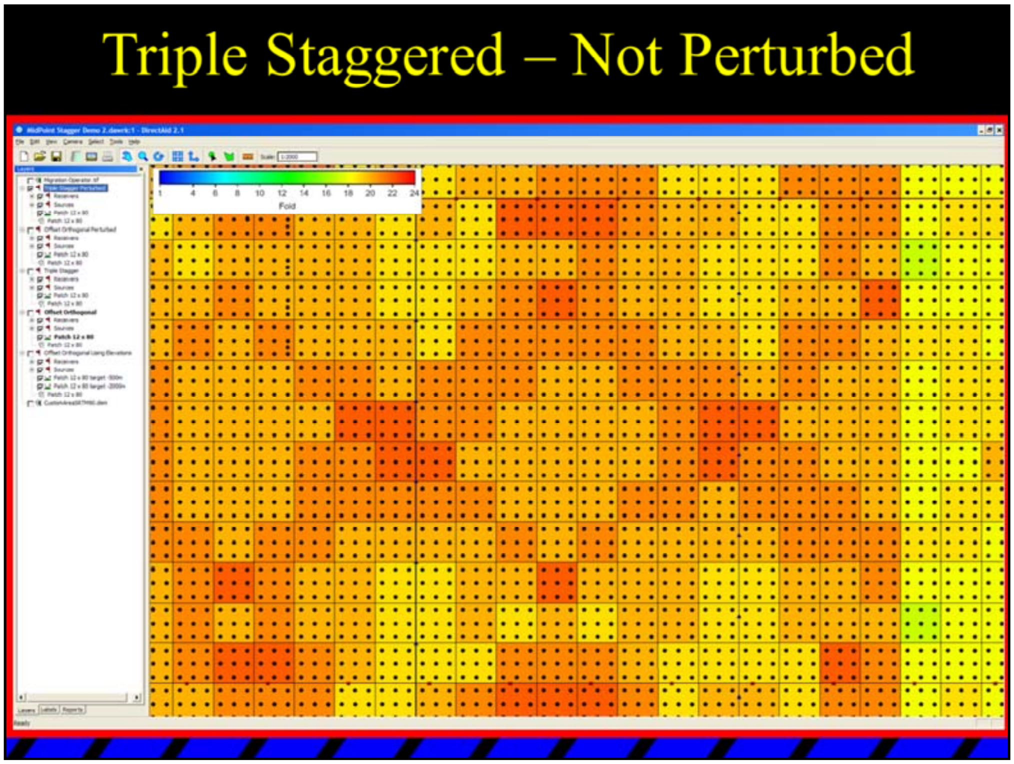


Here is a Triple Staggered design (mid-point scattered) showing a fairly regular area (red square) and an area where sources and receivers have been moved (perturbed – green square).

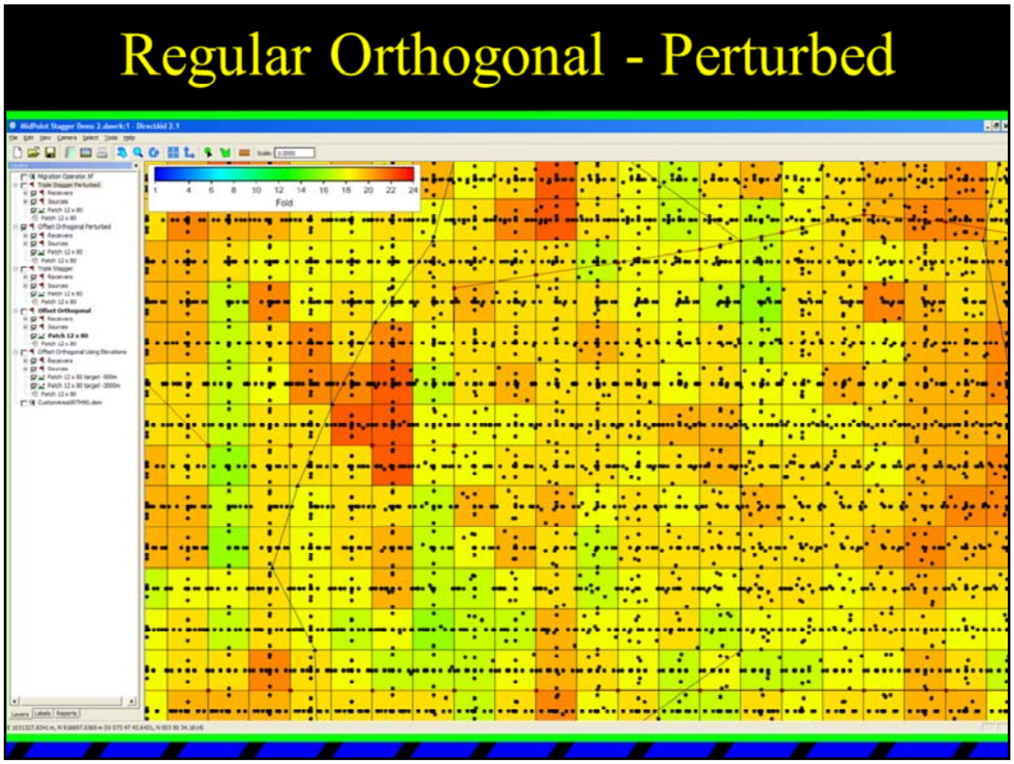
Notice that regular fold patterns (and patterns of other more important statistics) are disrupted by perturbation.



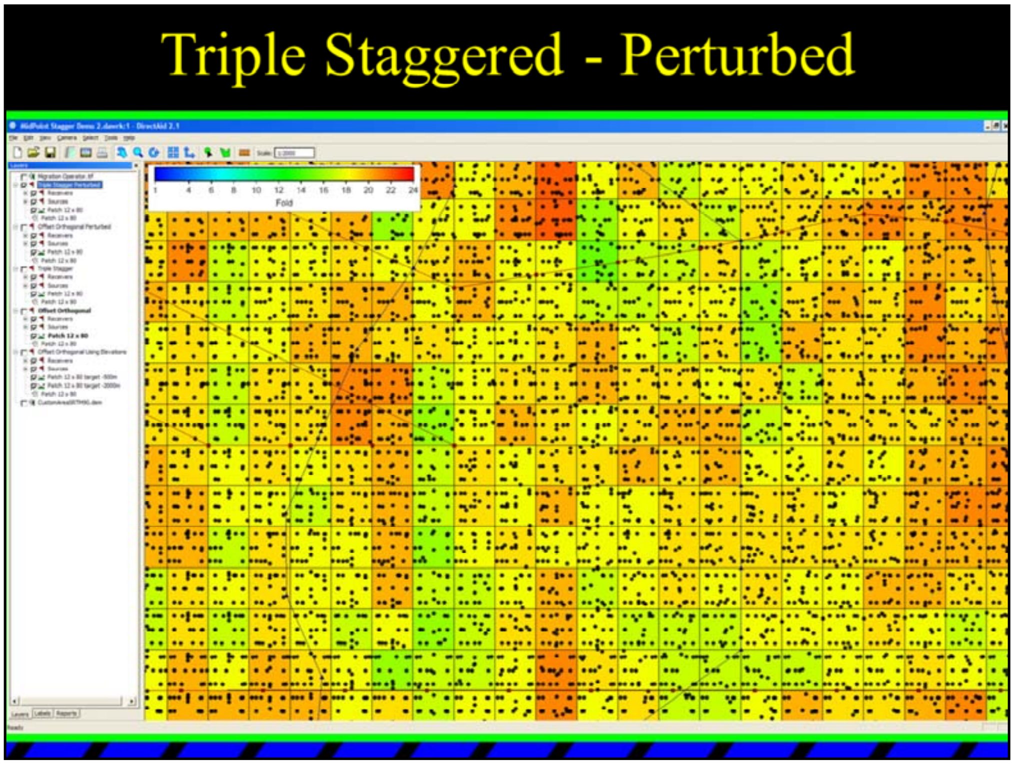
A detail of the un-perturbed area of the regular orthogonal 3D shows the mid-point focused nature of the design.



A detail of the un-perturbed area of the triple staggered 3D shows the mid-point scattering.

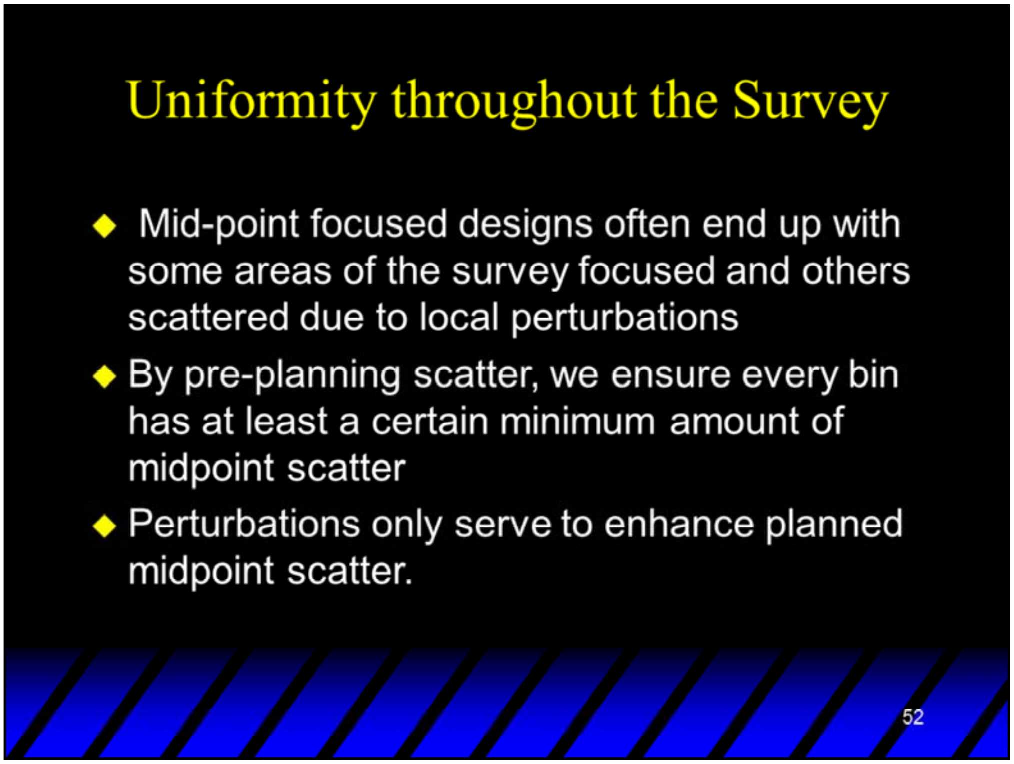


A detail of the perturbed area of the regular orthogonal 3D shows that mid-points are no longer focused in this area. Typical perturbations produce mid-point scatter.



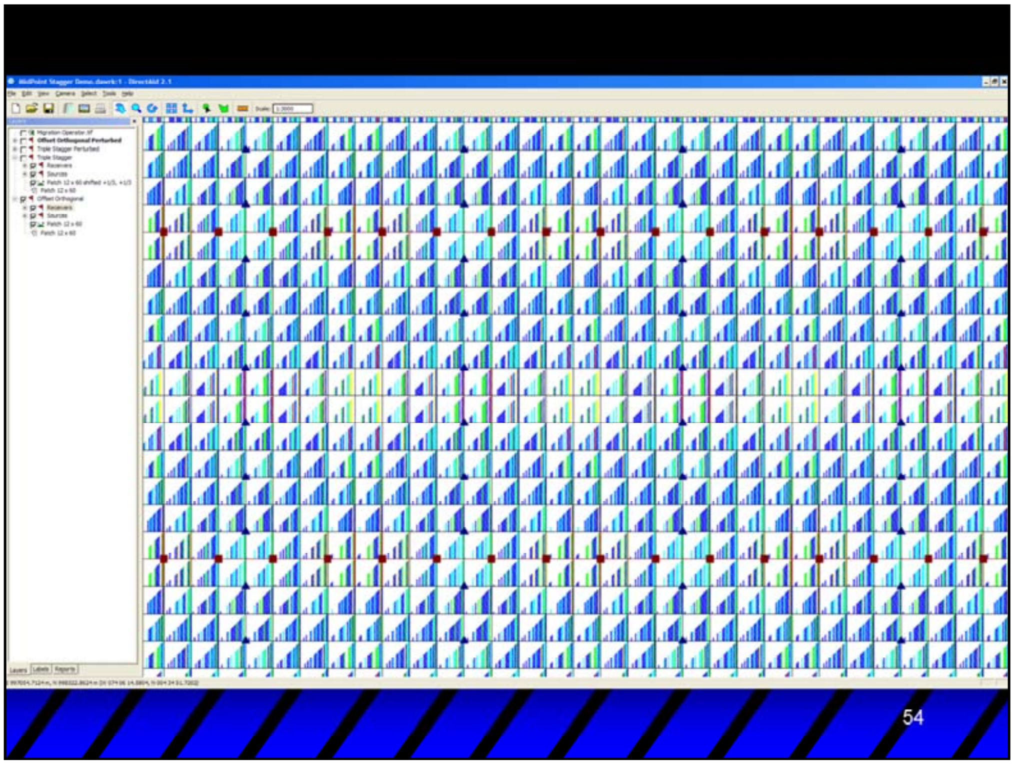
A detail of the perturbed area of the triple staggered 3D shows the mid-point scattering is further enhanced by perturbation.

The regular pattern of mid-points is disrupted (possibly a problem for the flexible binning concept), but this is actually desirable for most of our identified advantages of scattering.



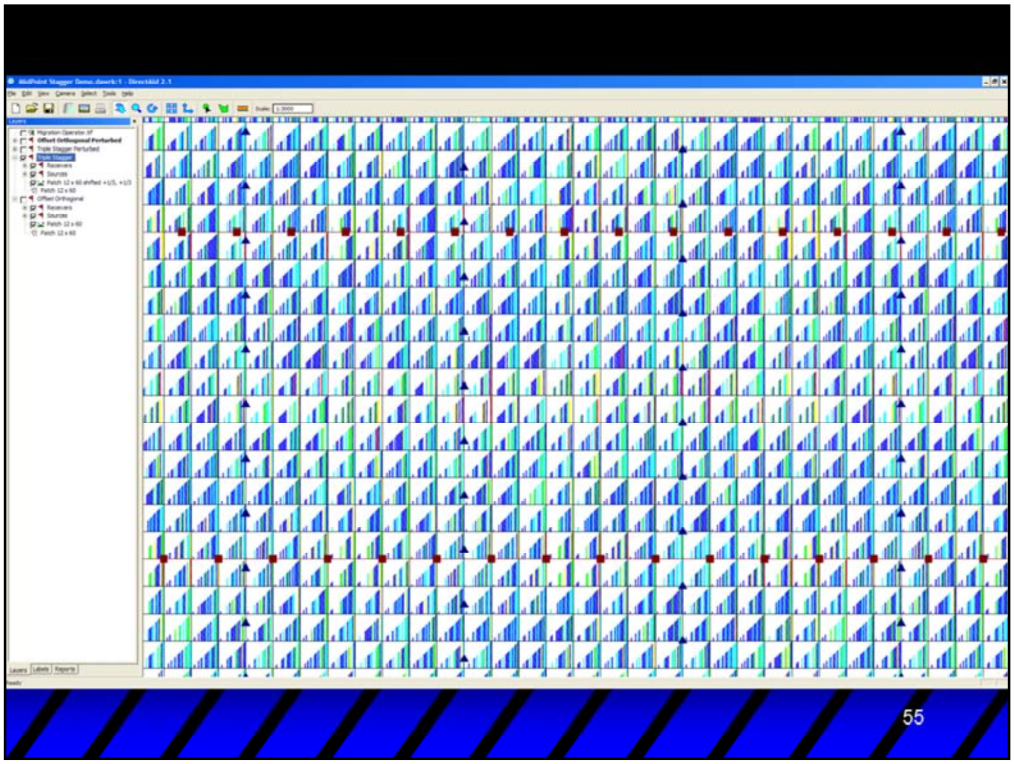
Planned mid-point scatter in a design ensures that no local area in a survey has substantially different mid-point scatter than other areas.

Introducing mid-point scatter creates greater diversity in offsets and azimuths within each CDP gather.

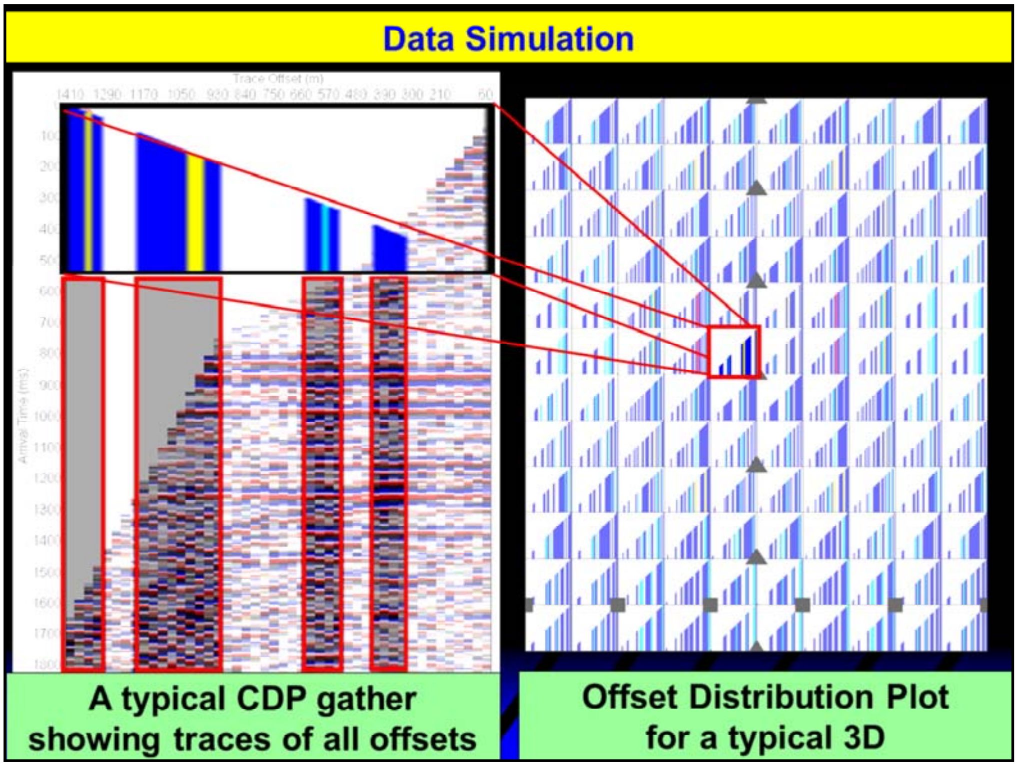


Statistical distributions are very important to the noise-cancellation qualities of a 3D. This diagram shows the offset distributions obtained by a typical regular orthogonal model. Notice that these patterns repeat from one box to the next in an un-perturbed survey.

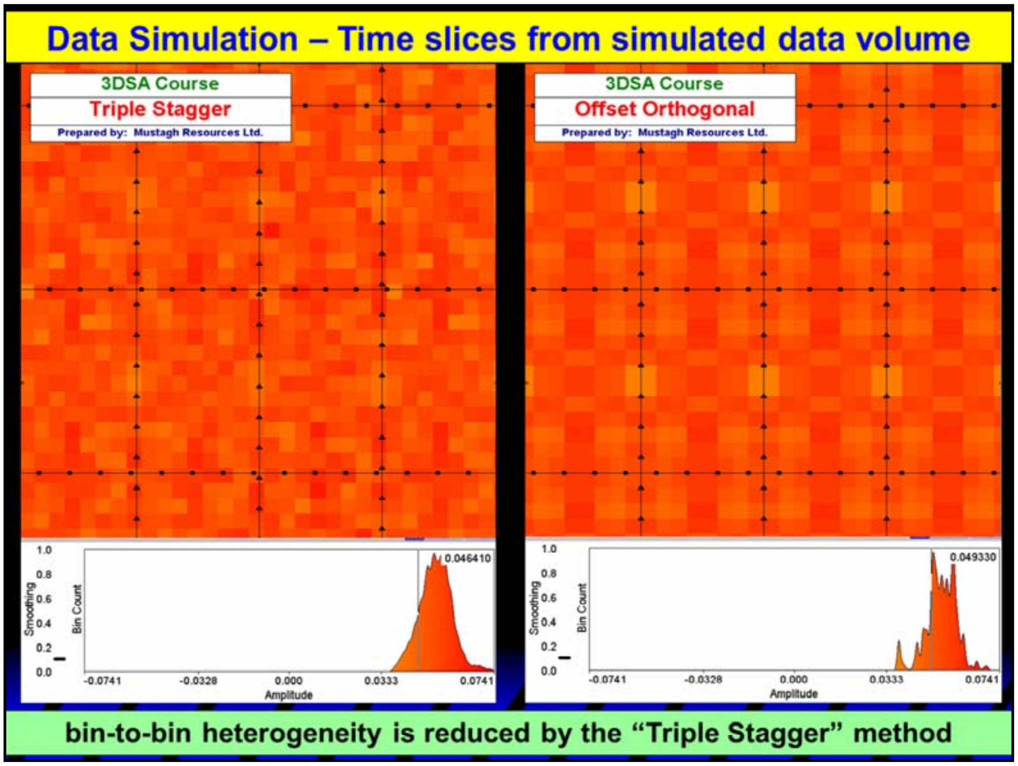
(Recall a “box” is the area enclosed by two adjacent receiver lines and two adjacent source lines.) The “unit cell” for this model is one box and all statistics in one box will repeat in the adjacent boxes.



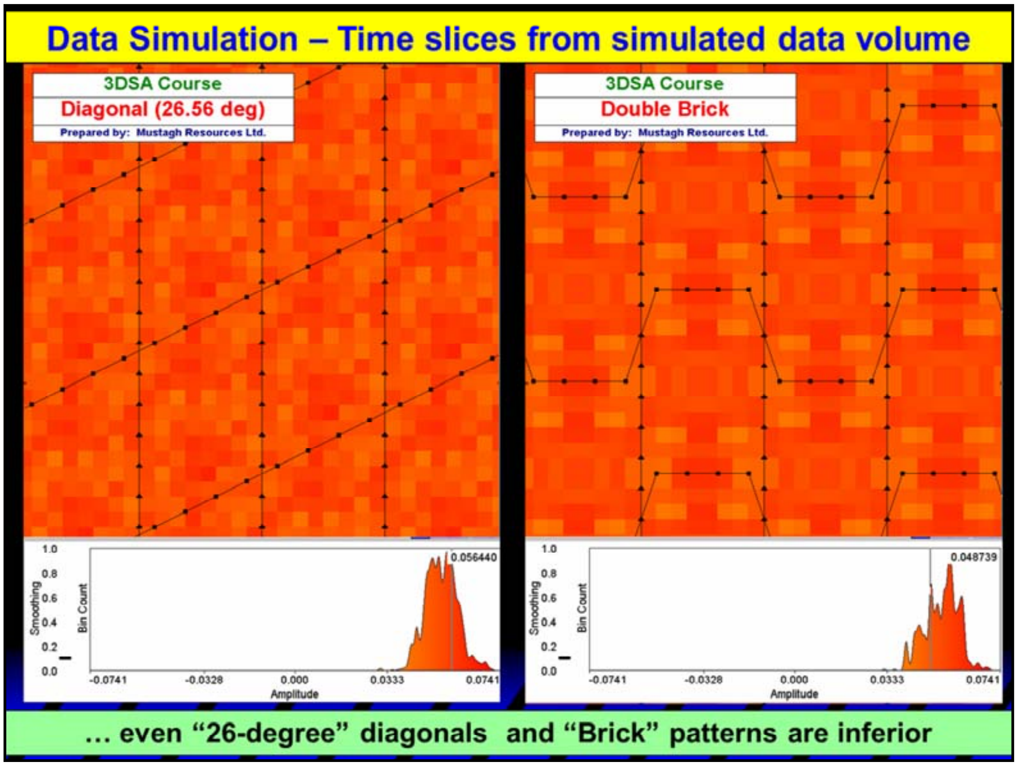
Using a triple-staggered orthogonal design, the statistical distributions become more diverse. Notice that the patterns above will only re-occur every 3 x 3 boxes. Geometrically, the “unit cell” is nine times larger than in a regular orthogonal and therefore the statistics are that much more diverse. This results in better sampling of offset-dependent noise such as direct waves, refractions, ground roll, and air blast. But more importantly, offset dependent noise also includes reverberations, shear-converted surface waves and short-wavelength, chaotically scattered waves. These are very common sources of noise in many seismic environments and the triple-staggered model provides superior sampling of short-wavelength noise due to its enhanced statistical diversity.



We also use Mustagh's "Data Simulation" to illustrate additional advantages. From the model, we determine which offsets belong in a particular bin. We identify traces of these offsets in the reference trace gather. By averaging those only those traces, we produce a simulated stacked trace for that bin. In this manner, we simulate unique stacked traces for each and every bin in the model. Since we use the same reference trace set for all simulations, then the simulated data volume contains no geology. Trace-to-trace differences will reflect the geometric imprint expected from our model.



One of the most powerful diagnostics of a survey is to examine time slices from the simulated data volume near zones of interest. The amplitude of our zone of interest in each bin should be the same since there are no geologic changes in the simulation. Amplitude variations are a result of bin-to-bin heterogeneity. A histogram showing the distribution of bins reflecting each amplitude should resemble a normal Gaussian distribution. The standard deviation of this distribution is a good indicator of the ability of the 3D model to reliably predict the reflectivity of our various geologic events. Mustagh has conducted many studies using data simulation on a variety of models and has found the "Triple Stagger" model to consistently give a more stable response than other models tested.



As a side-note: We have found that a well-designed "Triple Stagger" orthogonal is consistently better than all other tested models of comparable parameters. The second best design is usually the 26-degree diagonal.


Array
Considerations
59

Review of "Stacking Chart" - CDP index vs Source-Receiver Offset

Stacking Chart Demo

Imagine a 2D line with 25 m receiver interval and 100 m source interval
(every 4th receiver, but shot on the half station):

60

Review of "Stacking Chart" - CDP index vs Source-Receiver Offset

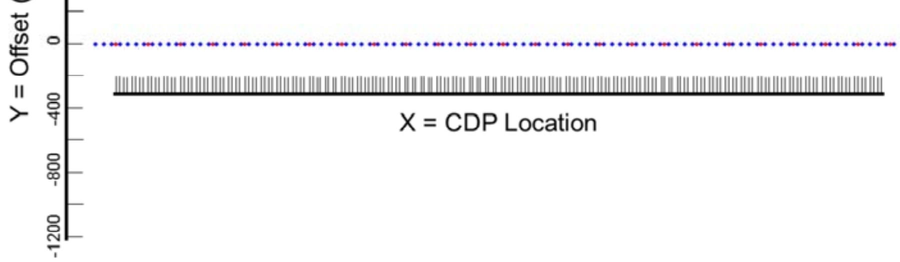
Stacking Chart Demo

This page is an X-Y graph of the statistics generated by recorded traces,

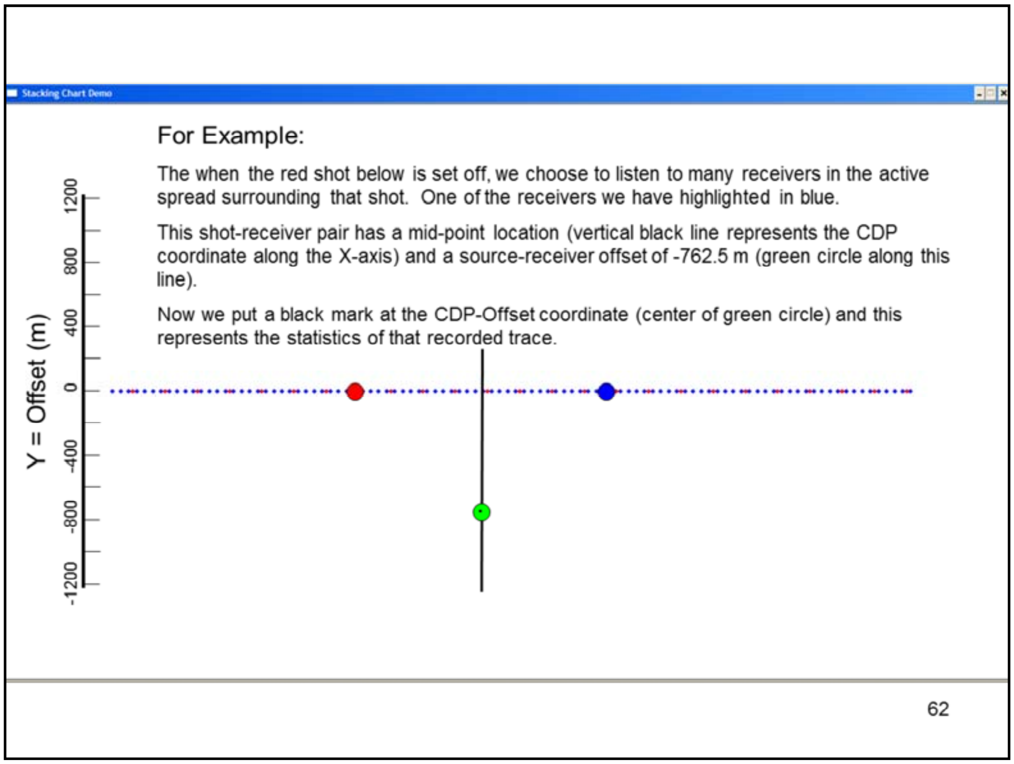
The X-axis coordinate corresponds to the mid-point between the source and receiver

And the Y-axis coordinate corresponds to the distance (offset) between the source and receiver.
(we usually compress this scale by a factor of 2)

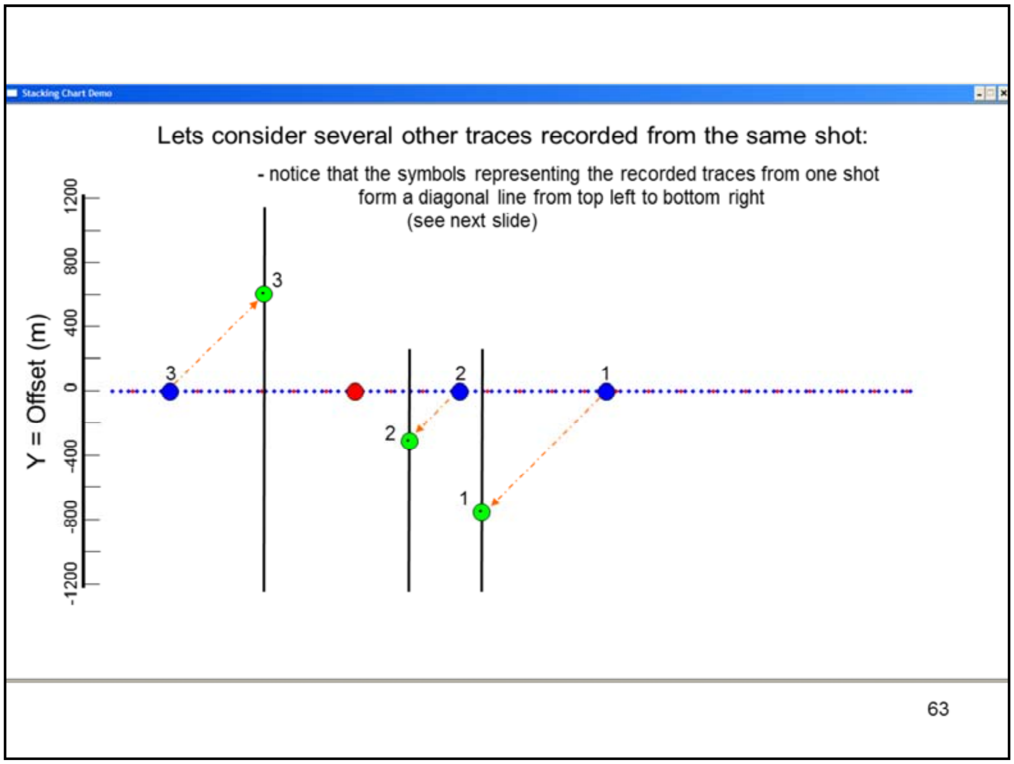
If the source is the right of the receiver, we will call that a Positive offset.
If the source is to the left of the receiver, we will call that a Negative offset.



61



Stacking Chart Demo
For Example:
The when the red shot below is set off, we choose to listen to many receivers in the active spread surrounding that shot. One of the receivers we have highlighted in blue.
This shot-receiver pair has a mid-point location (vertical black line represents the CDP coordinate along the X-axis) and a source-receiver offset of -762.5 m (green circle along this line).
Now we put a black mark at the CDP-Offset coordinate (center of green circle) and this represents the statistics of that recorded trace.
Y = Offset (m)
1200
800
400
0
-400
-800
-1200
62



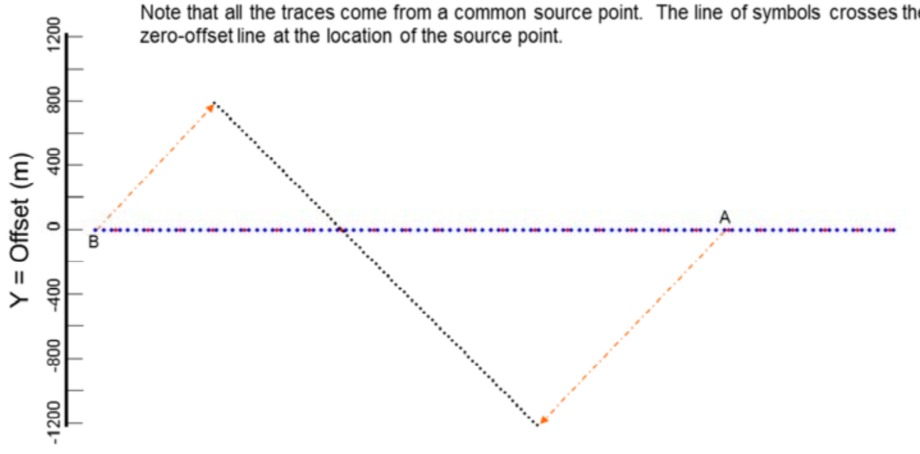
Stacking Chart Demo
Lets consider several other traces recorded from the same shot:
- notice that the symbols representing the recorded traces from one shot
form a diagonal line from top left to bottom right
(see next slide)
Y = Offset (m)
1200
800
400
0
-400
-800
-1200
3
3
2
2
1
1
63

Stacking Chart Demo

All the black symbols represent traces recorded from all the receivers from point A to point B
- in this case from 48 channels to the right of the shot to the end of the line to the left of the shot

Obviously each receiver recorded by a single shot illuminates different CDPs
- a range in the subsurface equal to half the distance of what is recorded on the surface

Note that all the traces come from a common source point. The line of symbols crosses the zero-offset line at the location of the source point.

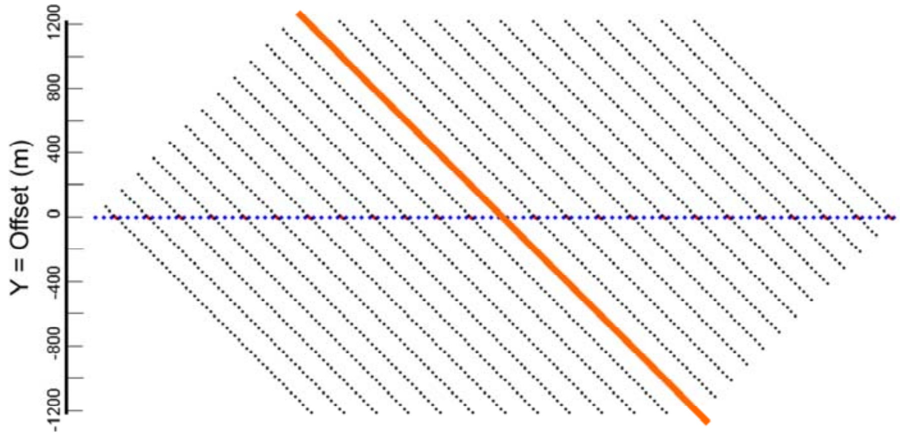


64

Now we show all the traces generated by all of the shots along this line using 96 channel recording

Stacking Chart Demo

Symbols that line up from top-left to bottom-right lie along the "Common Source" orientation and represent traces the were generated from a common source point.

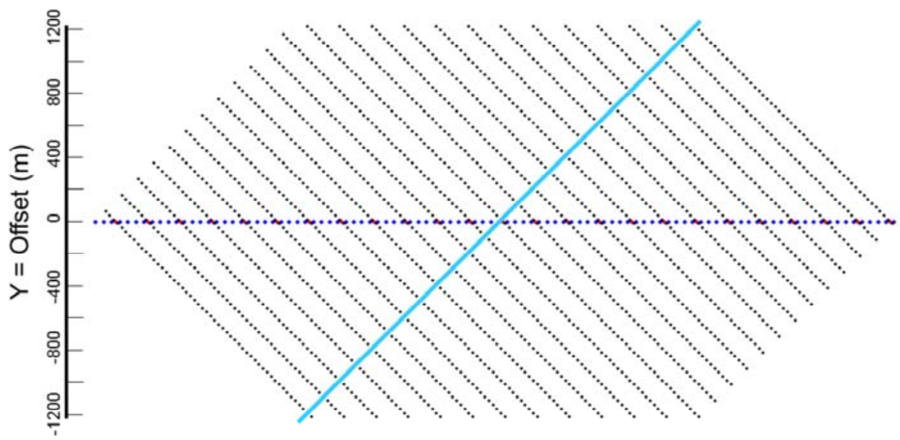


Common Source Orientation

65

Stacking Chart Demo

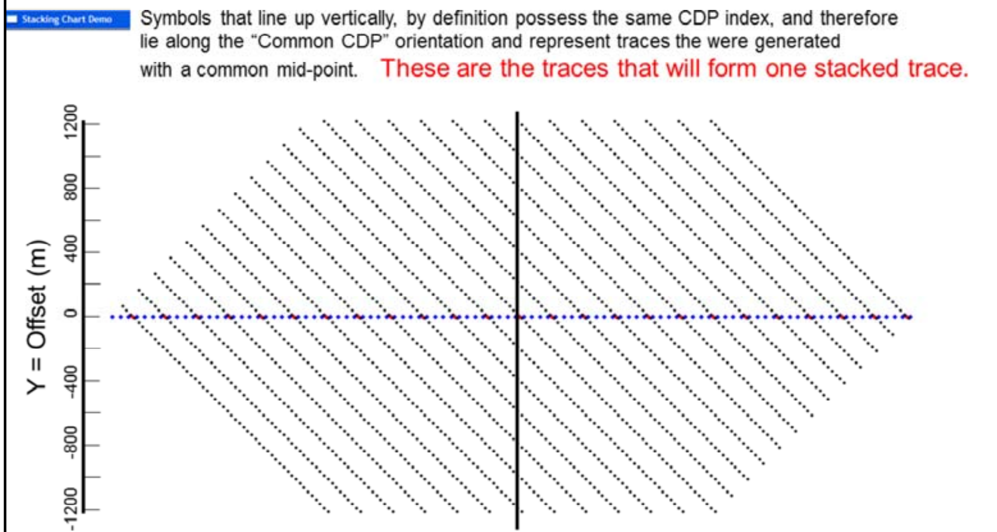
Symbols that line up from top-right to bottom-left lie along the "Common Receiver" orientation and represent traces the were generated from a common source point.



Common Receiver Orientation

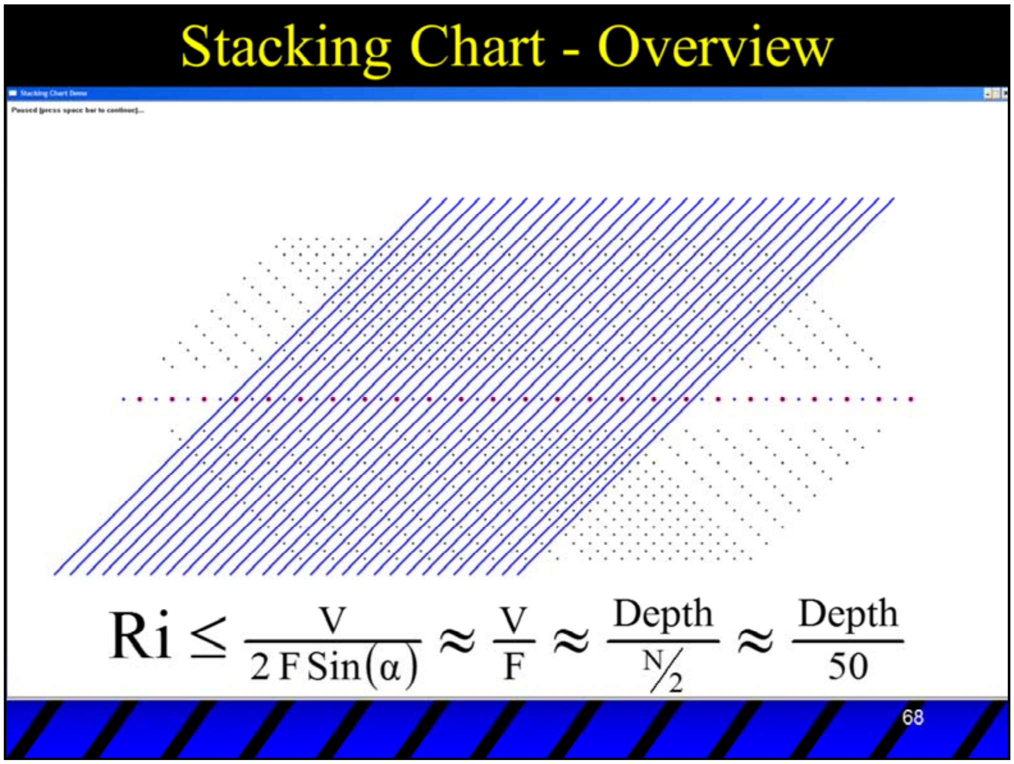
66

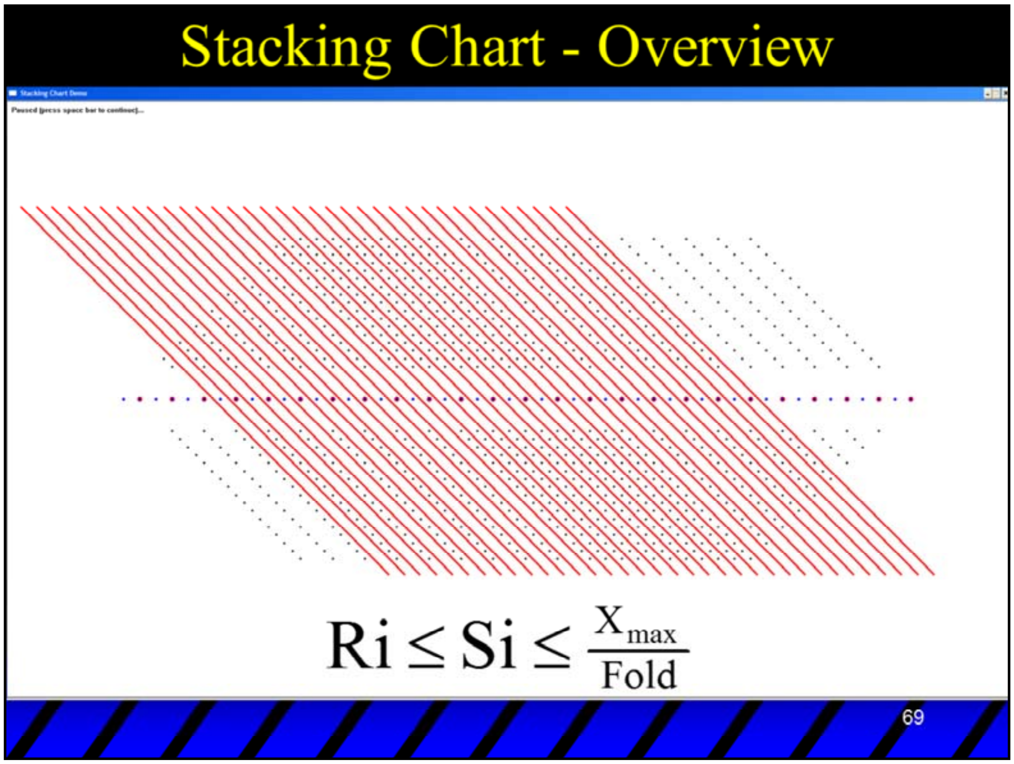
Symbols that line up vertically, by definition possess the same CDP index, and therefore lie along the "Common CDP" orientation and represent traces the were generated with a common mid-point. These are the traces that will form one stacked trace.



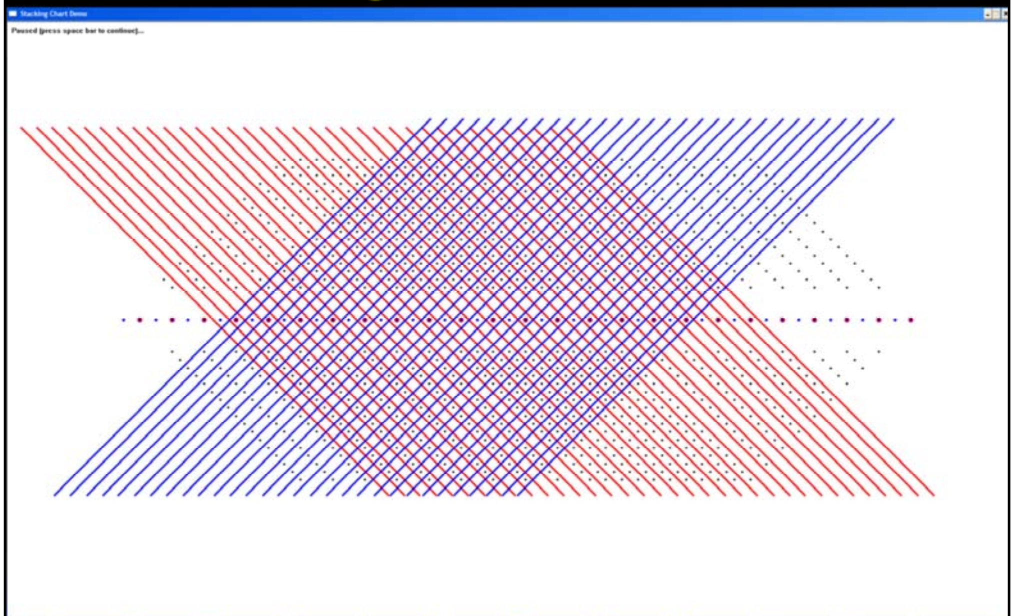
Common CDP Orientation

67

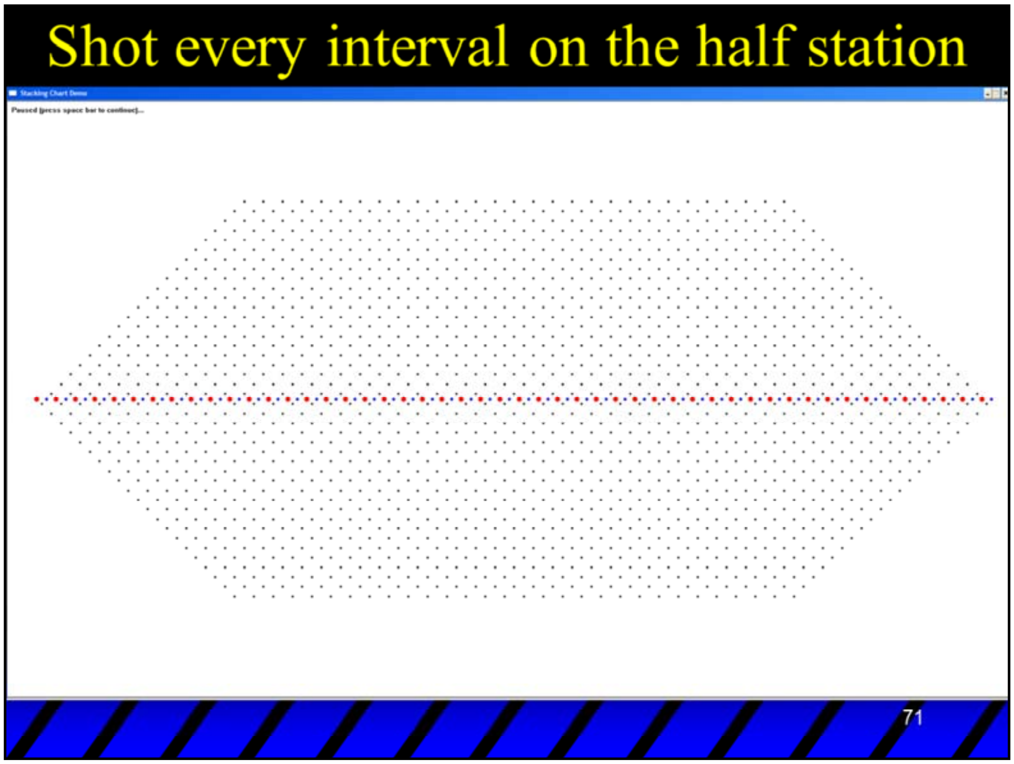

Stacking Chart - Overview
$Ri \le \frac{V}{2\,F\,Sin(\alpha)} \approx \frac{V}{F} \approx \frac{Depth}{N/2} \approx \frac{Depth}{50}$
68

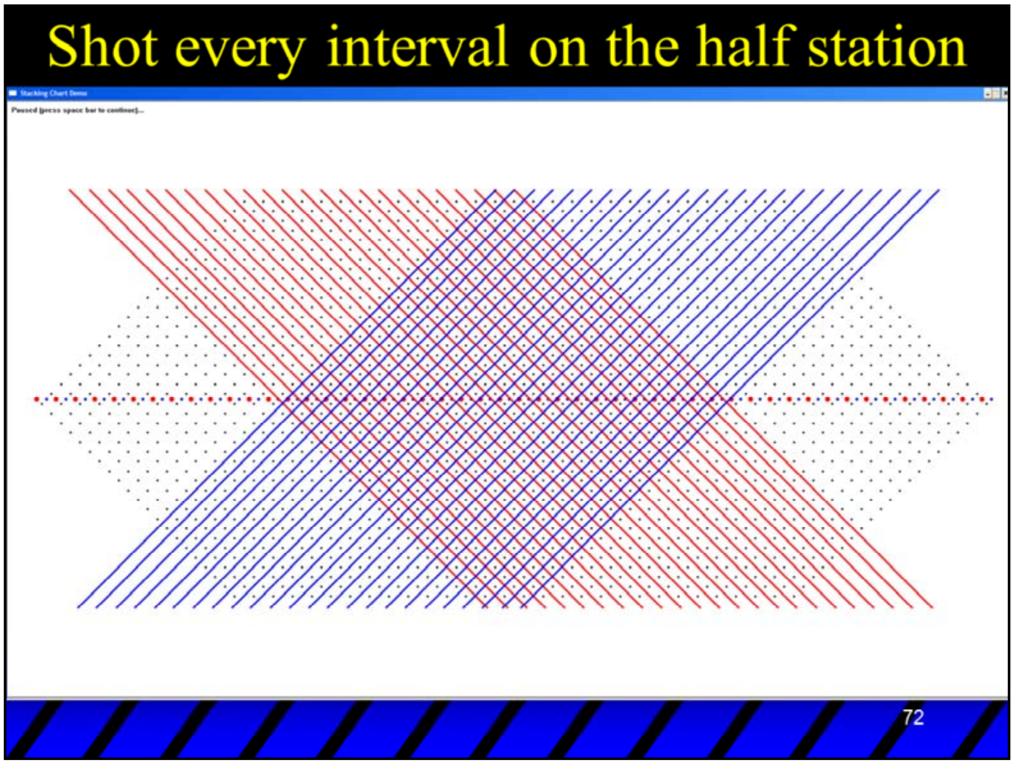

Stacking Chart - Overview
Stacking Chart Demo
Paused [press space bar to continue]...
$$Ri \le Si \le \frac{X_{max}}{Fold}$$
69

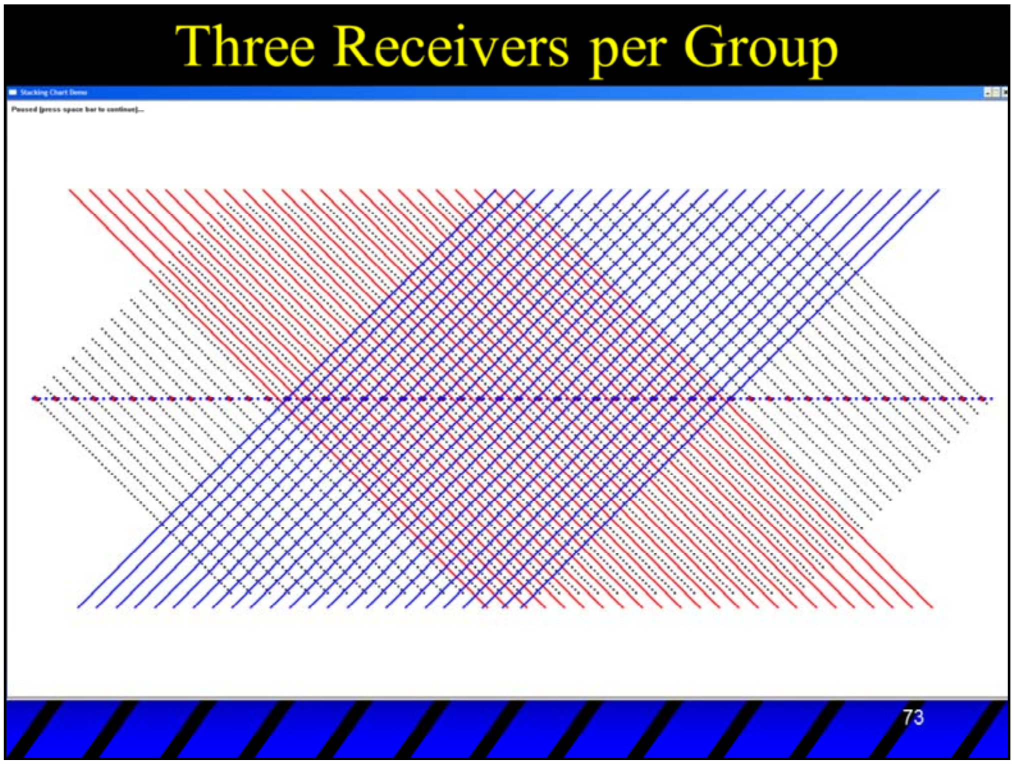
Stacking Chart - Overview



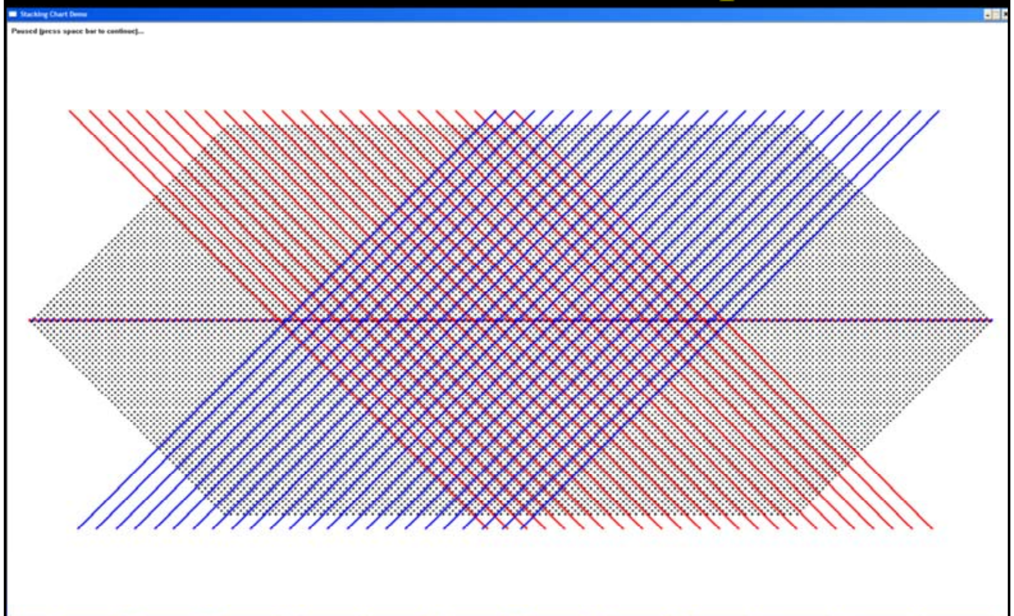
70


Shot every interval on the half station
Stacking Chart Demo
Paused [press space bar to continue]...
71

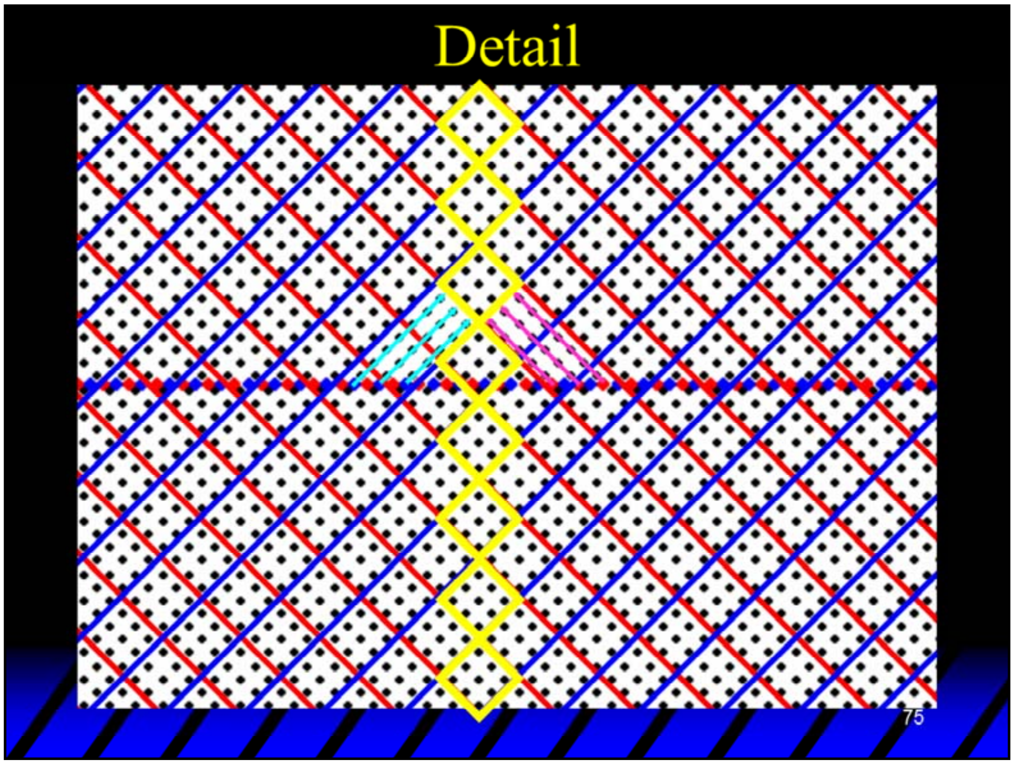

Shot every interval on the half station
Stacking Chart Demo
Paused [press space bar to continue]...
72


Three Receivers per Group
Stacking Chart Demo
Paused (press space bar to continue)...
73

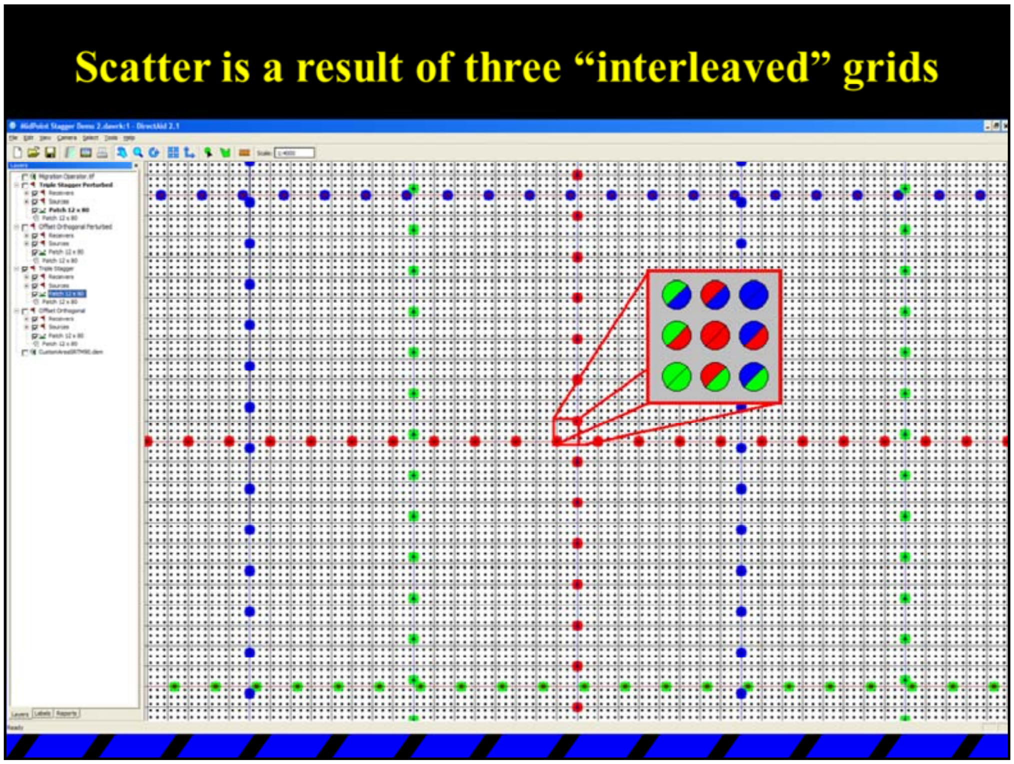
… AND Three Sources per SP



74

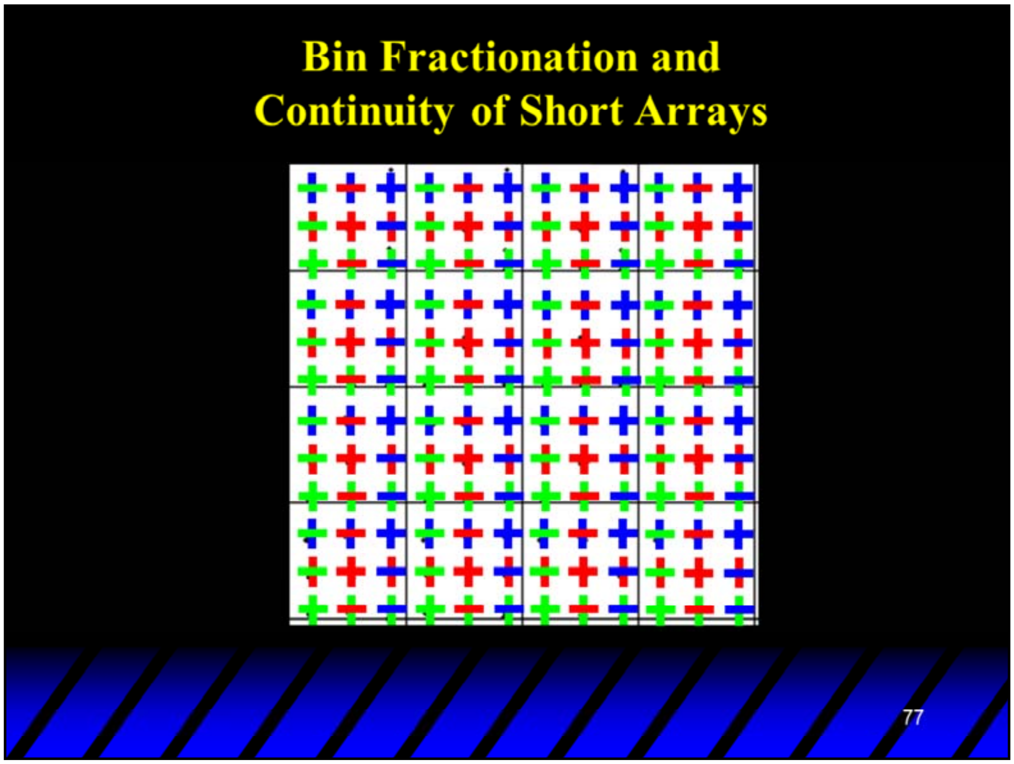


Detail
75



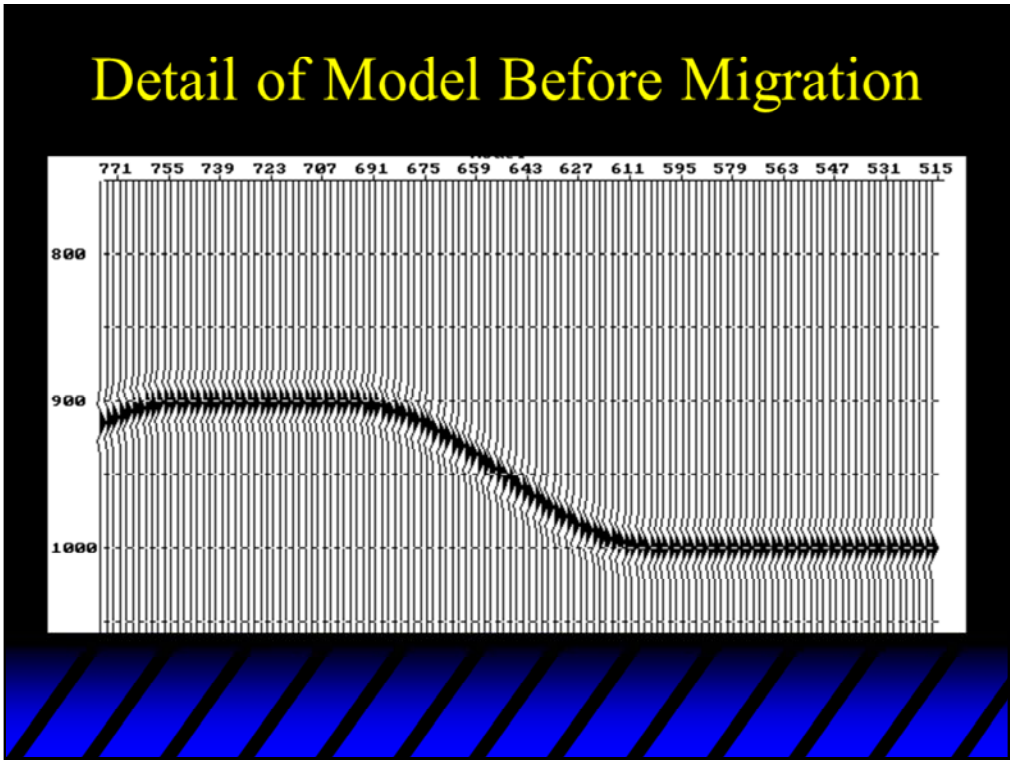
Triple stagger, in effect, produces three interleaved grids that together produce the desired midpoint scatter.

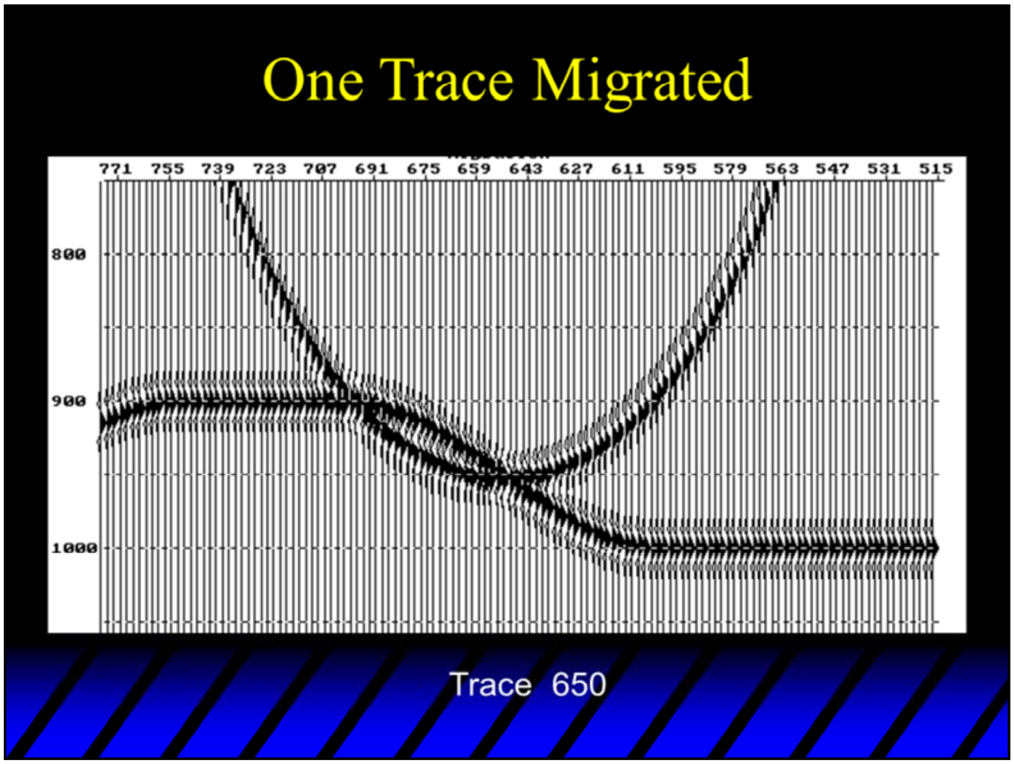
We have observed many advantages to midpoint scatter. One advantage of this comes in sub-sampling due to arrays.

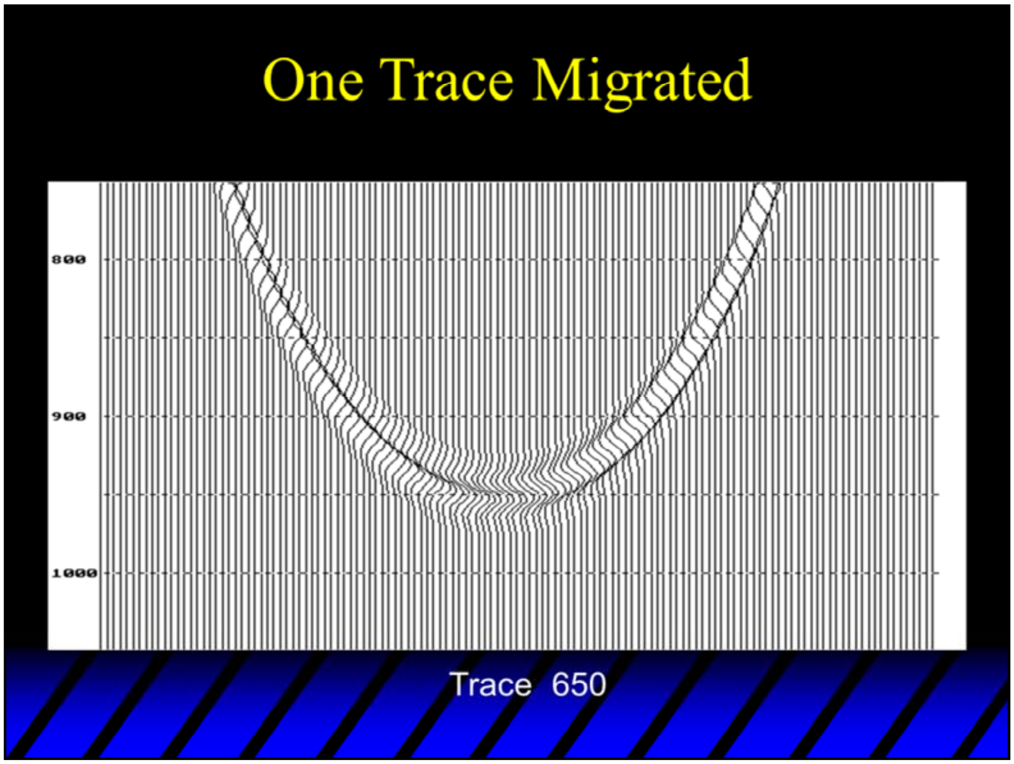


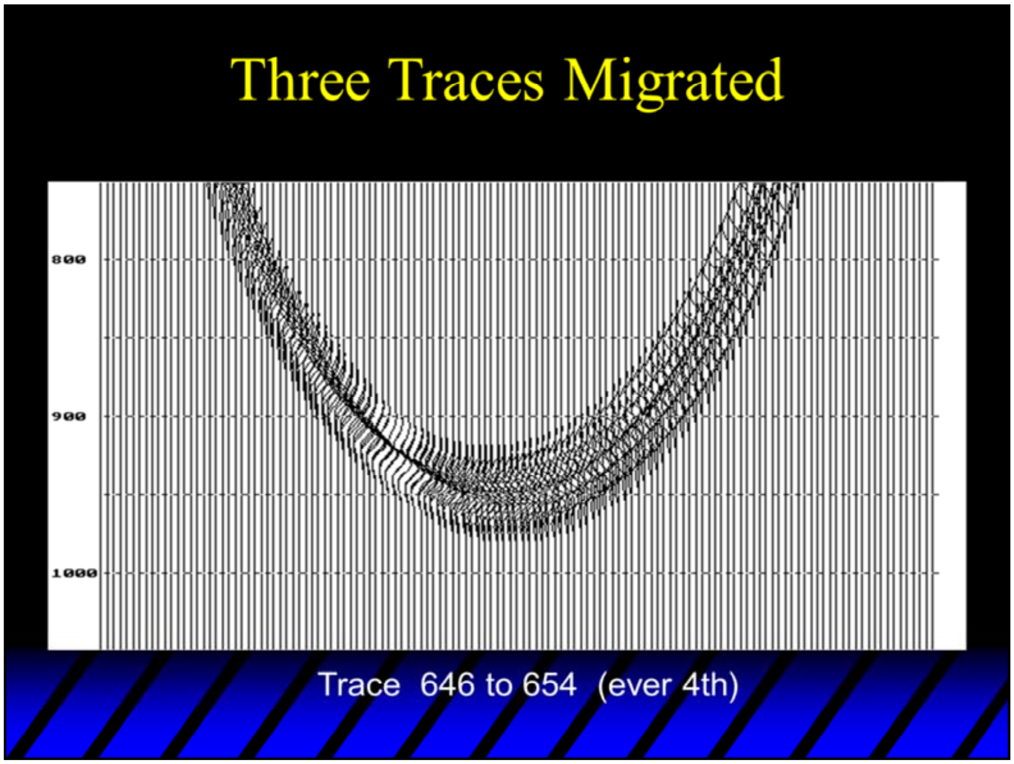
Another advantage is that we can use short source and receiver arrays on the surface (1/3 of a group interval) and still retain subsurface continuous sub-sampling through the use of arrays.

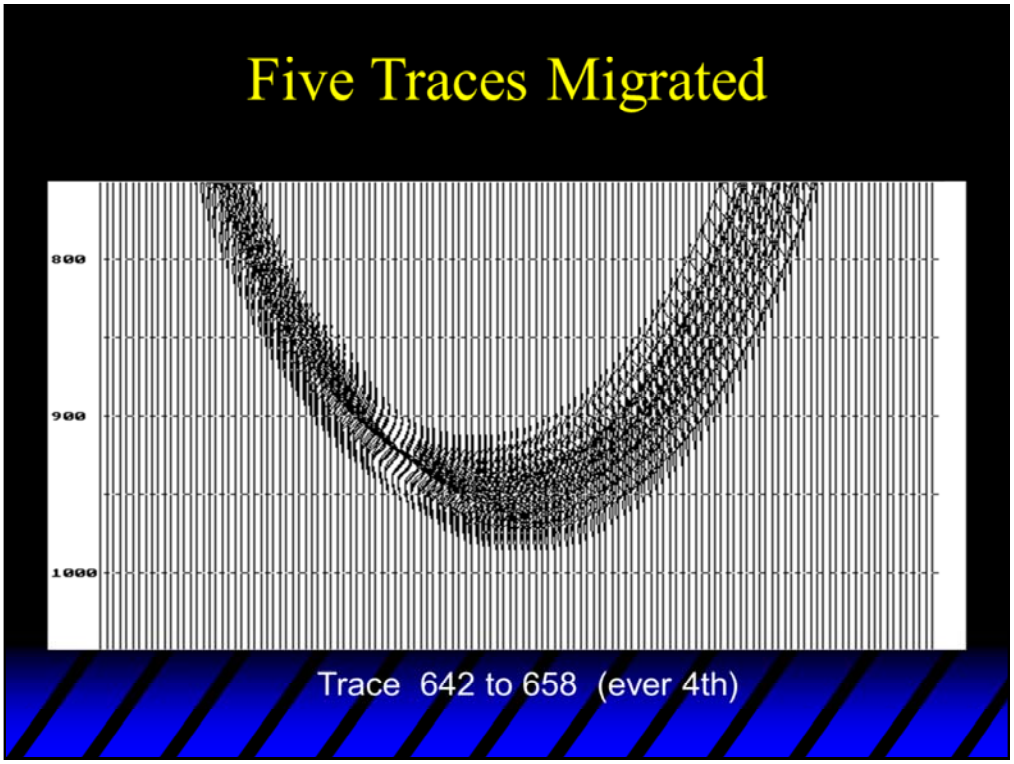

Migration
Considerations
78

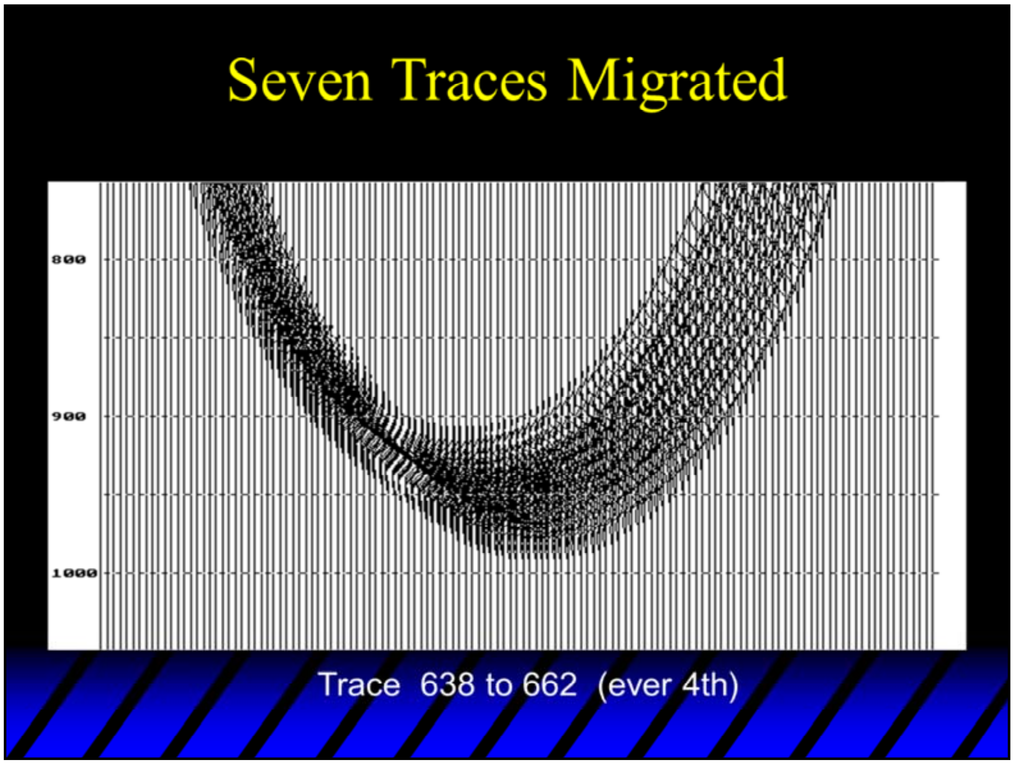

Detail of Model Before Migration
771 755 739 723 707 691 675 659 643 627 611 595 579 563 547 531 515
800
900
1000

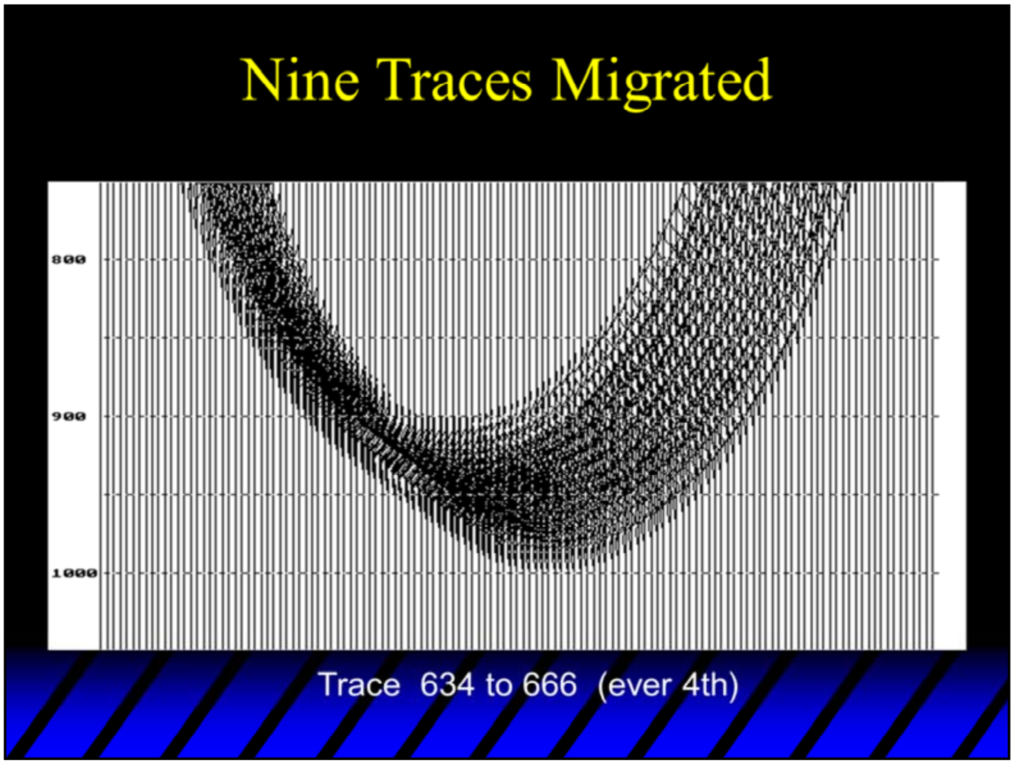

One Trace Migrated
771 755 739 723 707 691 675 659 643 627 611 595 579 563 547 531 515
800
900
1000
Trace 650

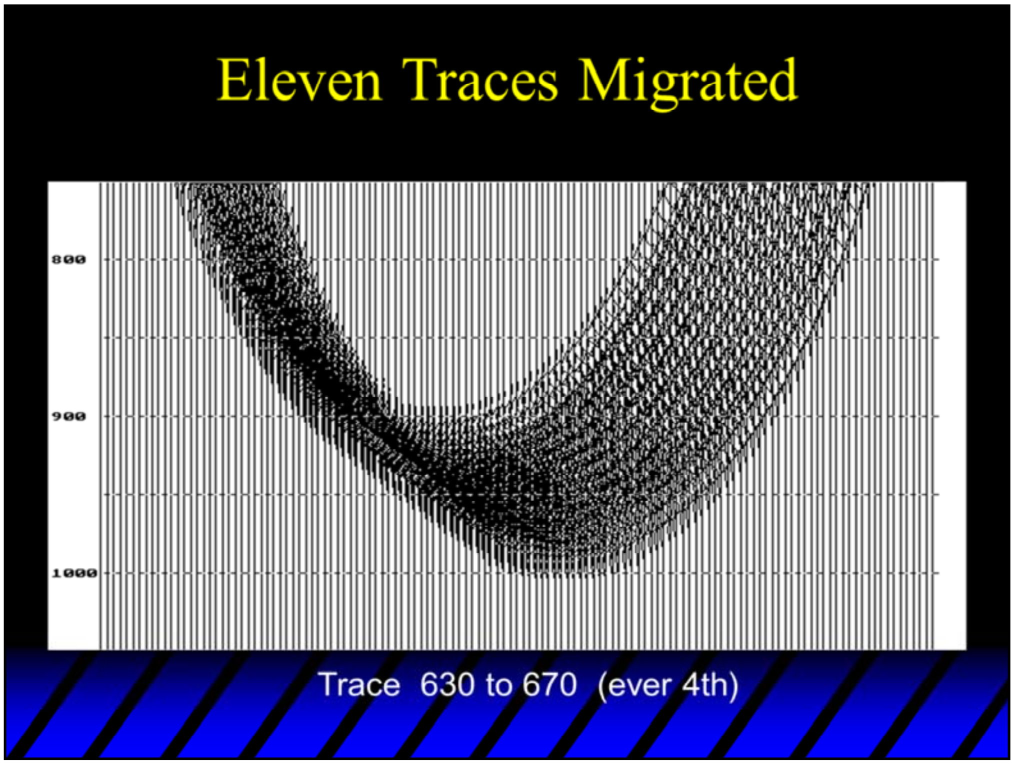

One Trace Migrated
800
900
1000
Trace 650

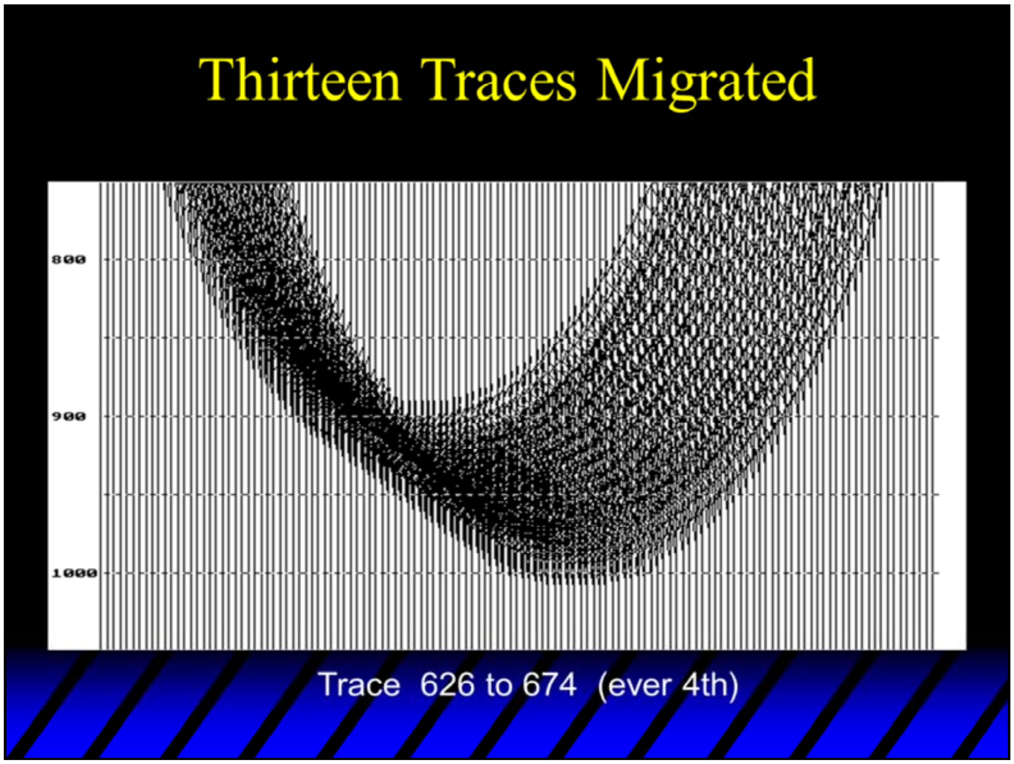

Three Traces Migrated
800
900
1000
Trace 646 to 654 (ever 4th)

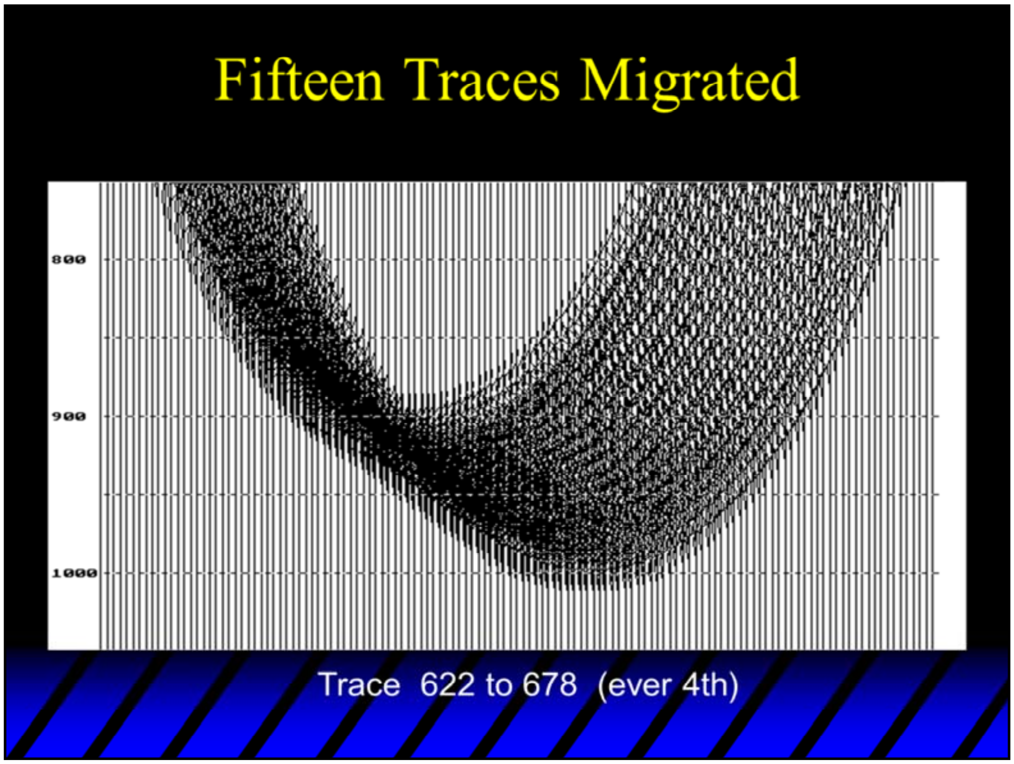

Five Traces Migrated
800
900
1000
Trace 642 to 658 (ever 4th)

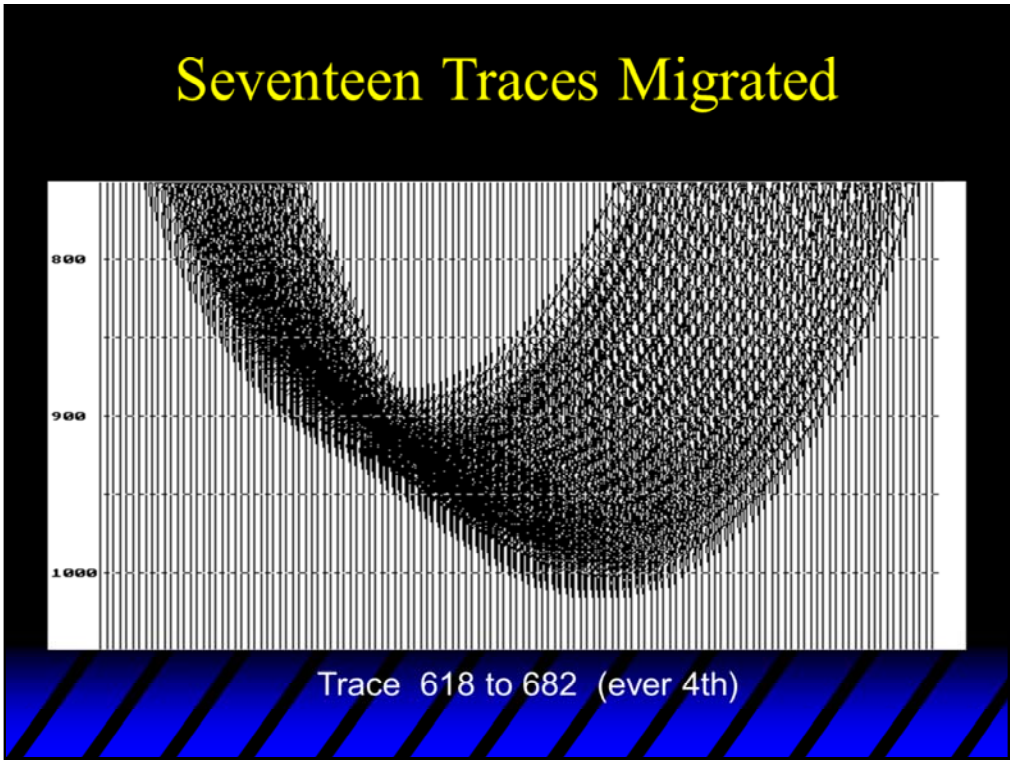

Seven Traces Migrated
800
900
1000
Trace 638 to 662 (ever 4th)


Nine Traces Migrated
800
900
1000
Trace 634 to 666 (ever 4th)

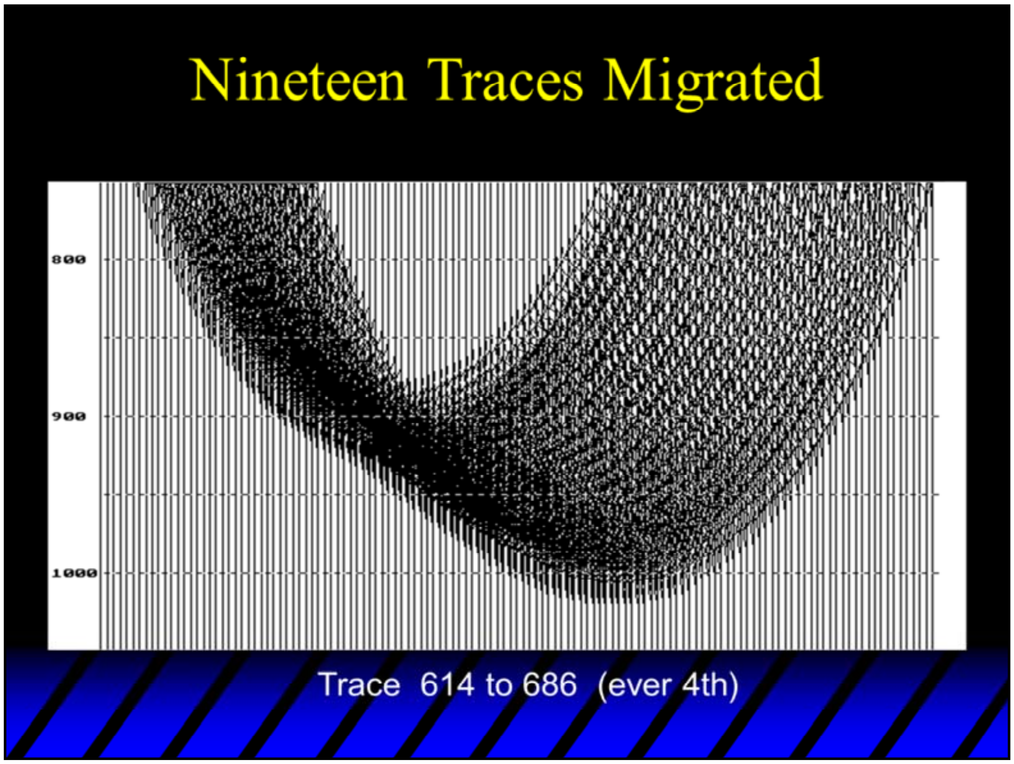

Eleven Traces Migrated
800
900
1000
Trace 630 to 670 (ever 4th)


Thirteen Traces Migrated
800
900
1000
Trace 626 to 674 (ever 4th)

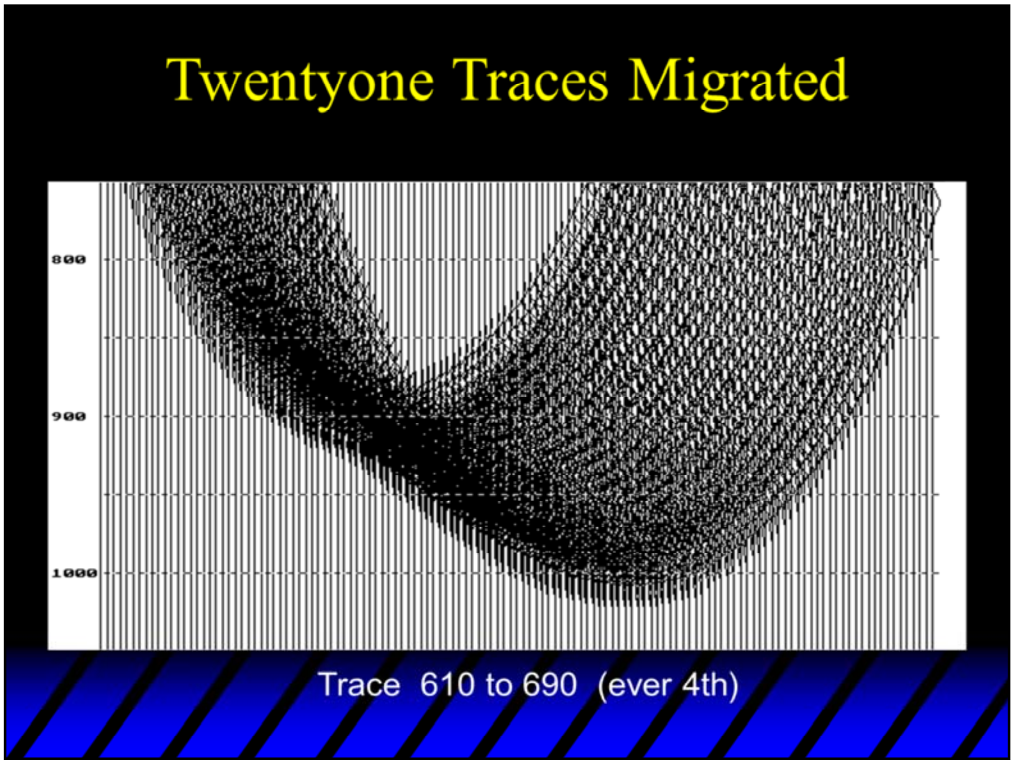

Fifteen Traces Migrated
800
900
1000
Trace 622 to 678 (ever 4th)

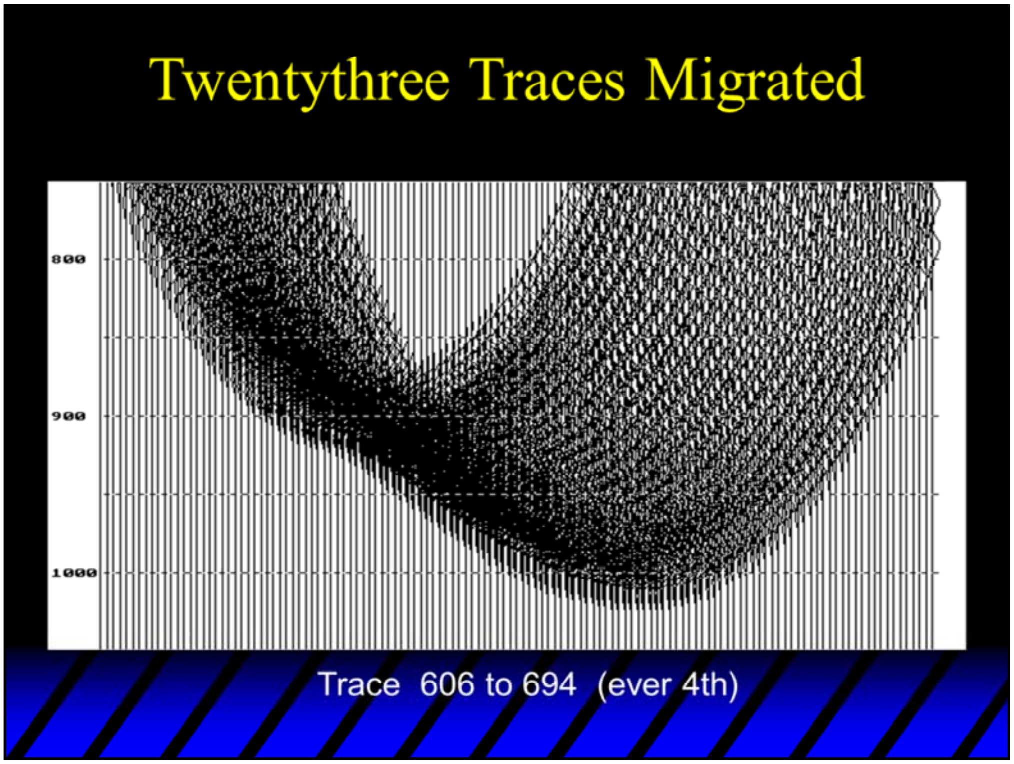


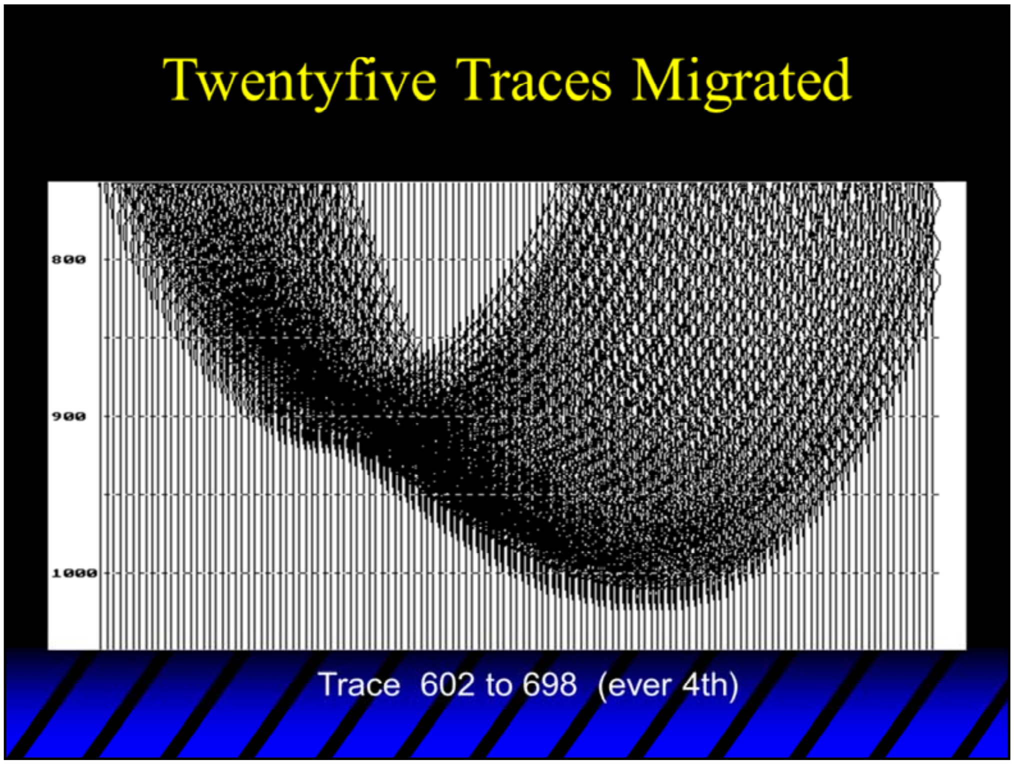
Seventeen Traces Migrated
800
900
1000
Trace 618 to 682 (ever 4th)

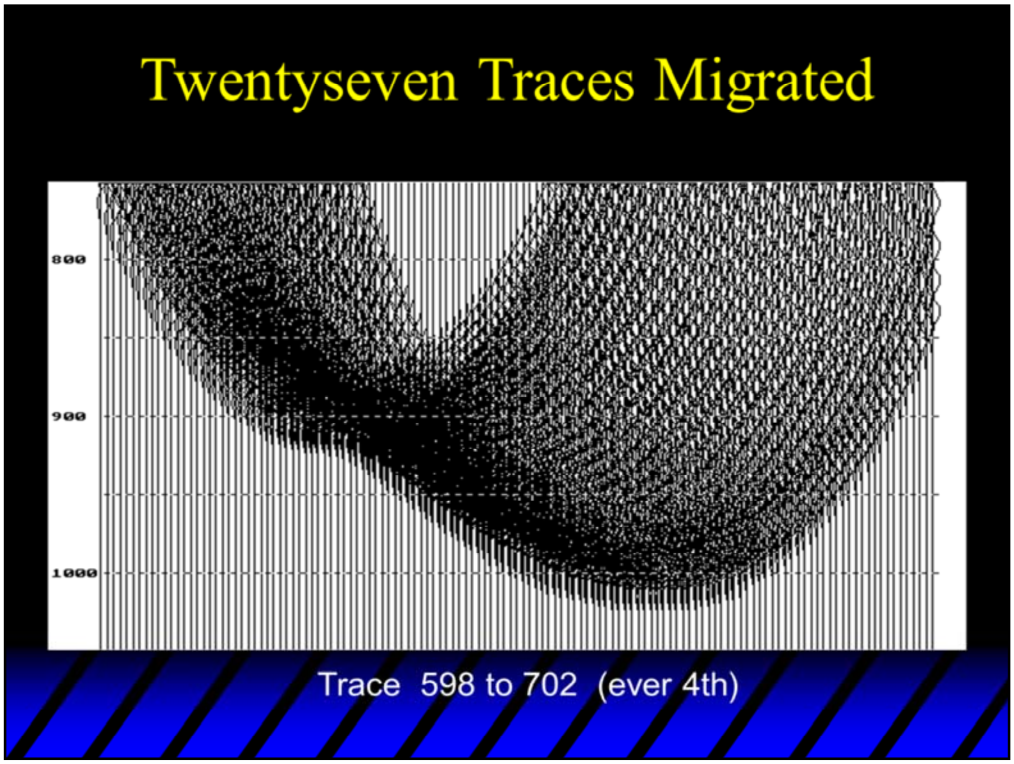


Nineteen Traces Migrated
800
900
1000
Trace 614 to 686 (ever 4th)

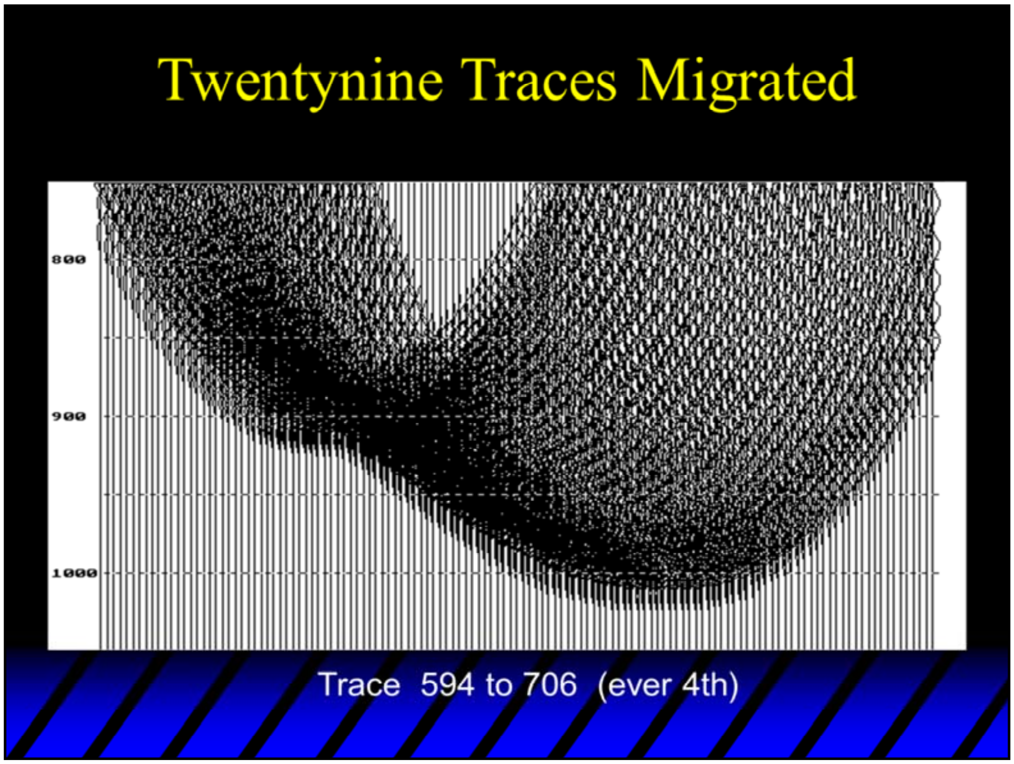

Twentyone Traces Migrated
800
900
1000
Trace 610 to 690 (ever 4th)

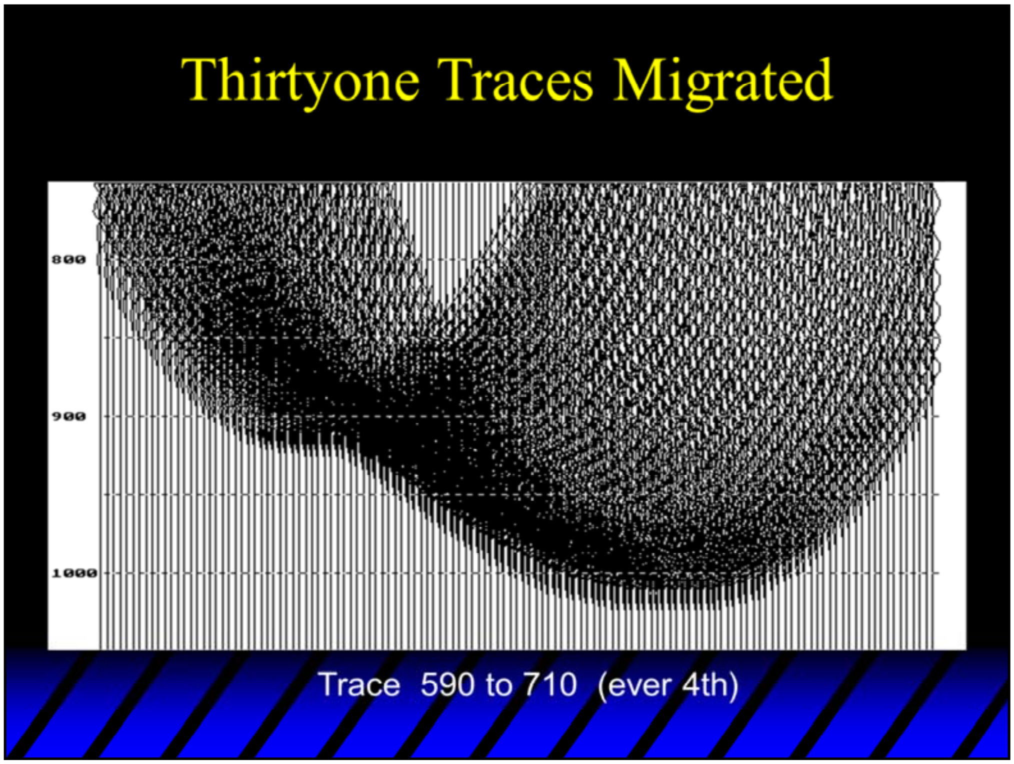

Twentythree Traces Migrated
800
900
1000
Trace 606 to 694 (ever 4th)

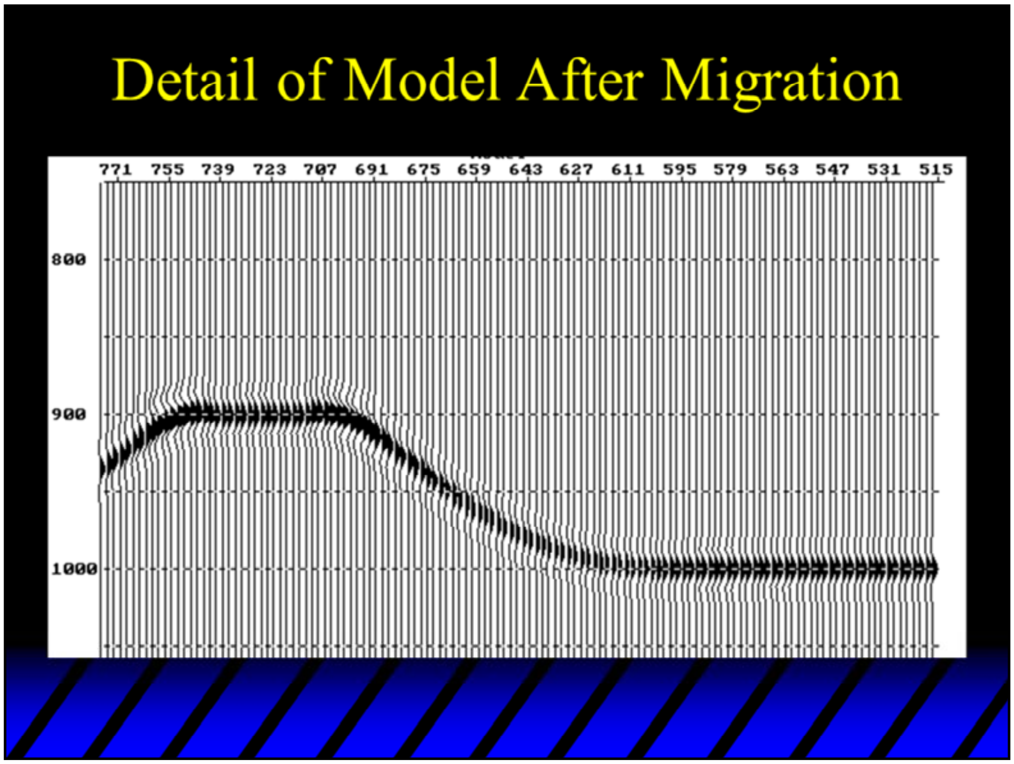

Twentyfive Traces Migrated
800
900
1000
Trace 602 to 698 (ever 4th)

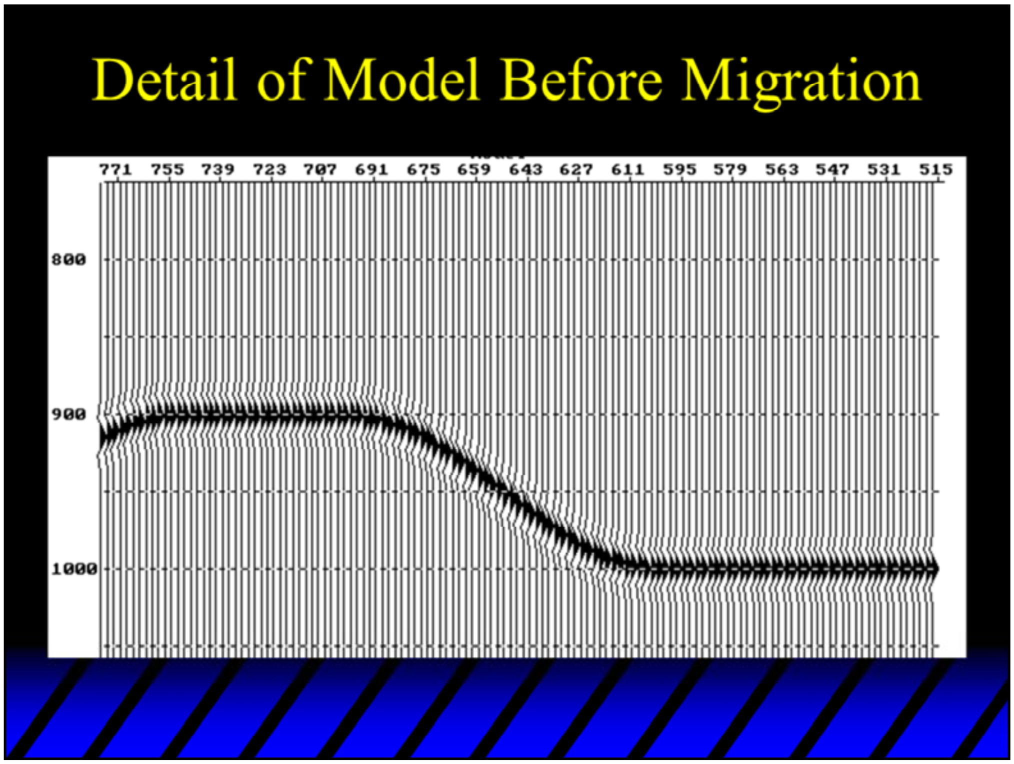


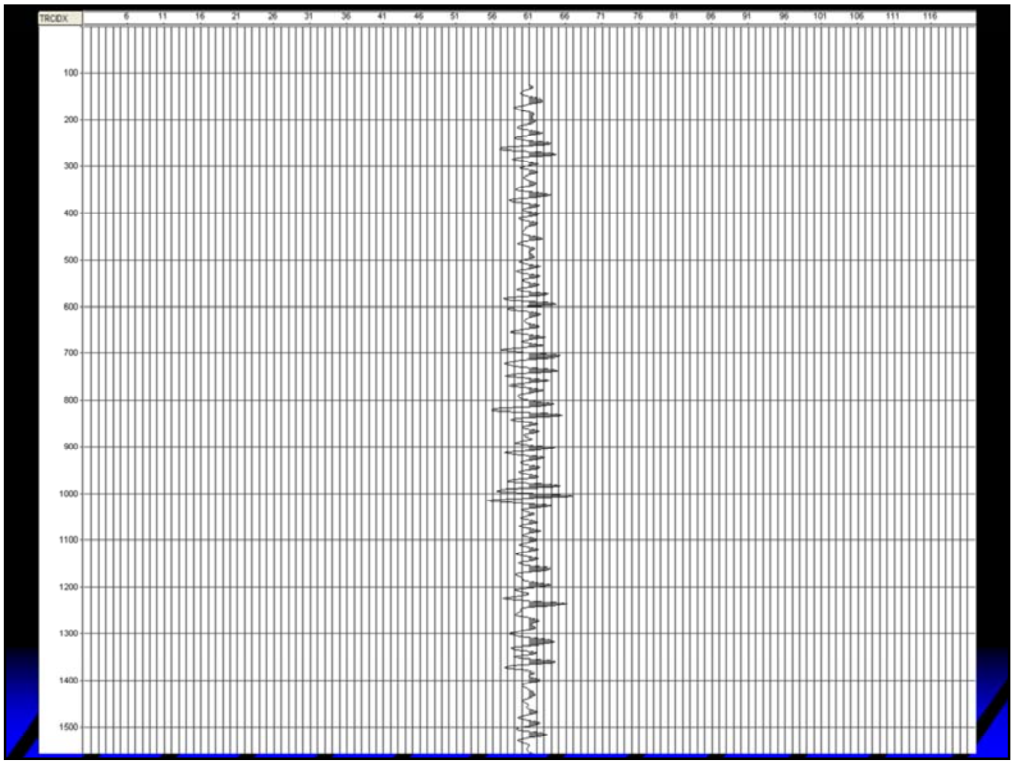
Twentyseven Traces Migrated
800
900
1000
Trace 598 to 702 (ever 4th)


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

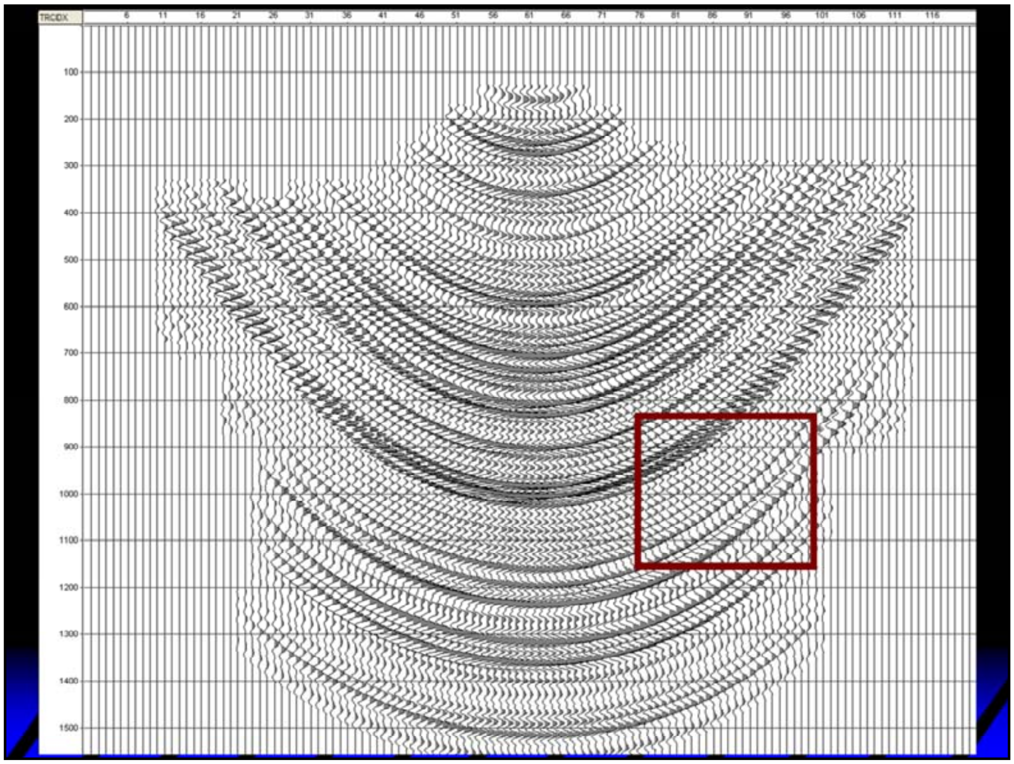

Thirtyone Traces Migrated
800
900
1000
Trace 590 to 710 (ever 4th)


Detail of Model After Migration
771 755 739 723 707 691 675 659 643 627 611 595 579 563 547 531 515
800
900
1000

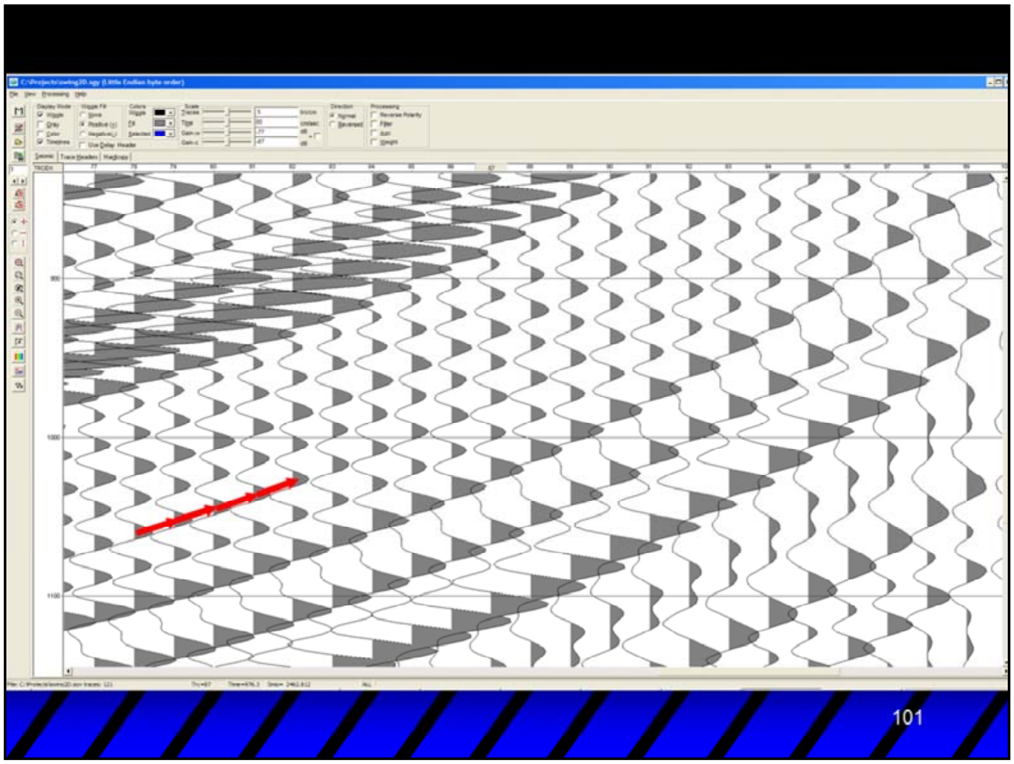

Detail of Model Before Migration
771 755 739 723 707 691 675 659 643 627 611 595 579 563 547 531 515
800
900
1000



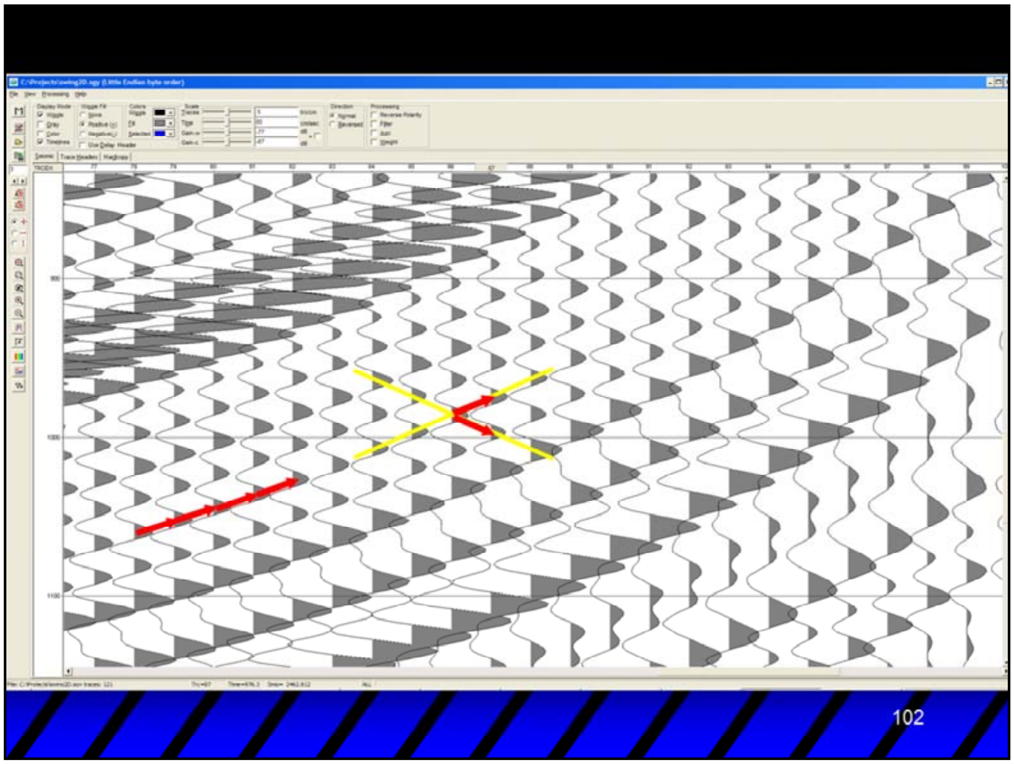
Consider a single trace of a 3-D data volume and all other traces in the volume are dead. If we migrate this volume we will produce a migration “swing operator” or “migration impulse response” for a single trace. This is shown in the next slide.



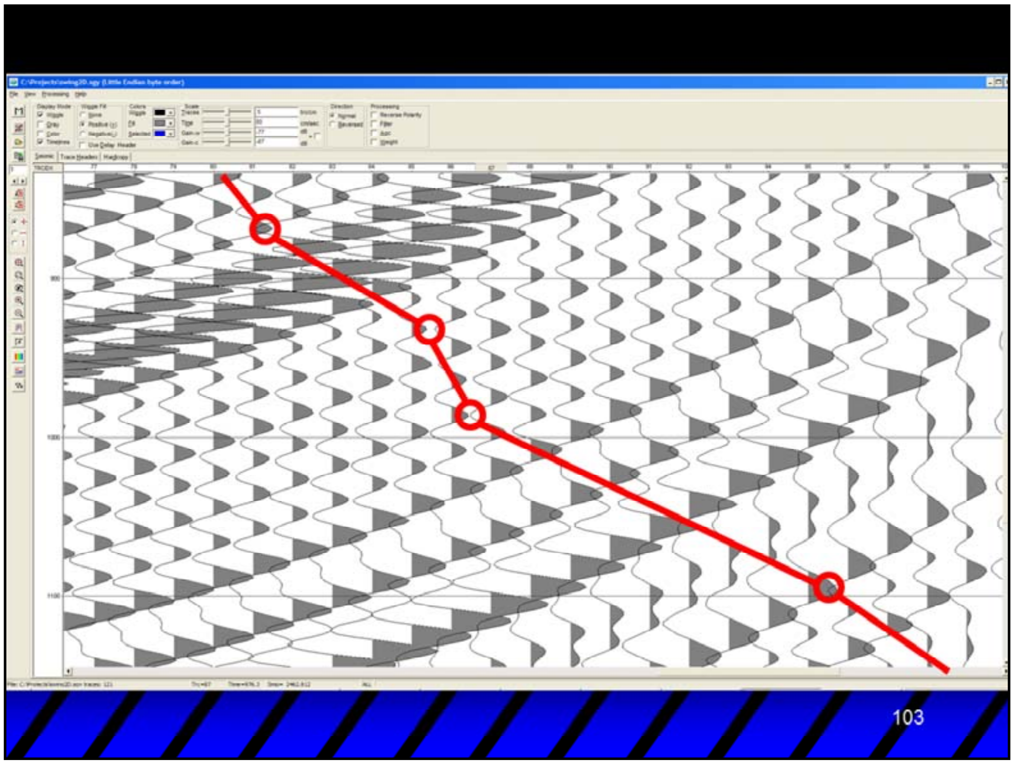
Normally, anti-aliasing of the operator would suppress the far-offset upper limbs (the “arms” of this “paper doll” shape). It is not wise to allow the migration to spatially alias data at slow apparent velocities and high frequencies (ie at apparent wavelengths small compared to the trace sampling). For post-stack migration, the trace spacing is the stacked trace interval (normally the natural bins). This is also true for Pre-Stack migration of data with focused mid-points. However, mid-point scatter via the triple stagger method yields traces with greater diversity of geographic indexes (ie smaller delta-x and delta-y). Therefore, by decreasing delta-x, each migration operator is better sampled in space, and this allows for migration of steeper dips and/or higher frequencies.



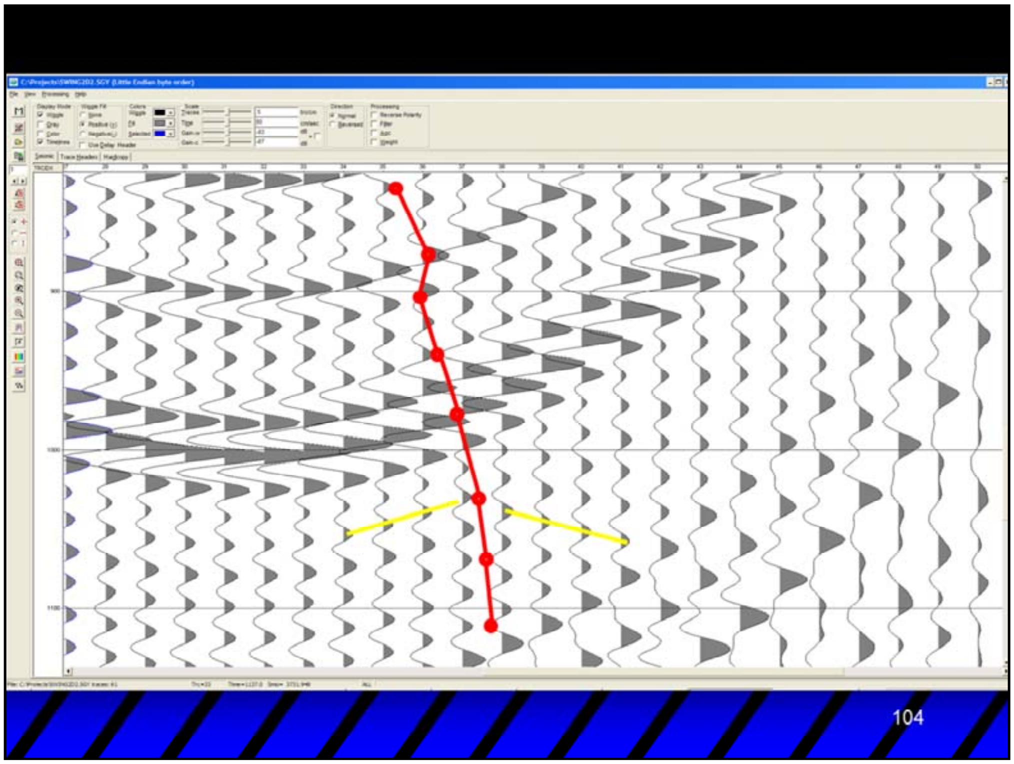
This is a detailed display from the red box in the previous display. We determine reflection continuity by following one peak from trace to trace, in each case "connecting" to the nearest peak in time on the adjacent trace.



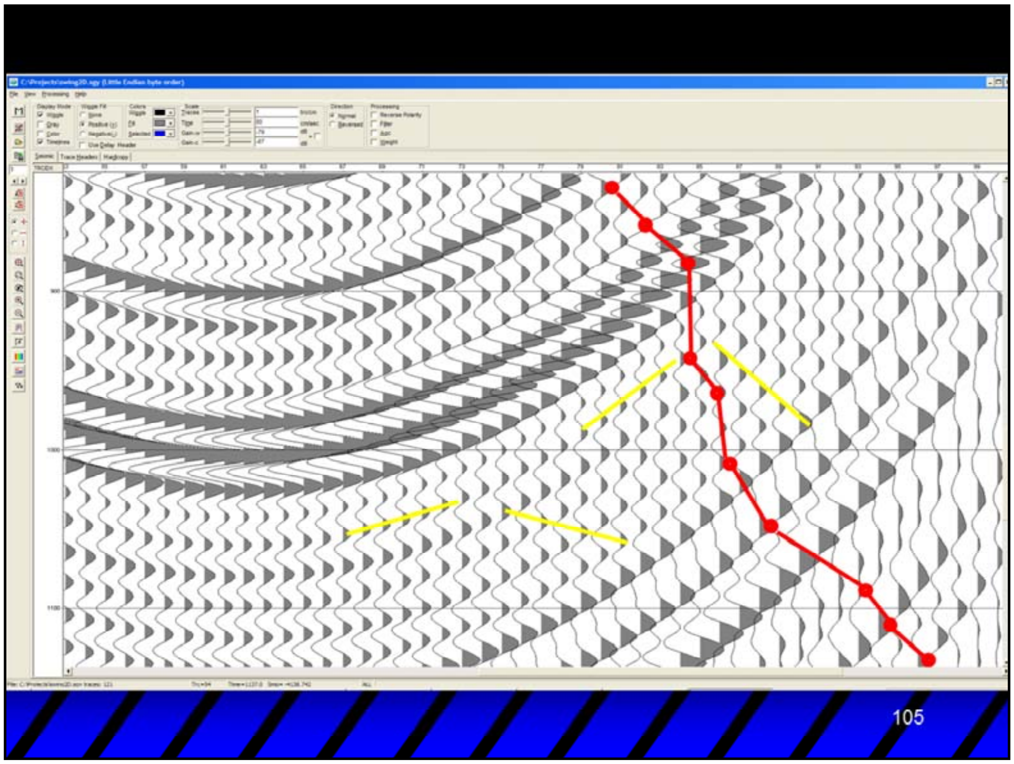
The aliasing point is the point where dip increases such that a peak on one trace is exactly opposite a trough on the next trace. At this point, there are two peaks on the adjacent trace that are equally close to the peak on the trace we are connecting from. This dilemma presents alternative interpretations of two very different dips. It is very important NOT to include such aliased data in the migration operator.



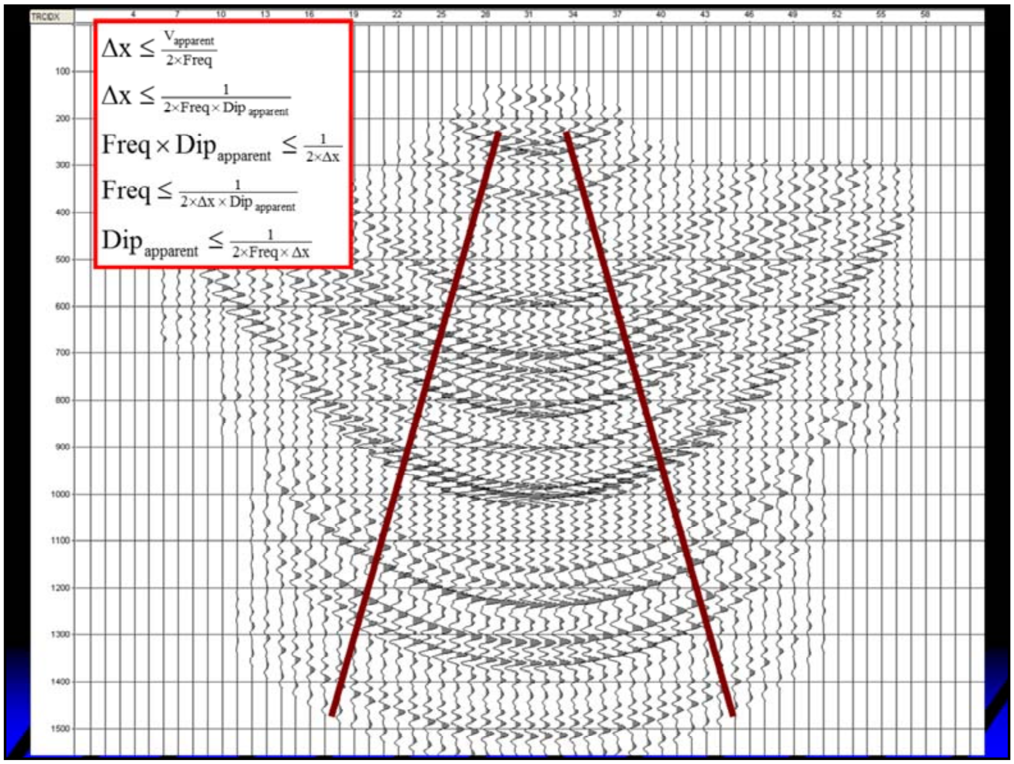
For any data set, the apparent dips and frequencies will define an aliasing limit beyond which we should truncate our migration operator.



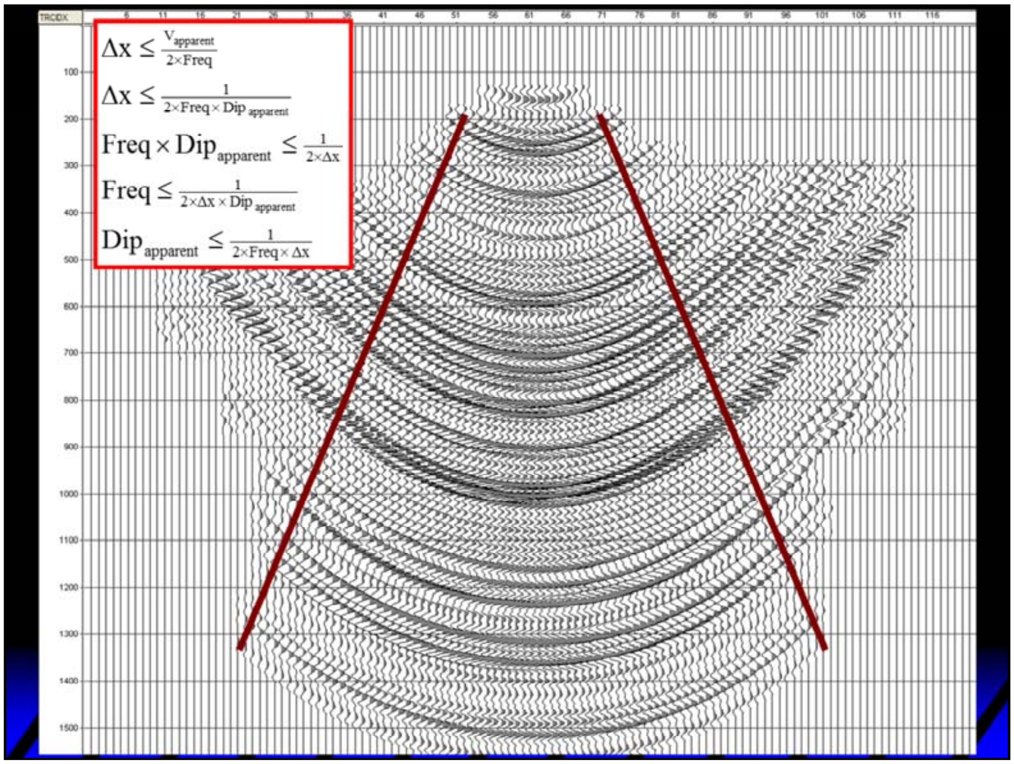
For this data set, we have drawn the Anti-Alias limit on the migration operator. To the left, data will be correctly migrated. To the right, erroneous dips will be migrated.



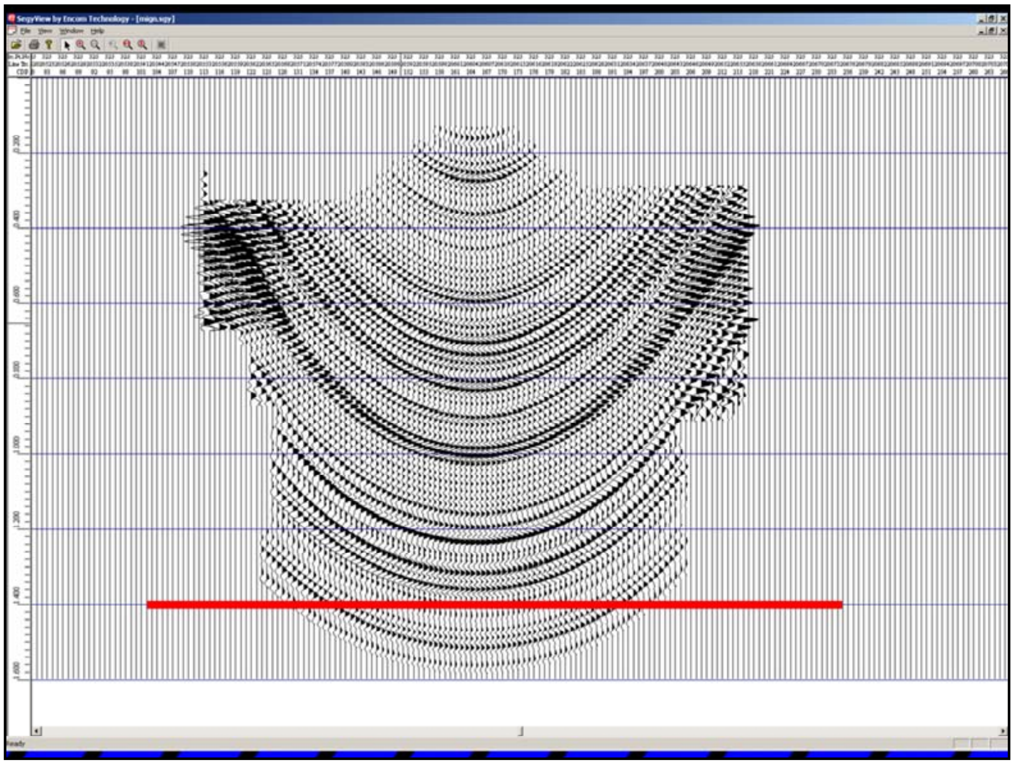
This is the same data set as the previous slide, but sampled with twice as many traces. That is, the trace spacing has been reduced to one half of that in the previous slide. Notice that we are able to successfully migrate higher frequencies to stronger dips.



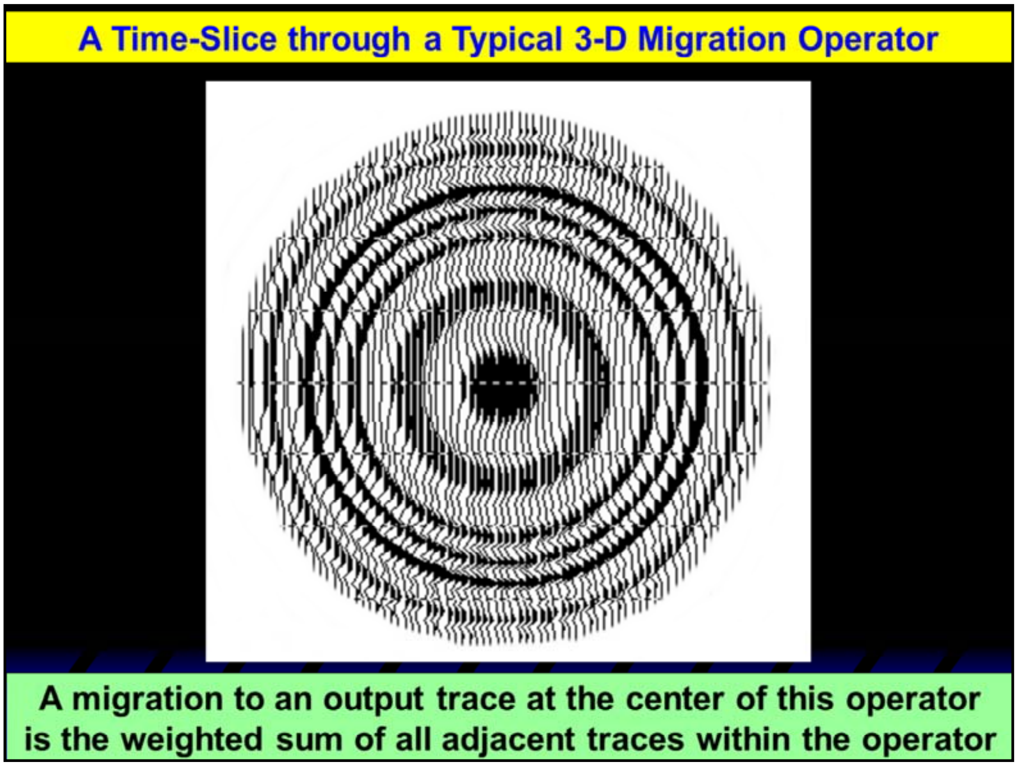
Here is the full operator, sparsely sampled, showing an approximate Anti-Alias limiting function (brown lines).



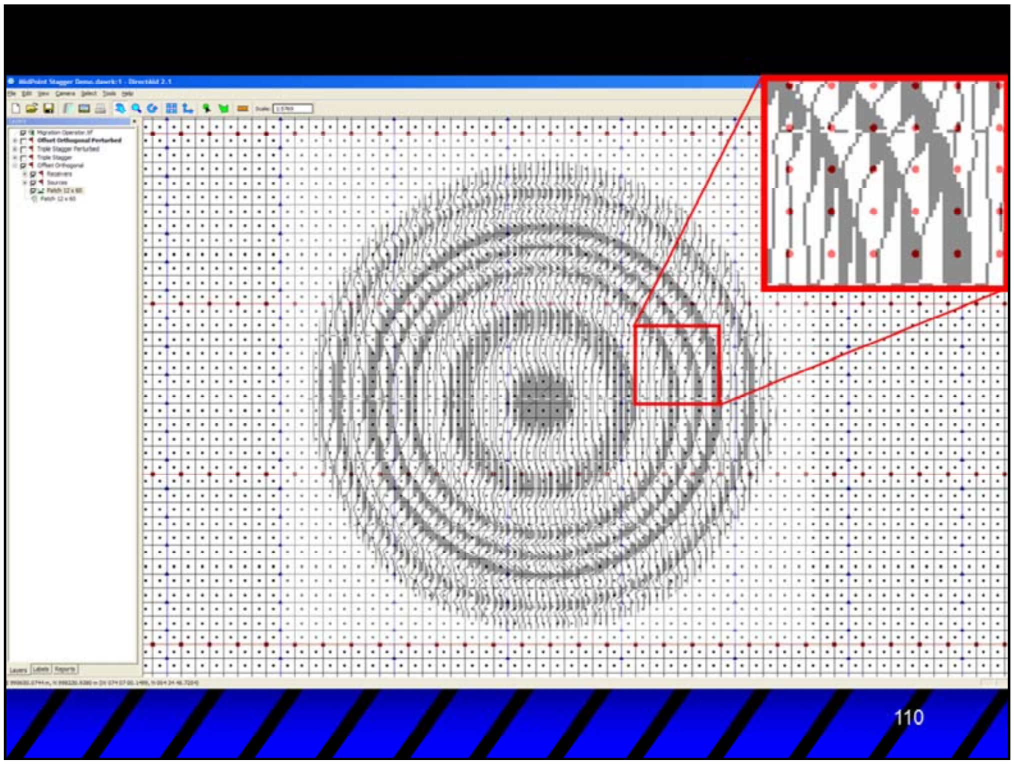
Here is the same operator, but sampled with a smaller trace spacing. Notice how the anti alias limit embraces higher frequencies migrated to stronger dips. The Nyquist equation for apparent wavelengths demonstrates the same concepts mathematically.



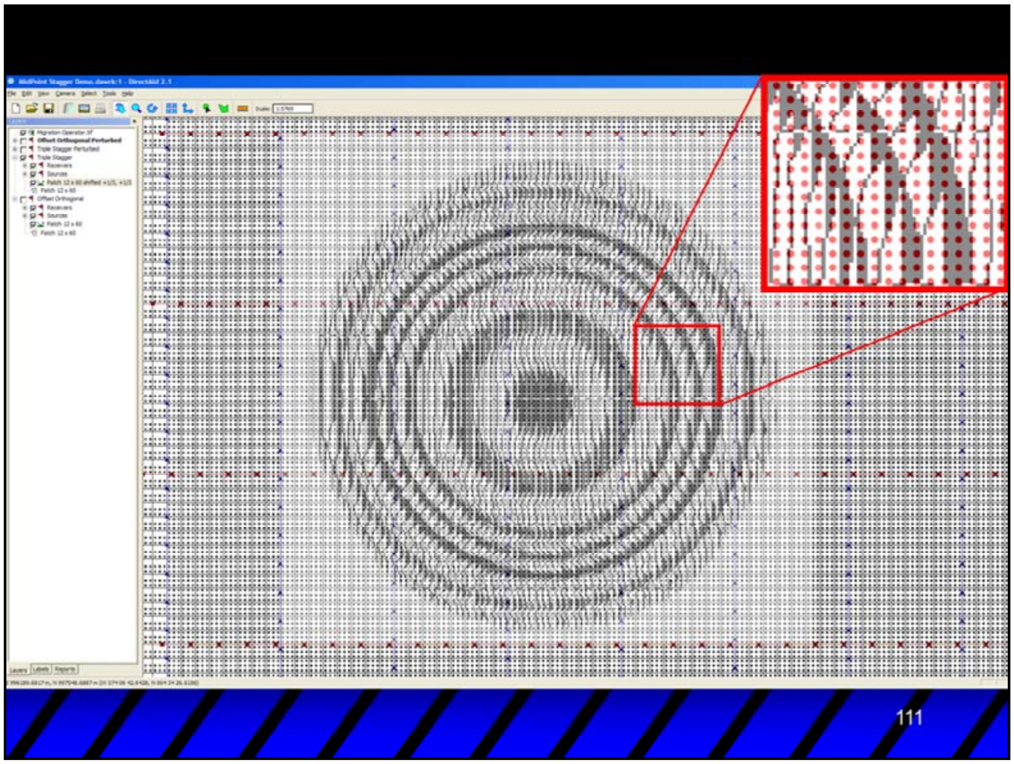
Now imagine a time slice of a full 3D operator. The full time slice might look like the following diagram.



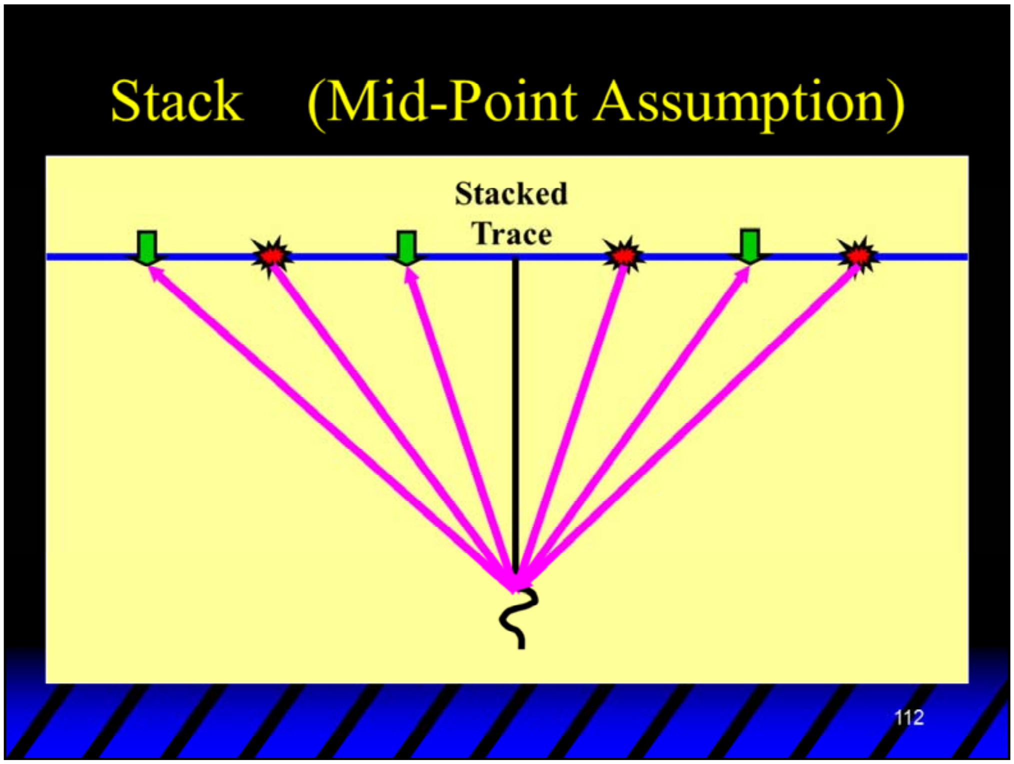
Appreciate that migration can be regarded as the weighted sum of all points within a "Migration Operator" The weighting function has a spatial wavelength related to the bandwidth of the data and the apparent dips.

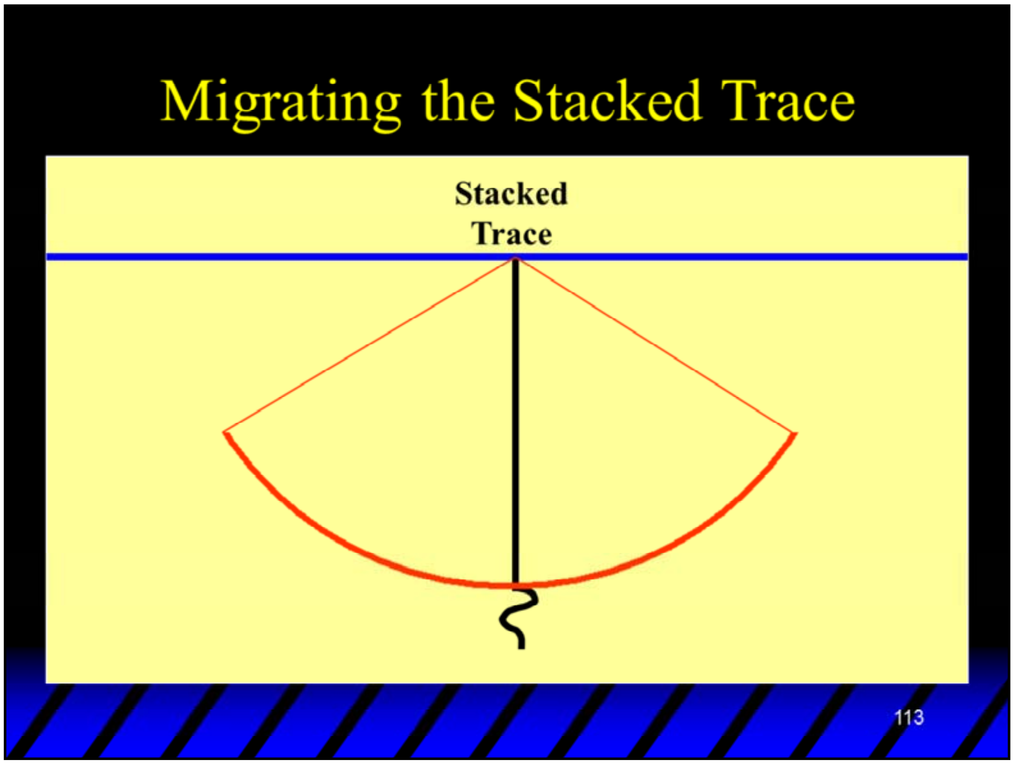


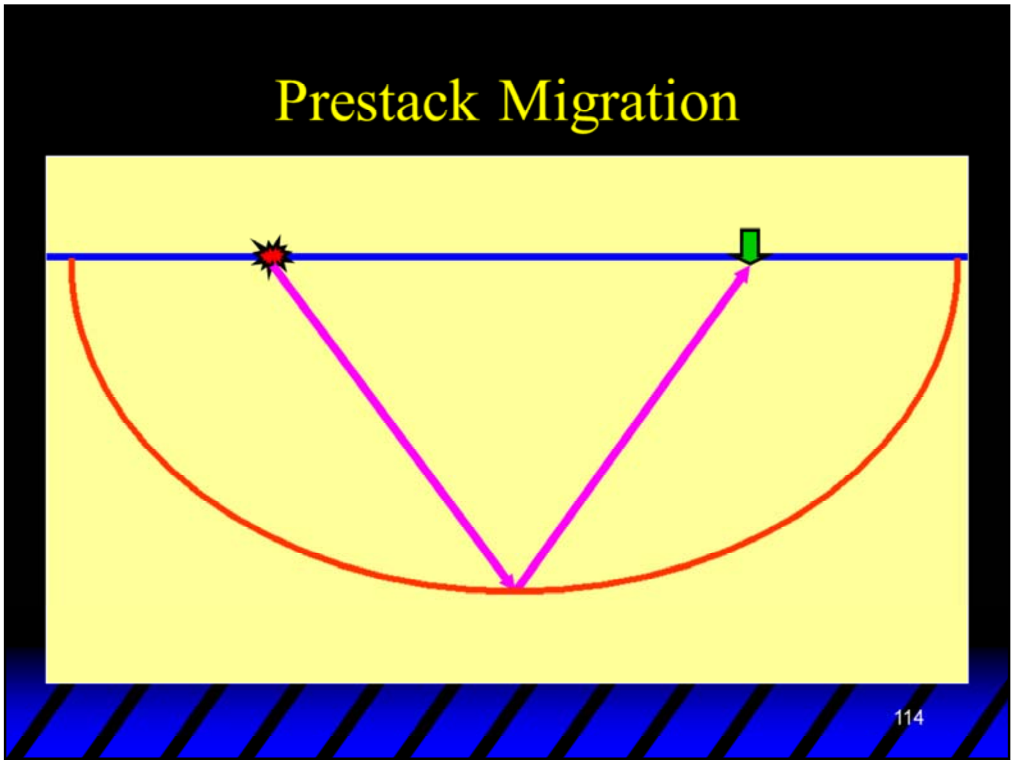
This migration operator has an aperture (radius) of about 480 meters, corresponding to a very shallow reflector. The model is a normal orthogonal with no forced midpoint scatter. Note that we have traces represented by mid-point indexes separated by the natural bin size. Notice that some of the shorter apparent wavelengths (resulting from migration of higher frequencies) are sampled by less than two traces per wavelength. This represents an aliased part of the operator and it will not be included in the migration.

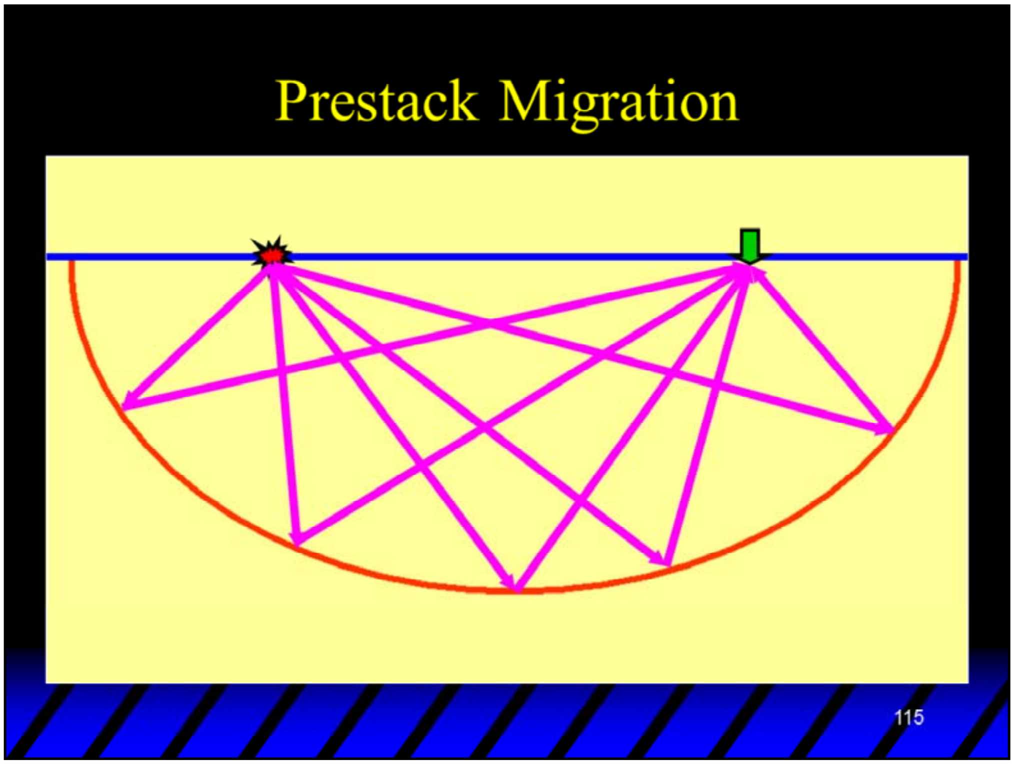


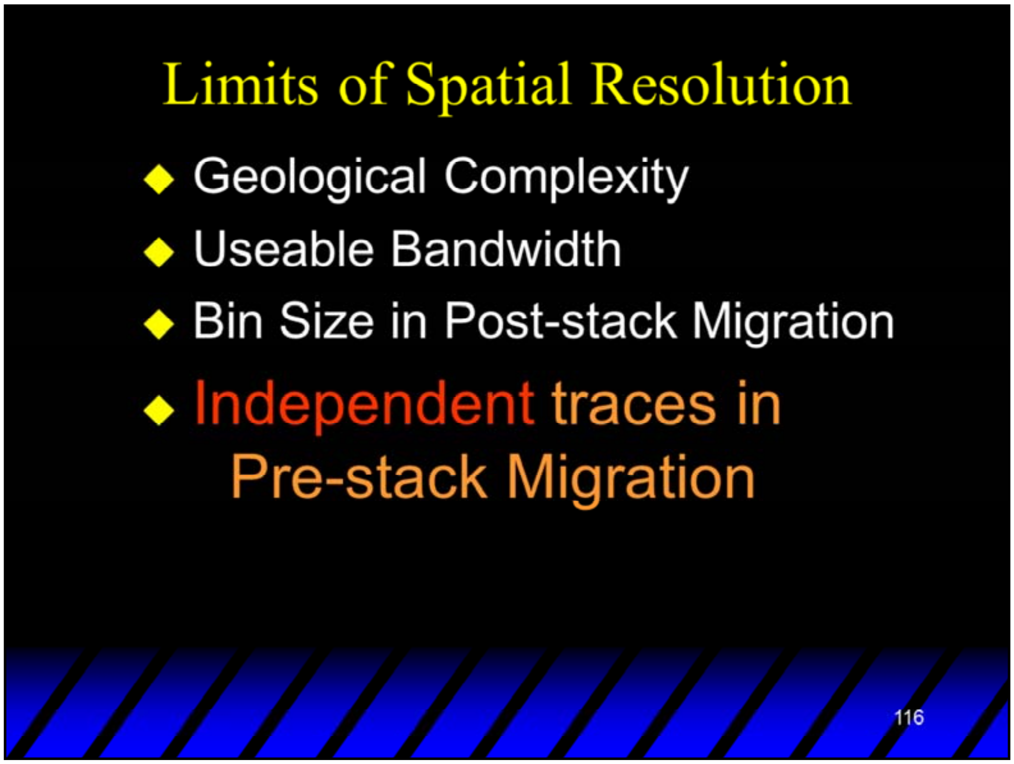
This model is a tiple-staggered orthogonal with a 3x3 forced midpoint scatter. This provides the opportunity for sub-binning at the time of pre-stack migration and therefore better spatial sampling of the migration operator. Notice the improved sampling of peaks and troughs such that there is always more than two samples per wavelength. Higher frequencies and steeper dips will be preserved.

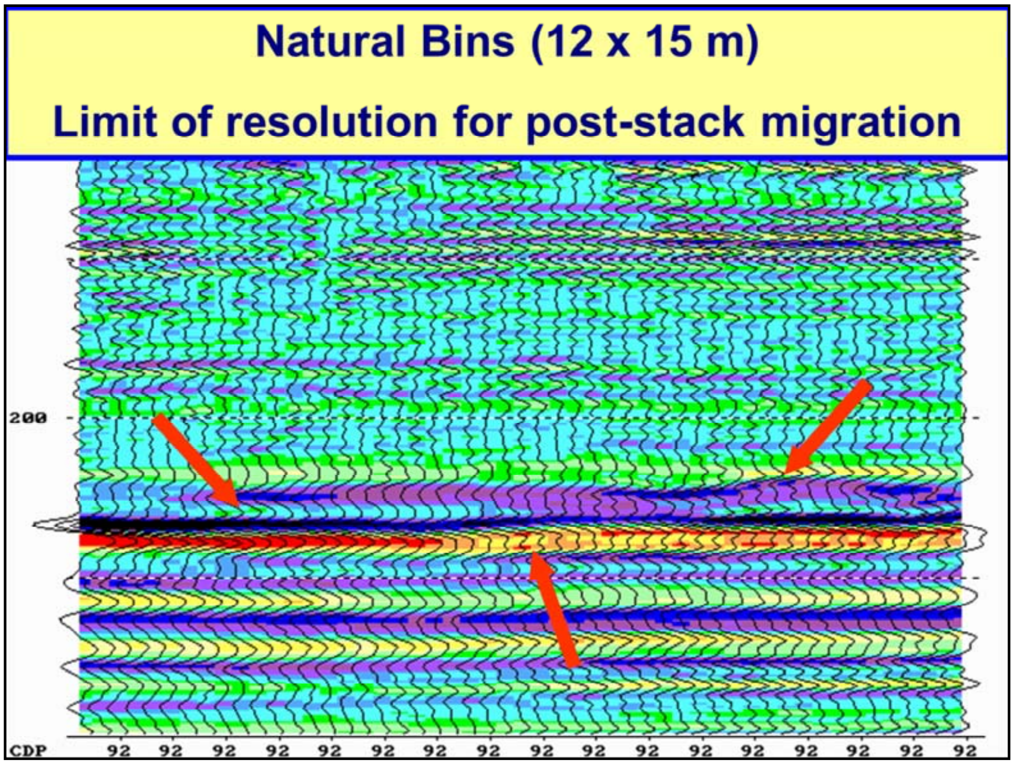

Stack (Mid-Point Assumption)
Stacked
Trace
112


Migrating the Stacked Trace
Stacked
Trace
113

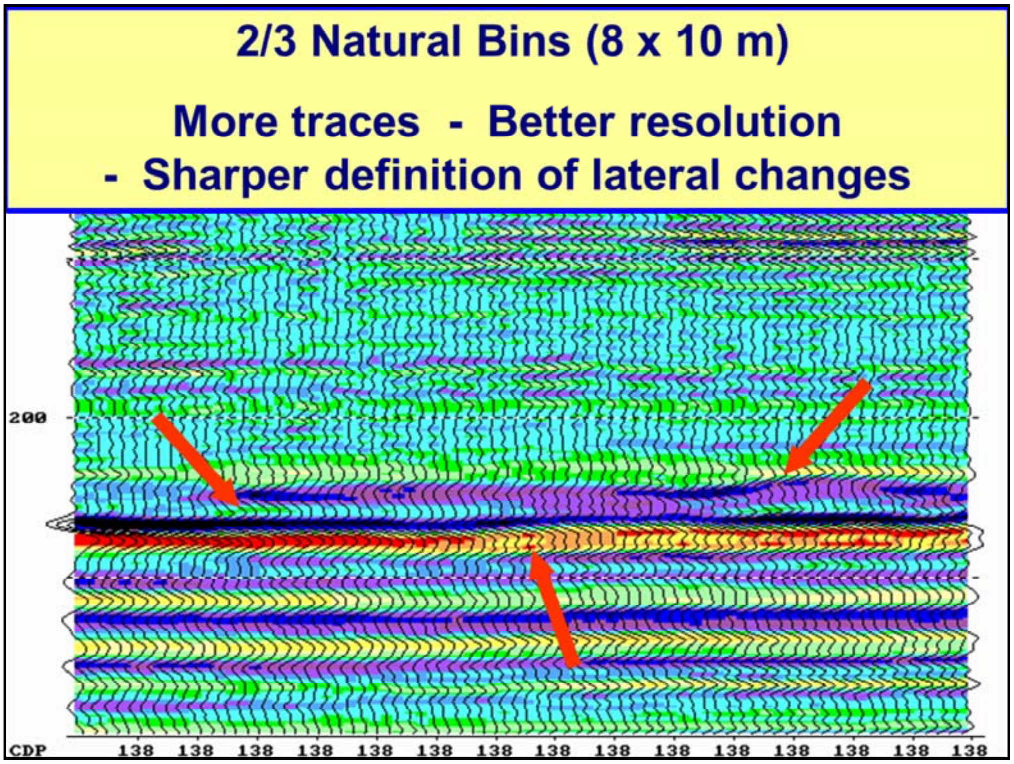

Prestack Migration
114


Prestack Migration
115

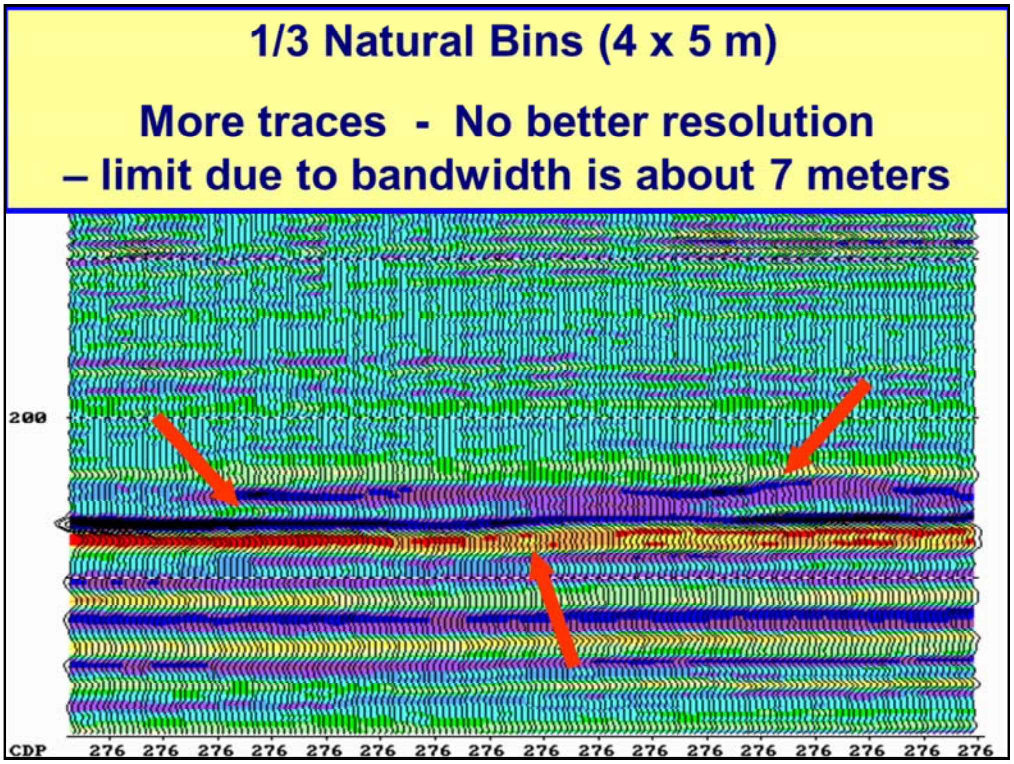

Limits of Spatial Resolution
Geological Complexity
Useable Bandwidth
Bin Size in Post-stack Migration
Independent traces in Pre-stack Migration
116



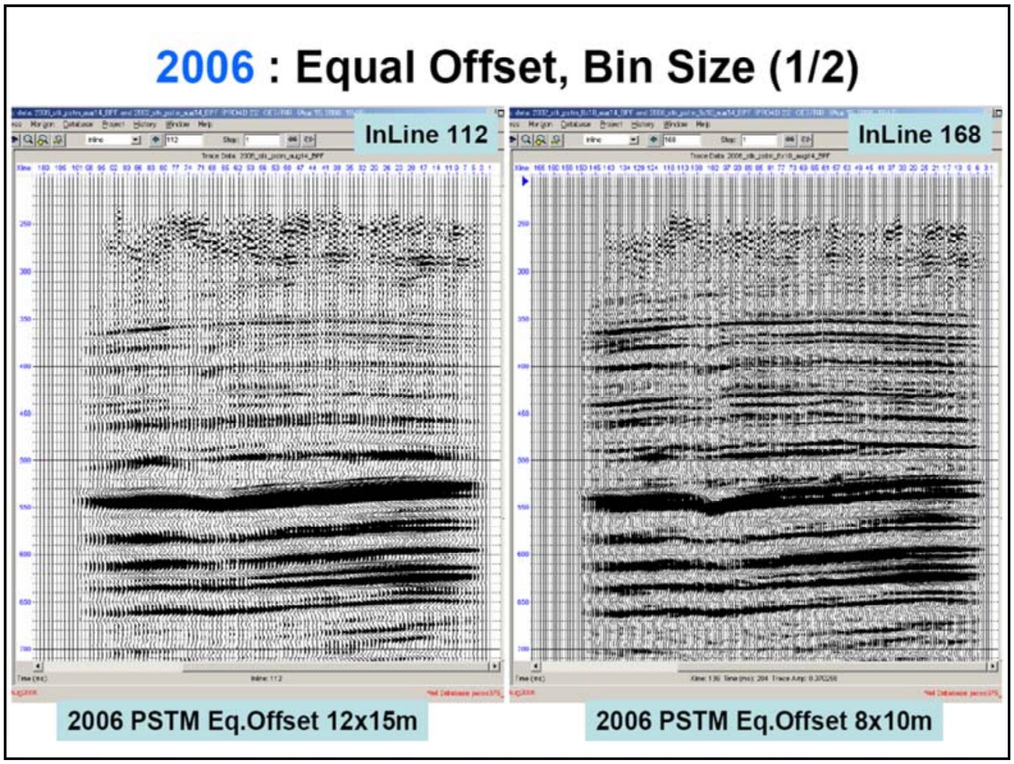
The area on the right is a SAGD project where two pairs of horizontal wells have intersected the plane of section perpendicular to the plane presented. The heat from these SAGD pairs causes an apparent thickening in time of the reservoir (indicated by the right arrow) due to a slowing of velocity in heated sandstone reservoirs. In this in-line display, the final output trace spacing of the PSTM operator was set to 12 meters. This is equal to the natural bin size for the survey and is consistent with the results expected from a post-stack migration of data stacked in natural bins. Just to the left of the right-hand arrow, we expect a change in temperature (and interval velocity) that occurs over a distance of a few meters. Note the rate of change in this 12-meter output of PSTM.



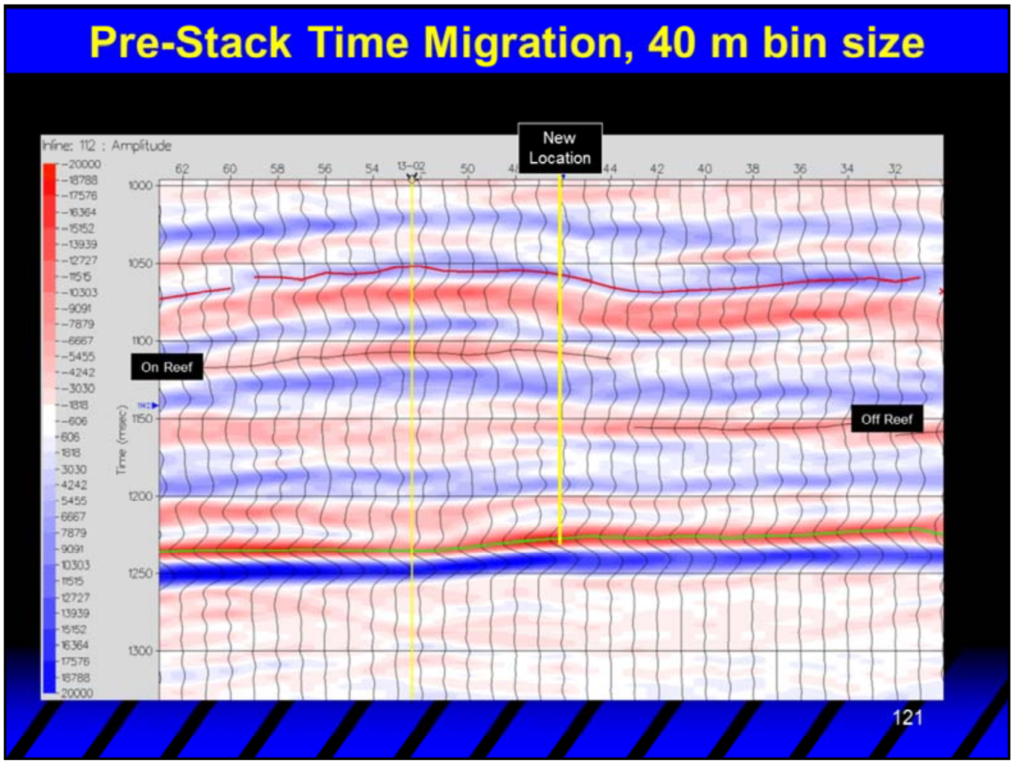
This is the same input data but with a PSTM output spacing of 2/3 natural bins (8 meters in this in-line section). Note the increase of real resolution on the edge of the steam chamber.



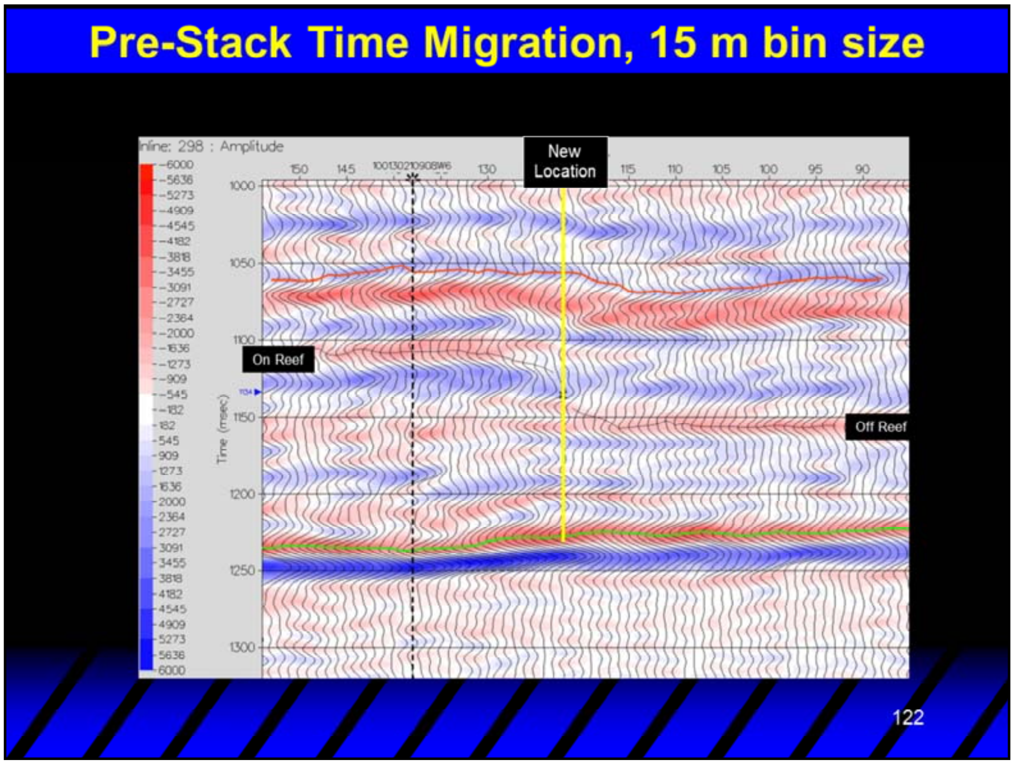
This is the same input data but with a PSTM output spacing of 1/3 natural bins (4 meters in this in-line section). Note the lack of increase of real resolution on the edge of the steam chamber. This looks more like the added traces are just interpolations of the traces in the previous slide. The theoretical limit of spatial resolution for this data is $\lambda/2 = V / 2F$. For this area, V = 2200 m/s and Fmax is about 160 Hz, so $V / 2F$ is about 7 meters. This explains why we fail to see any real increase in resolution when we create migrated traces at 4 meters outputs. In other areas (with better surface conditions), we are able to recover up to 240 Hz and then we see real increased resolution when migrating to 4-meter output bins. However, we have not seen the same results when starting with natural bins of 12 meters where the design does not provide mid-point scattering.



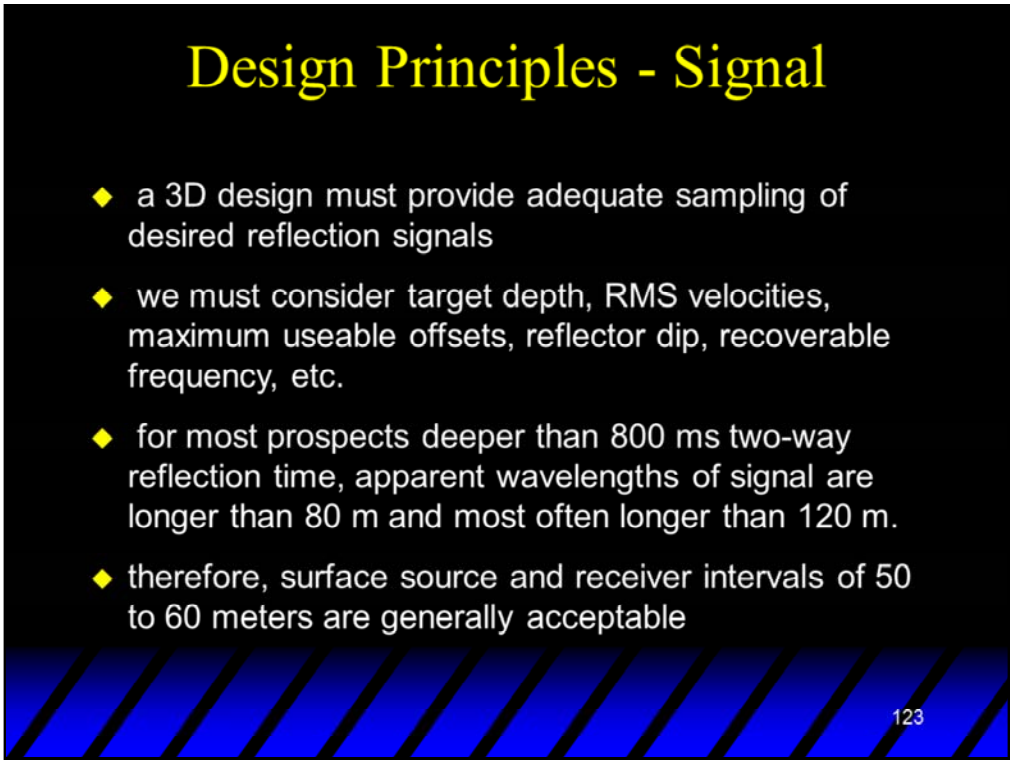
This is another example for a more recent data set of the increased resolution through mid-point scatter and PSTM. The in-line numbers are different (due to the revised output grid), but the lines are in the same physical location. There are differences in amplitude scaling that the processor has not yet resolved. But the difference in horizontal resolution and migrated frequency content is evident. Again, we have not seen the same results when non-scattered surveys are evaluated.



In this Keg-River reef test, an existing gas well (13-2) confirmed a lagoonal facies of an atoll reef buildup. A well was drilled in an attempt to test the interpreted rim-margin of the atoll. Unfortunately the well was picked on an interpretation based on a PSTM of the data where the trace spacing was assumed to be the natural bin size. It missed the face of the reef and encountered a partial build-up of the debris shield that lies over the platform (off reef) at the base of the reef rim. The well was then whip-stocked to a location about 50 meters to the left of the "new location" and encountered a full reef-rim build up. Unfortunately, due to poor hole conditions, the engineers were unable to get a good cement job behind casing and the well was abandoned (even though it had proven reservoir and production capability far in excess of the original well location).

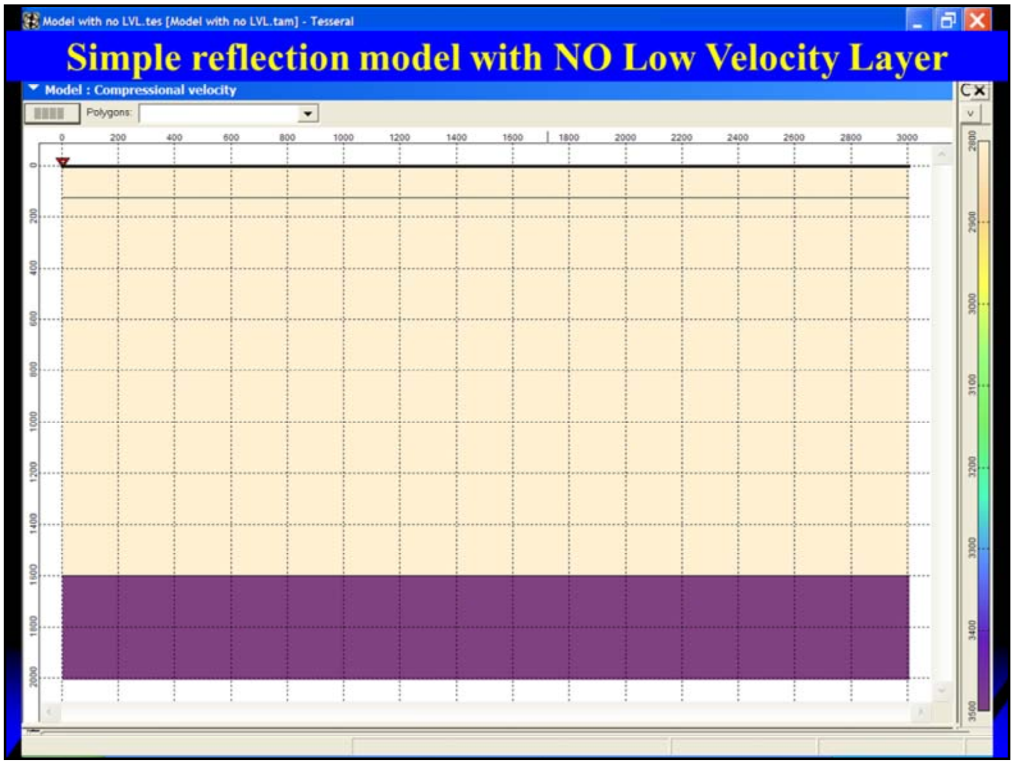


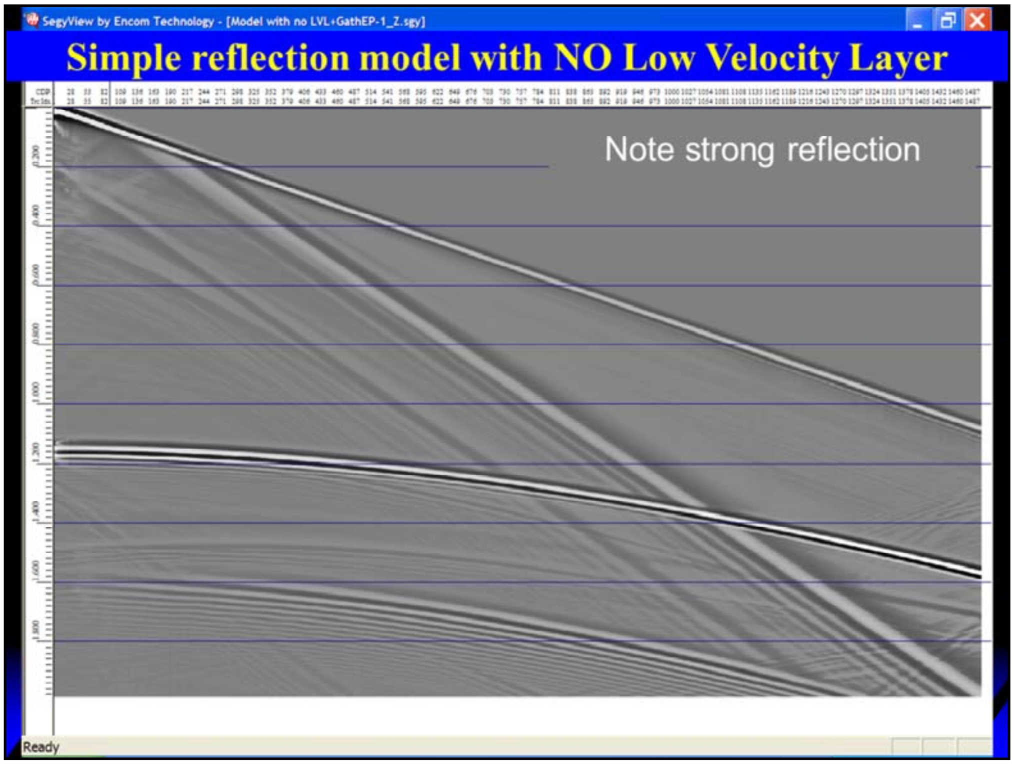
After the fact, the data volume was recognized as having been designed with intentional mid-point scatter and was re-migrated to a smaller bin size more commensurate with the anticipated potential lateral resolution (V/2F). In this result (please disregard the interpreter's pencil line near the top of the reef), it is clear that the reef rim is evidenced by the four traces with a strong trough just below 1100 ms and just to the left of the yellow line (the original location of the new well). With this image, the correct location could have been selected some 50 meters to the left and, with a clean entry into the reef, it is likely the well could have been completed.

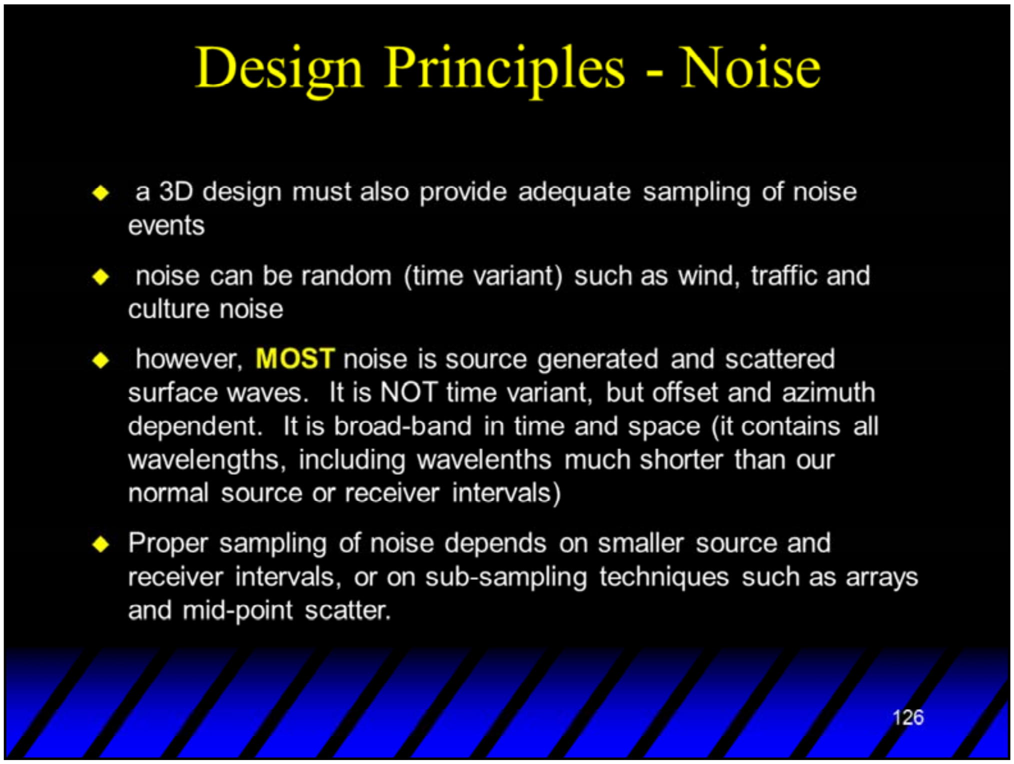


The wide-spread promotion of the concept of flexible binning during the 1990's led to many mis-understandings and mis-conceptions about the benefits of mid-point scatter.

Many of these mis-conceptions prevail today.

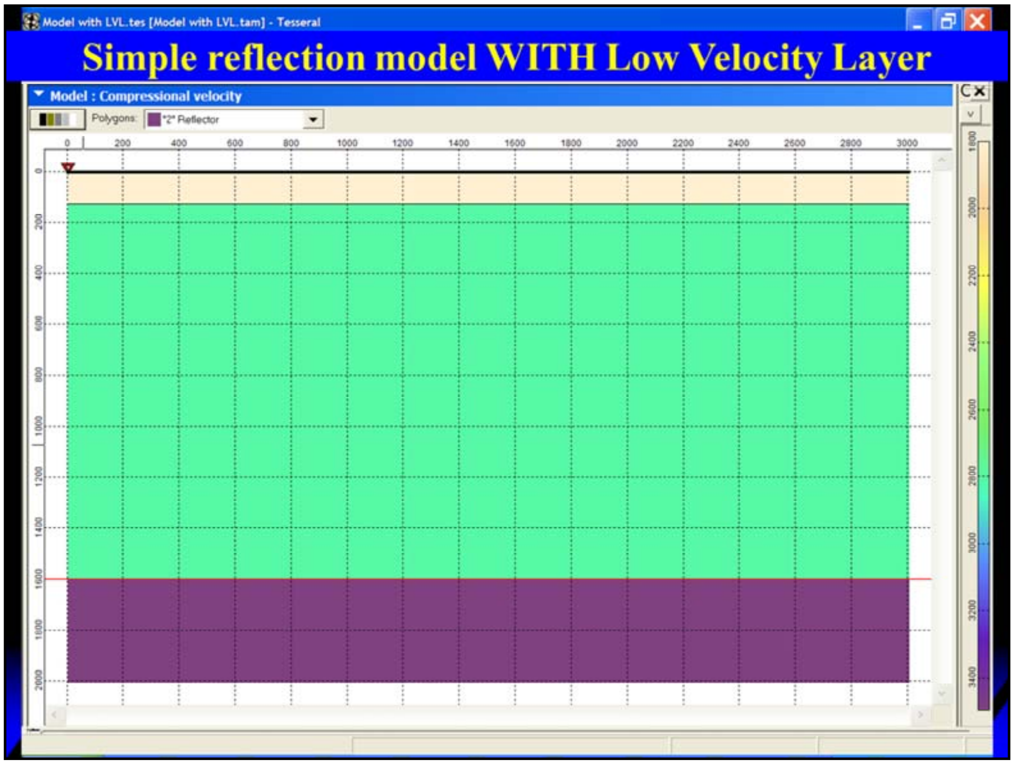

Model with no LVL.tes [Model with no LVL.tam] - Tesseral
Simple reflection model with NO Low Velocity Layer
Model : Compressional velocity
Polygons:
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
2800 2900 3000 3100 3200 3300 3400 3500


SegyView by Encom Technology - [Model with no LVL+GathEP-1_Z.sgy]
Simple reflection model with NO Low Velocity Layer
Note strong reflection
Ready

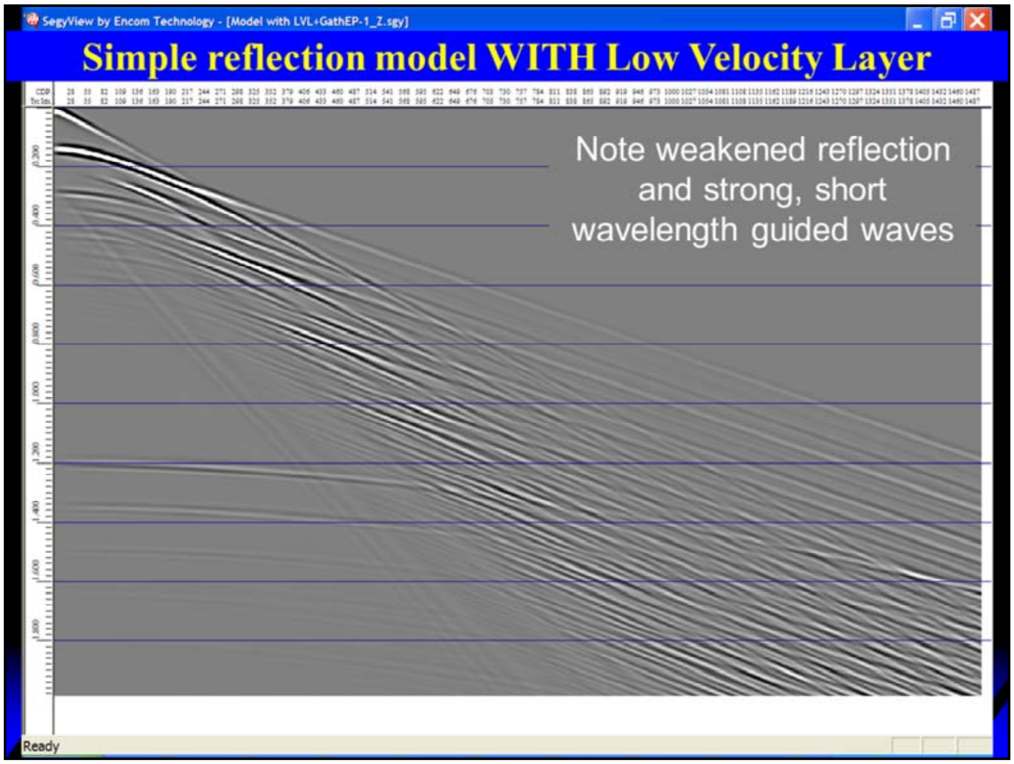


The wide-spread promotion of the concept of flexible binning during the 1990’s led to many mis-understandings and mis-conceptions about the benefits of mid-point scatter.

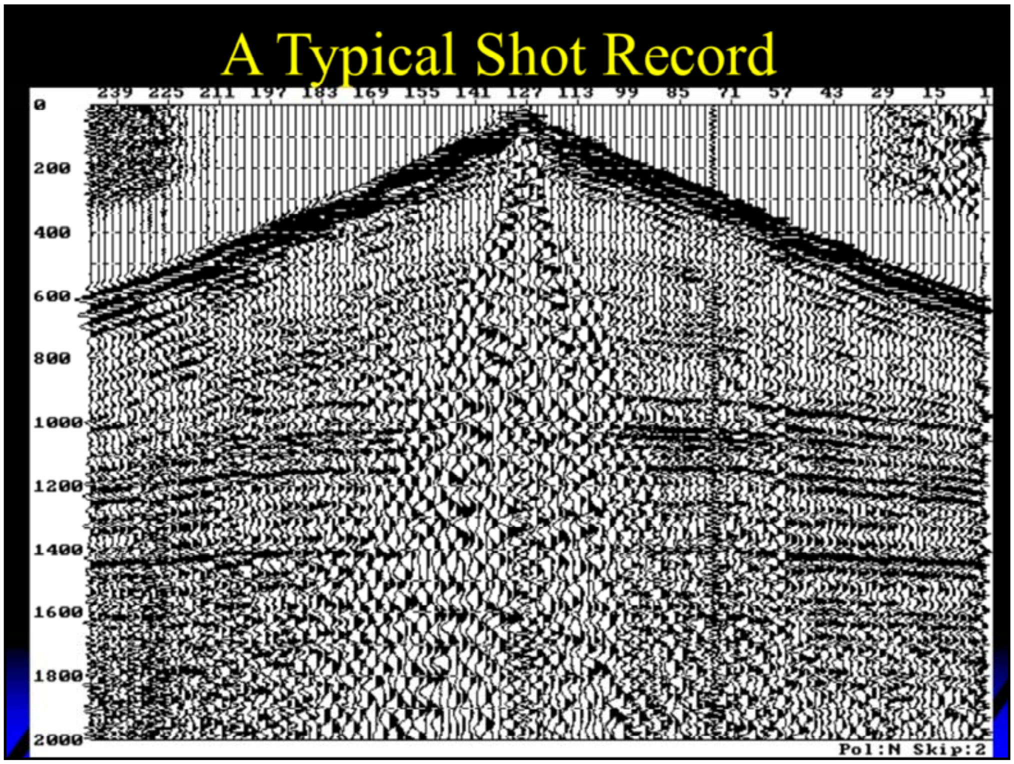
Many of these mis-conceptions prevail today.

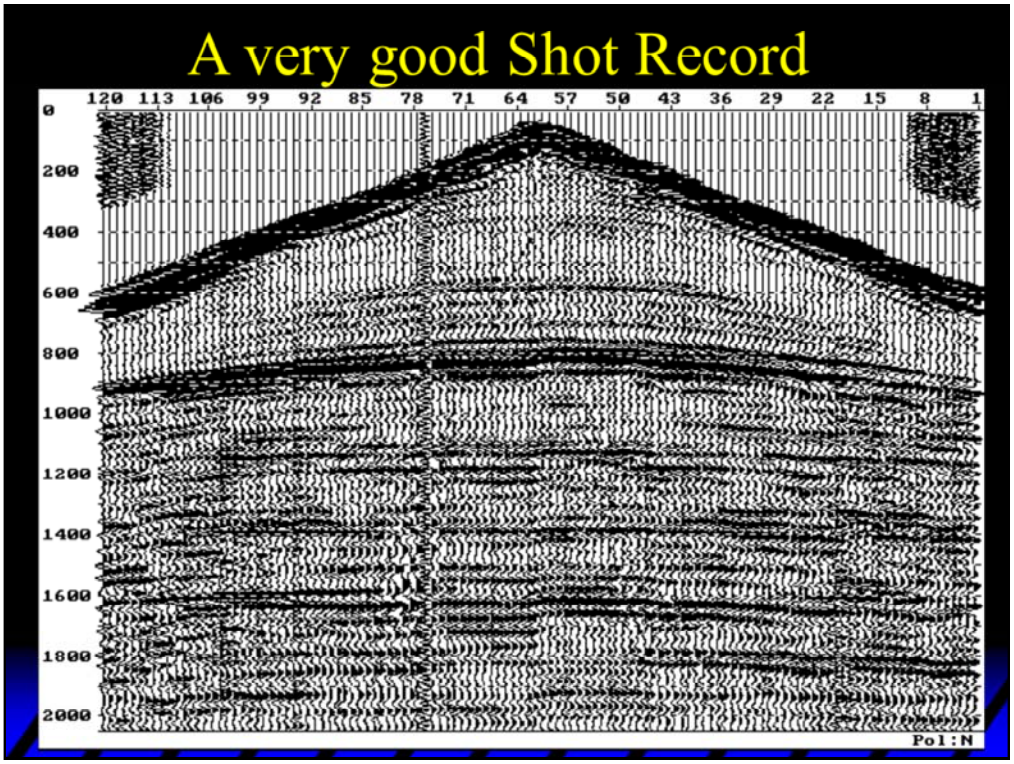


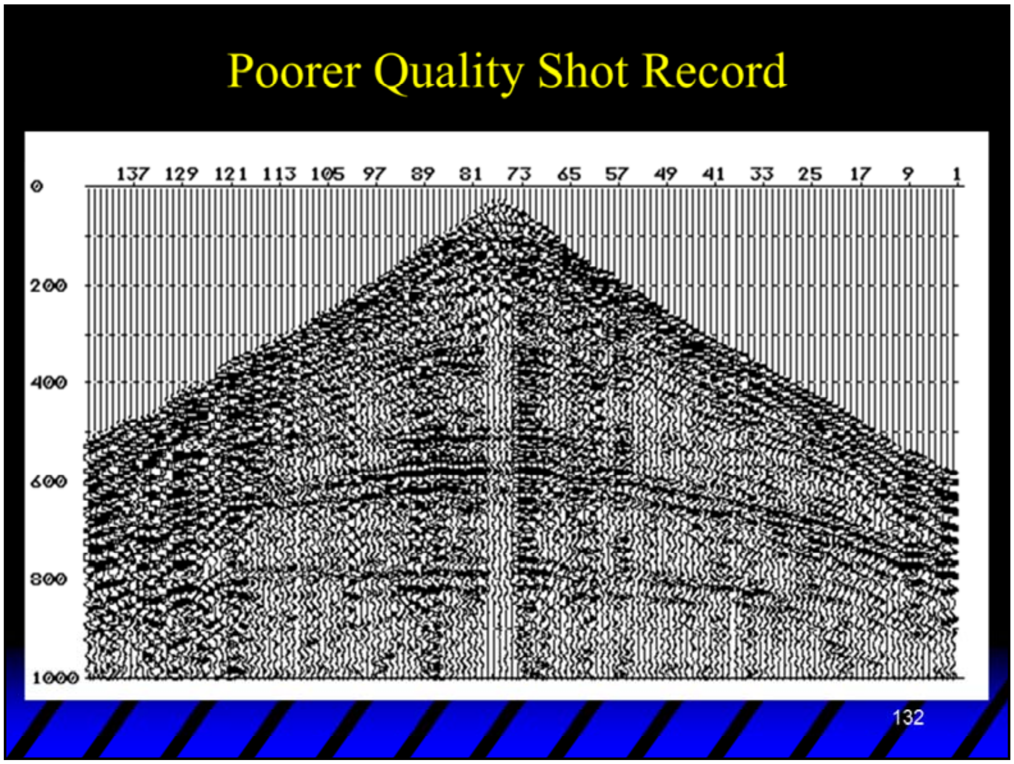
Model with LVL.tes [Model with LVL.tam] - Tesseral
Simple reflection model WITH Low Velocity Layer
Model : Compressional velocity
Polygons:
"2" Reflector

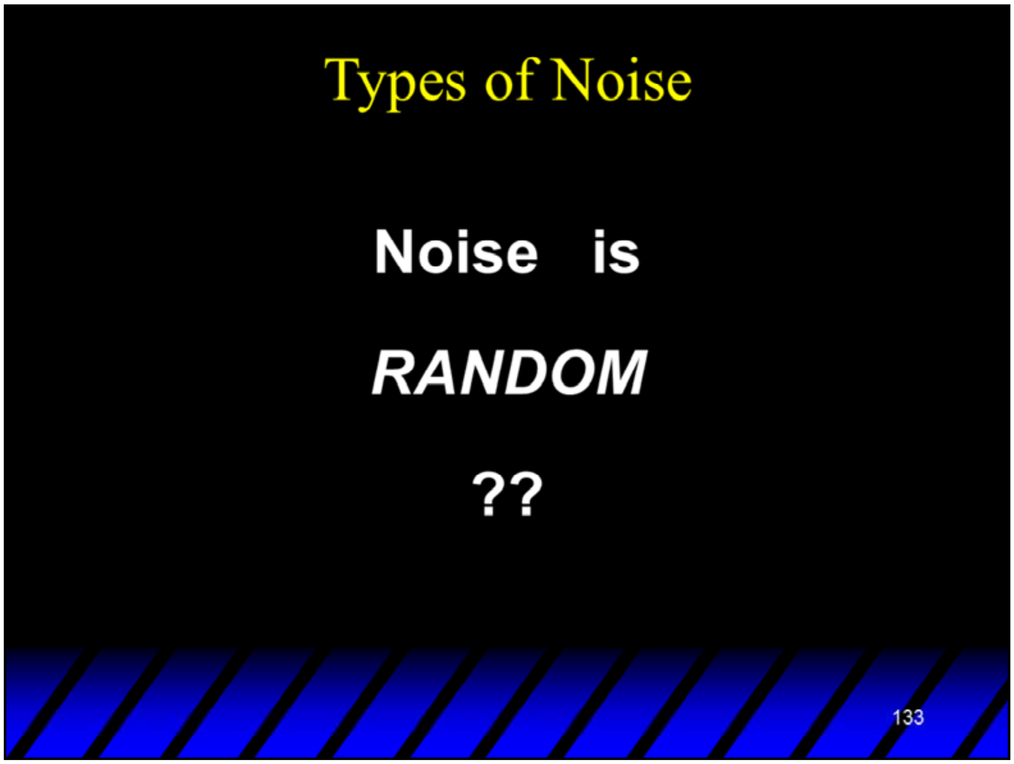

SegyView by Encom Technology - [Model with LVL+GathEP-1_Z.sgy]
Simple reflection model WITH Low Velocity Layer
Note weakened reflection and strong, short wavelength guided waves
Ready

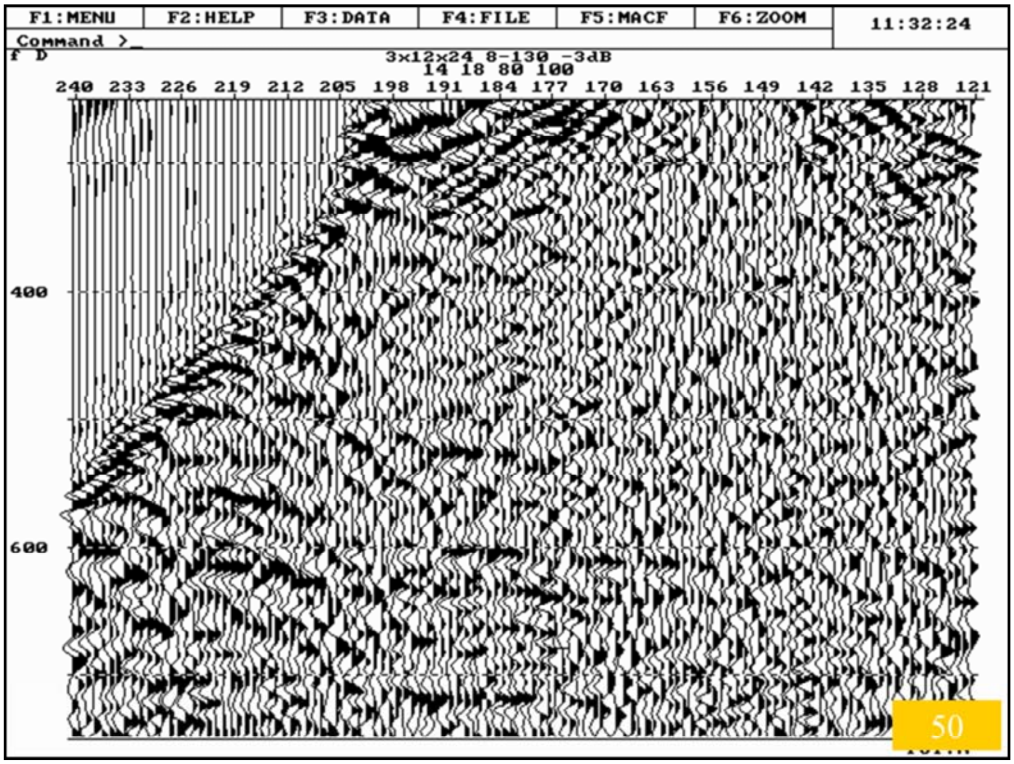

More on Noise
129

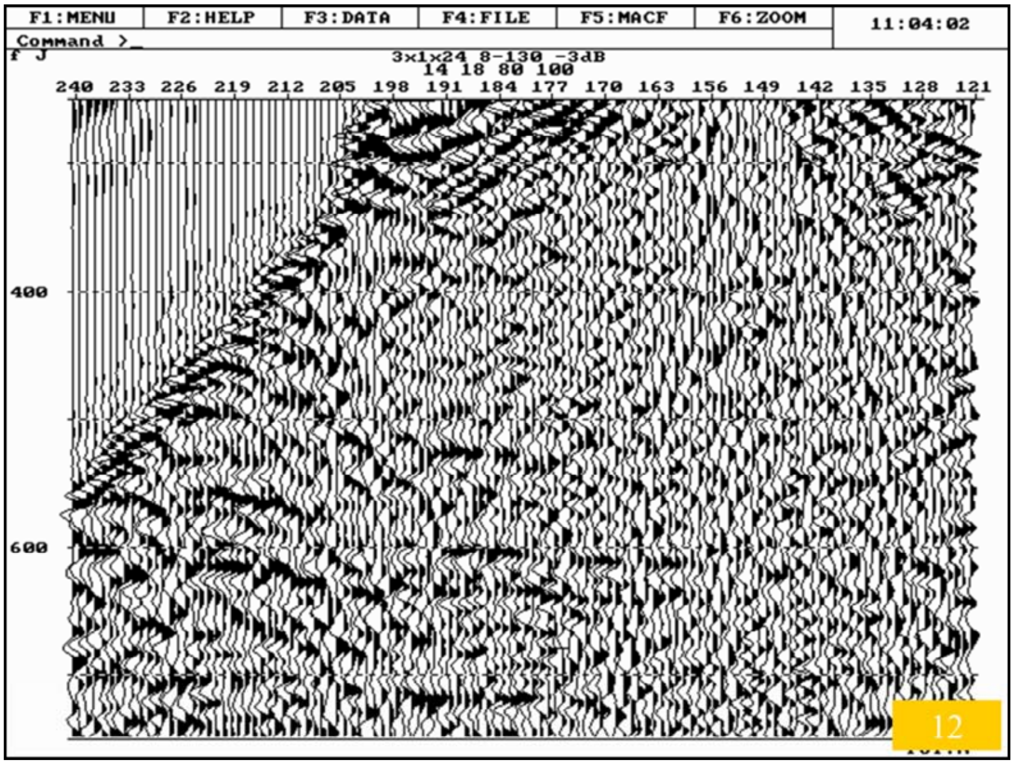

A Typical Shot Record
239 225 211 197 183 169 155 141 127 113 99 85 71 57 43 29 15 1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Pol:N Skip:2

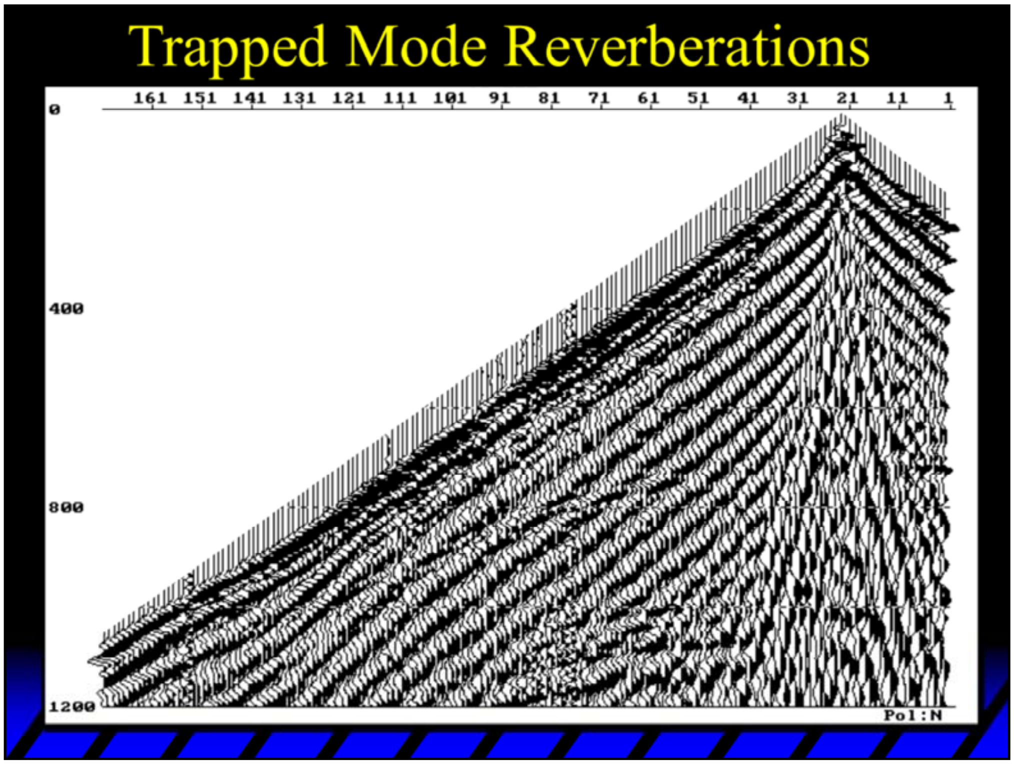

A very good Shot Record
120 113 106 99 92 85 78 71 64 57 50 43 36 29 22 15 8 1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Pol:N

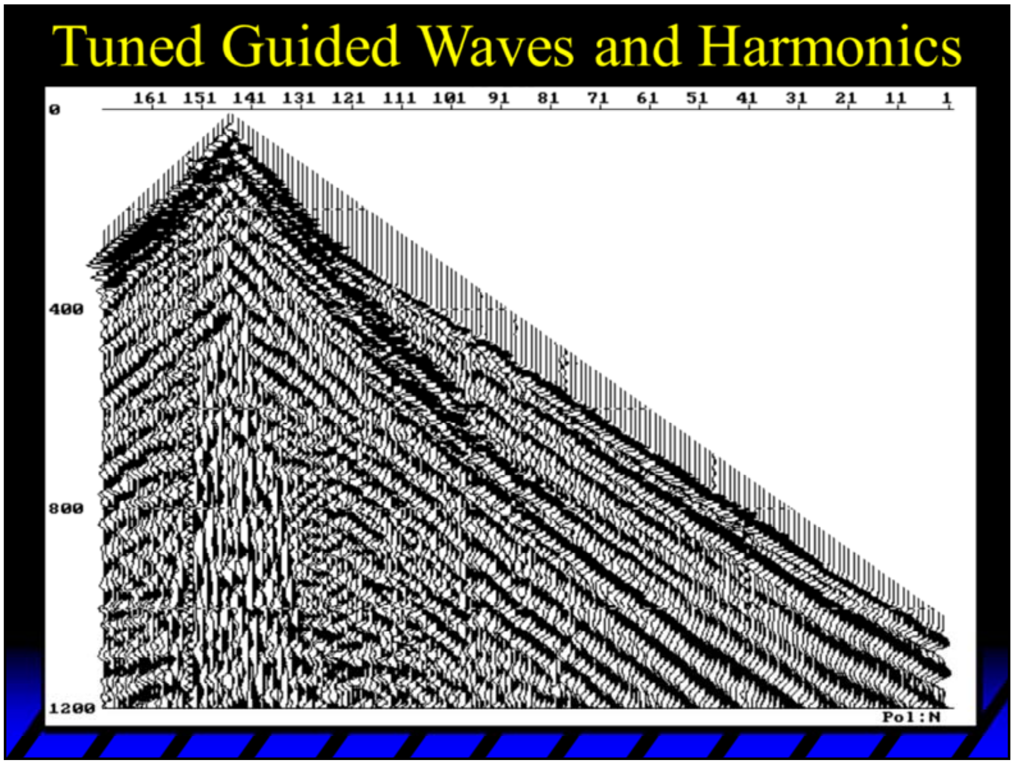

Poorer Quality Shot Record
137 129 121 113 105 97 89 81 73 65 57 49 41 33 25 17 9 1
0
200
400
600
800
1000
132


Types of Noise
Noise is
RANDOM
??
133

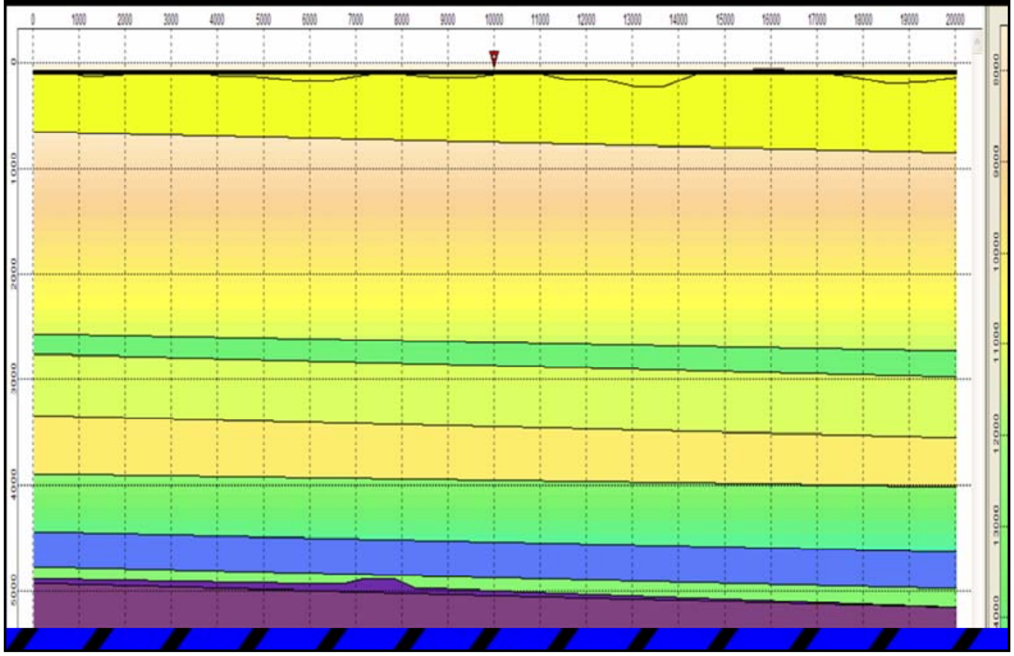

F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
11:32:24
Command >_
f D
3x12x24 8-130 -3dB
14 18 80 100
240 233 226 219 212 205 198 191 184 177 170 163 156 149 142 135 128 121
400
600
50

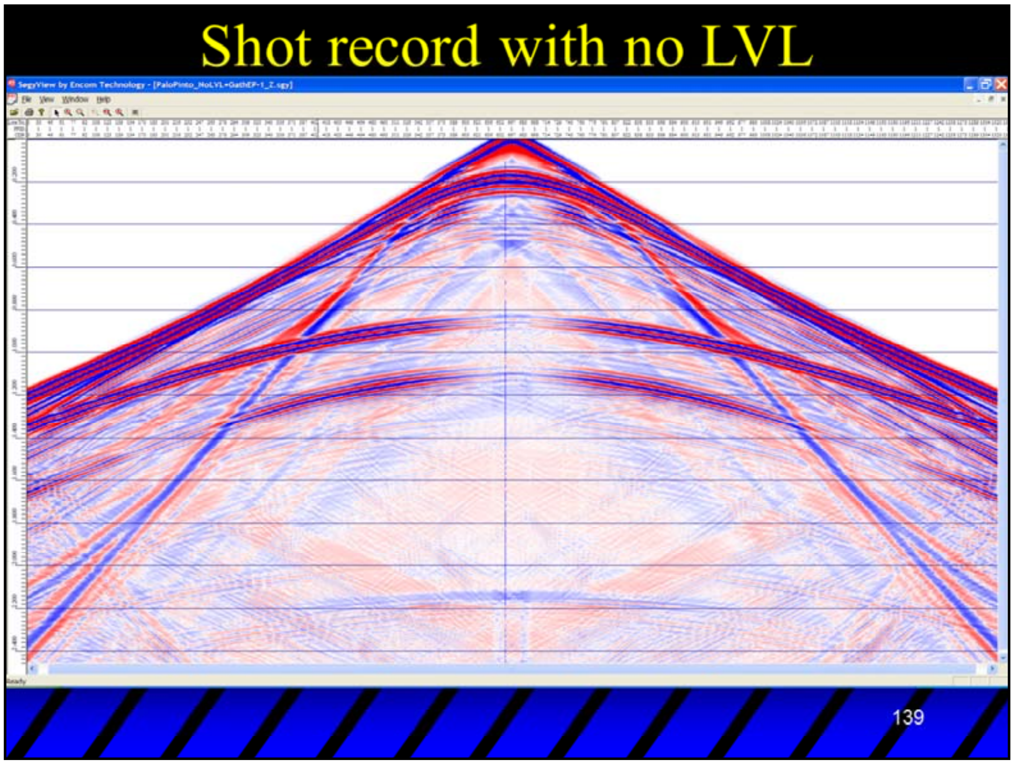

F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
11:04:02
Command >_
3x1x24 8-130 -3dB
14 18 80 100
240 233 226 219 212 205 198 191 184 177 170 163 156 149 142 135 128 121
400
600
12


Trapped Mode Reverberations
161 151 141 131 121 111 101 91 81 71 61 51 41 31 21 11 1
0
400
800
1200
Pol:N

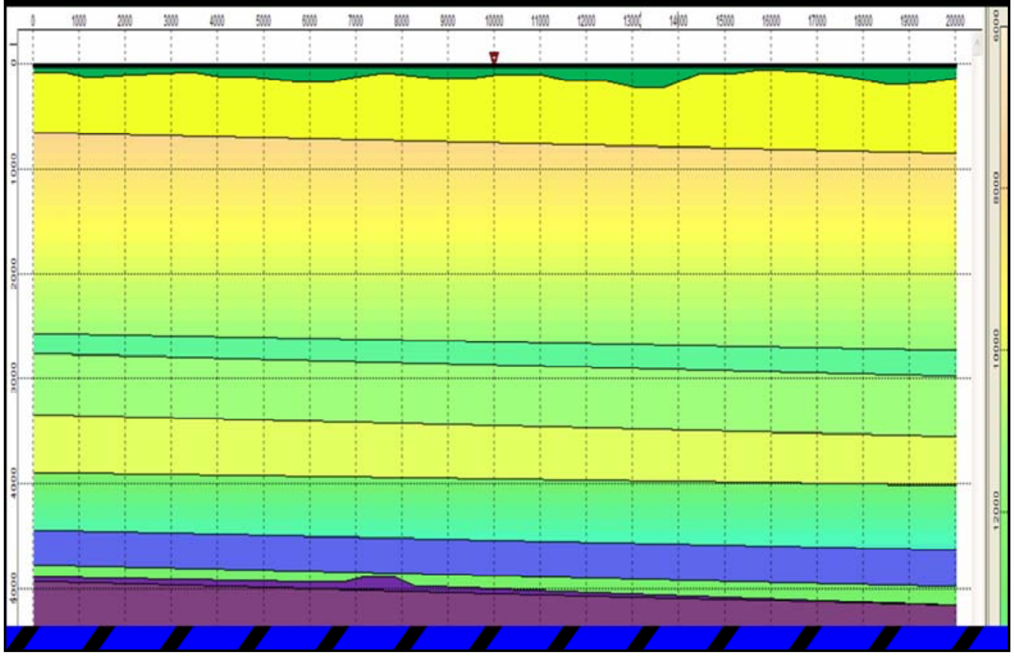

Tuned Guided Waves and Harmonics
161 151 141 131 121 111 101 91 81 71 61 51 41 31 21 11 1
0
400
800
1200
Pol:N

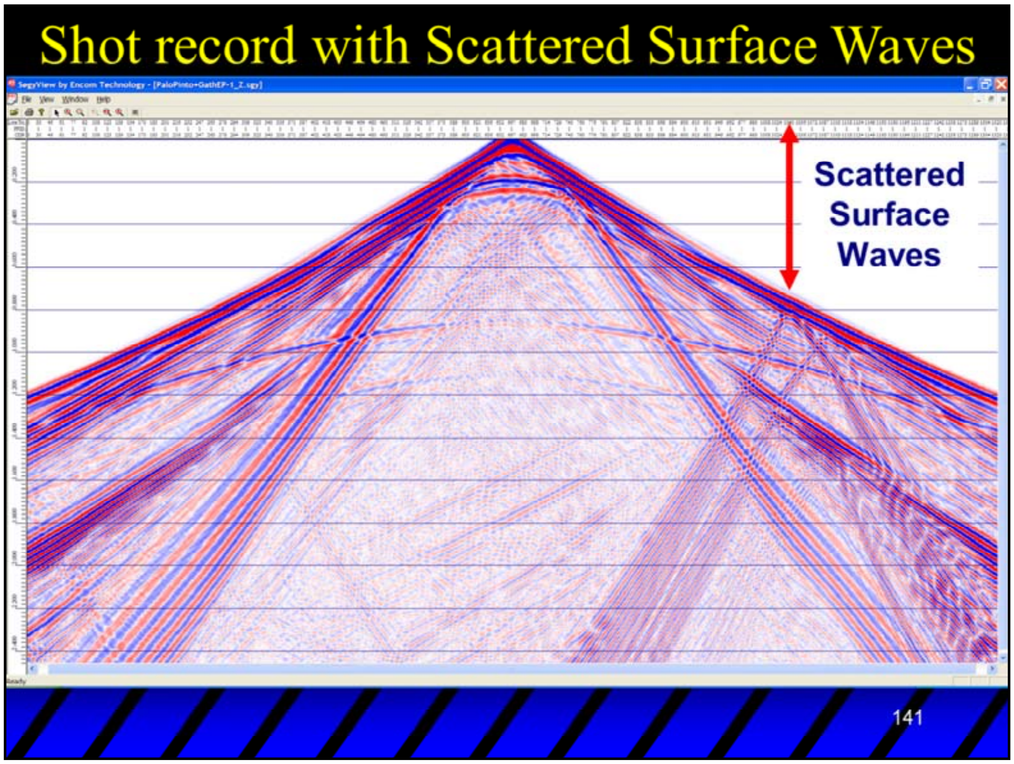
Model with no LVL

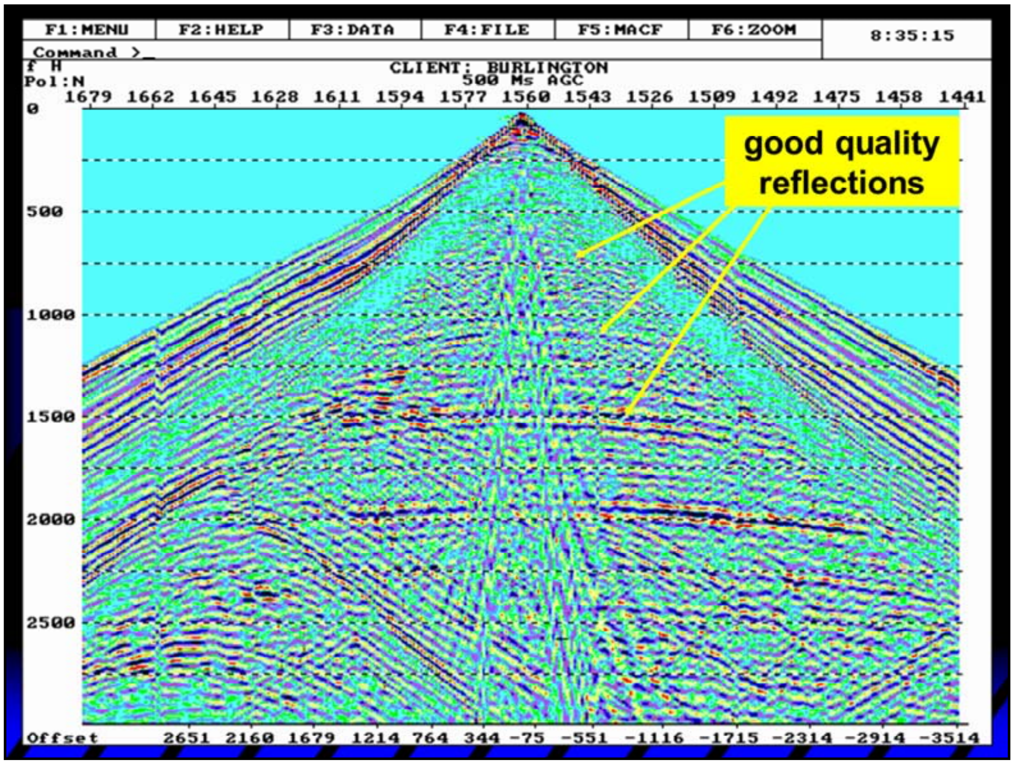



Shot record with no LVL
139

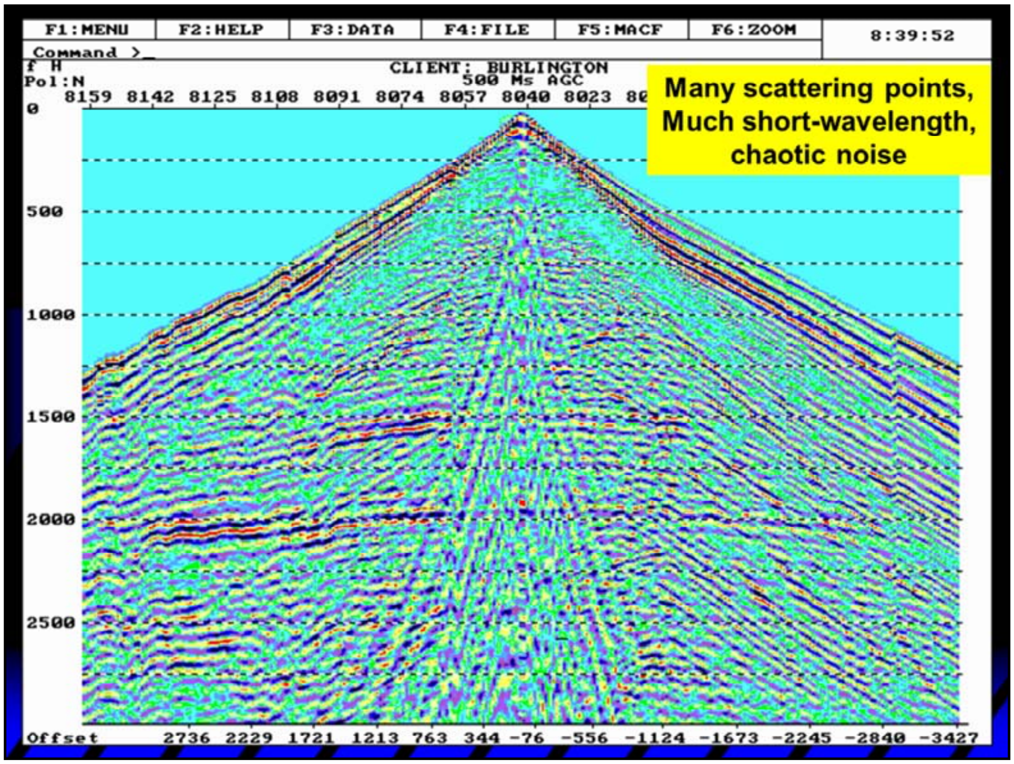
Model with LVL inhomogeneity



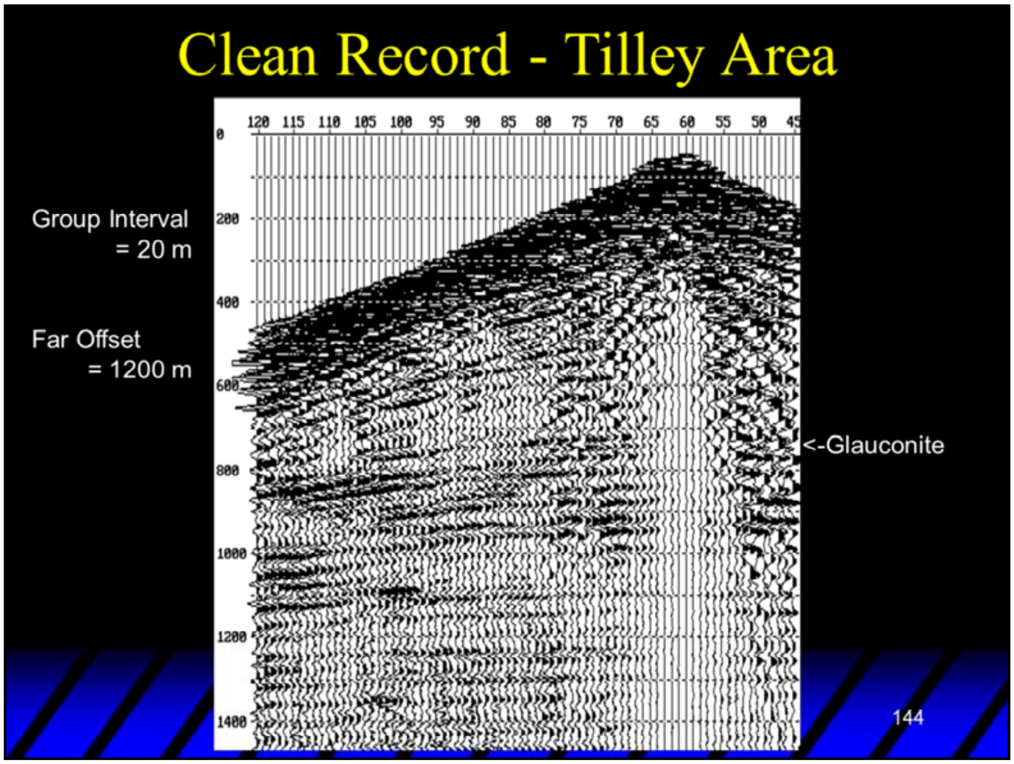

Shot record with Scattered Surface Waves
Scattered
Surface
Waves
141

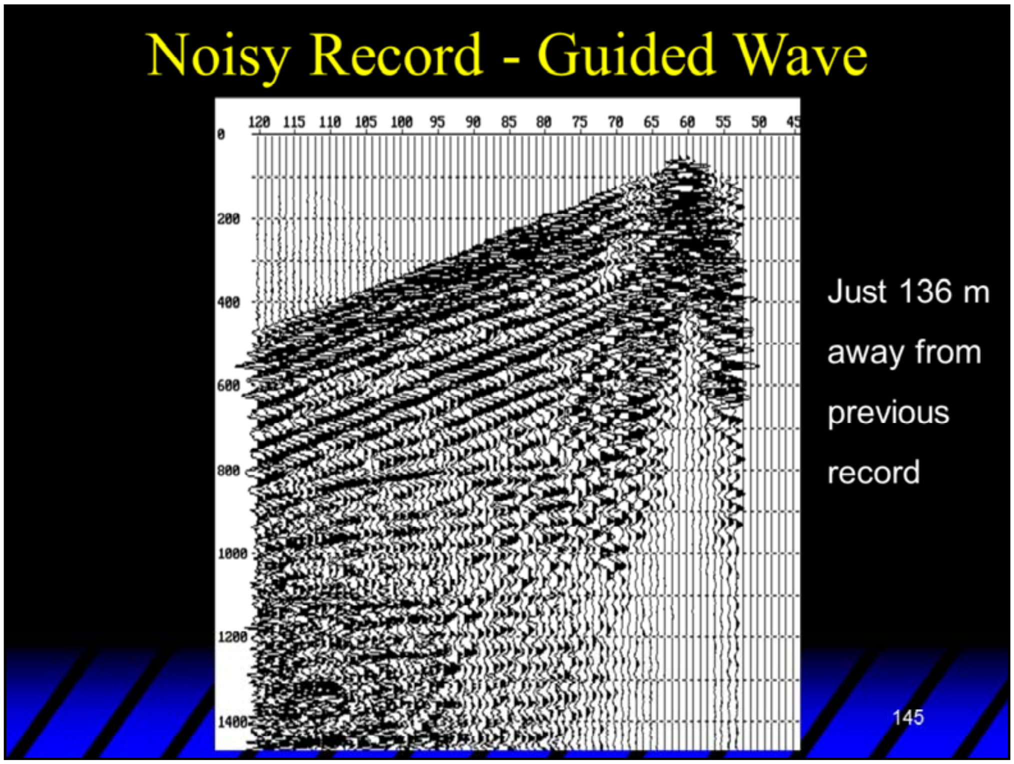


F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
8:35:15
Command >_
f H
Pol:N
CLIENT: BURLINGTON
500 Ms AGC
1679 1662 1645 1628 1611 1594 1577 1560 1543 1526 1509 1492 1475 1458 1441
0
500
1000
1500
2000
2500
good quality reflections
Offset 2651 2160 1679 1214 764 344 -75 -551 -1116 -1715 -2314 -2914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



F1:MENU
F2:HELP
F3:DATA
F4:FILE
F5:MACF
F6:ZOOM
8:39:52
Command >_
CLIENT: BURLINGTON
500 Ms AGC
Many scattering points,
Much short-wavelength,
chaotic noise
Offset


Clean Record - Tilley Area
Group Interval
= 20 m
Far Offset
= 1200 m
<-Glauconite
120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45
0
200
400
600
800
1000
1200
1400
144


Noisy Record - Guided Wave
120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45
0
200
400
600
800
1000
1200
1400
Just 136 m
away from
previous
record
145

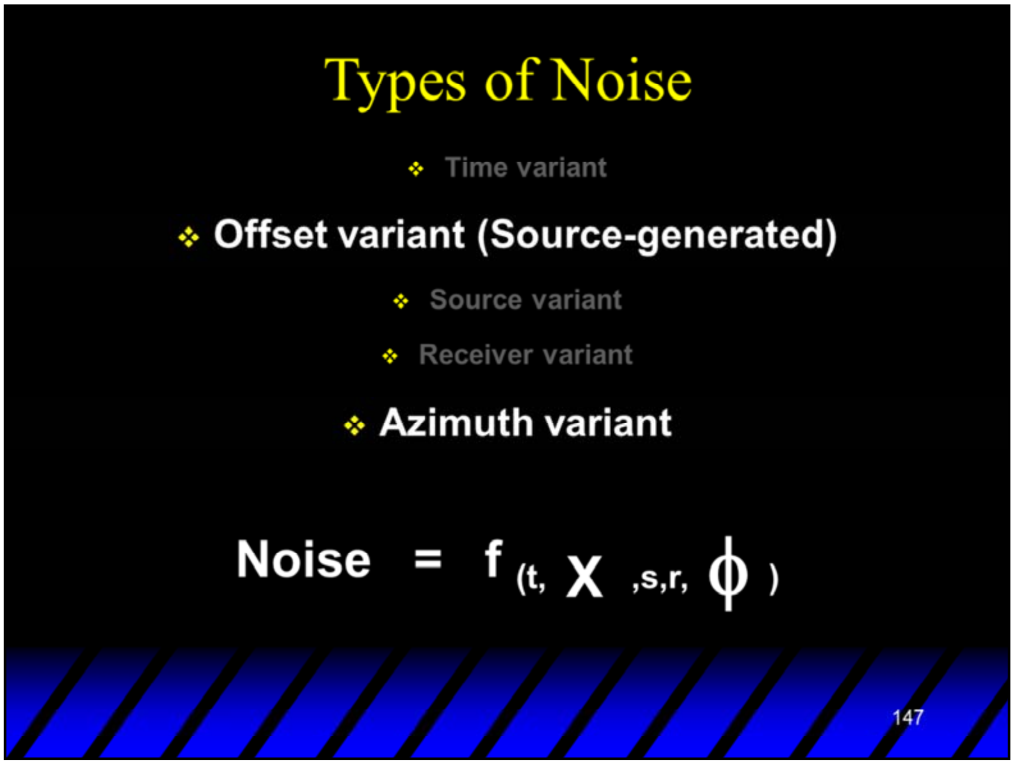
Types of Noise

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

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

146

MUSTAGH RESOURCES LTD.




MUSTAGH RESOURCES LTD.
We specialize in geophysical consulting of all types including the
design and management of 3D seismic programs.
We also provide training programs in
3D design, Vibroseis Theory,
Land Seismic Acquisition and
Instrumentation.
148

MUSTAGH RESOURCES LTD.

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

phone (403) 609-3866

fax (403) 609-3877

e:mail ncooper@mustagh.com

or yajaira@mustagh.com

web page http://www.mustagh.com

149


Or write us at:
MUSTAGH
RESOURCES LTD.
134 Hubman Landing
Canmore, Alberta
T1W 3L3
Canada
150