Seismic Acquisition – Tools and Techniques – 2002

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Overview

Many geophysicists are of the opinion that seismic acquisition consists of standard procedures and practices that have been well established and agreed on in the past. Therefore, apart from a little management to interface with government regulators and surface land owners, very little effort need be spent in organizing the field operation.

In fact, both the tools and techniques for acquisition have evolved very rapidly over the past ten years. Our understanding of the physical processes of acquisition continues to expand. If we do not pay proper attention to the subtleties of acquisition design and implementation, we run many risks: obtaining data that images our objectives poorly; data of sub-standard quality in both bandwidth and signal to noise ratio; operations that violate current environmental standards; and costs that run out of control.

This presentation will be a short overview of the many aspects of seismic acquistion with hi-lites on equipment or concepts that have changed the face of acquisition.

Recording Instruments

Perhaps one of the most misunderstood changes in the field has been the evolution and adoption of large channel distributed recording systems implementing Delta-Sigma technology. The significance of these systems is that reduced power consumption and nodal network-based digital telemetry has opened the door wide for recording more channels with enhanced spatial sampling. Increased instantaneous dynamic range has replaced the previous two-stage combination of instantaneous and time variable dynamic range. This has led some geophysicists to expect increased bandwidth that, in fact, is seldom realizable. There is also a strong belief that one millisecond recording should become more of a standard. The fact is, more frequent output samples reduces oversampling in the Delta-Sigma modulator and reduces dynamic range of the system. Furthermore, unnecessary one millisecond sampling results in unnecessary loading of the distributed network system, leading to more cable failures and more costly acquisition.

An encouraging development in recent years has been the “Vector Seis” digital sensor. This remains in a testing and development stage, but has now become incorporated in a few production systems and is showing encouraging results. A note of caution is that dynamic range limitations of current processing may inhibit our ability to fairly judge this new technology.

Dynamite Charge Sizes and Depths

As our understanding of the near-source inelastic behaviour of dynamite has been increasing, our use of this energy source has also been evolving. We are recognizing more the importance of matching the charge size and its inelastic radius to the expected inhomogeneity of the near surface. Large 3D programs with many thousands of shots are encouraging us to minimize charge depth as much as possible. A good understanding of the near surface materials is necessary to exercise good judgement in this respect.

Current Vibroseis Philosophies

More people are becoming alert to the fact that a vibrator is an imperfect machine devoted to generating a signal that matches a desired input waveform as closely as possible. Taking account of the imperfect nature of this machine leads us to a better appreciation of the behaviour resulting from various vibrator parameters. The result is that more geophysicists are tending toward a few number of long sweeps in order to reduce sweep rates. Low frequency emphasis is often used to meet the requirements of imaging multiple target zones at diverse depths. We are focusing more on the types of noise we must deal with in seismic data. In particular, we recognize that random, time-variant noise is generally our least problem while we are recognizing more forms of source-generated, offset-variant noise in both coherent and scattered forms. The repeatability of this noise within the source group reduces the benefit of a large number of vertical stacks. Non-linear sweeps must be considered not only with regard to their potential to compensate for earth absorption, but must also be carefully scrutinized for their impact on distortion artifacts. Over many years of experience, we are coming to realize that Vibroseis is a very “non-intuitive” energy source.

Fold, Offset and Other “Quality Indicators”

For reasons similar to those identified in the previous paragraph (the offset-consistent nature of most noise), we are recognizing that Fold, in and of itself, is a poor measure of data quality. Offset distribution within the contributing components of each stacked trace and offset homogeneity from one stacked trace to the next have become our most noble objectives in designing and implementing seismic programs. In some 3D programs, azimuth distribution is also recognized as in important quality with regards to lateral anisotropic effects.

At the program design stage, the relevance of these measures is now being evaluated through the use of data simulations. Existing data from the prospect area can be used to simulate the impact of geometric artifacts on the quality and mappability of stacked data. The pursuit of stacking stability has lead to many varied 3D design styles. The significance of many of these model geometries and their robustness under normal perturbation in implementation remains a topic of ongoing investigation.

Bent Lines, Gaps and Field Methods

The need for minimizing geometric artifacts in both 2D and 3D has resulted in the realization that a certain amount of irregularity in field designs may be desirable. Revised 2D bent-line guidelines allow a wandering trail over a narrow corridor provided the corridor itself maintains a radius greater than an easily calculated value. This freedom to allow a line to wander somewhat grants us the freedom to produce more irregular seismic trails. Studies in "Pseudo-Random" 3D programs have lead to a similar phenomenon in the world of 3D acquisition.

LIS (Low Impact Seismic) has been evolving for many years. Hand cutting has been complemented by Mulchers, small cats with maneuverable blades, calibrated inertial navigation systems, helicopter supported survey and recording techniques, and many inovative operational techniques. The result is that a geophysicist can now stand proudly in the aftermath of a high-density seismic program … knowing that the environmental and cultural impact of his operation has been minimized.

Gaps in coverage used to cause concern solely from the perspective of weakened fold. Now we recognize that the effect of a source or receiver gap results in perturbed offset distributions over an area equal to one half our useable offset. In these days of subtle character interpretation and rock property attribute extractions, such perturbations can mislead the interpreter dangerously. Many tools and techniques are now being developed to infill missing data areas. Sources such as airguns (for water bodies and transition zones); mini-vibrators and low energy impulsive sources (for highly cultured areas); and small machine or hand-portable drills (for those hard-to-reach areas) are now forming a frequent companion to our more conventional sources. It is imperative that we continue to develop low-impact and environmentally friendly methods.

Summary

Seismic data is being used for more and more detailed interpretation. At the same time, the maturity of exploration in Canada means that our prospect areas are tending toward the more awkward areas that we previously bypassed. The growing demand for more spatial sampling and more continuous coverage demands continuous evolution in all aspects of geophysics. Seismic acquisition represents the first step in this process and as such remains a critical link in the chain of data quality. We are evolving new tools that represent potential improvements in methodology, quality and economics. We are operating in an environment where regulating authorities and cultural/environmental concerns present intimidating boundaries. It is imperative that we become familiar with these new tools and recognize both their strengths and limitations. Sometimes we must give up old habits in order to reap the benefits of new methods.

It is too easy in this time of specialization to neglect our broader learning as geophysicists. We must all be aware of the tools of our trade and not succumb to the fate of the old Swedish logger. You may remember the story of the hardworking wood-cutter who disappeared into the forest each day with a large, sharp hand saw. He would return each night having cut and stacked 1.5 cords of wood. One day, a young salesman introduced the old Swede to a new tool, the chain saw. He assured the woodsman that he would triple or quadruple his output with this great new invention. After three days of exceedingly hard work, the exhausted worker returned the saw to the salesman. "I've tried my hardest …" he said, "… but I can't get more than a cord a day with this contraption. I'm afraid it just doesn't work as well as you claimed!"

The young man looked puzzled and took the saw. "There must be something not adjusted correctly " he stated. "Let me try it out." And he started the gas engine with no difficulty. The surprised Swede jumped back and shouted "What's all that noise?"

Given an ever changing set of tools, we must be sure we understand their power as well as how and when to apply them. Without this understanding, we will be disappointed and overworked, indeed.

Update of Land Seismic Acquisition Tools and Techniques

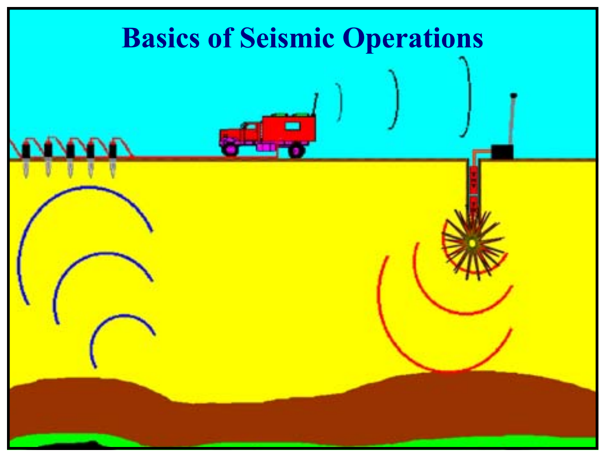
Norm Cooper
and Yajaira Herrera

Acquisition Tools …

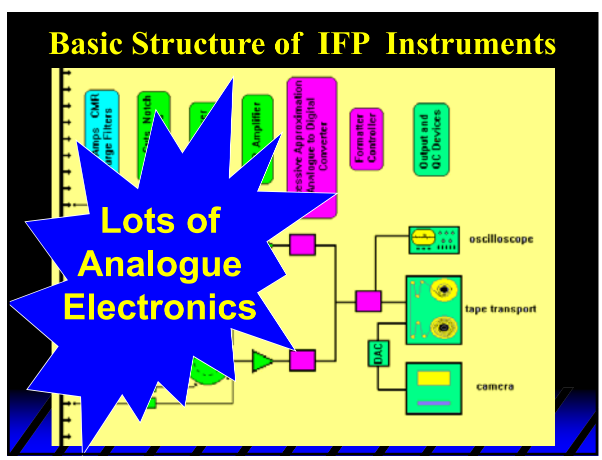
- Instruments
- Receivers and Sensors
- Sources

… and Techniques

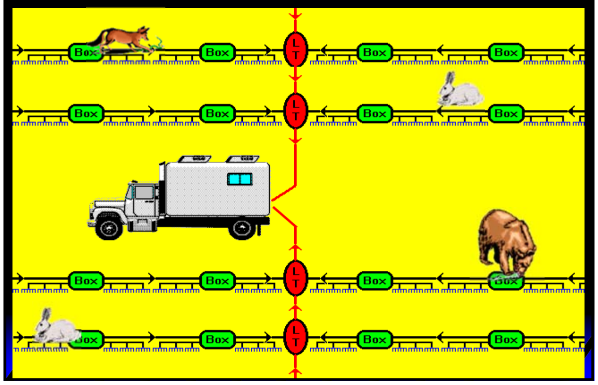
- Stack Array
- Sweep Design
- Field Methods
- Design Implications



Recording Systems



Distributed Telemetry Systems



Cable Size for Analogue versus Digital Telemetry

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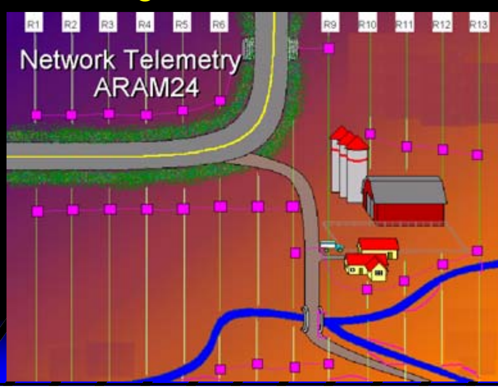
Networking and Redundant Data Paths



Light Weight and Power Efficient

Practical implementation of a single channel per “box”

Sercel 408UL

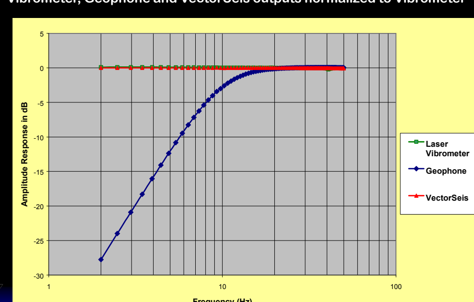
13

I/O Digital Sensor (VectorSeis)

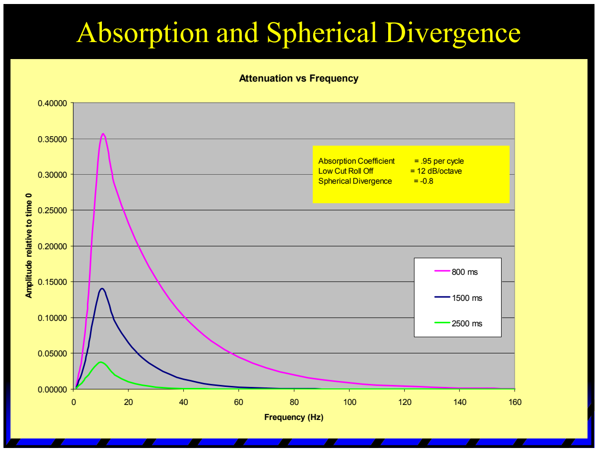
14

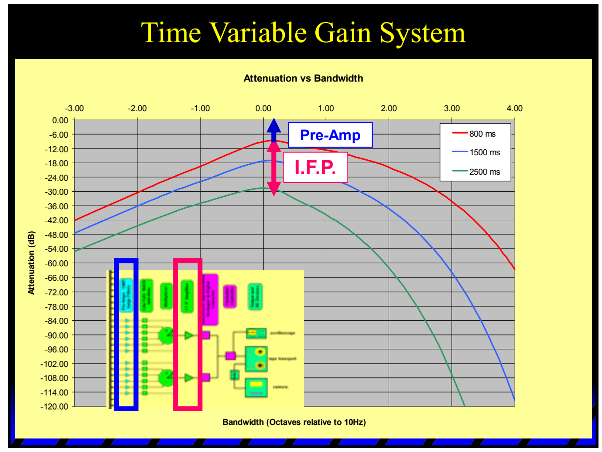
Low Frequency Response

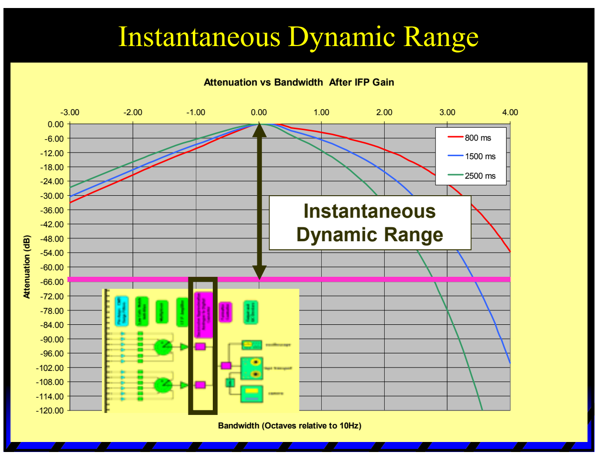
Geophone & VectorSeis™ simultaneously shaken, table motion measured by Laser Vibrometer, Geophone and VectorSeis outputs normalized to Vibrometer

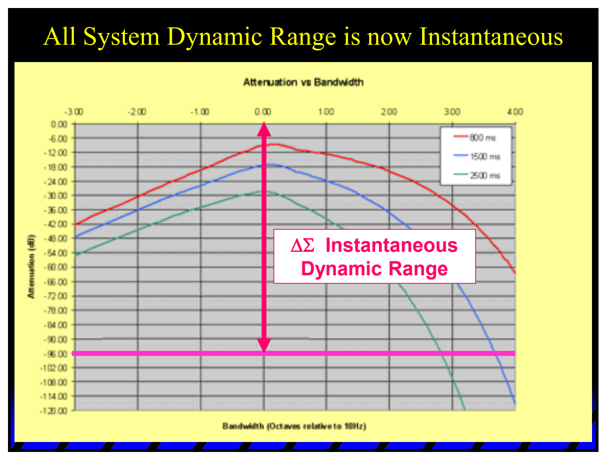


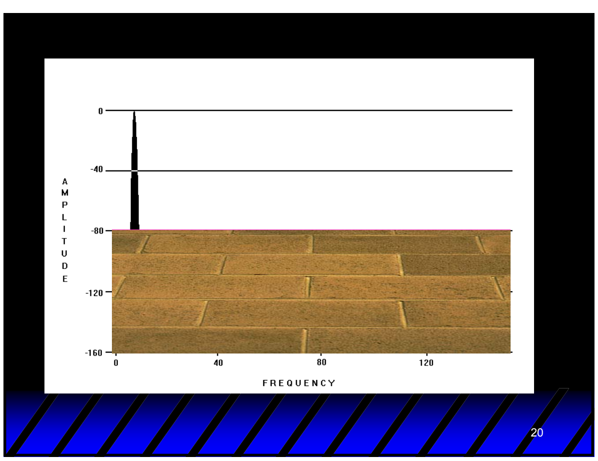
15

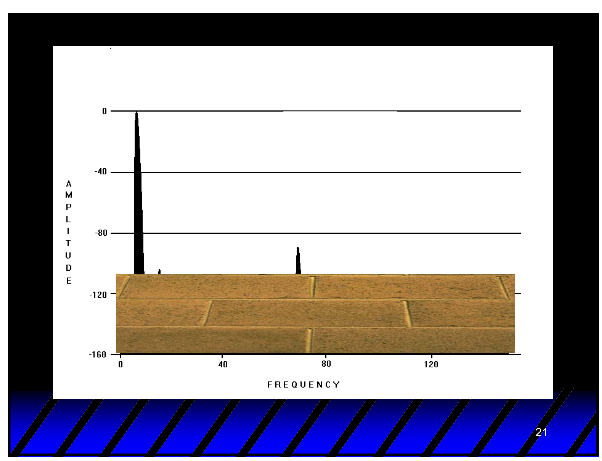

Absorption and Spherical Divergence
Attenuation vs Frequency
Absorption Coefficient = .95 per cycle
Low Cut Roll Off = 12 dB/octave
Spherical Divergence = -0.8
800 ms
1500 ms
2500 ms
Amplitude relative to time 0
Frequency (Hz)

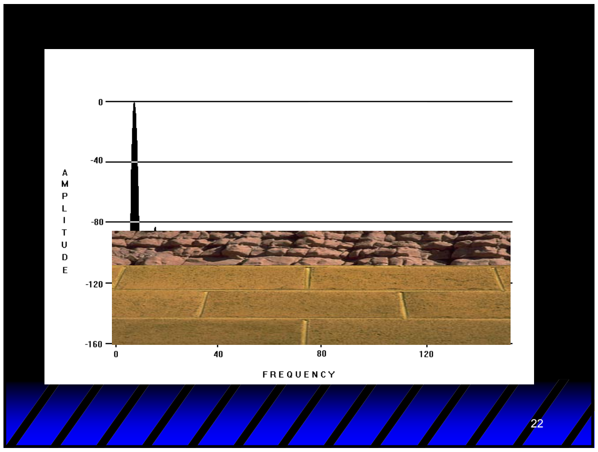

Time Variable Gain System
Attenuation vs Bandwidth
Pre-Amp
I.F.P.
800 ms
1500 ms
2500 ms
Attenuation (dB)
Bandwidth (Octaves relative to 10Hz)

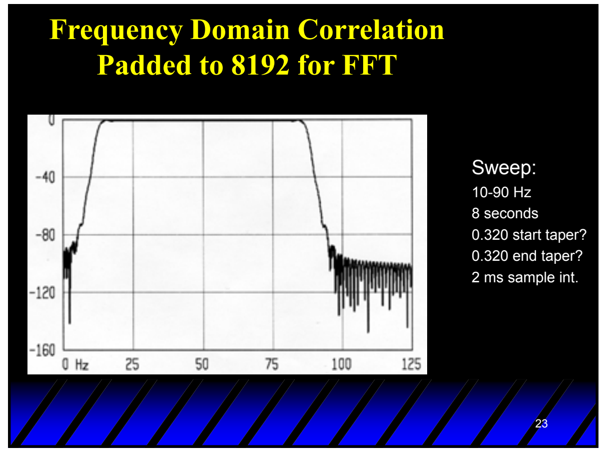

Instantaneous Dynamic Range
Attenuation vs Bandwidth After IFP Gain
800 ms
1500 ms
2500 ms
Instantaneous
Dynamic Range
Attenuation (dB)
Bandwidth (Octaves relative to 10Hz)

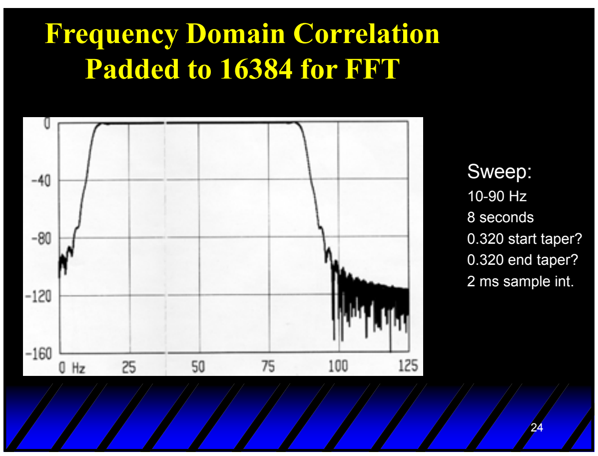

All System Dynamic Range is now Instantaneous
Attenuation vs Bandwidth
800 ms
1500 ms
2500 ms
ΔΣ Instantaneous
Dynamic Range
Attenuation (dB)
Bandwidth (Octaves relative to 10Hz)

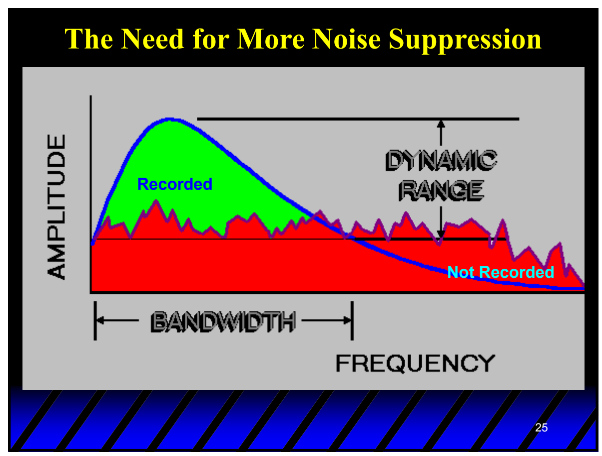

AMPLITUDE
FREQUENCY
20

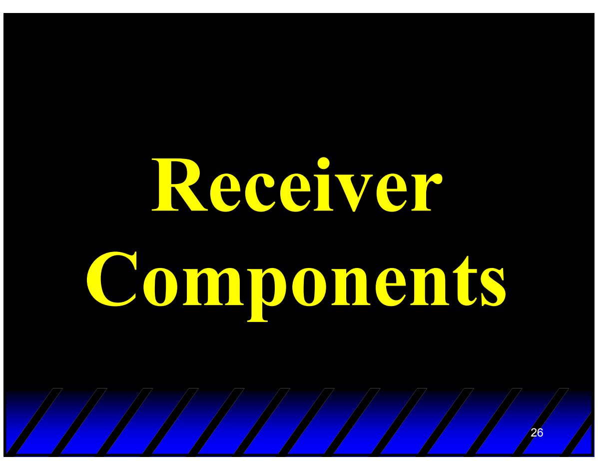

AMPLITUDE
FREQUENCY
21

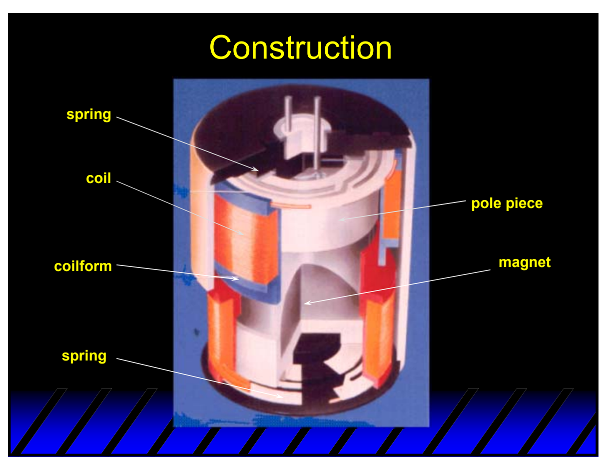

0
-40
-80
-120
-160
AMPLITUDE
0
40
80
120
FREQUENCY
22


Frequency Domain Correlation
Padded to 8192 for FFT
0
-40
-80
-120
-160
0 Hz
25
50
75
100
125
Sweep:
10-90 Hz
8 seconds
0.320 start taper?
0.320 end taper?
2 ms sample int.
23

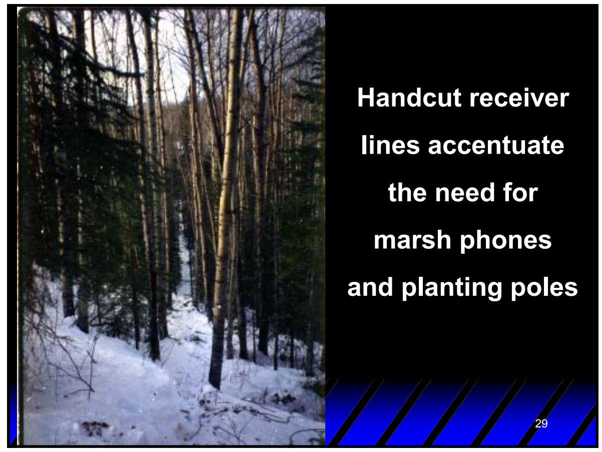

Frequency Domain Correlation
Padded to 16384 for FFT
0
-40
-80
-120
-160
0 Hz
25
50
75
100
125
Sweep:
10-90 Hz
8 seconds
0.320 start taper?
0.320 end taper?
2 ms sample int.
24


The Need for More Noise Suppression
AMPLITUDE
Recorded
DYNAMIC
RANGE
Not Recorded
BANDWIDTH
FREQUENCY
25

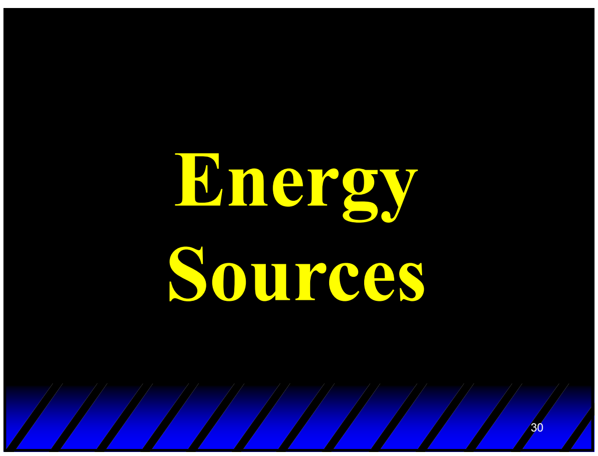

Receiver
Components
26


Construction
spring
coil
coilform
spring
pole piece
magnet

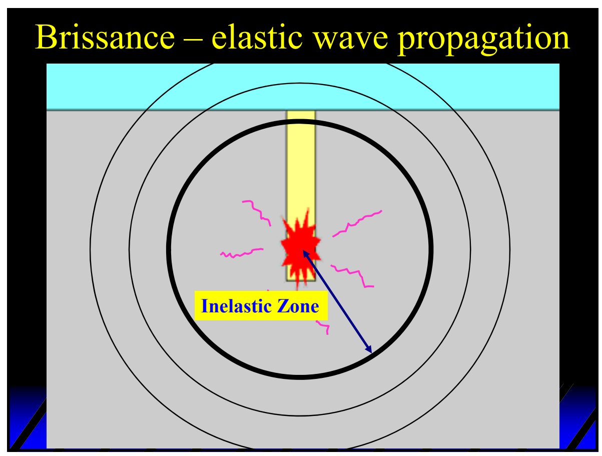
“Marsh”
Cases



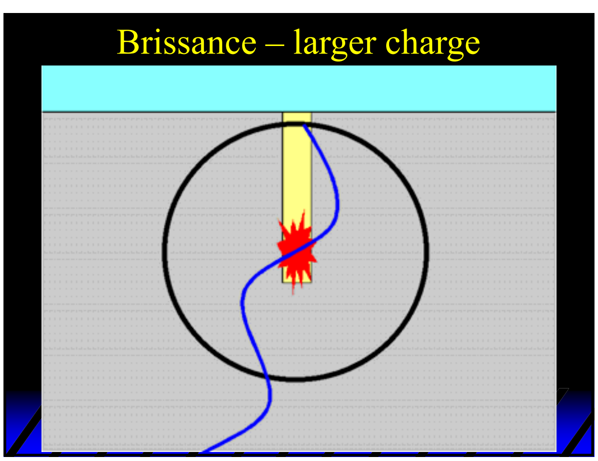
Handcut receiver lines accentuate the need for marsh phones and planting poles
29



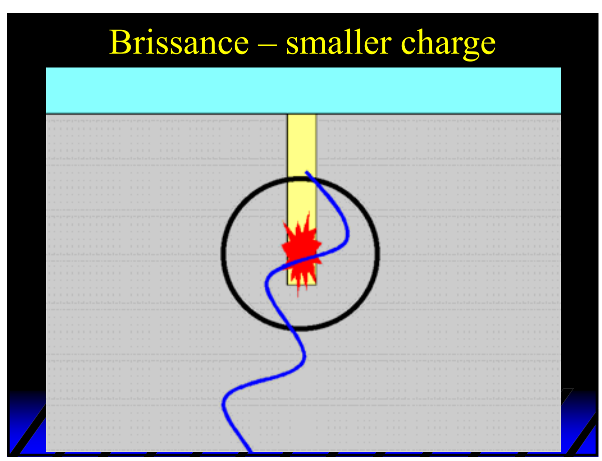
Energy Sources
30



Brissance – elastic wave propagation
Inelastic Zone

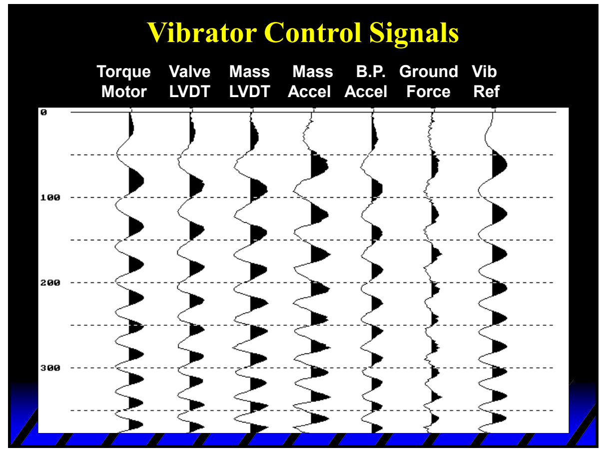


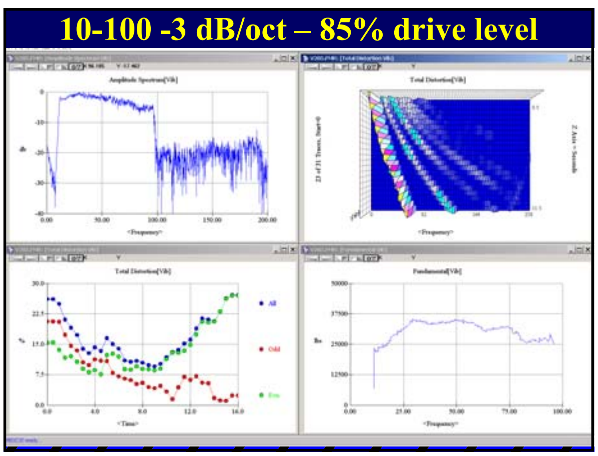
Brissance – larger charge

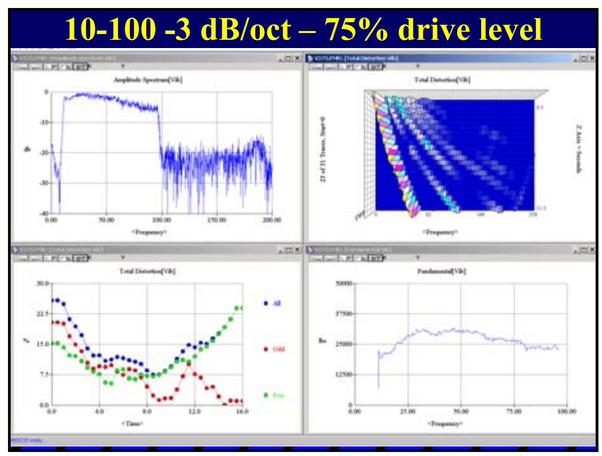


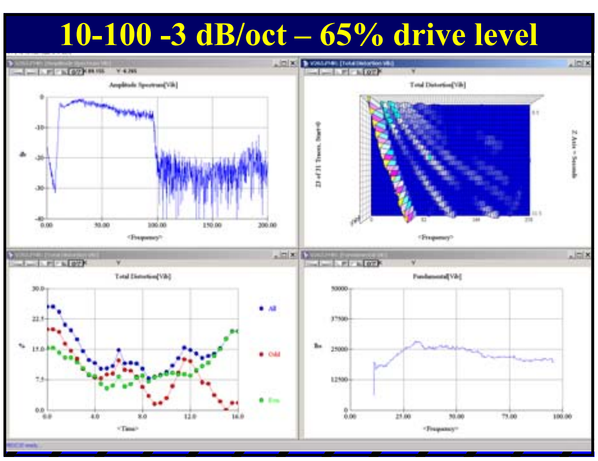
Brissance – smaller charge

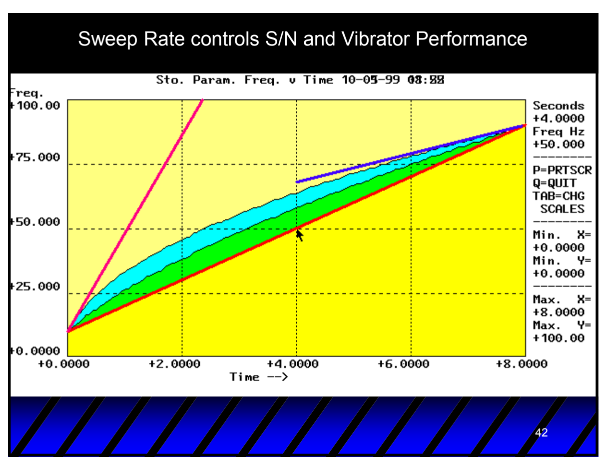

Typical Vibrator Mounted on a Buggy Carrier


Vibrator Control Signals
Torque Motor
Valve LVDT
Mass LVDT
Mass Accel
B.P. Accel
Ground Force
Vib Ref
0
100
200
300

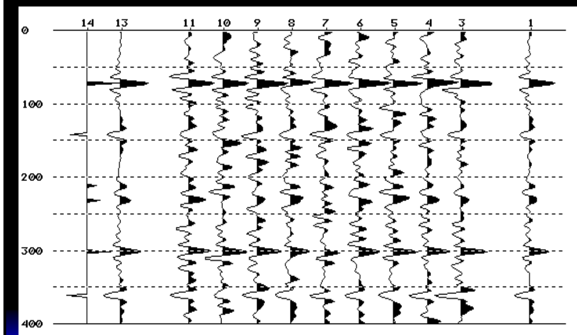

10-100 -3 dB/oct – 85% drive level


10-100 -3 dB/oct – 75% drive level

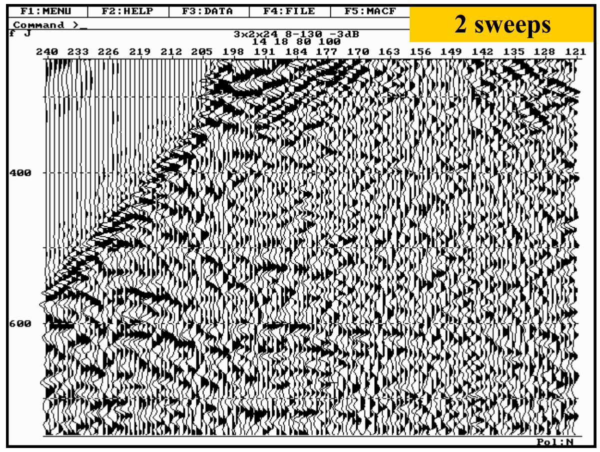

10-100 -3 dB/oct – 65% drive level

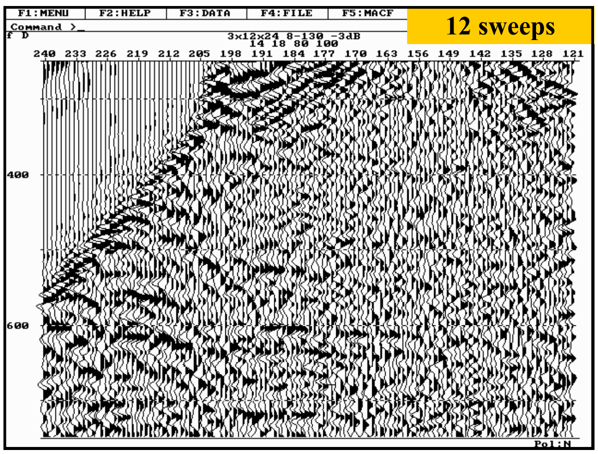

Sweep Rate controls S/N and Vibrator Performance
Sto. Param. Freq. v Time
Freq.
100.00
75.000
50.000
25.000
0.0000
+0.0000
+2.0000
+4.0000
+6.0000
+8.0000
Time -->
Seconds
+4.0000
Freq Hz
+50.000
P=PRTSCR
Q=QUIT
TAB=CHG
SCALES
Min. X=
+0.0000
Min. Y=
+0.0000
Max. X=
+8.0000
Max. Y=
+100.00
42

Superposition – Vertical Stacking



43





Sweeps, Length vs Production

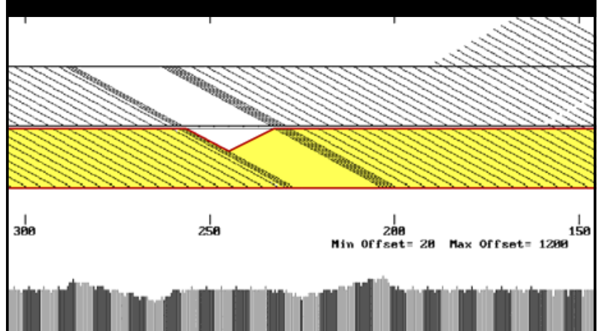
	VP's / day	Km's / day
8 sweeps of 8 sec	123	9.8
12 sweeps of 8 sec	89	7.1
8 sweeps of 12 sec (at 80 m source intervals)	103	8.3
2 sweeps of 12 sec (at 20 m source intervals)	415	8.3

46

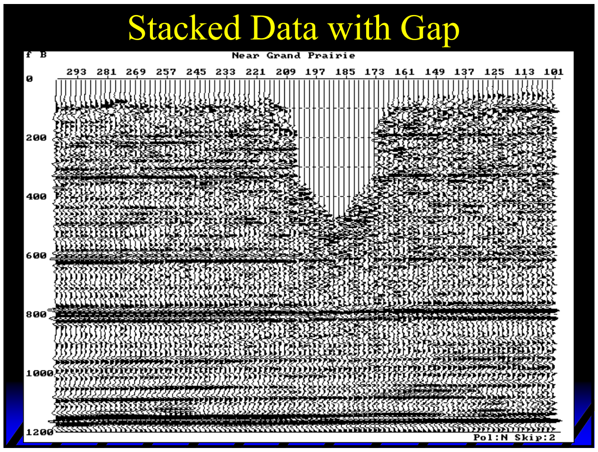
Field Operations

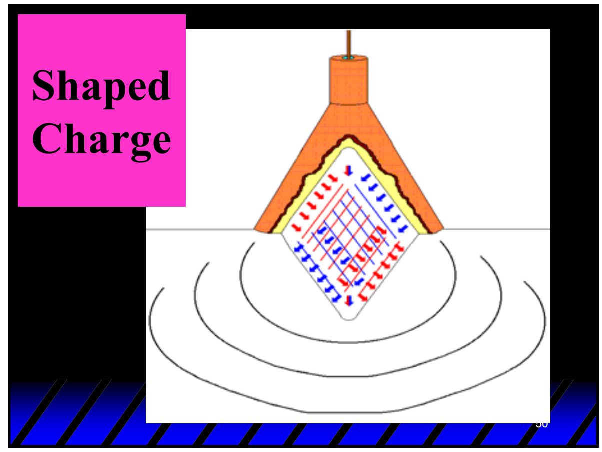
47

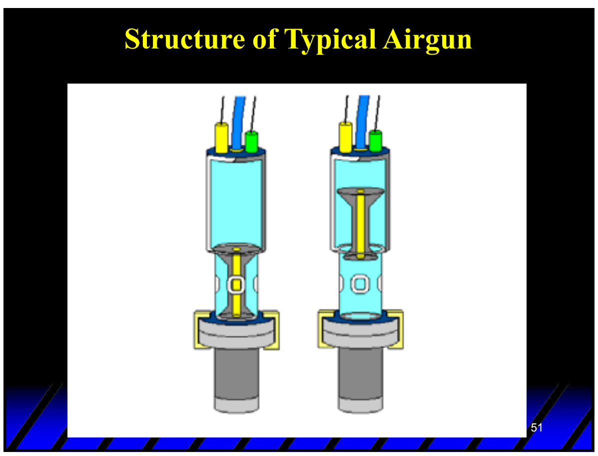
Source Gap - with make ups

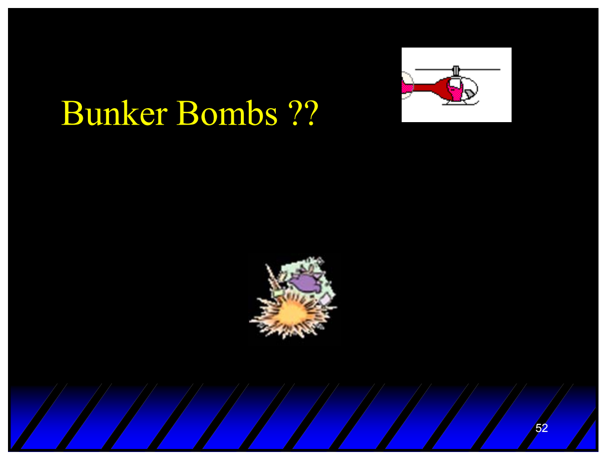


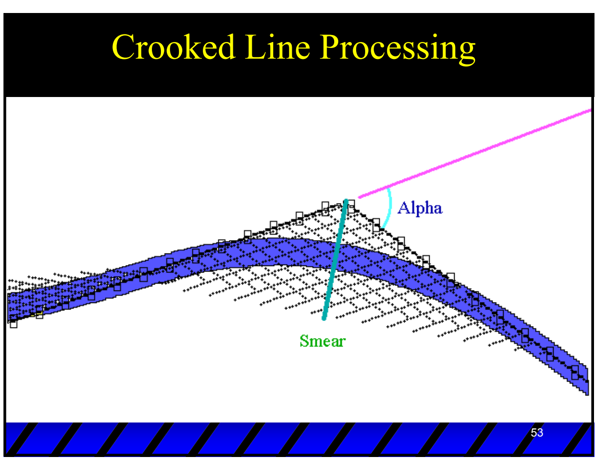
48

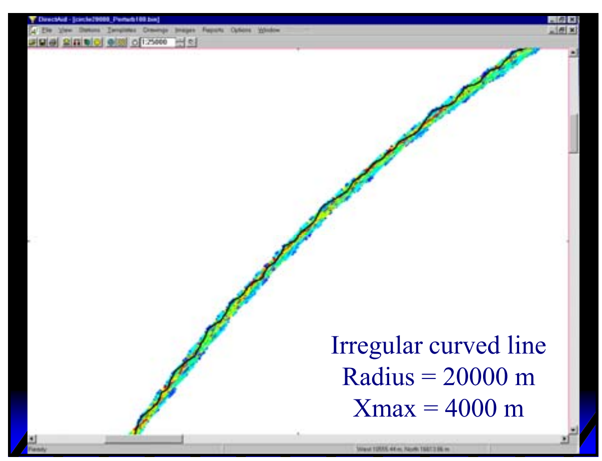

Stacked Data with Gap
Near Grand Prairie
293 281 269 257 245 233 221 209 197 185 173 161 149 137 125 113 101
0
200
400
600
800
1000
1200
Pol:N Skip:2

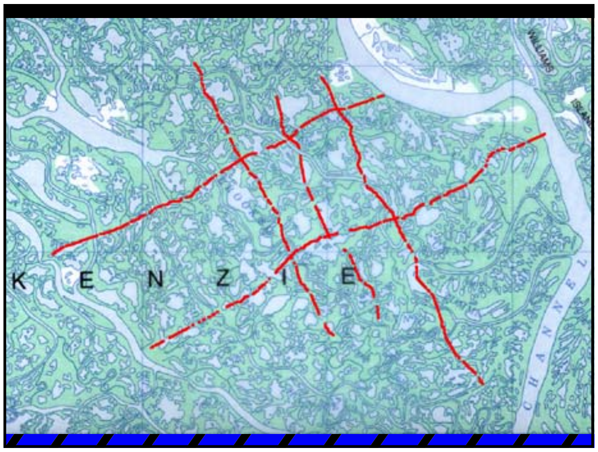

Shaped Charge


Structure of Typical Airgun
51


Bunker Bombs ??
52


Crooked Line Processing
Alpha
Smear
53


Irregular curved line
Radius = 20000 m
Xmax = 4000 m


K E N Z I E
C H A N N E L


Typical Seismic Trail from Past Years
8 m width
56


Modern Mulcher Operation
57


Modern Mulcher Operation
58


Modern Mulcher Operation
59


L.I.S. Mulcher-Cut Trail
2.3 m width
60

No Soil Disturbance   No Slash Pile

61

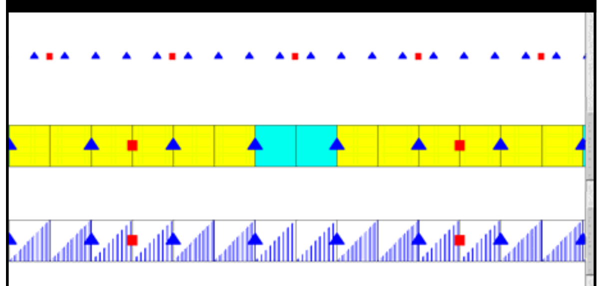
Enviro – Drills

62

2-D Geometry Lessons

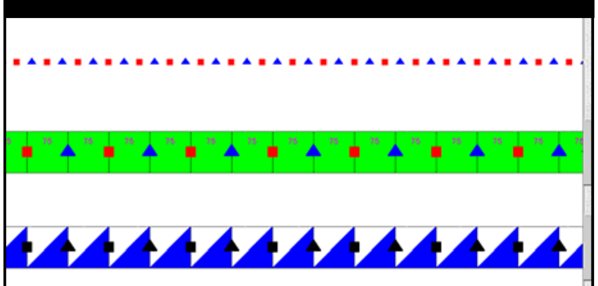
63

Sparse 2D x 4
(0-1500 m) Fold = 18-19



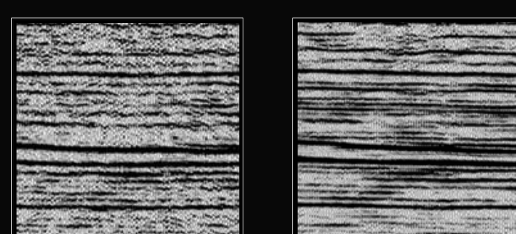
64

Stack Array 2D
(0-1500 m) Fold = 75



65

S. I. = 4 x R. I.   S. I. = R. I.



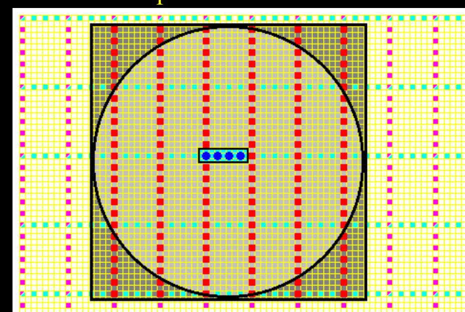
66

MUSTAGH RESOURCES LTD.

Patch Size, Model Type and Pre-Stack Statistical Diversity

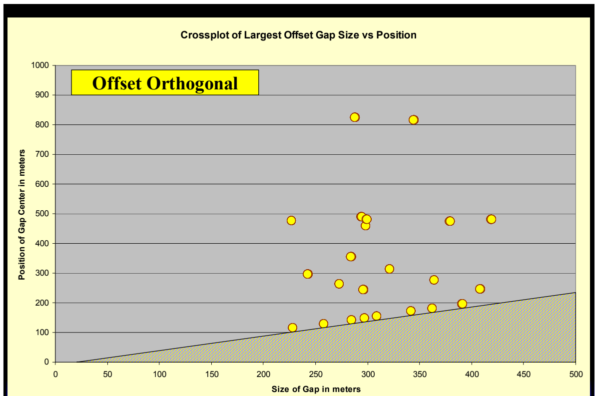
67

Our patch should be large enough to encompass all useable offsets

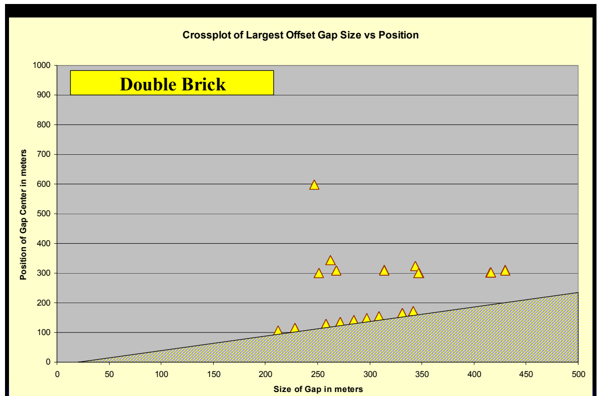


. . . Mutes, PreStack Migration Operators, . . .

68



69



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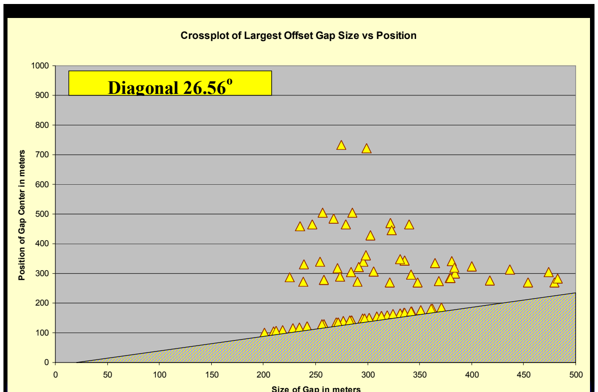

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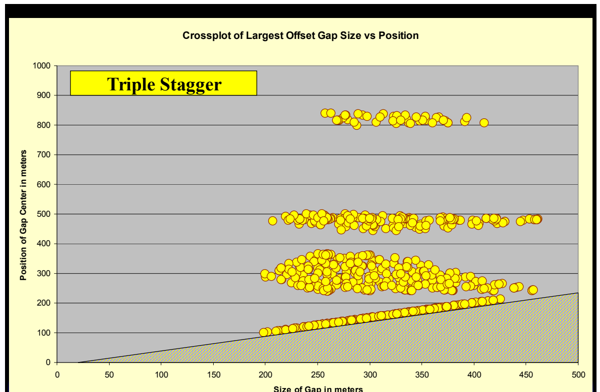

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Data Simulation

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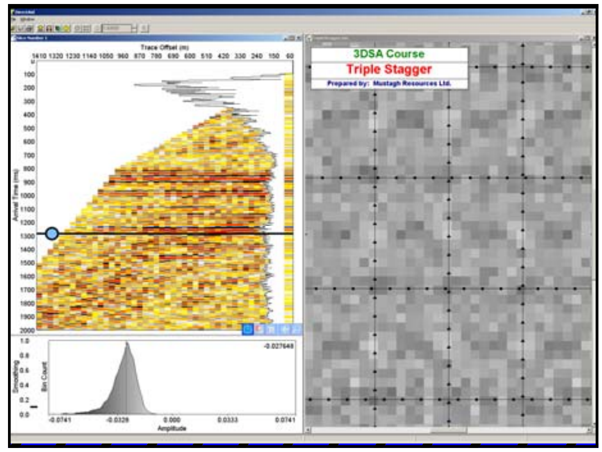

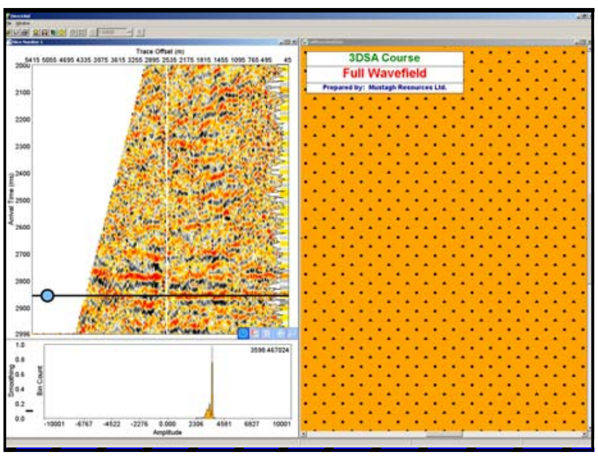

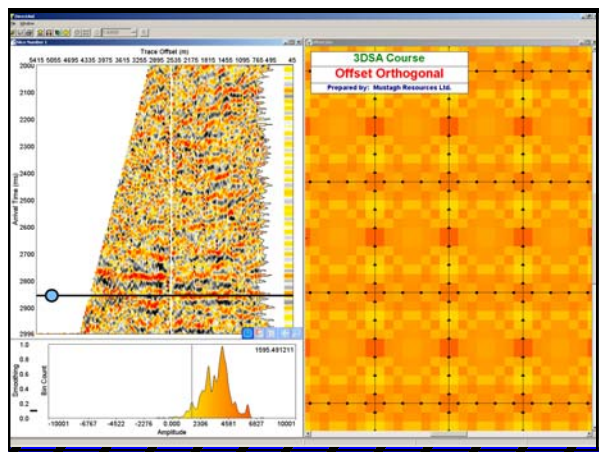

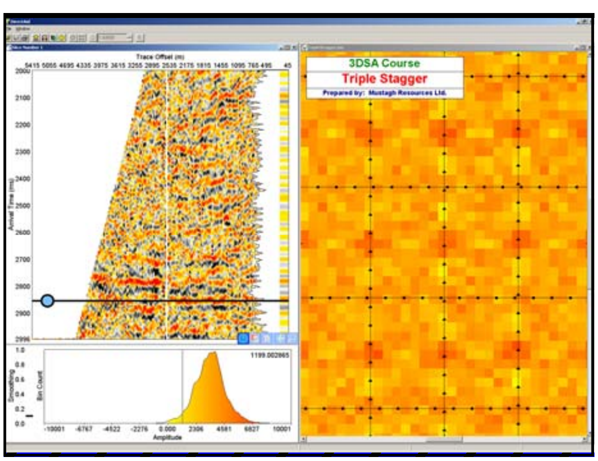

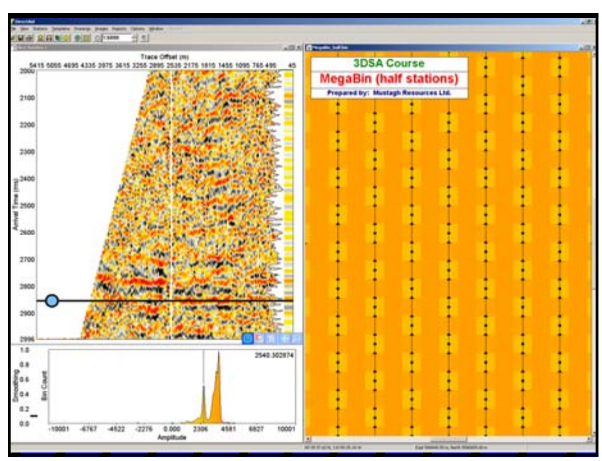

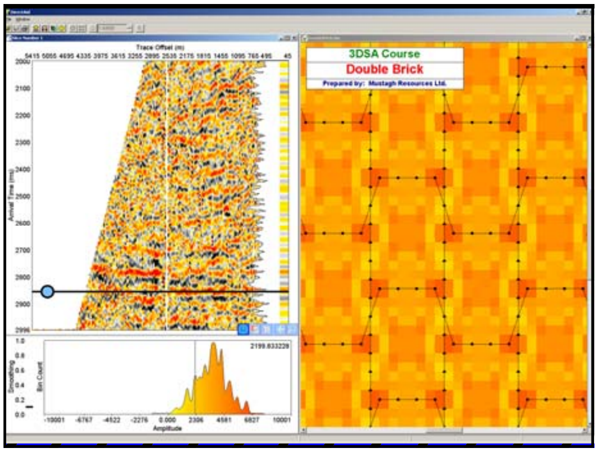
3DSA Course
Double Brick
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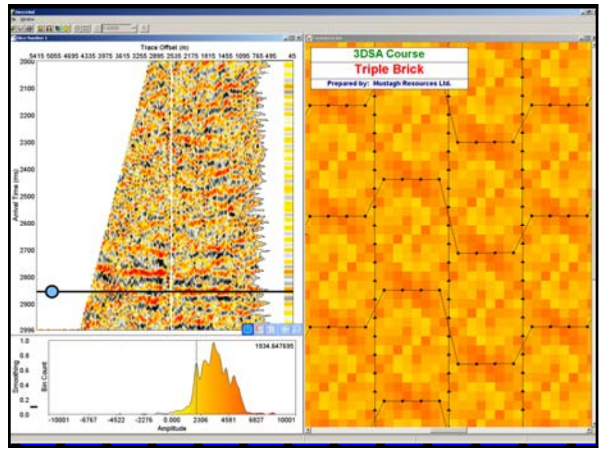
3DSA Course
Triple Brick
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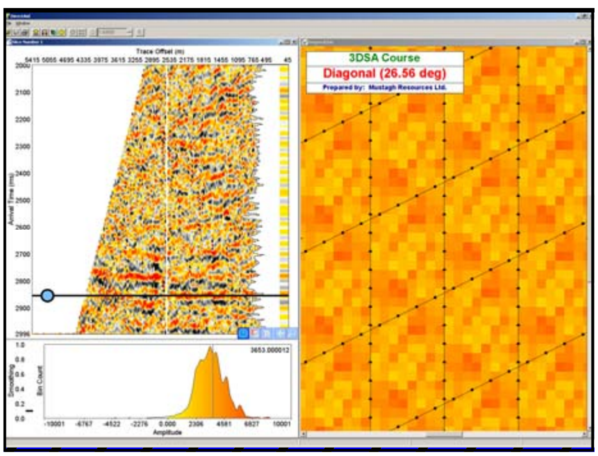
3DSA Course
Diagonal (26.56 deg)
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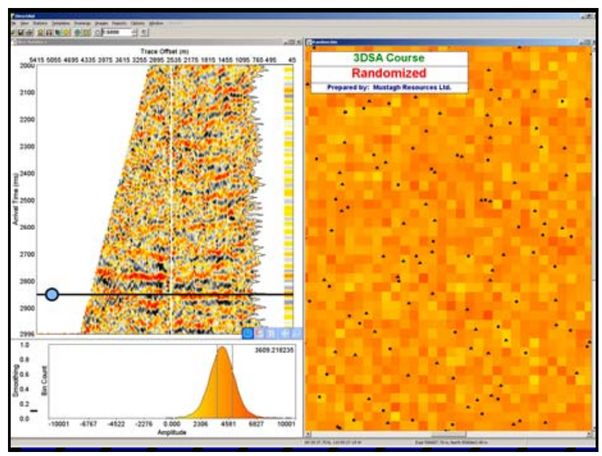
3DSA Course
Randomized
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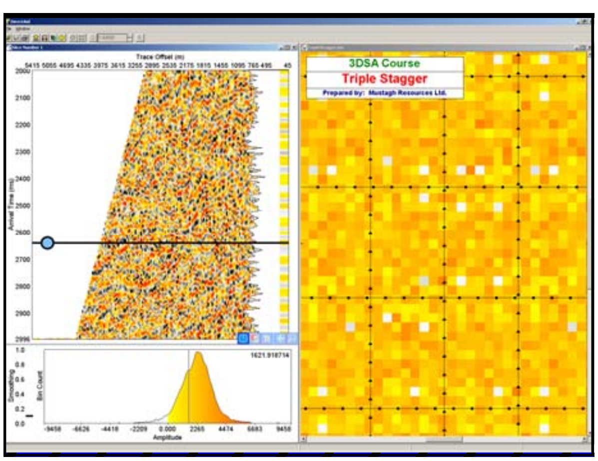
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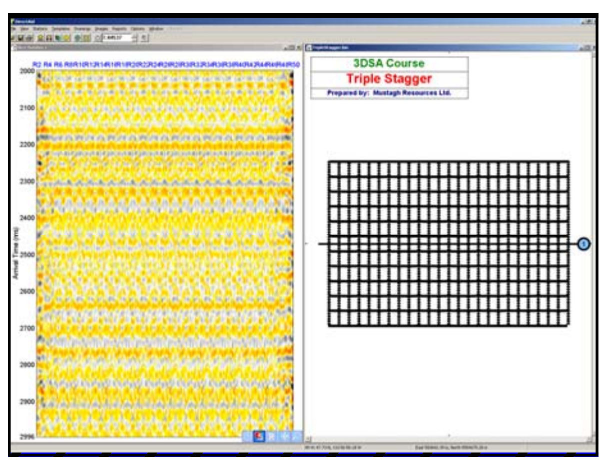
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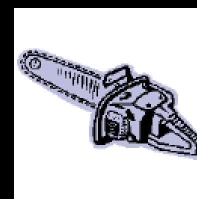

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If you desire more information or would like a copy of this tutorial, please contact Norm Cooper or Yajaira Herrera

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