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 acquisition 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 an 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 innovative 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

Basics of Seismic Operations

Recording Systems

Basic Structure of IFP Instruments

Lots of Analogue Electronics
Distributed Telemetry Systems

Networking and Redundant Data Paths

I/O Digital Sensor (VectorSeis)

Cable Size for Analogue versus Digital Telemetry

Light Weight and Power Efficient

Practical implementation of a single channel per “box”

Sercel 408UL

Low Frequency Response

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

Attenuation vs Frequency

- Absorption Coefficient = .95 per cycle
- Low Cut Roll Off = 12 dB/octave
- Spherical Divergence = -0.8

Time Variable Gain System

Attenuation vs Bandwidth

- Pre-Amp
- I.F.P.

Instantaneous Dynamic Range

Attenuation vs Bandwidth: After IFP Gain

- Instantaneous Dynamic Range

All System Dynamic Range is now Instantaneous

Attenuation vs Bandwidth

- ΔΣ Instantaneous Dynamic Range
Frequency Domain Correlation
Padded to 8192 for FFT
Sweep:
10-90 Hz
8 seconds
0.320 start taper?
0.320 end taper?
2 ms sample int.

Frequency Domain Correlation
Padded to 16384 for FFT
Sweep:
10-90 Hz
8 seconds
0.320 start taper?
0.320 end taper?
2 ms sample int.

The Need for More Noise Suppression

Receiver Components

Construction
“Marsh” Cases

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

Energy Sources

Brissance – elastic wave propagation

Brissance – larger charge

Brissance – smaller charge
Typical Vibrator Mounted on a Buggy Carrier

Vibrator Control Signals

<table>
<thead>
<tr>
<th>Torque</th>
<th>Motor</th>
<th>Valve</th>
<th>LVDT</th>
<th>Mass</th>
<th>Mass</th>
<th>B.P.</th>
<th>Mass</th>
<th>Ground</th>
<th>Force</th>
<th>Vib</th>
<th>Ref</th>
</tr>
</thead>
</table>

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
Superposition – Vertical Stacking

Sweeps, Length vs Production

<table>
<thead>
<tr>
<th>Sweeps of Length</th>
<th>VP's / day</th>
<th>Km's / day</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 sweeps of 8 sec</td>
<td>123</td>
<td>9.8</td>
</tr>
<tr>
<td>12 sweeps of 8 sec</td>
<td>89</td>
<td>7.1</td>
</tr>
<tr>
<td>8 sweeps of 12 sec</td>
<td>103</td>
<td>8.3</td>
</tr>
<tr>
<td>(at 80 m source intervals)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 sweeps of 12 sec</td>
<td>415</td>
<td>8.3</td>
</tr>
<tr>
<td>(at 20 m source intervals)</td>
<td></td>
<td></td>
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</tbody>
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Source Gap - with make ups

Field Operations
Stacked Data with Gap

Structure of Typical Airgun

Bunker Bombs ??

Crooked Line Processing

Irregular curved line
Radius = 20000 m
Xmax = 4000 m
Typical Seismic Trail from Past Years

Modern Mulcher Operation

Modern Mulcher Operation

Modern Mulcher Operation

L.I.S. Mulcher-Cut Trail
Our patch should be large enough to encompass all useable offsets.

Crossplot of Largest Offset Gap Size vs Position

- Offset Orthogonal
- Double Brick
- Diagonal 26.56°
- Triple Stagger

Patch Size, Model Type and Pre-Stack Statistical Diversity

Mutes, PreStack Migration Operators...
Data Simulation
If you desire more information or would like a copy of this tutorial, please contact Norm Cooper or Yajaira Herrera:

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