Using seismic data to verify 3D geometry - some new approaches to Field QC.

Mike Galbraith

Seismic Image Software Ltd.

Abstract
In today's 3D surveys, the volume of data can be overwhelming. It is essential to have methods that quickly identify errors and/or bad data. Modern field QC uses seismic trace attributes (energy levels within specified windows, energy decay factors, first arrival times) in combination with survey information (shot and receiver positions) to create new quality control measurements and displays. Such QC displays can quickly pinpoint location and other errors at both shot and receiver positions. Examples of verifying 3D geometry, energy decay maps, and finding position errors will illustrate the latest QC methods.

Field Quality Control Processing

In Field QC, we verify:

Positional data quality: To verify position data we can perform conventional offline geodetic Q.C. The most useful method is to overlay final survey co-ordinates onto a map or image (TIFF or DXF files) . The visual tie between shot and receiver positions and the actual ground is a compelling verification of accuracy.

Seismic data quality: A display of seismic data can reveal much about potential position errors. For example: Do the first breaks look as expected (make a theoretical first break template overlay)? Is the number of shots and number of traces per shot as expected? Is the data quality as expected (are there any reflections)?

Seismic/Positional data relationship: The "relationship" between shot and CMP and receiver positions dictates how the data will look. In other words, the first breaks will appear at a certain time and the amplitude of the data will follow the laws of spherical divergence and inelastic attenuation.

The last is the most important item. By examining the relationship between seismic data and the position in which the energy was initiated (shot-point), the sub-surface through which it traveled (CMP) and the position where it was received (field station or receiver), we can determine the accuracy of the position data and the quality of the seismic data. By relationship we mean such things as the first break times, trace to trace variations in amplitude and the expected spatial continuity of data attributes like exponential amplitude decay.

Seismic Data Trace Attributes

Among the trace "attributes" we study here, will be the following:

First Break Times. The time is related to the horizontal distance between shot and receiver. Thus we can verify relative position correctness.

Amplitude - within a window around the first breaks, and within the data. The average amplitude within such windows will tell us a lot about how much spherical divergence there has been.

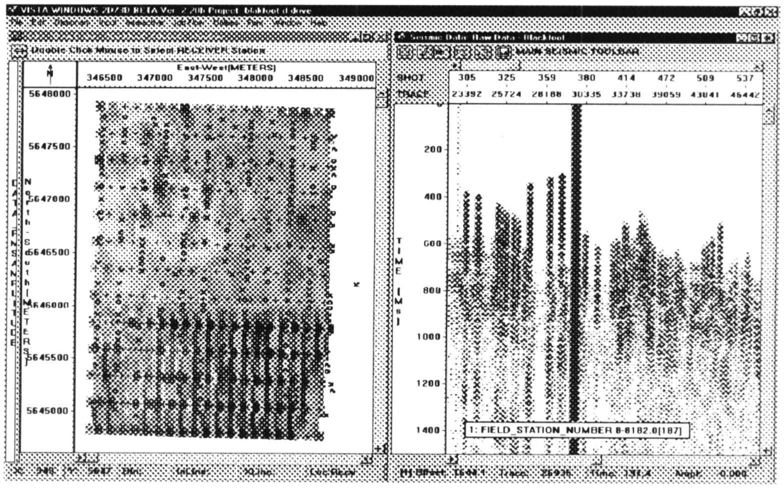
Amplitude Decay factor. This attribute tells us about the path taken by the energy traveling from shot to receiver. Other attributes can be similarly classified as to their use in verifying or even determining shot and receiver position.

Relationship Diagnostics for Shots / Receivers

We now present some examples of diagnostic displays which will emphasize the relationship between shot/receiver positions and the attributes.

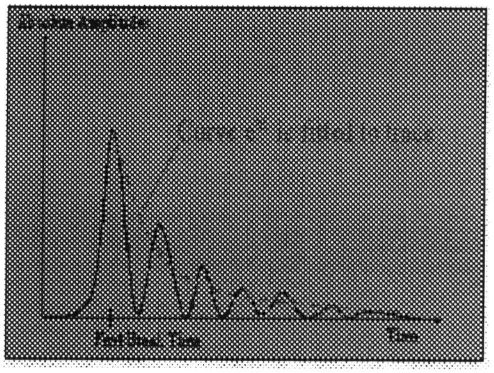
Mean RMS levels by Receiver

In this figure we have calculated the RMS amplitude in a window centered on the first breaks. The average of these RMS amplitudes is calculated at each receiver and displayed. On the right of the display, we selected one of the receivers showing very strong amplitude (red colour). We then displayed the traces which were collected at that receiver (from many different shots). One trace stands out, because it has a high DC value.



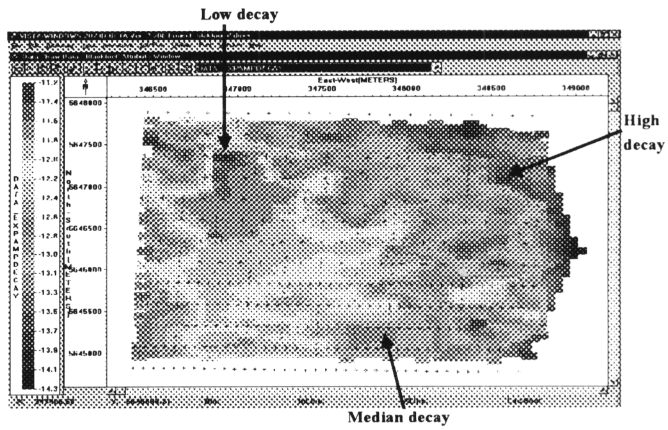
Definition of amplitude decay

We define a single parameter "a" which is the exponential decay of each trace by a least squares fit of the curve e^{at} to the peaks of the absolute trace amplitudes. This parameter is directly related to the energy travel path - and therefore to sub-surface geology. We can expect this parameter to show spatial variations related to geology.

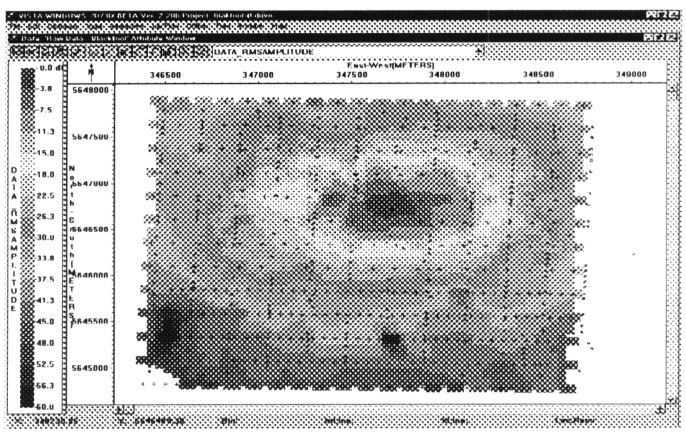


Shot Average Amplitude Decay

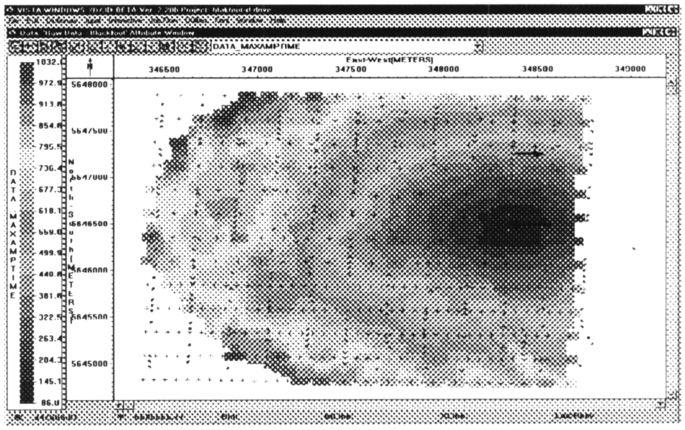
On the right we see the average amplitude decay parameter at each shot position. There is good spatial continuity - a strong indication that the shot positions are correct.



RMS by receivers for one shot
Here we see the RMS amplitudes of all the traces for one shot (the window was around the first breaks), plotted at the receiver positions. Clearly the shot energy increases for traces near the shot. This confirms the relative positions of shots and receivers.

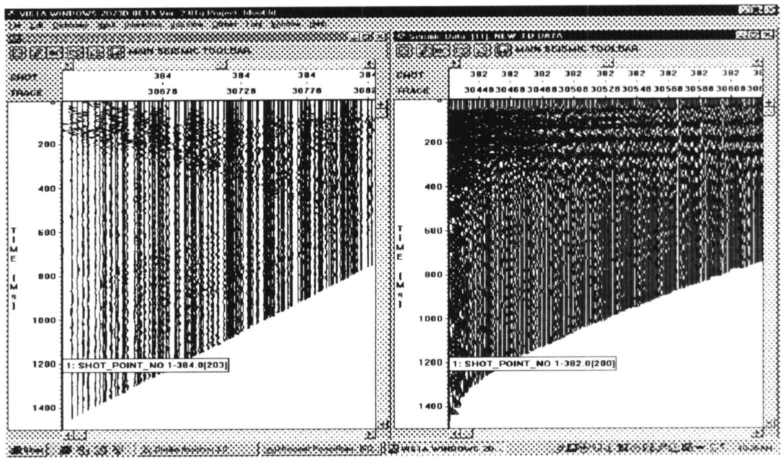


Predicting Shot locations from First Breaks with Times of Maximum Amplitudes for each receiver plotted as a check.
We can predict the shot location based on a knowledge of all receiver coordinates for each shot and the first break time. In the display below, we can see 2 small arrows on the right hand side. These indicate shots that should be moved. In other words the shot at the "tail" of the arrow should be moved to the "head" of the arrow to satisfy the combination of first break pick times and shot location. The maximum amplitude times appear to be centered around the head of the arrow. This indicates the correctness of the prediction.



LMO of badly located shot - and previous (good) shot

This diagram shows the appearance of a "good" shot (correct position with respect to its receivers) and a "bad" shot (incorrect position). LMO has been applied and the bad shot is evident from the uneven appearance of the first breaks.



Other QC diagnostics

Many QC diagnostics can further confirm (or deny) the accuracy of geometry information. Some of the most useful and enduring of these are:

- 100% displays
- Field stacks
- Raw record displays
- Use of Inline / Crossline displays
- Time slice

The main use of each is to emphasize spatial continuity if geometry is correct. Discontinuities generally mean an error exists.

Field QC to enable Fast Track Processing

We have seen how Field QC can establish the correctness of the survey geometry and can inform us about the signal content of the data. In general QC can identify and quantify these items:

- Q.C. Position / Seismic attribute relationship
- List of Dead / Reverse traces (Shots, Receivers, Channels)
- Pre-process data
- Pick velocities and build database
- Processing trials - establish sequence & parameters
- List of unusual aspects

All of these items will contribute to faster throughput in the processing center and to a more successful result from your 3D survey.