GC Horizontal Wave Testing*

Bob Hardage[1]

Search and Discovery Article #40502 (2010)
Posted January 19, 2010

*Adapted from the Geophysical Corner column, prepared by the author, in AAPG Explorer, December, 2009, and entitled “Horizontal Wave Testing Helps”. Editor of Geophysical Corner is Bob A. Hardage (bob.hardage@beg.utexas.edu). Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director. Please refer to closely related article by Bob Hardage, 2010, Vertical Wave Testing, Search and Discovery article #40503.

[1] Bureau of Economic Geology, The University of Texas at Austin (**bob.hardage@beg.utexas.edu**)

General Statement

Collecting optimal quality seismic data across some onshore prospects can be a challenge for numerous reasons:

- Near-surface conditions may produce strong refraction noise.
- Ambient noise may exist because of local culture.
- Different energy sources, such as shot hole explosives, vibrators and impulsive impactors, need to be considered.
- Several receiver-patch dimensions should be evaluated for effectiveness.

Because of these factors, a source that produces good-quality data across a sandy-soil grassland may produce poor data across an area of hard rock outcrops, and a receiver dimension that cancels ground-roll noise at prospect A may fail to do so at prospect B. Before a seismic data-acquisition effort is launched across a prospect, seismic test data need to be acquired to determine:

- The type of energy source.
- The dimension of the receiver patch.
- The specific source-receiver geometry that will yield data with appropriate signal bandwidth and signal-to-noise character.

The effort expended in acquiring this basic planning information is commonly referred to as wave testing or noise testing.

Horizontal Wave Test Methodology

Seismic wave-test data are usually acquired using a “walkaway,” or moving source geometry, such as illustrated on Figure 1. When recording the data, the receiver spread remains stationary and source stations are moved away from the receiver patch at distance increments L that equal the receiver spread length. The maximum source-to-receiver offset distance X should equal or exceed the depth to the deepest target that needs to be imaged with the surface-recorded seismic data. Each receiver station within the receiver patch should be occupied by a single geophone – not by a string of geophones that extend over an appreciable distance – which prevents the cancellation of short-wavelength energy modes that need to be analyzed. There should be no skipped source stations along the line of profile.

If a source station is inaccessible for any reason, that source point should be moved closer to the receiver spread to prevent gaps in the offset profile. Successive source stations should then be moved forward by the same distance to preserve a uniform spacing L between the remaining source-station positions.

Site selection is important when recording wave-test data because the data sample only a small portion of a prospect. A wave-test site should be representative of the entire prospect. If surface conditions change over a prospect, more than one wave-test site should be considered.

Example

Wave-test data acquired across one prospect area circa 1975, using a recording geometry such as described on Figure 1, are illustrated on Figure 2. These data illustrate several coherent noise modes. The dominant noises are a refraction event that has an apparent velocity of 9,500 feet/second (2,900 meters/second) and a band of surface waves with apparent velocities ranging from 2,750 to 4,200 ft/s (825 to 1,280 m/s).

Several reflection events can be seen between 1.5 and 2.5 s at large offset distances beyond the surface-wave noise cone. Because wave-test data are acquired using a small trace spacing d, any arbitrary-length inline receiver array can be simulated by summing an appropriate number of adjacent traces. For example, the data on Figure 3 show the effect of adding 11 consecutive traces of wave-test data acquired with a geophone spacing d = 20 feet (Figure 1) to simulate data that would be acquired with a string of geophones spanning 220 feet (67 meters) at each offset station.

A 12-Hz low-cut filter has been applied to these data to aid in reducing low-frequency noise. The frequency and wavelength content of the data inside the indicated Transform window is illustrated on Figure 4 and confirms that the data are dominated by high-velocity reflection signals. Running sums can be made using different numbers of test-data traces to simulate how receiver groups spanning any desired distance affect the frequency content and signal-to-noise ratio of prospect data.

Conclusions

With this knowledge, seismic contractors can deploy receiver groups that have dimensions that will produce optimal quality data when production data recording is done. Similarly, different sources can be deployed at each source station SP1 to SPN (Figure 1) to compare data quality produced by vibrators versus impactors or by small explosive charges deployed at shallow depth versus large explosive charges placed at deep depths. By comparing data quality generated by each source option, a contractor will know the best source to use across a specific prospect.

The concept described here should really be called horizontal wave testing, meaning geophones are deployed horizontally across the Earth surface when acquiring the test data. In Search and Discovery Article #40503 we will consider the concept of vertical wave testing, where geophones are deployed vertically in a deep well as test data are acquired.

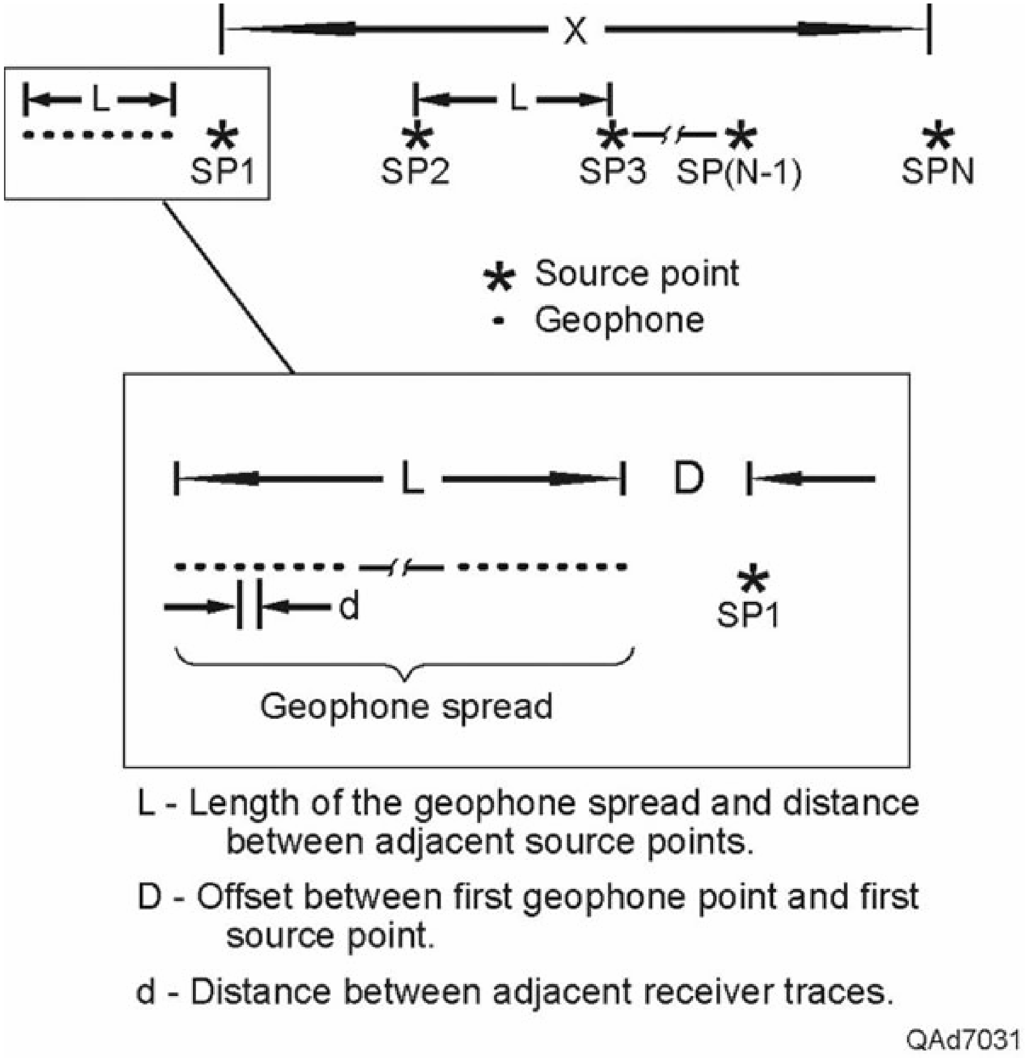

Figure 1. Source-receiver geometry employed when recording seismic wave-test data. The distance “X” from source point SP1 to source point SPN should equal or exceed the depth to the deepest target that needs to be imaged. Distance “L” between successive source stations is the same as the length of the stationary geophone spread. The separation “d” between successive geophones stations should be small (two to three meters), and the receiver-patch length L needs to be reasonably long (200 to 400 meters).

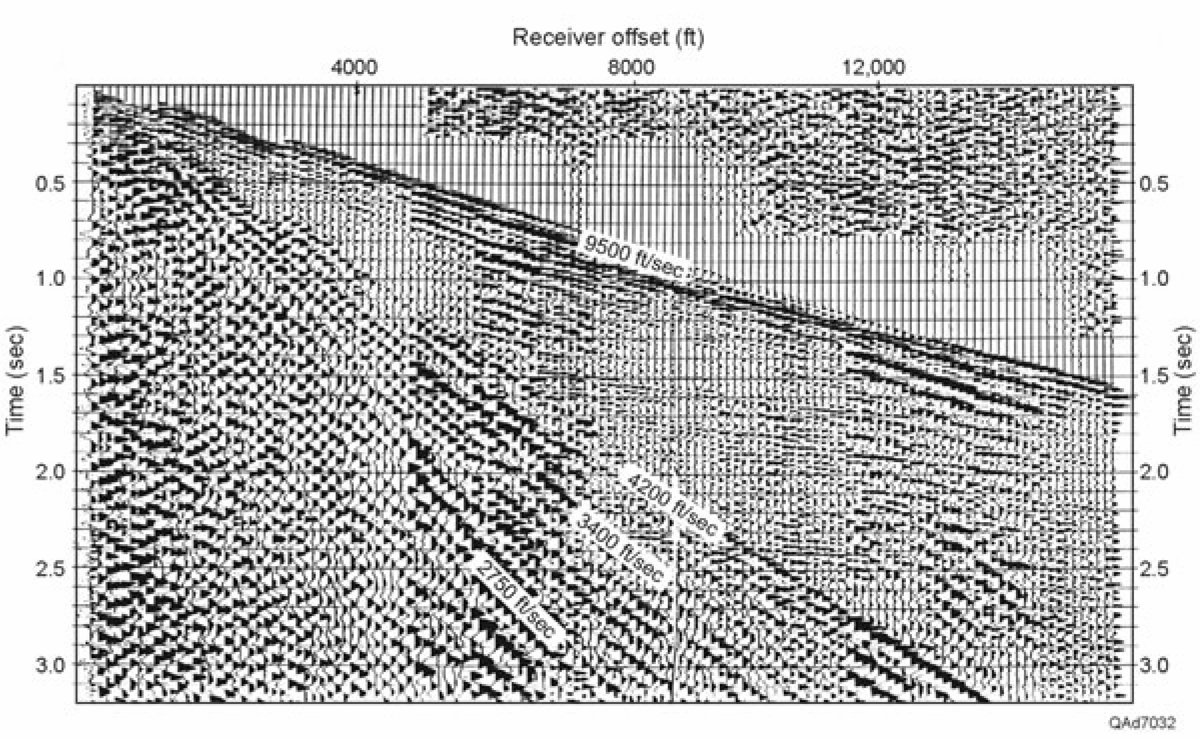

Figure 2. Wave-test data recorded for the purpose of analyzing signal frequency bandwidth, identifying coherent and ambient noise modes and quantifying signal-to-noise character of seismic data across a prospect area. In this example, closely spaced test-data traces have been summed to represent data acquired with a geophone array length of 110 feet (33.5 meters). The apparent velocities of several modes embedded in the test data are labeled in units of feet/second.

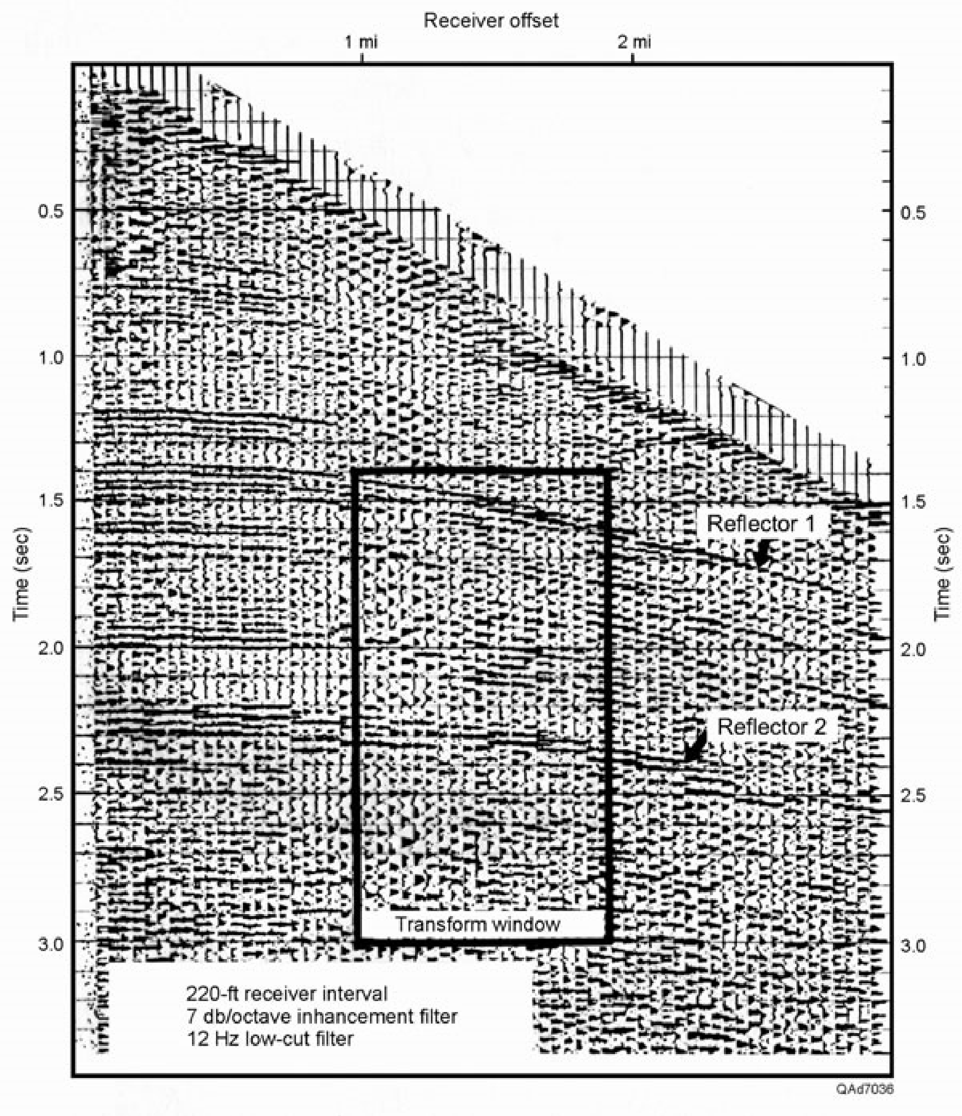

Figure 3. Wave-test data acquired with d = 20 feet (six meters) after a 12-Hz low-cut filter is applied and a running sum of 11 adjacent traces is calculated to simulate data that would be acquired with an inline receiver array spanning 220 feet (67 meters). Hard evidence now has been produced that defines the receiver patch dimension (220 feet) that should be used at each receiver station to optimize data quality.

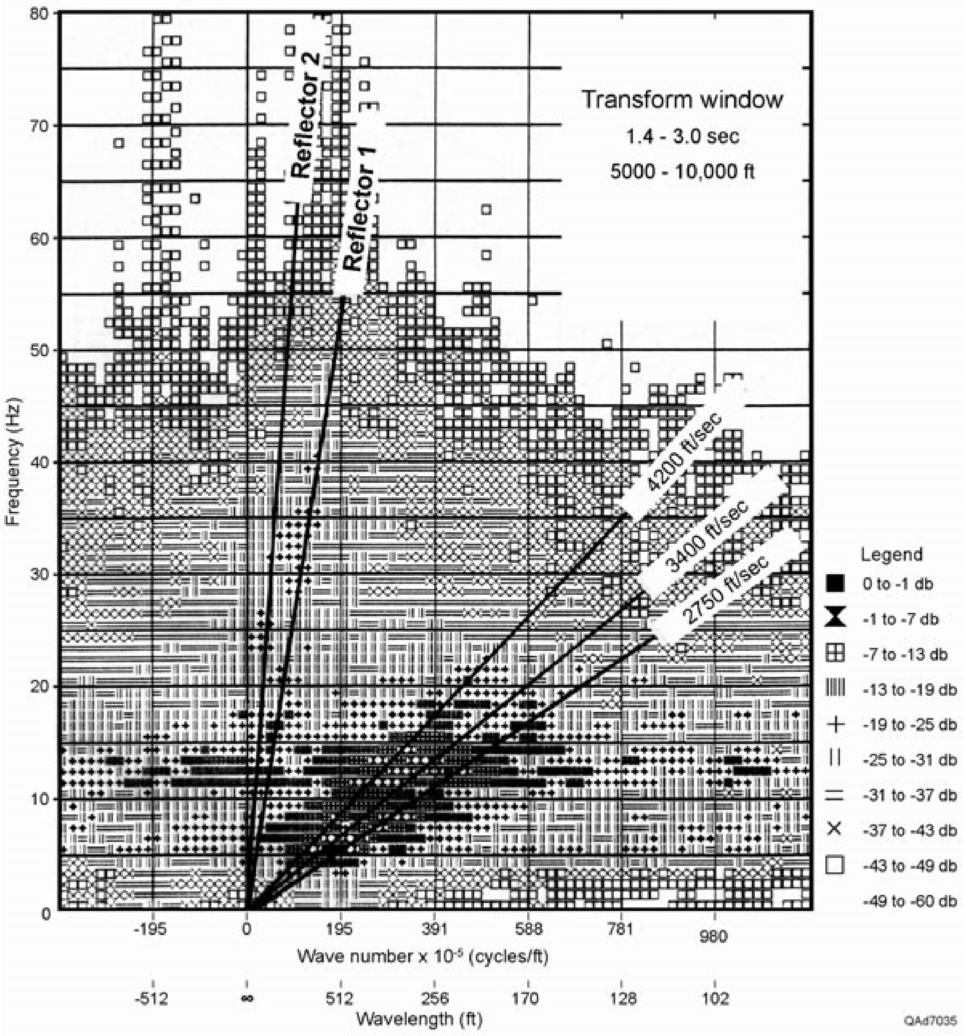

Figure 4. Seismic frequency (vertical axis) and wavelength (horizontal axis) information embedded in the data window labeled Transform window on Figure 3. This data analysis shows that if production seismic data are acquired at this test site with a 220-foot receiver array (Figure 3), the frequency bandwidth should span approximately 80 Hz and each field record should be dominated by high-velocity reflection signals (events labeled Reflector 1 and Reflector 2). The format used to exhibit this frequency-wavelength information on a black/white printer shows how geophysicists had to display data analyses in the field in olden days before color plotters were field portable.