Receiver Type and Receiver Station Spacing Comparisons from an Acquisition Test in Eddy County, New Mexico

A. Lewis[1], B. Karr[1], S. Klug[1], L. Zheng[2], S. Sun[2]

[1] Fairfield Geotechnologies; [2] Viridien Group

Summary

Summary is not available.

Introduction

The Cenozoic sedimentary fill is a complex geological phenomenon prevalent through much of the Delaware Basin. Dense surface-seismic sampling in conjunction with accurate near-surface geophysics are required to provide ample seismic resolution at the underlying reservoir level. "The Fill" is thought to be primarily caused by the dissolution of salt from the Salado formation below the Rustler (Anderson, 1981). Upon dissolution, the Rustler formation collapses, and a mix of late Tertiary and early Quaternary sediments are then deposited on top of those collapsed zones. This complex near-surface depositional setting significantly degrades the vertical resolution of the seismic image at the reservoir level.

An industry supported seismic acquisition design test in southeast Eddy County, New Mexico, was acquired as part of a larger multi-client survey to gain insights related to the cause of resolution degradation beneath "The Fill." A 2013 vintage 3D seismic survey over a relatively deep part of "The Fill" illustrates the resolution degradation that the acquisition test attempts to minimize (Figure 1). There are many potential causes of this phenomenon including scattering, absorption, signal-to-noise, and insufficient source energy to name a few.

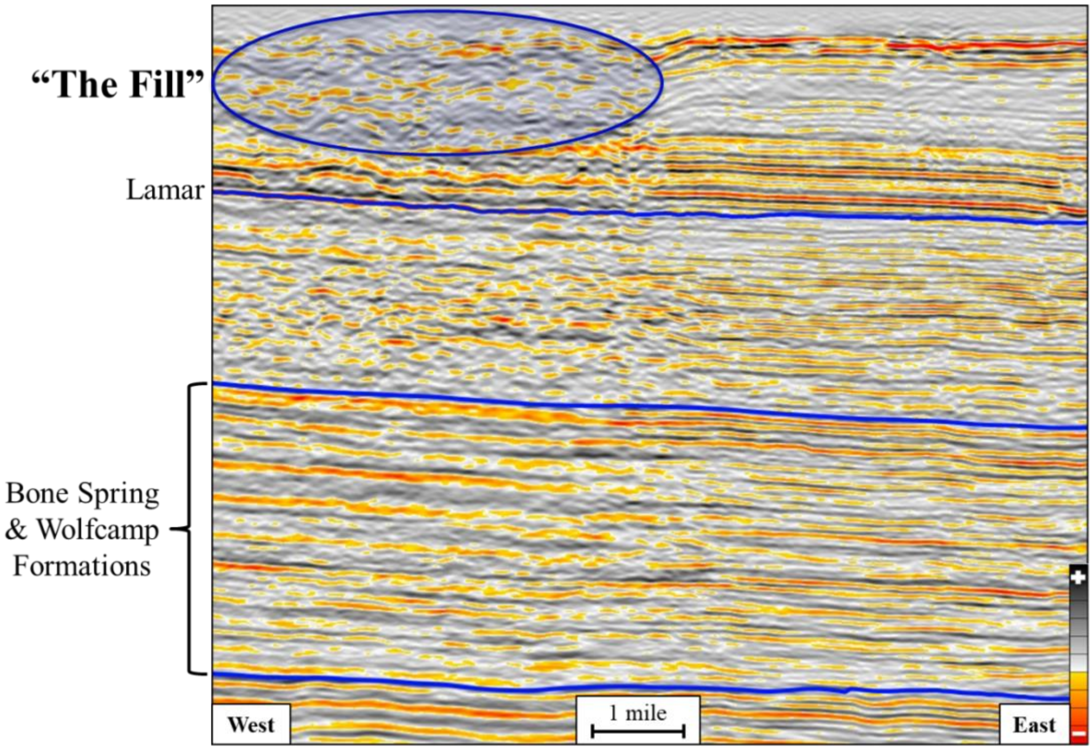

Figure 1. *Resolution degradation caused by the Cenozoic sedimentary fill highlighted by the blue oval in the shallow part of the seismic stack. Note the loss of frequency content beneath "the Fill."*

Part of the acquisition design test includes three different 3D seismic surveys. These were shot at the same time over the same area with a source configuration consisting of three vibroseis trucks in a line per station into three different types of receivers with variable line and station spacings. This study focuses on comparing the bandwidth, phase fidelity, and signal-to-noise ratio of these sensors. Additionally, this study assesses the impact of receiver station spacing on the sampling of ground roll down a receiver line. Conceptually, an adequately sampled survey with accurate applications of velocities, statics, and noise attenuation should minimize the apparent frequency degradation at the Bone Spring and Wolfcamp reservoir level beneath "The Fill."

Acquisition Design Test Geometries and Receiver Comparison Methodology

The receiver types compared in this study include Geospace GSR 10 Hz geophones (three geophone string connected to a battery), INOVA Quantum 5 Hz nodes, and Stryde nodes (accelerometers) in a four square mile area. Each of these sensors are co-located with different line and station spacings. A total of 2,816 GSR 10 Hz geophones were laid out with 495 ft. receiver line spacings and 82.5 ft. receiver station spacings. An additional 11,008 INOVA Quantum 5 Hz nodes halved both receiver line and station spacings to 247.5 ft. and 41.25 ft. respectively. Finally, another 22,016 Stryde nodes were laid out with 247.5 ft. line spacings and further halved the station spacing to 20.625 ft.

All the receivers were recording as the vibroseis trucks rolled through the field test area, simultaneously acquiring three separate 3D seismic surveys. The source line and station spacings are constant at 495 ft. and 41.25 ft. respectively. The source configuration includes three 64,000-pound vibroseis trucks in a line offset by a tire width each so that each truck created its own set of tracks. The sweep was 24 seconds long from 2 – 84 Hz and stayed beneath 10 Hz for the first five seconds.

To accurately compare each of these sensors, it was necessary to decimate the 5 Hz Quantum geophones and the Stryde nodes to the GSR 10 Hz geophone spacings. Raw shots along a receiver line from the center of the survey area were compared after the Stryde nodes were integrated into the velocity domain. Then the same shots were undecimated to their native spacings and compared. The frequency content of the Stryde nodes were compared between the acceleration domain and the velocity domain to illustrate the difference in apparent bandwidth from the integration calculation. Finally, separate low frequency geophone corrections were applied to both the GSR 10 Hz geophones and the Quantum 5 Hz nodes respectively to boost amplitudes and correct for phase roll while the Stryde nodes remain in the velocity domain for comparison. FK plots were generated from each of these raw shots to illustrate the effect of receiver station spacing on ground roll sampling.

Observations from Receiver Comparisons

The initial comparison of decimated raw shots appears similar, but there are some notable differences. Most notably, the low frequency content recorded by each receiver varies. It appears that the GSR 10 Hz geophone records lower amplitude ground roll on the East side of this receiver line than the Quantum 5 Hz nodes and Stryde nodes. Each of the decimated raw shots shows aliased ground roll due to sparse receiver station spacing (Figure 2).

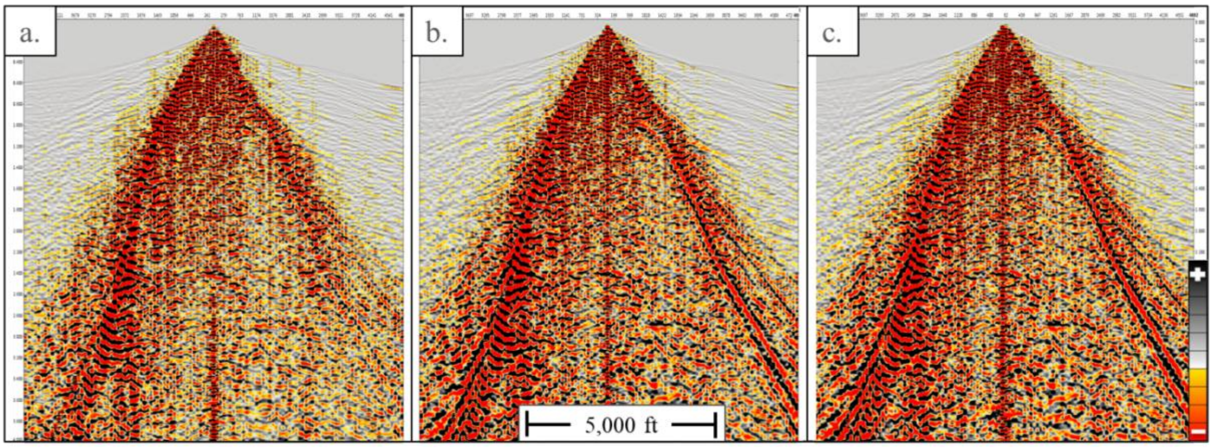

Figure 2. *Raw shots from (a.) GSR 10 Hz geophones at 82.5' station spacing, (b.) Quantum 5 Hz nodes decimated to 82.5' station spacing, and (c.) Stryde nodes in velocity domain decimated to 82.5' station spacing.*

Comparing the raw shots of each sensor at their native spacing shows the impact of finer receiver station spacing on ground roll sampling. Once the geophone corrections are applied to the GSR 10 Hz geophones and the Quantum 5 Hz geophones, the low frequency content of each receiver type is much more similar. The GSR 10 Hz geophones at 82.5’ station spacing show significant backscatter in the FK plot. The Quantum 5 Hz node at 41.25’ station spacing still shows some backscatter in the FK plot, but significantly less than the GSR 10 Hz geophones. The Stryde node, deployed every 20.625’, collects unaliased ground roll with no backscatter evident in the FK plot (Figure 3).

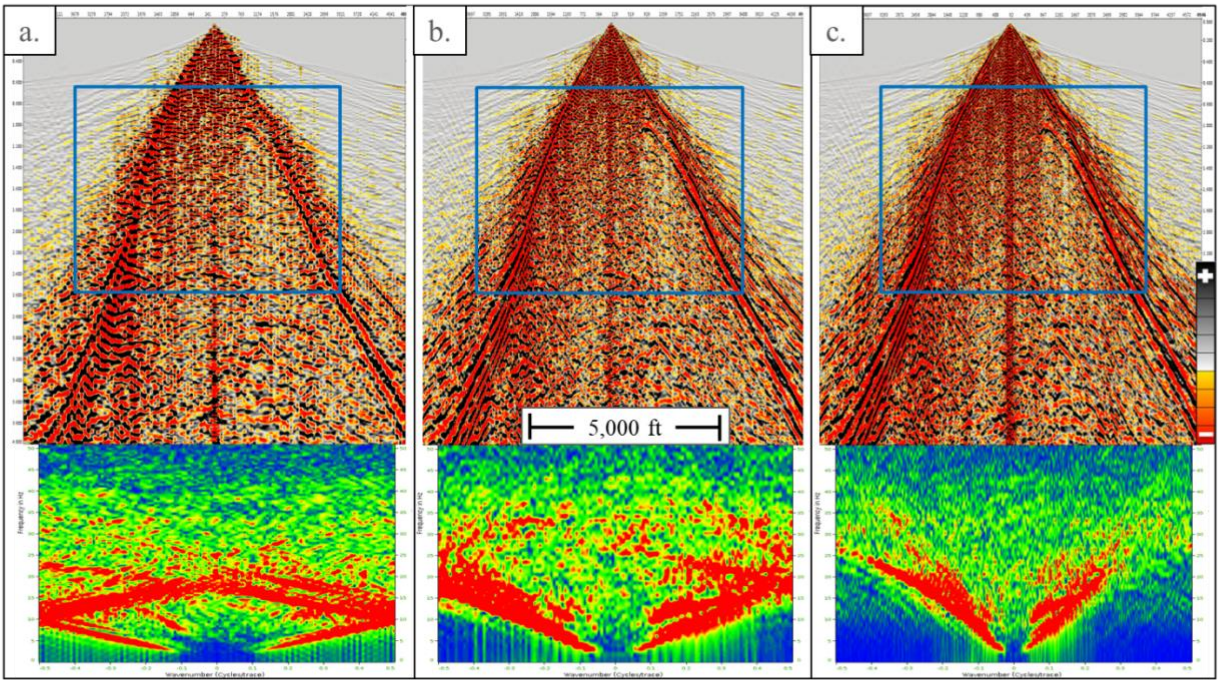

Figure 3. *Raw shots and FK plots for (a.) GSR 10 Hz geophones with low frequency geophone correction at 82.5’ station spacing, (b.) Quantum 5 Hz nodes with low frequency geophone correction at 41.25’ station spacing, and (c.) Stryde nodes in velocity domain at 20.625’ station spacing.*

Each receiver type records slightly different bandwidth. For comparison purposes, the Stryde nodes were integrated from the acceleration domain into the velocity domain, which is the native domain for geophone recording. In the acceleration domain, the Stryde nodes appear to have a dearth of low frequency content. Theoretically, these sensors record seismic data down to direct current or 0 Hz and thus have no need for low frequency correction (Mougenot and Thorburn, 2004). Once integrated from the acceleration domain to the velocity domain, the amplitudes in the low frequency band are significantly boosted, and the overall bandwidth is more comparable. The GSR 10 Hz geophones contain the least bandwidth on both low and high frequencies. The Quantum 5 Hz node contains more low frequency content than the GSR 10 Hz geophones and slightly less than the Stryde nodes. However, after low frequency geophone corrections were applied to the GSR 10 Hz geophones and the Quantum 5 Hz nodes, the low frequency content of each receiver is very similar (Figure 4).

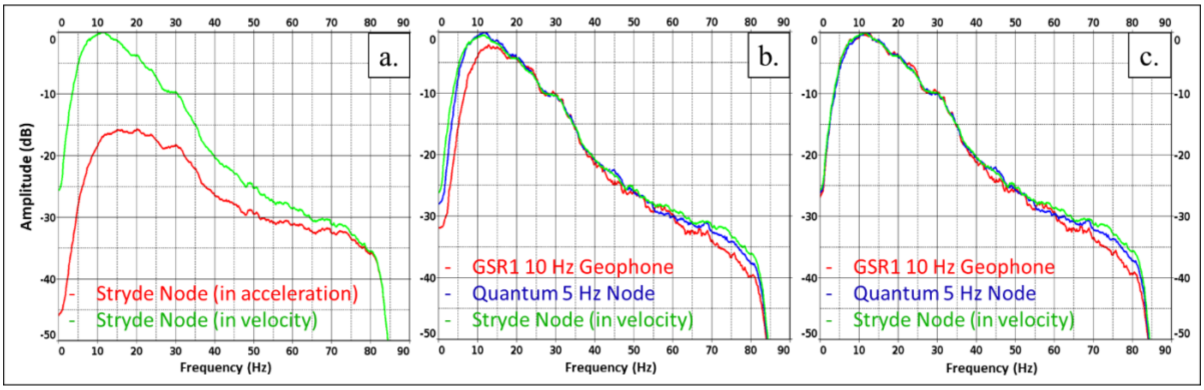

Figure 4. *Frequency spectrum comparisons of (a.) Stryde nodes in acceleration domain and Stryde nodes in velocity domain, (b.) GSR 10 Hz geophones, Quantum 5 Hz nodes, and Stryde nodes in the velocity domain, and (c.) GSR 10 Hz geophones with low frequency correction, Quantum 5 Hz nodes with low frequency correction, and Stryde nodes in the velocity domain.*

Conclusions

Within this four square mile acquisition design test, 35,840 receivers were deployed and co-located albeit at different receiver line and station spacings for comparison. The low frequency geophone corrections applied to the GSR 10 Hz geophones and the Quantum 5 Hz node result in very similar bandwidth between these sensors. Once the Stryde nodes are integrated into the velocity domain, they also compare very similarly to both the GSR 10 Hz geophones and Quantum 5 Hz nodes. However, the GSR 10 Hz geophone shows slightly less high frequency content potentially due to the array effect of the three-geophone string. The signal to noise ratio is also similar between sensors, but the Quantum 5 Hz geophones and the Stryde nodes appear slightly superior to the GSR 10 Hz geophones. The comparison of FK plots generated from the Quantum 5 Hz geophones and Stryde nodes illustrate that unaliased ground roll would require receiver station spacing between 41.25’ and 20.625’. Overall, each of the three receiver types are capable of recording data required to gain insights into the geophysical challenges associated with the Cenozoic sedimentary fill in the Delaware basin. The ideal sensor to use in this setting should be determined by other factors such as deployment time and cost of the sensor.

Acknowledgements

Thanks to Fairfield Geotechnologies for permission to publish this study. Thanks to Dawson Geophysical and Skyway Field Services for receiver deployment and acquisition. Many thanks to Viridien for their collaboration in processing these data.

References

Anderson, R. Y., 1981, Deep-seated salt dissolution in the Delaware Basin, Texas and New Mexico; pp. 133-145. Environmental geology and hydrology in New Mexico: New Mexico Geological Society, Special Publication no. 10.

Mougenot, D., and Thorburn, N., 2004, MEMS-based 3D accelerometers for land seismic acquisition: Is it time? pp. 246-250. The Leading Edge Vol. 23 no. 10.