How to ensure you acquire the frequencies you need in your seismic program

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Summary

The frequency content of a seismic survey is dependent on several factors. The first consideration is that the desired frequencies must be sampled correctly. Secondly, the desired frequencies must be generated, and finally, the desired frequencies must be recorded. When planning a new seismic survey, or when reprocessing an existing seismic survey, all three factors need to be considered in order to get the most value out of the data. In this presentation, we will examine how the frequency content of the data is impacted by decisions made in selecting geometry, seismic source, and receiver parameters.

Geometry: Sampling the desired frequencies

Traditionally, a survey is designed with a spatial sampling interval that is small enough to avoid aliasing seismic reflections from the zones of interest (Cordsen, 2000). At a minimum, two samples per wavelet are required, with slower velocity reflections requiring finer spatial sampling to avoid aliasing. Figure 1 shows shot records recorded with 5m and 50m spatial sampling. At 5m, both the signal and the noise are properly sampled, but at 50m, the noise, which has a much slower velocity, is strongly aliased.

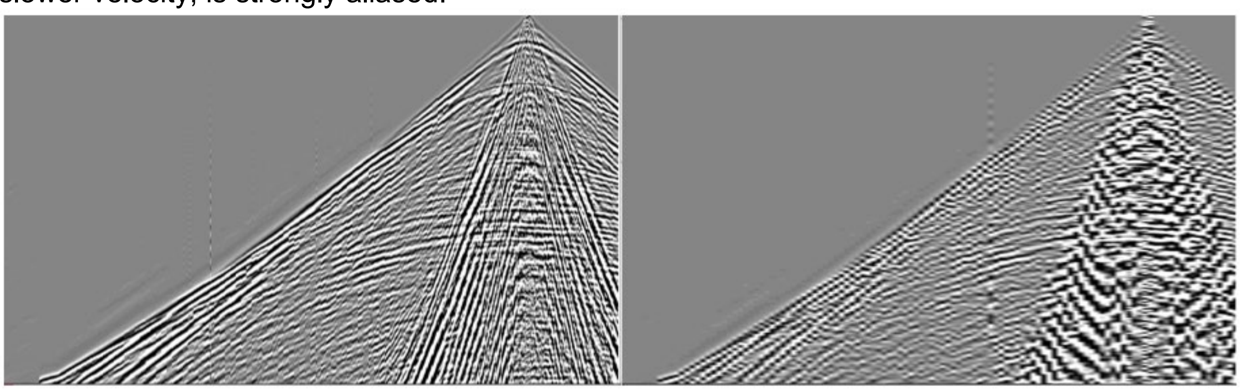

Figure 1: Left = 5m spatial sampling; all reflections are unaliased, Right = 50m spatial sampling; aliasing is visible on slower velocity reflections.

Although we primarily focus on spatial sampling, one important consideration when recording high frequencies is to ensure that the temporal sampling is sufficient to record the high frequencies unaliased. This is not normally an issue on modern data where 1 ms sample rates / 500 Hz Nyquist Frequency are common. However, it is a consideration when examining older datasets that may have had a 4 ms / 125 Nyquist Frequency.

Other factors to consider when selecting the sampling interval of a survey are the reflector dip and the S/N of the data. For surveys with steeper dips, a smaller spatial sampling interval is required in order to record unaliased high frequencies (Crook, 2021). In areas with poor S/N, smaller spatial sampling intervals are needed to either sample the noise so that it can easily be removed in processing, or to increase the trace density to improve the signal-to-noise content of the data.

Seismic Source: Generating the desired frequencies

Even if a survey is designed with the required spatial sampling to record unaliased frequencies, if the frequencies of interest (high and/or low) are not generated by the source, then these frequencies will not be present in the final dataset. A lot of emphasis is put on high frequencies – they are necessary for good resolution on a seismic section, but equally, if not more importantly, are the low frequencies, which are of particular importance for accurate inversion results. Typically, low frequency signal is relatively easy to acquire compared to low frequency noise, which requires finer sampling. However, this is only true if the source being utilized on the survey can generate the required low frequencies.

For surveys with an explosive source, charge size and depth can have an impact on frequency content. Near surface conditions are also an important consideration when drilling shot holes, and tests of the charge size, depth, and pattern (single vs. multiple shot holes) are beneficial. When acquiring data with a Vibroseis source, the frequency content of Vibroseis data will be limited by the start and end frequencies of the sweep, and this, along with all other sweep parameters should be tested. Larger Vibroseis can more easily generate low frequencies but may not be able to operate at full force at the low or high end of the sweep range. Smaller Vibroseis can often outperform large Vibroseis at high frequencies (>150 Hz) but may not be able to acquire low frequencies without a significant sweep taper. Ground conditions will impact results; therefore, it is recommended to test Vibroseis sweep parameters at the start of every seismic program.

Although these challenges can mostly be overcome in Vibroseis by customizing the sweep parameters, or in explosive sources by optimizing the charge size and depth, care must be taken during the design process to ensure the desired frequencies will be generated by the chosen source type.

Seismic Receiver: Recording the desired frequencies

Finally, even if the survey geometry has been designed to correctly sample the frequencies of interest and the chosen source can generate the desired frequencies, the desired frequencies still may not be present if the data was not recorded properly. Therefore, the geophone and recording parameters should be examined. Factors such as the geophone resonant frequency (10 Hz vs. 5 Hz) and the geophone pre-amplifier gain setting can have an impact on the frequency content of the recorded data.

Although most modern acquisition is now acquired with node type geophones, cabled systems are still used in some locations and were common on older datasets. It is important to understand how geophone arrays commonly used with cabled systems affect the frequency content of the recorded data. Longer arrays (receiver or source) can attenuate high frequencies, but they are also beneficial in reducing noise. Although geophone parameters are important, the ground conditions, near surface velocity variations, and/or the presence of absorbing layers such as coal will also have an impact on the ability to record the desired frequencies.

Acknowledgements

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References

Cordsen, A., Galbraith, M. and Peirce. J. [2000] Planning Land 3-D Seismic Surveys. Society of Exploration Geophysicists, Tulsa.

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