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High Density Vibroseis 3D in NW Alberta – A Case Study

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Summary

In the winter of 2016 a 3D vibroseis seismic survey was acquired in northwestern Alberta using a variety of leading edge technologies and procedures to deliver more than an order of magnitude increase in the pre-stack trace density and much improved spatial sampling when compared to typical WCSB surveys. These two changes resulted in improved seismic data quality with both increased frequency content and improved signal-to-noise when compared to an adjacent dynamite-source survey. The program was acquired using a 3-component nodal point receiver recording system that was deployed without pre-staking the receiver positions. The seismic source methodology employed single-vibrator, single-sweep, slip-sweep techniques entirely in stakeless mode with real-time positioning. Extensive GIS pre-planning included the use of hundreds of layers of GIS data as well as newly acquired LiDAR and aerial imagery to ensure an efficient and safe field operation.

Introduction

The seismic industry is moving towards increased pre-stack trace density using wide azimuth geometries and tighter spatial sampling in 3D data acquisition to deliver improved seismic image quality in terms of both resolution and signal-to-noise. A variety of papers published over the last few years (see Ourabah, 2015 for background and references) have shown that high density, wide azimuth, 3D seismic data sets can deliver exceptional images of the subsurface both onshore and offshore, and can improve both the quality and the reliability of conventional and azimuthal attributes. This quality improvement in turn enables the sub-surface geoscience teams to deliver increased business value for the initial seismic investment. Explor has planned and acquired several high density seismic surveys in Western Canada, and this paper shares some of the quality improvements from one of them.

Method

Several steps are required to achieve the successful execution of a high density vibroseis 3D survey in the Western Canada environment. In this survey the initial survey parameter selection, a detailed GIS survey planning process, pro-active source and receiver position skid and offset design, close cooperation with the seismic acquisition and processing contractors and infield data quality control all contributed towards a successful outcome.

The survey area of approximately 120 sq km consisted predominantly of mixed farm land, but included significant wooded areas and several deeply incised river valleys. Therefore three different source types were deployed: five heavy vibrators on the farmland (87%), two lightweight mini-vibrators in the wooded areas (12%) and heli-drilling dynamite points in the valleys (1%). In addition, receiver infill lines were added around some of the valleys to compensate for the locally reduced source density.

The survey parameter selection was based on requirements for reflection frequency content at multiple geologic targets, which resulted in a 40m receiver station spacing and a 10m vibrator station spacing. An adjacent existing 3D dynamite survey in this area used 60m source and receiver spacings, delivering a pre-stack trace density of about 55,000 traces per square km. By contrast, Explor's design parameters delivered a pre-stack trace density of 1.2 million traces per square km within the same offset range. However, during the field operations Explor took advantage of the crew logistics to locally double the source line density and thereby deliver up to 2.4 million pre-stack traces per square km across part of the survey area.

The decision to use the single vibrator, single sweep methodology was based on Explor's prior operating experience within the WCSB. The same sweep parameters were used for both types of vibrator and all vibrators were distance separated as part of the slip sweep parameterisation. In addition, the two types of vibrator were not allowed to share slip time. The vibroseis acquisition crew operated on a 24 hour basis and acquired approximately 47,000 VP's during 335 operating hours.

Examples

A key step in the overall success of this survey was the detailed, desktop integrated GIS survey design process using a variety of remote sensing data. Figure 1 shows a bare earth LiDAR image across part of a pipeline right of way within the survey area. This image was enhanced by Explor, and shows clearly that the actual pipe line route differs from that recorded in an industry database. Fence lines and other cultural features that would impact the field operations were also identified during the GIS planning process. The integration of a wide variety of information, from land permitting through to local slope intensity, within a single GIS database allowed Explor and the seismic acquisition contractor to develop a detailed operational plan well in advance of the actual crew mobilisation.

The GIS planning allowed the seismic crew to deploy the nodal receivers in a stakeless manner using hand-held GPS units loaded with the pre-plot locations. Subsequently, the precise final locations of the receivers were derived from the GPS data recorded by the nodes (Châtenay, 2016). Similarly, the vibrator drivers also used a real-time navigation system to drive to their pre-planned VP locations, with the actual VP locations being defined from the on-board GPS data recorded within the vibrator QC files.

Figure 2 is a statistical analysis of the elapsed time between sequential VP's, and shows that 55% of the VP's were acquired within 15 seconds of each other, and that 97% of the VP's were recorded within 1 minute of each other. This analysis supports the contention that the single vibrator, single sweep method can be implemented in Western Canada in a time effective manner, provided that the necessary pre-planning is performed and that an appropriate simultaneous source technology is used (Thacker, 2014).

The nodal recording system delivered 99.95% of the acquired data, with only six nodes presenting data recovery problems out of the almost 13,000 deployed nodes. This degree of data recovery is far in excess of what used to be defined as "acceptable" for cabled recording systems, and is testimony to the rigorous quality control procedures used by the seismic acquisition contractor.

Figure 3 shows two seismic sections taken from the overlap zone between this survey and the pre-existing dynamite 3D survey that was acquired with a 60 meter station spacing. The superior frequency content, event continuity and overall signal-to-noise of the high density vibroseis survey is evident. A frequency analysis of the two sections is shown as Figure 4, and this demonstrates the higher frequency content delivered by the high density vibroseis survey.

Conclusions

This case study shows that the single-vibrator, single-sweep, simultaneous-source methodology combined with a 3-component nodal recording system can deliver high density 3D seismic data in Western Canada in a cost effective manner. This methodology delivers improved data quality that can be exploited by the sub-surface geoscience teams to deliver increased business value to the operating E&P companies.

Acknowledgements

Explor thanks SAE for their participation in the pre-planning process and the subsequently successful data acquisition, C&C for the data processing, and our clients for sharing the data quality comparisons. The LiDAR image is derived from data licensed by Explor from Airborne Imaging.

References

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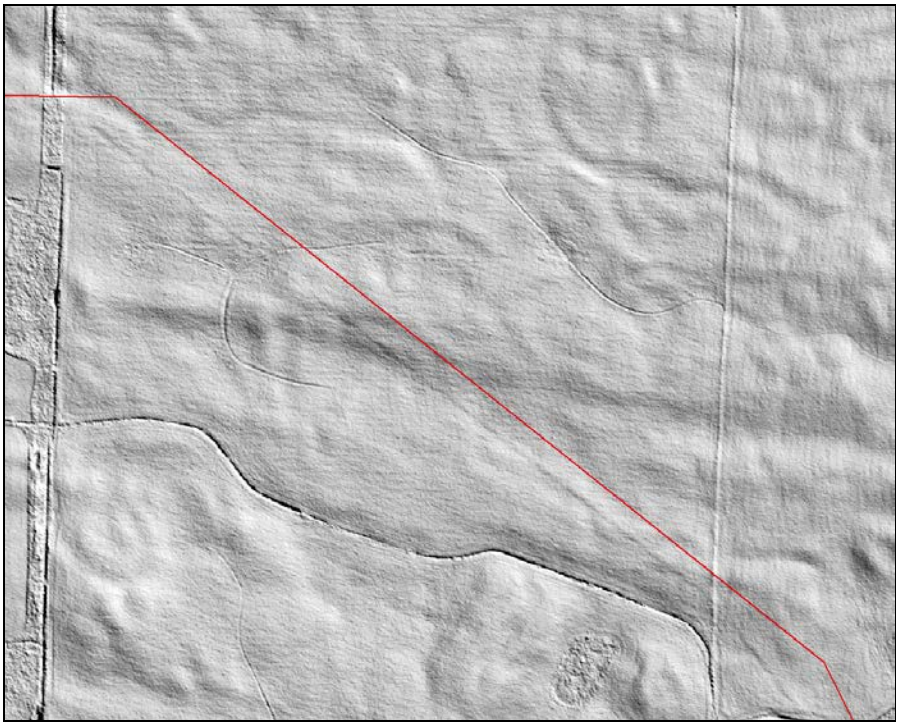

Figure 1 – LiDAR image showing a pipeline route. The theoretical pipeline route is shown as the red line

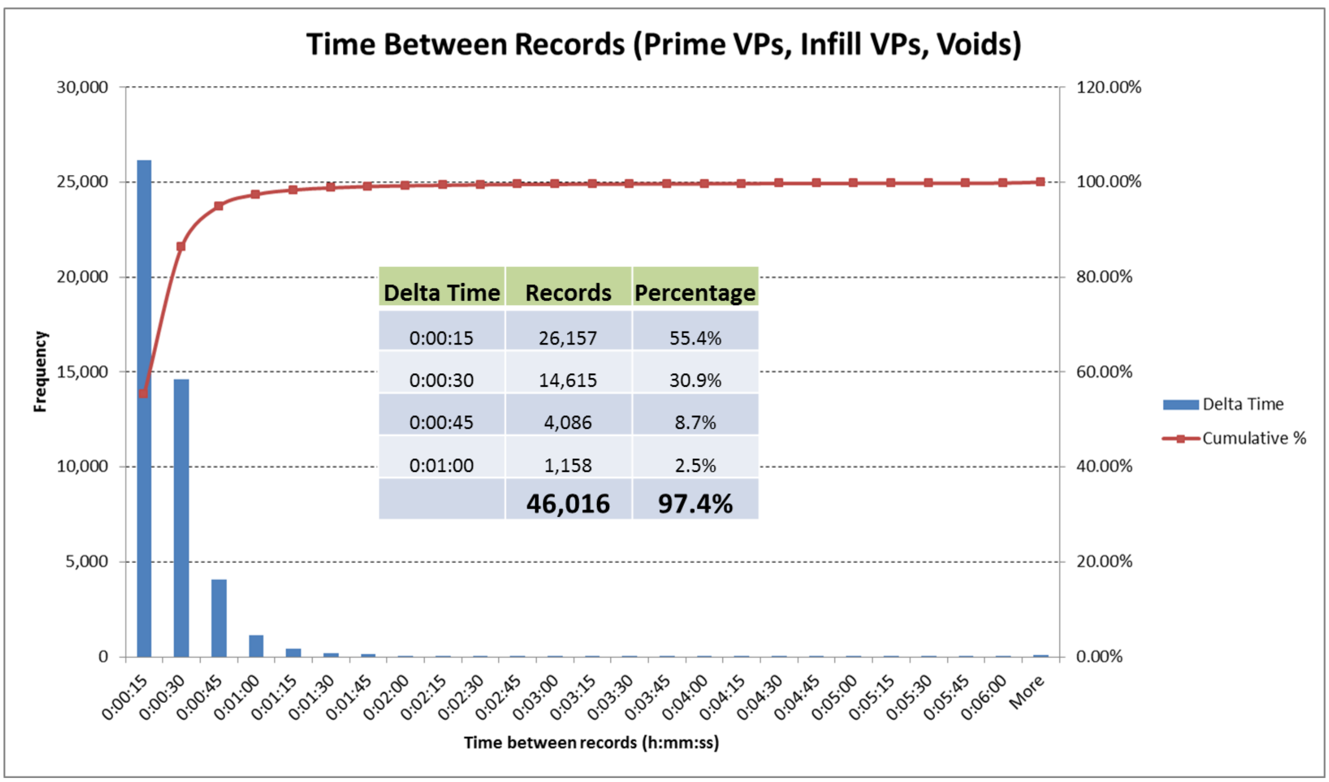

Figure 2 – Elapsed time analysis for the seismic data acquisition

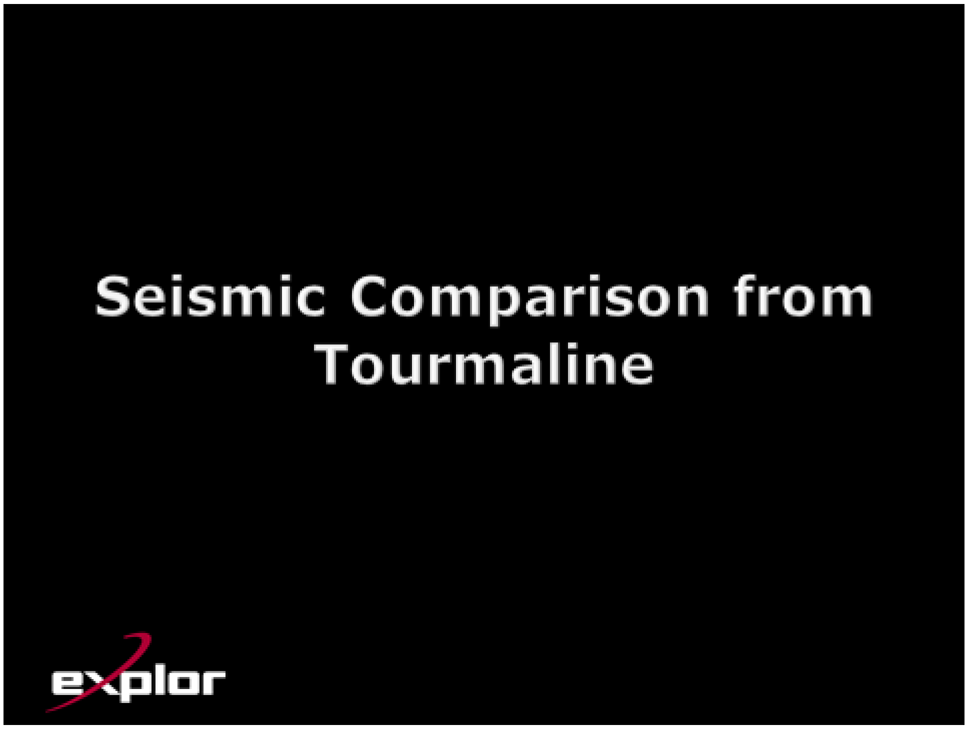

Figure 3 – Seismic data comparison

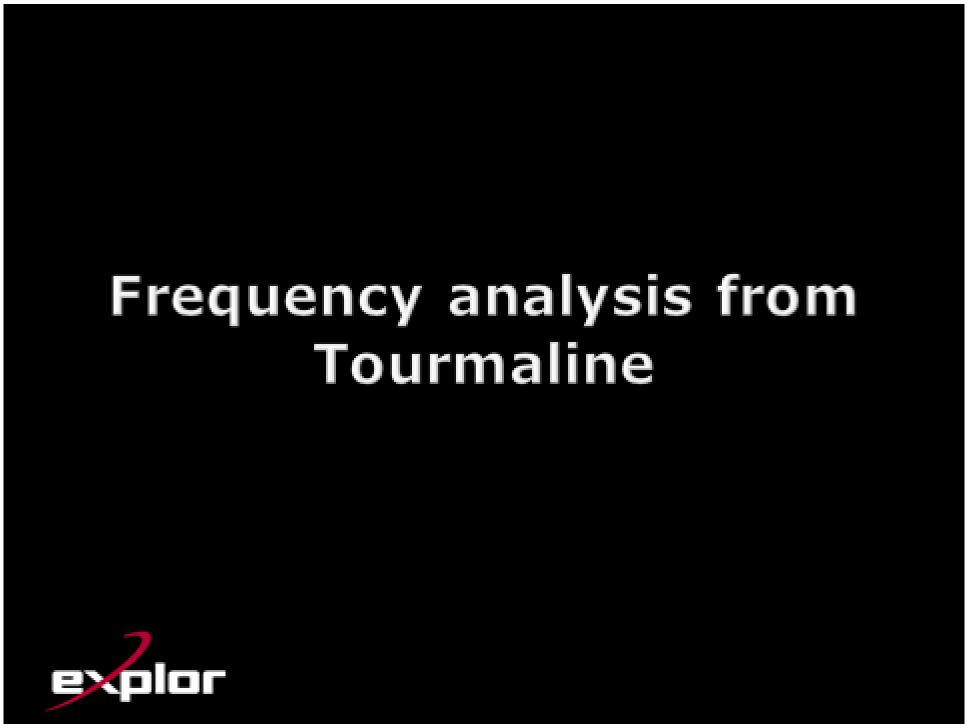

Figure 4 – Frequency content comparison