Seismic source selection within Alberta's woodlands

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Summary

The recording of seismic surveys within the Alberta Woodlands has been historically undertaken with dynamite sources. While planning a 3D seismic program in the Pembina area we established the belief that government-regulated drilling restrictions and setback distances would have a negative impact on the acquisition process, and accordingly we considered the use of an alternative (Vibroseis) source type. Specifically, by using a Vibroseis source we could avoid drilling restrictions, eliminate environmental impact and liability due to flowing holes, and also minimize spatial gaps in source coverage imposed by setback regulations. A 2D test was conducted and the Vibroseis post-stack section was observed to be of comparable quality to the dynamite section. However, Vibroseis pre-stack data quality was observed to be inferior compared to the dynamite case Our test further suggests that certain modifications to the Vibroseis strategy would improve the pre-stack signal quality.

Introduction

Although dynamite acquisition has been successfully used for decades in the Alberta Woodlands. a combination of factors led us to consider the use of the Vibroseis source as an alternative. Specifically, we wanted to avoid drilling restrictions and sampling gaps imposed by setback distances; also, and most fundamentally, we sought to operate in a more environmentally responsible manner.

It is worth noting that almost half of the sections in (TWP48-50 R11) carry drilling restrictions, largely due to the presence of shallow aquifers and a high-water table, with a majority of those stipulating the hole depths cannot exceed 9 metres (Figure 1). This means that drilling deep shot holes in many sections would not be possible. Moreover, in sections where drilling deep holes is possible, lateral changes in the drilling restrictions can lead to source type inconsistency (e.g. smaller charges tend to perform best in cases where restrictions stipulate the use of shallow holes). Finally, the existence of aquifers and/or the high water table triggers the possibility of flowing holes, a major liability with implications for environmental impact and associated mitigation-related expenditures.

In addition to these challenges imposed by drilling restrictions, challenges related to setback distances also hamper dynamite acquisition. For example, high-pressure pipelines have a regulated setback of 32 m for a 2 kg charge size, which could be reduced to 15 m when utilizing a non-explosive source. Moreover, a two-thirds reduction in the setback distance for certain concrete structures could be obtained if a non-explosive source were used, reducing setbacks from 180 m to 50 m, thereby improving the spatial sampling.

In light of these considerations, we adopted the sentiment that if Vibroseis imaging quality were deemed acceptable, then dynamite could be used on an infill basis only, avoiding the above complications. In order to assess Vibroseis imaging quality and field functionality for a full 3D program, we decided to execute a 2D vibe experiment which carried two related objectives: first we sought to optimize Vibroseis acquisition in the area, and second we hoped to establish general recommendations for future 3D vibe acquisition. In addition to these two main objectives, we also decided to examine whether a low-dwell sweep would allow us to generate useful signal at frequencies lower than the nominal Vibrator specifications would permit, and perhaps, at frequencies lower than one would obtain using a reasonable dynamite charge. Obviously, spending time dwelling in the low-end frequency band at a low drive level adds time to the acquisition process, so this endeavor was pursued cautiously without exploring to extremely low frequencies near 1 Hz.

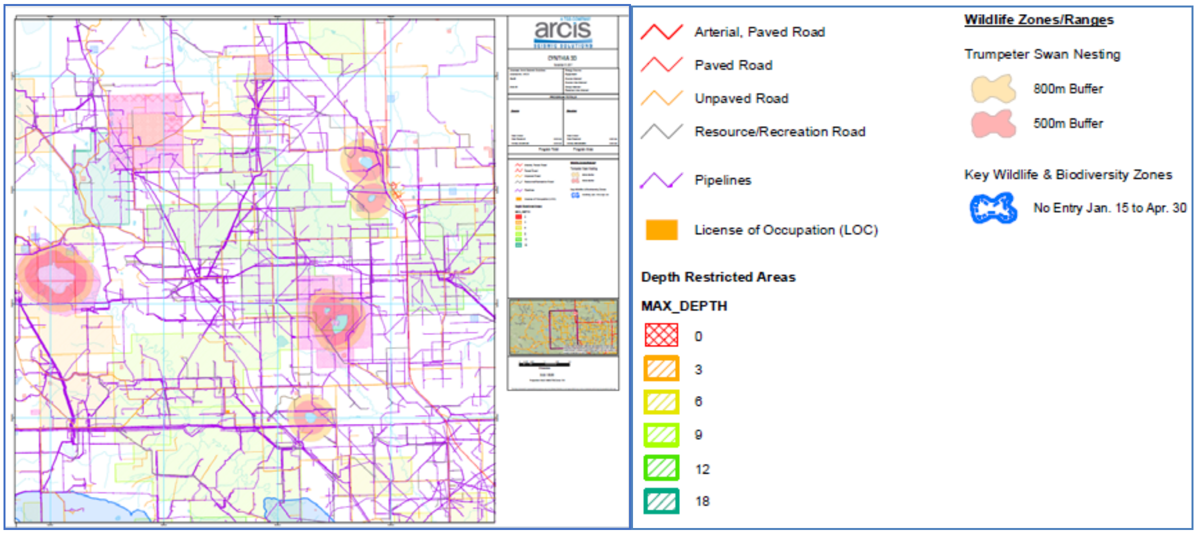

Figure 1: Map showing drilling-restricted areas (colored polygons) and setback-inducing infrustructure (colored polylines). 2D test line runs north-south in the middle of the map. Detialed legend provided at right.

A key element of our experiment was the acquisition of a 2D dynamite seismic line over the same sample area which could serve as a “baseline” against which the vibroseis results would be compared. The present work will navigate a broad scope of acquistion geophysics topics including design and planning, field operations, sweep testing and data comparision.

Theory

In 2016, TGS conducted an experiment over 6.4 km of a single 2D seismic line west of Drayton Valley, north central Alberta, where both setback distances and drilling restrictions impact dynamite acquisition. Over 600 428-DSU3 3-component digital sensors were deployed at 10 m intervals in order to record shots from both vibe and dynamite (baseline) sources. The baseline dataset was acquired at a 40 m shot point (SP) interval with a hole depth of 9 m and a 2 kg charge size. The Vibroseis acquisition accessed the same receiver geometry as the dynamite baseline but in this scenario, the vibe point (VP) interval was set to 10 m intervals, amounting to a 4:1, (VP:SP) ratio. We chose this high ratio based on our a priori knowledge that the Vibroseis traces would likely be noisier than their dynamite counterparts (i.e., for a reasonably equivalent field effort), with the idea that we could decimate the vibe data should signal quality permit.

The dynamite source was selected primarily based on operation constraints. As drilling can be a major expense, a single hole pattern was a practical choice. The choice to drill 9 m holes was due to the fact that most of the drilling-restricted hole depths were 9 m or less. A 2 kg charge size was implemented for two reasons. Firstly, this relatively large charge size produces better quality low-end frequencies and secondly, anything larger than 2 kg would trigger farther setback distances. This source selection gave good results compared to four alternative dynamite configurations which we tested in five separate locations, and which incorporated 2 and 3 hole patterns, with charge sizes of 1 kg, 1.5 kg and 2 kg at 9 and 12m.

The UNIVIB was deemed to be the best option for the Alberta Woodlands. Heavier than a traditional mini Vibe, with a wheel base of 2.54 m, the UNIVIB could operate within the 2.75 m cut-lines while providing greater ground force for improved subsurface penetration. Sweep testing was performed in order to identify the maximum recoverable frequency and optimal sweep length. In addition, the impact of fleet size (i.e, number of vibrators per VP) on shot record quality was investigated. Finally, testing of the custom low-dwell sweeps was performed including 4 Hz, 3 Hz and 2 Hz trials and inspected. In the end, we chose to use 2 vibrators per fleet, sweeping once between 3 Hz and 110 Hz for 32 s.

Vibroseis and dynamite test lines were imaged independently in order to optimize processing parameters for both source types. Key elements of the comparison between the two data sets included first-break picking quality and its ultimate influence on refraction statics, bandwidth characteristics and signal-to-noise ratio (S/N). Note that S/N was examined independently at early and later arrival times, as we were concerned about the Vibroseis source's ability to penetrate to large depths.

Figure 2: Shows a comparison of final migrated stacks for dynamite and Vibroseis sources. Note that image quality is, qualitatively speaking, similar between the two sections. Additional pre-stack displays will be shown in the oral presentation, where it will be demonstrated that pre-stack data quality was significantly better in the dynamite case.

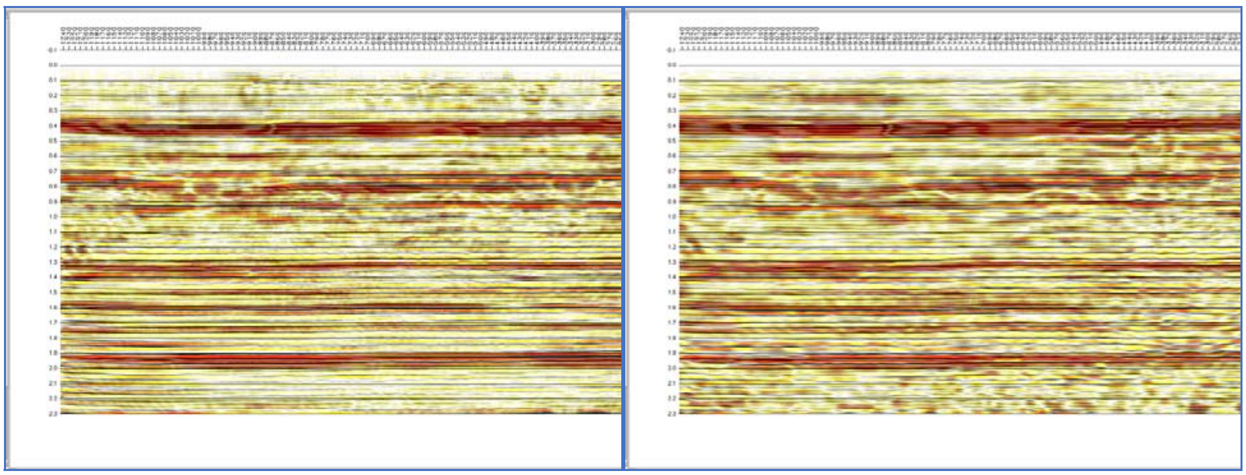

Figure 2: Final migrated stacks for dynamite (left and Vibroseis (right) tests.

Conclusions

Although the dynamite source yielded the highest quality seismic data, the Vibroseis source was deemed viable for seismic acquisition in our area. During Vibroseis acquisition, several unanticipated challenges presented themselves, Including the presence of steep terrain (resulting in dropped VP's), the coupling of the vibrator on soft ground or when operating on newly mulched lines, and finally the cost for rig matting to cover pipelines which were traversed by the vibrators. These above challenges, when combined with the desire to utilizing the existing seismic line (to minimize the environmental impact), together with the requirement to maintain a source line spacing greater than 300 m (to avoid lengthy consultations), imply that an effective Vibroseis program would be managed quite differently compared to tradition Vibroseis acquisition.

The knowledge gained from the 2D experiment presented questions regarding future 3D design parameters and vibrator source setup. While it might be tempting to large numbers of vibe points, with the goal of improving signal quality, this action quickly reaches a point of dimensioning returns due to limited surface area associated with the existing lines. Examples of source adjustments could include an increased sweep length, change in vibrator drive level, and/or an increase in the number of vibrators per fleet. Such modifications would incur cost increases between 10 % to 20 %, which may be detrimental to the economics of the Vibroseis program, extending the price beyond that of a high-quality dynamite program. To offset such increases, we recommend abandoning the low-dwell source effort in this area. The costs associated with the extra effort spent on the low-dwell sweep were significant, yet very little, if any, imaging uplift was observed at the low end. Our tests further suggest that using a linear sweep at full drive force (26,000 lbf), sweeping form the UNIVIB full drive starting frequency of 6.98 Hz, would improve signal-to-noise throughout the primary bandwidth, while maintaining Vibroseis economics comparable to that of dynamite acquisition.