South Halfway 3D. An example of a challenging onshore acquisition and subsequent processing and a unique way of performing a pre-stack elastic inversion on a difficult dataset

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Summary

The 3D survey, South Halfway was acquired in December 2019 in Wonowan, BC, Canada. The size of the survey is 94 km^2 and covers a bog and river valley area. Over the bog area, the seismic is limited to 30 Hz and has a higher noise level. The seismic data quality is much improved in the river valley. This caused special challenges for the seismic data processing and pre-stack elastic inversion. We will be discussing these issues and how we solved them in this publication.

Introduction

In 2019 a 94 km^2 onshore 3D seismic survey was acquired in Wonowan, BC, Canada. This survey covers a bog and a river valley. The data over the boggy area is riddled with noise and signal is lower in frequency when compared to the data over the river valley area. The ground roll behaves differently and one solution fits all approach could not be used (figure 1). The receivers for the solid ground shot example (top) are split, half in the boggy area and half on solid ground. This example illustrates the change in ground roll character, with the ground roll being well behaved on the right side and the left demonstrating slower, incoherent, and more aliased. The soft ground shot taken in the boggy area (bottom) contains the same ground roll characteristics as receivers located in the blog, but also demonstrates a strong primary reverberation. It was hypotheses, the reverberation was triggered by a frozen surface supported by a soft unfrozen muddy near surface. The unfrozen base allowed the frozen surface a mechanism to move. At the time of acquisition, it is important to note the seismic source detonation gave no typical indication of poor source coupling. Typical indications being blowouts, venting, low acoustic volume at surface, or visual observations of surface waves propagation.

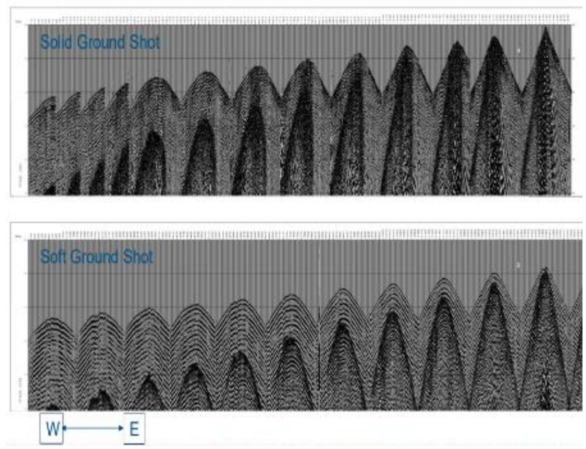

Figure 1: Shot records over solid (top) and soft (bottom) ground.

Figure 2 shows the dominant frequencies around the main target interval. The lower frequencies are observed over the boggy area where they don't exceed 30 Hz compared to 45 – 50 Hz over solid ground. This caused issues not only in the seismic processing and imaging but also when performing an elastic inversion since the wavelets between boggy and river valley area are different.

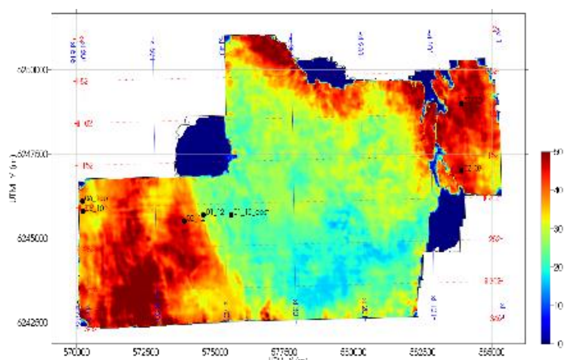

Figure 2: Map view of dominant frequency around the main target interval.

Table 1 outlines a summary of the acquisition parameters which are based on detailed analysis of a modeling study

Recording Patch	
Patch:	24 lines x 144 stations - total 3,456
Maximum Crossline/ Inline Offset	3600m/3600m
Radial Offset	5086m
Recording Geometry	
Receiver/Source Line Interval	400m/300m
Receiver/Source Interval	50m/50m
Natural Bin Size	25m/25m
Fold Bin Size	25m/25m
Recording Parameters	
Weight	2 kg
Charge Depth	15m
Number of Holes	1
Acqusition Values	
Program Size	96.1 km
Total Receiver/Source	6552/5016

Table 1: Recording summary

During the time processing flow, special attention was paid to attenuating the ground roll and to increase the signal to noise ratio especially over the bog. The refraction tomography was also a challenge . After a satisfactory time processing workflow, the data were depth migrated using a TTI pre-stack depth migration approach. Well data were utilized to build the first velocity model. Using sonic logs, together with time picked converted to depth horizons, an interval velocity model was created.

Methodology

Prior to acquisition, the wet boggy area was identified but seismic shot hole drilling yield promising clay for coupling. Meaning there was no surface or near surface indication the bog would be particularly problematic for surface seismic. Post-Acquisition however, extensive modeling, not only of the reflectivity and ground roll, but also of the AVO behavior was performed using 3D rRay modeling.

The seismic data displayed an attenuation above 30 Hz over the boggy area with a sharp transition to high Q attenuation. Furthermore, there was a big surface static and velocity contrast and a distinct difference in ground roll from west to east is present. This is caused by strong direct wave reverberations from shots in the bog.

As mentioned in previously, surface geology posed challenges when computing statics and with the noise attenuation workflow. To overcome these challenges, special attention was given to ground roll attenuation where multiple domains were employed to attenuate the noise. The linear noise was heavily aliased and dispersive, and the noise masked the signal in the bog area completely. Figure 3 shows the difference in the noise content in the river valley, left versus the bog, right.

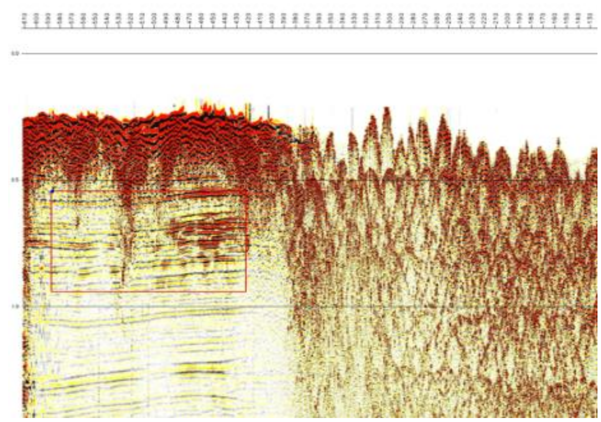

Figure 3: Stacked inline. West (left) side shows the data acquired in the river valley. East (right) side shows the data acquired in the bog

Figure 4 displays the comparison between the initial model velocities and the measured sonic logs. For initial anisotropy values, delta and epsilon were estimated to be 2% and 4% respectively.

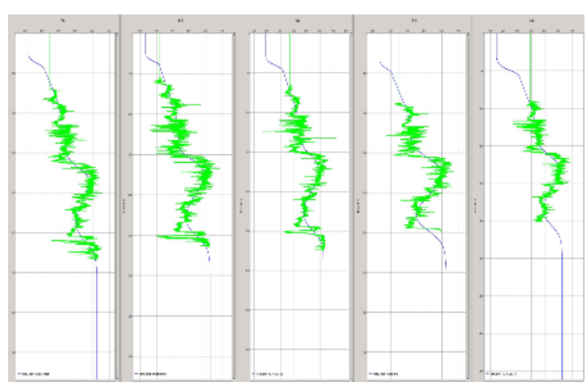

Figure 4: Initial velocity model profile (blue) overlain on sonic logs.

The 1st iteration velocity model update was undertaken using multi-azimuth multi-layer tomography. The 2nd iteration velocity update was also a multi-azimuth multi-layer tomography update. This velocity update further improved the velocity model by introducing more details in the velocity, which conformed to the structures of the events.

Reducing well misties and updating the Thomsen anisotropic parameters ε (epsilon) and δ (delta) are accomplished using well calibration. This process consists of first calculating the mistie between a seismic event and its corresponding formation well top. Then these misties were used to determine and apply a velocity scalar, which will adjust the seismic events to minimize their mistie magnitudes. The anisotropic models are updated simultaneously to maintain gather flatness. The final PSDM data were stretched to time and input into an elastic inversion process.

As discussed previously, large spatial variations in frequency and amplitudes were noticeable throughout the seismic survey. This can clearly be seen in Figure 5. Not only the frequency content and amplitude values are different but also the shape of the spectra.

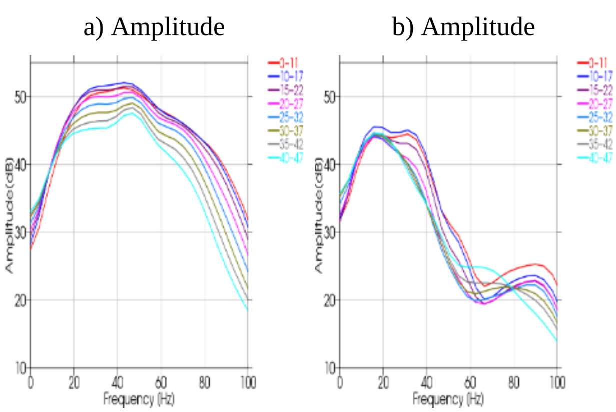

Figure 5: a) frequency spectra over solid ground and b) over Bog.

The seismic data needed additional pre-conditioning applied. A mild Radon de-multiple together with a residual NMO correction were tested and used. The offset gathers were stacked into 8 partial angle stacks from 0 – 42 degrees incidence angle to obtain sufficiently small angle bands which help improving the inversion flow and maintaining sufficient fold and signal in each sub-stack.

The inversion parameters were tested at certain key well locations. As the frequency varies between the solid ground and boggy area, 2 individual inversions were performed. One using a higher frequency wavelet and one a lower frequency. Then, a mask based on the mean frequency at each sample of the volume was built to seamlessly blend the inversion results obtained with each set of parameters. The results were very favorable and a smooth transition between the low and high frequencies areas was achieved.

Figure 6 shows the acoustic impedance before the merge along the frequency bands at the top and after at the bottom. Note the much cleaner appearance of the results.

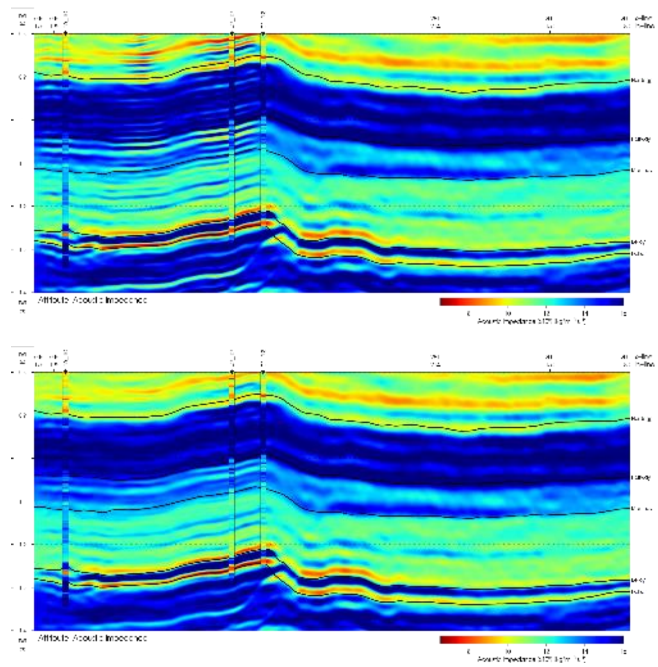

Figure 6: top acoustic impedance before merge, bottom after merge.

Results

Although the seismic acquisition was challenging due to difficult and rapidly varying surface terrain, the resulting seismic was of reasonable quality. However, a difference between seismic over solid ground and boggy surface was clearly observed. The ground roll contamination was much higher towards the eastern part where we intersected the bog. In the same area, the signal to noise ratio was much lower and the frequency and amplitudes were also attenuated. A careful time processing flow was followed by a TTI pre-stack depth migration. Sonic logs were utilized to build the initial model followed by layer-based tomography. Well makers were used to estimate the anisotropy parameter delta and to minimize the mistie between well and seismic data. The PSDM results were converted to time and a pre-stack elastic inversion was performed.

Challenging acquisition, processing and pre-stack inversion

Performing any attribute analysis, post-stack or pre-stack is challenging over a dataset that shows frequency and amplitude variations like South Halfway. To overcome this, wavelets were extracted over the 2 distinct areas and 2 individual inversions were performed. One with a low and one with a high frequency wavelet. The final goal was to generate an inversion product that can be interpreted as one single attribute. This was achieved by merging the 2 individual inversion results along frequency bands. The outcome was a seamless, smooth inversion product. The difficulties caused by changing near surface conditions were overcome through a carefully planned acquisition, a detail oriented seismic processing flow and an innovative approach to merging individual pre-stack inversion attributes.

Acknowledgements

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