Evaluation of PP and PS binning for a multicomponent seismic survey from west-central Alberta

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Abstract

A multicomponent seismic survey undertaken recently in west-central Alberta is evaluated for PP and PS binning methods. A 50 km² subset of the real survey was selected for analysis and subsequent processing. A major step in seismic processing is binning and deciding on the optimum bin size, especially for PS data. One of the common methods is ACP (Asymptotic Common Point), because it requires only an average V_p/V_s ratio and the binning is independent of the depth of the target horizon.

The simulated design is used to test for the optimum ACP binning parameters. It was designed based on the acquisition parameters of the real survey, and on the analysis made on the synthetic data set. A synthetic seismogram was created by convolving well log reflectivity data (from V_p, V_s and density logs) from a nearby well with a wavelet that represents the data. The reflection amplitudes and transmission losses are calculated using the Zoeppritz equations. Maximum useable offset was chosen based on the actual survey geometry for the depth of interest. Then it was used for the simulated survey design to evaluate the fold and offset distribution for both PP and PS datasets of the field survey.

Introduction

Synthetic seismogram (or simply synthetic) is usually used to increase the correlation between the seismic and well data. Synthetic is calculated by using sonic and density logs to derive velocity and density data, respectively. Then, acoustic impedance curve is generated. Form this curve, we can compute reflection coefficients at each interface between contrasting velocities.

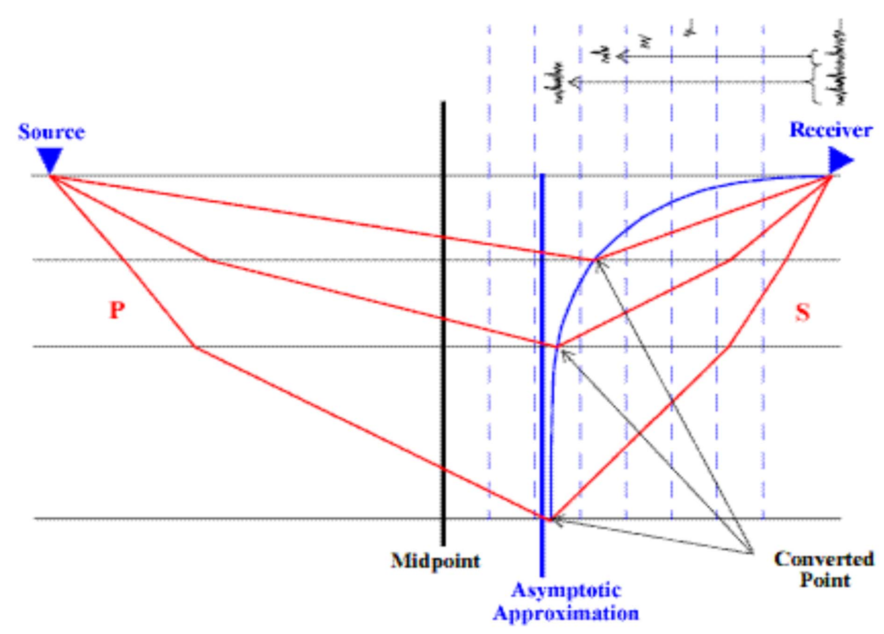
The other parameter needed is the wavelet:

*Synthetic = wavelet * reflection coefficient*, where (*) is convolution.

Wavelet is the link between synthetic traces and the geology (reflection coefficients) that is being interpreted.

For P wave data, the binning process was completed using the conventional midpoint binning formula to create the grid of the survey. However, the P-S waves is assumed to be the conversion of P waves reflected from the interface to the receiver. Thus, the travel path of the P-S is asymmetric for flat reflectors which rules out the use of the standard common midpoint gridding used for P waves data as a correct solution.

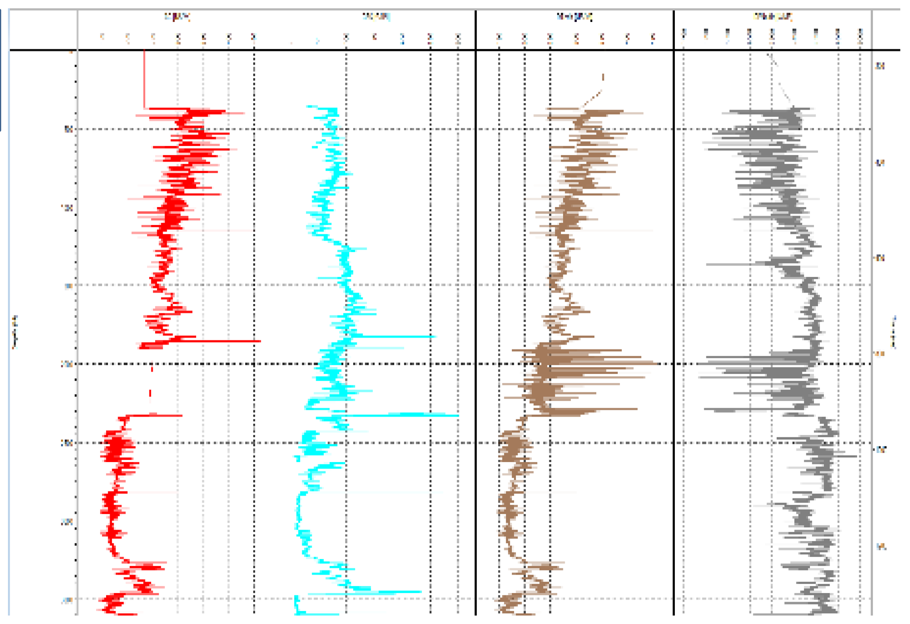
The raypaths of the converted waves are asymmetric and the reflection points in the subsurface are always closer to the receiver. Different techniques are required to stack such data where common conversion point (CCP) is considered instead of common mid-point (CMP) in the conventional surveys (Lawton, 1993). The CCP techniques could be asymptotic (Behle and Dohr, 1985; Fromm et al., 1985), single depth (Tessmer and Behle, 1988; Tessmer et al., 1990), depth-variant CCP mapping (Eaton et al, 1990; Stewart, 1991), and converted-wave DMO (Harrison, 1992). In this paper we will only consider the asymptotic approach (ACP).



Midpoint, Conversion points and asymptotic approximation

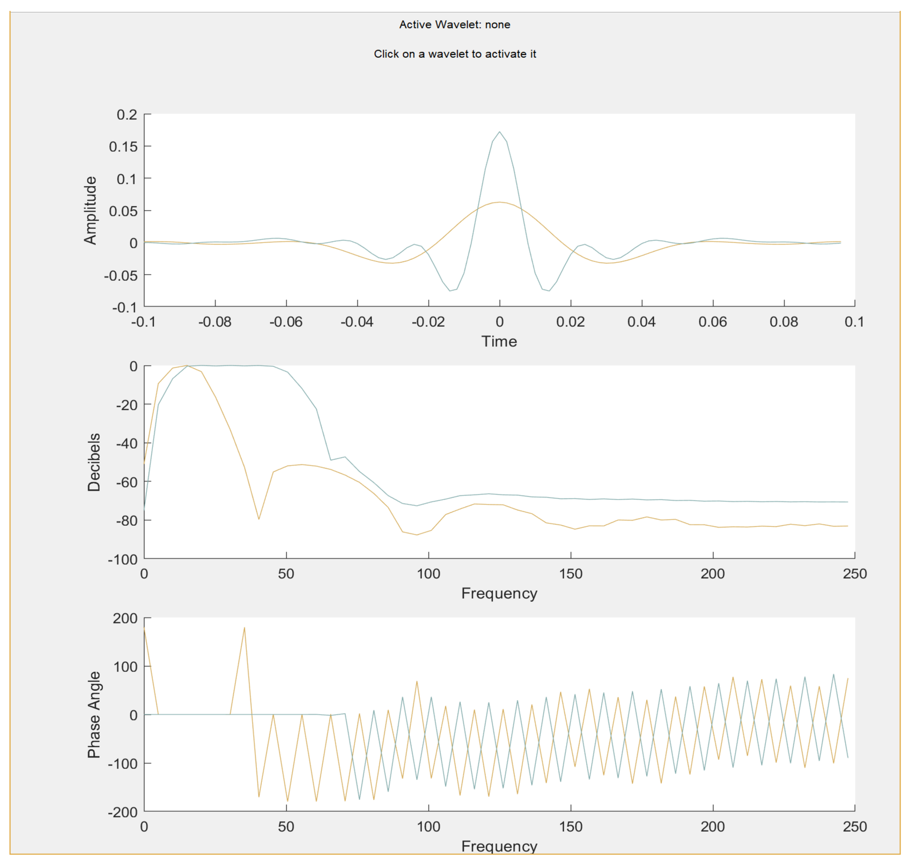
Data

The real survey covers approximately 200 sq. km. A segment of that area was selected for processing. The simulated survey design is based on the segmented area. As for the well data, well logs are measured in a well that lies in the original big survey and nearby to the segmented area of the survey.



Well logs from left to right: sonic interval transit time, gamma ray, delta transit time and bulk density

Synthetic Data

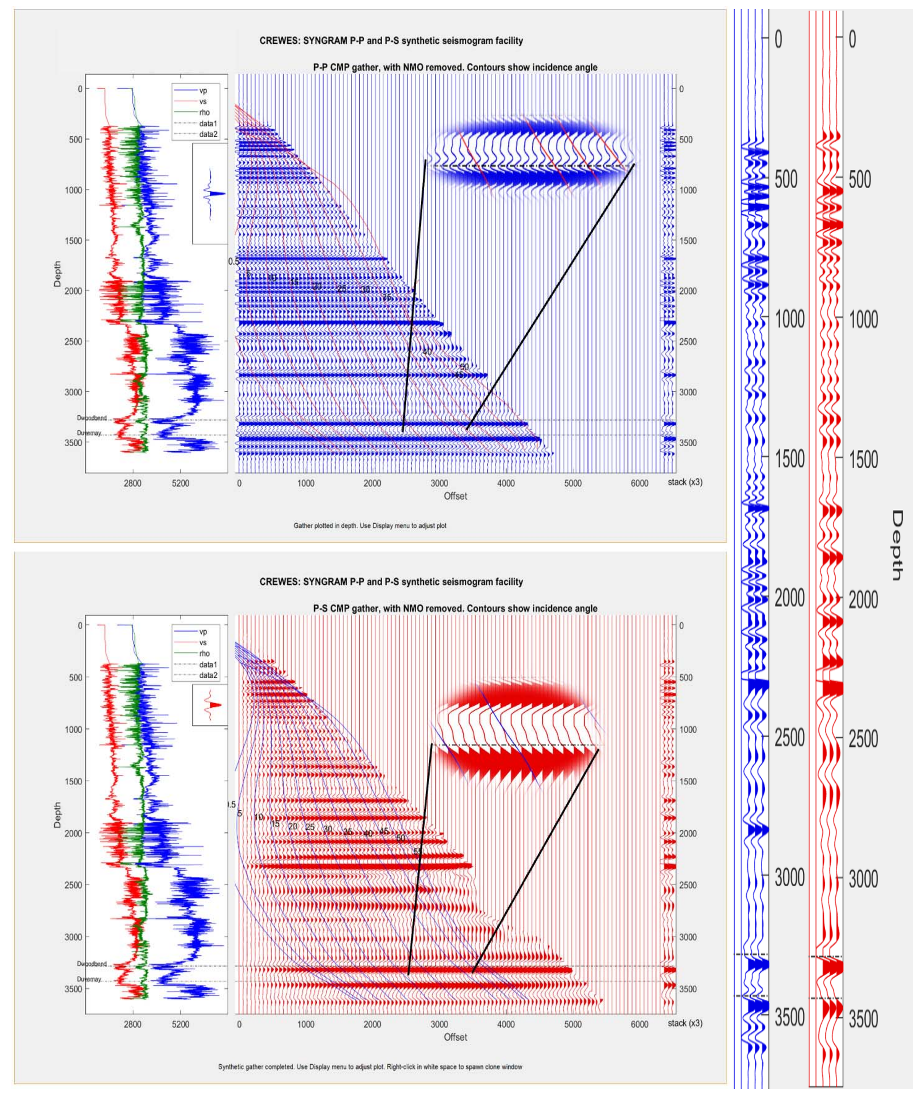


P-P (green) and P-S (yellow) wavelets overlapped. The P-P wavelet bandwidth is: 5, 10, 50, 60 Hz. The P-S wavelet bandwidth is: 4, 8, 20, 26 Hz.

Using both logs data and constructing the appropriate wavelets, SYNGRAM convolves the earth model given by the well logs with the wavelets to generate synthetic offset gathers and stacks for both P-P and P-S. The maximum offset from the real data survey is approximately 6200 m.

Changing the maximum offset-depth ratio allows us to mute distorted traces at far offsets. So, the offset-depth ratio works as a mute function excluding uninterpretable traces. Ratios used are 1.3 and 1.5 for P-P and P-S, respectively.

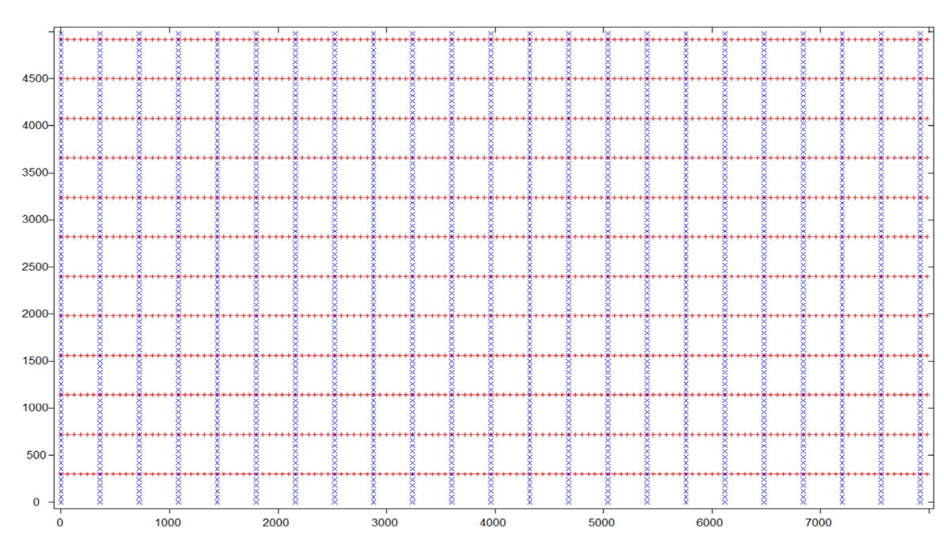
Analyzing both synthetic seismograms, a stretch and phase rotation are observed in some traces at certain offsets and depths. That will help us decide on the maximum useable offsets when we design our P-P and P-S surveys. Our target is at 3400 – 2430 m deep. Traces at that depth are distorted around 3000 m offset.



Traces start to get distorted for P-P (top) and P-S (bottom) around offset 3000 m. So, the maximum useable offset will be used for P-P and P-S designs is 3000 m. Stacks show good tie between P-P and P-S.

Survey Design

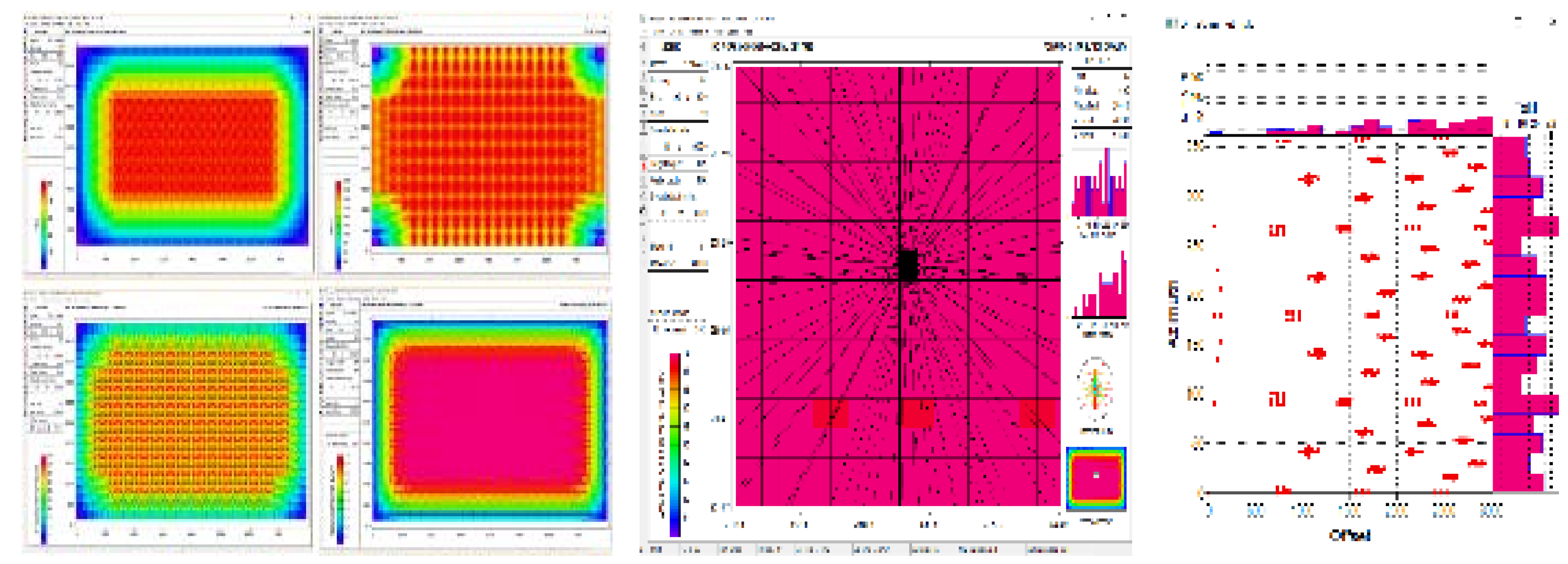
Source Interval	60 m
Source Line Interval	420 m
Receiver Interval	60 m
Receiver Line Interval	360 m



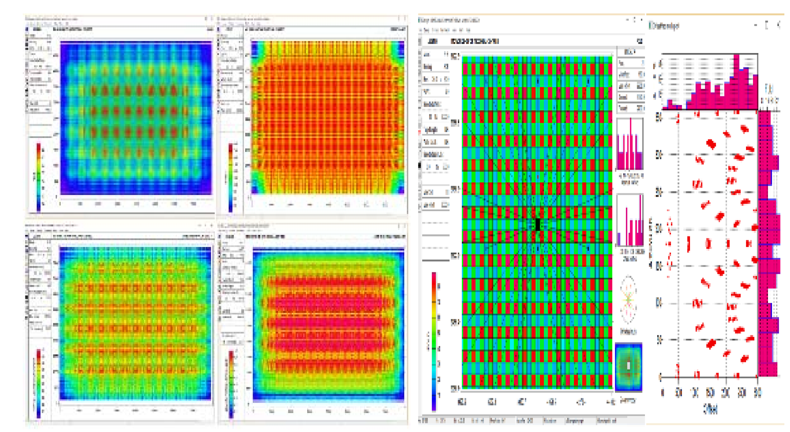
Shot-receiver of the simulated survey design. Shot lines are E-W and receiver lines are N-S.

PS Design software allows to run the conventional CMP binning for P-P data and two types of P-S survey design; asymptotic and depth specific. In this part, we will compare and evaluate the fold and azimuth for P-P, P-S asymptotic and depth specific, with and without the optimum bin size.

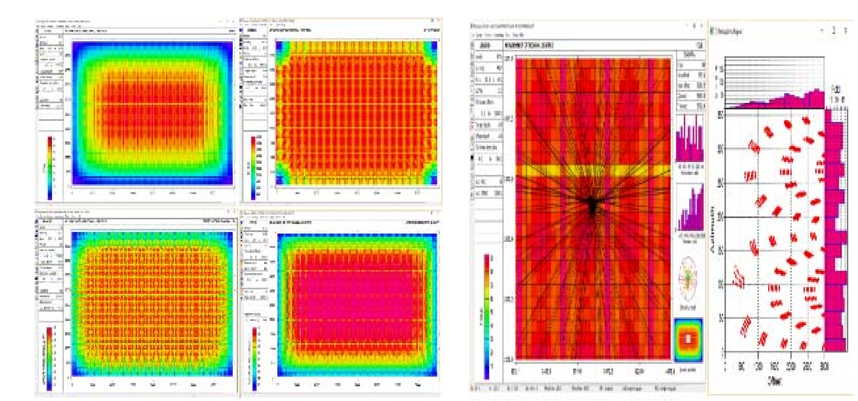
P-P design



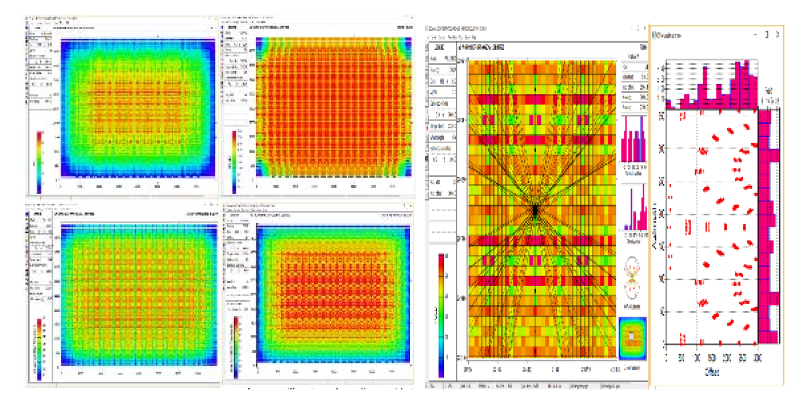
P-S Asymptotic



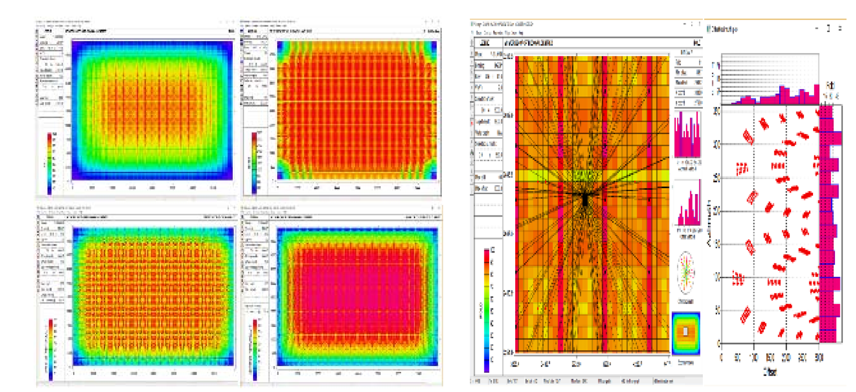
P-S Asymptotic after re-binning to 40x40 m



P-S Depth-specific



P-S Depth-specific after re-binning to 40x40 m



Attribute maps for P-P, P-S asymptotic and depth-specific before and after re-binning: fold (top left), offset range (top right), offset distribution (bottom left) and azimuth distribution (bottom right).

Conclusion

P-P survey designs are binned using the conventional CMP binning. That is why the fold map and other attribute maps do not have any irregularities. In our case here, the bin size was 30x30 m and the maximum offset is decided from the synthetics to be 3000 m. The nominal fold is 51 and it is regular through the nominal fold area in the middle of the survey.

For P-S asymptotic survey, Vp/Vs was provided to calculate the conversion points. The fold increased as expected. However, it was not regular along the nominal fold area. It is due to the change of conversion point locations with depth that the asymptotic method does not account for. One method to solve the issue of irregularities to re-bin the grid to the optimum bin size. The optimum bin size for this survey parameters is calculated to be 40x40 m. After re-binning, fold increased as bigger bin will include more traces. Moreover, the re-binning helped to smooth the irregularities in all attributes consistently, as confirmed in the illumination map.

For P-S depth-specific survey, similar procedures to the P-S asymptotic are followed. Except for this survey, the depth of interest is provided to evaluate the same attributes evaluated before but at specific depth this time. A drop in fold compared to the P-S asymptotic survey is expected. Because all the traces from smaller offsets that do not reach the chosen depth are not included in the fold map. However, the fold map shows better regularity than the P-S asymptotic before re-binning. That is because conversion points get closer to each other with depth. After re-binning, same thing happened as P-S asymptotic survey, fold increased. Furthermore, the illumination map shows better regularity as indicated by the color bar although we see a zig zag pattern in the map.