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2D Wideline Feasibility Study - A Synthetic Example in Foothills

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Summary

Elastic feasibility study was performed on a foothills synthetic model. A special focus was put on signal to noise ratio of the modelled data to mimic real shots as much as possible. Blind processing sequence was performed leading to PSTM sections. True velocity model was used for PSDM imaging. Results show gain for wider and denser acquisition patterns. The replacement of dense crossline sampling by CRS seams questionable.

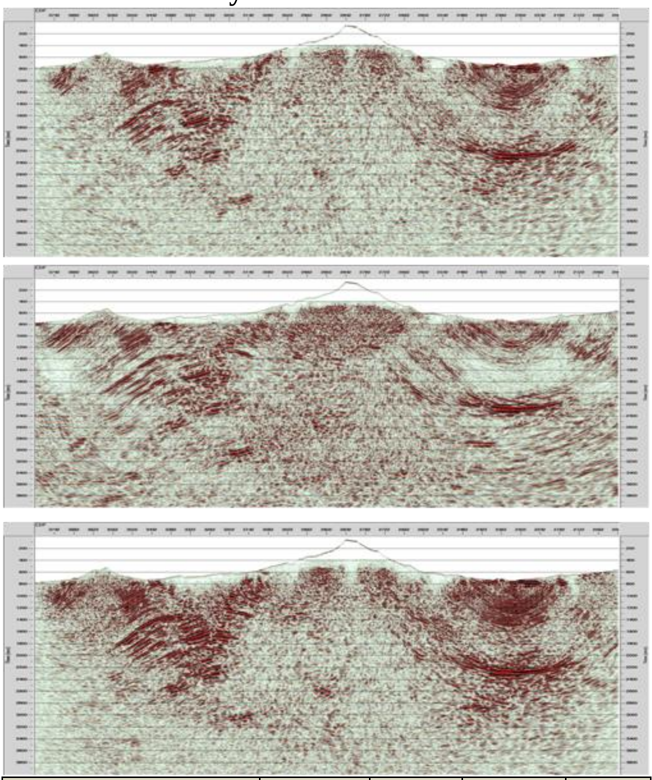
Introduction

Oil & gas exploration often rely on 2D seismic in foothills and hard to access environment where 3D is unaffordable. A lot of efforts have already been done to develop smarter sensors patterns (Stork, 2016), leading possibly to logistical issues (costly and heavy transport …). Still, a compromise may be found using a 2D wide line or “fat line” (Waheeduddin & al, 2002) (Hall & al, 2012). The use of cross line offset may bring significant added value compared to 2D acquisition (Yongqing & al, 2003) or on the contrary show some limitations (cf fig 0). This paper intends to present, on a synthetic example, how to take advantage of this wide line, how to optimize the seismic quality at given cost, and how improved processing sequence, and especially CRS (Common Reflection Stack) may influence this specific acquisition pattern, using synthetic elastic dataset.

Method and theory

This paper introduces a change in acquisition feasibility with an isotropic elastic dataset generated with added near surface noise and the comparison of images after “blind” time/depth processing sequence. This new workflow ensures more reliable results for a feasibility study, preventing any bias usually associated to synthetic dataset: SNR too high, lack of coherent and incoherent noise, shot and receiver density unreliable.

The ultimate goal was thus to compare 2D sections, 2D interpolated (with CRS algorithm), and 2D wide line, in time and in depth domain, to assess the differential benefits of innovative processing versus innovative pattern. The time imaging sequence was completely blind, and the PSDM was performed with true velocity model. For the wide line, six different datasets were generated, with various line numbers, line width varying from 480m to 1920m, and spacing varying from 60 to 240m. Shot interval and receiver interval was kept constant at 40m and 20m respectively.



Dataset	*SI(m)*	*RI(m)*	*RLI(m)*	*NRL*
#1 “2D”	***40***	***20***	***X***	***1***
#2 2DWL 480/60”	***40***	***20***	***60***	***8***
#3 2DWL 960/60	***40***	***20***	***60***	***16***
#4 2DWL 960/120	***40***	***20***	***120***	***8***
#5 2DWL 1440/120	***40***	***20***	***120***	***12***
#6 2DWL 1920/240	***40***	***20***	***240***	***8***

Figure 0*: PSTM sections of real 2D wide line test in foothills: 2D (top), 2D with CRS (middle), 2D wide line (bottom) and synthetic study parameters*

The Andean velocity model building

The cornerstone of this feasibility has been the construction of a 3D detailed elastic velocity model (V_p,V_s,ρ) which contains quite cylindrical structure, inspired by sub Andean foothills case. This model has been defined using a particular reflectivity type, introduced in Vp, Vs and Rho cubes, allowing easily reflectivity variations. The idea was to use a smooth background velocity model, and to add afterwards a reflectivity skeleton, following main structural horizons, and depicted as a velocity break of Gaussian derivative shape. This technique was introduced by H.Chauris (Mines Paris Tech) in 2015. This specific shape of interfaces was analyzed to mimic the conventional velocity step technique, in terms of frequency and phase spectrum.

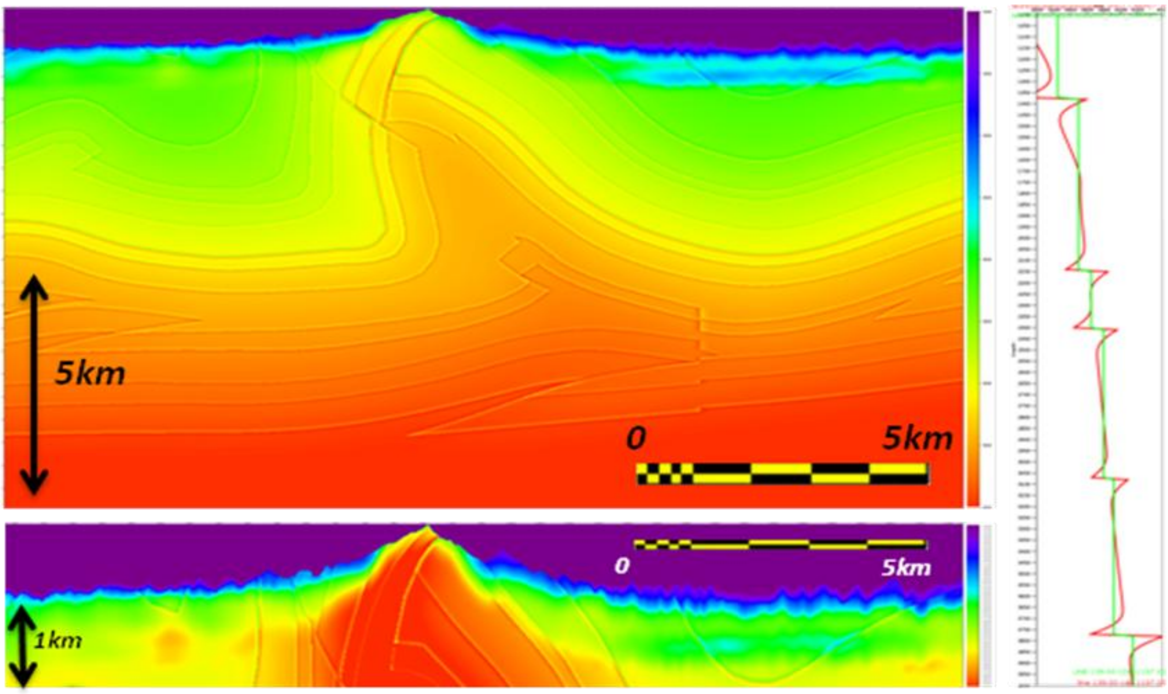


Figure 1: *Vp model (Inline 819) and zoom on near surface velocities (top and bottom), and Vp vertical profile extraction from blocky model right, green) and Vp model used in this study (right,red)*

The first kilometer of the velocity model below topography was taken from first break tomography computed on real dataset in this area. It reveals very low velocity (around 1000 m/s) till 1km depth, which generated dramatic difficulties in the processing sequence of the real dataset. In order to degrade as much as possible the SNR in the eastern syncline of the structure, velocities were artificially lowered to 700m/s for V_p cube and 400m/s for Vs. This use of extremely low velocity interval on the first hundreds of meters to generate very low SNR has already been studied (Gerea, 2011).

Dataset generation and processing

The 2D wide line dataset has been modeled internally, using Total's HPC infrastructure. The modeling parameters were the following: SI=40m, RI=RLI=20m, wavelet shape: Ricker of 2^{nd} order, f_{dom} = 15 Hz, max_time = 7 sec, fixed spread recording. The use of a single shot line to generate the six synthetic wide line dataset was done to limit as much as possible the computation time (external shooting lines would have led to unaffordable computation cost).

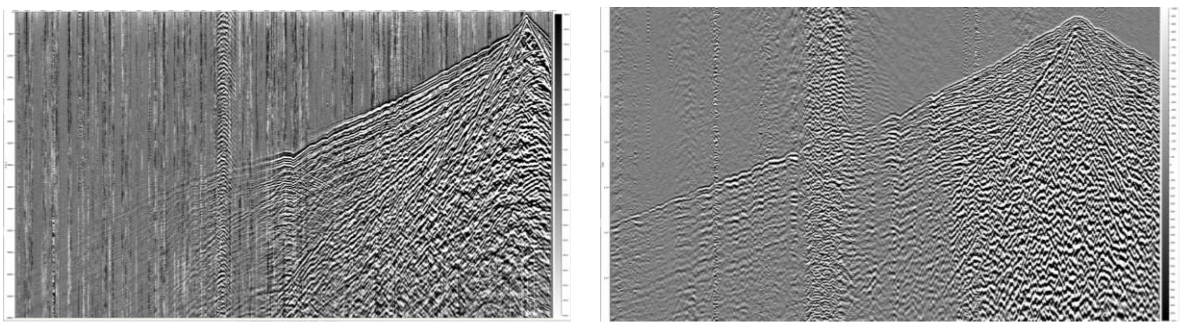


Figure 2 *Inline view of shot 400 (RI=20m), showing the influence of the pseudo random noise added (left) and real shot gather (RI=40m)*

The signal to noise ratio of the modeled dataset was already correct compared to former acoustic modeling, but still far from real shots. As a consequence, the use of artificially low SNR was decided to make the seismic data as much realistic as possible. This workflow has already been extensively described (Regone, 2013), on the SEAM 2 unconventional dataset in particular. The principle is to decompose the shot modeling in two different steps: one modeling done on the full model depth and one performed only in the near surface (here 1 km). By combining with different coefficients these two shots, generated at same (x,y,z), we are able to generate variable signal to noise ratio, to fit synthetic data with real data.

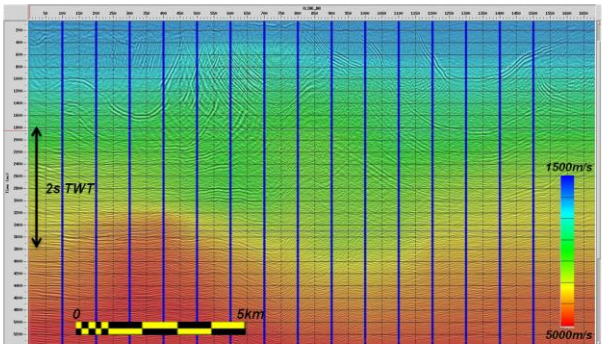


***Figure 3**: Vp migration model for PSTM estimated in 2D, no FDP applied*

The processing sequence applied was identical for all 6 datasets. The sequence starts with semi-automatic first break picking and GLI tomography (offset max picked 6km), to obtain refraction static corrections for compensation of influence of LVL in foothills. The correlation between the velocity model obtained and the true one is very high. Linear and random noise elimination was performed on the data. The velocity model estimation in time was done on the dataset 3 and used after for the others. Pre-stack time migration was performed from smoothed topography with application of static corrections (basic and residuals). Pre-stack depth migration was performed from topography (with applied source-receiver local flat datum) without long wave-length component of static corrections on the real velocity model. Migration parameters used were the following: dip limit 80° and aperture 5km. These were chosen to optimize vertical flank imaging and to limit migration smiles.

The velocity model estimation in time was done on the dataset 3 and used after for the others. Regarding the very low reflectivity at the heart of structure, velocity picking on semblance spectra appeared as quite robust only in the synclines, but out of range in the anticline, with errors between 1500 and 2000m/s. The dataset density does not seem to have an influence neither on the near surface velocity estimation, nor in the deeper zone.

The comparison of two datasets, 2D approach and WLP processed as 3D (bin 20m*20m), shows that definitely better image is obtained when 3D WLP approach is used instead of standard 2D. The differences are observed both in time, with manually picked velocity and application of static corrections, and in depth, when the real velocity model is used. The CRS approach shows the same dependences. The application of CRS increases the coherence of the signal but the relationship in data quality between the 2D approach and 3D WLP is unchanged. The number of recording lines seems to be the key parameter in terms of quality gain. The line width does not provide significant gain, which is probably linked to the relative cylindrical model, which leads to limited out of planes events to be eliminated in the processing sequence.

The use of CRS algorithm to enhance poor signal to noise ratio in foothills has already prvode to be efficient (Studer, 2016)(Spinner,2012). In this study, it clearly brings improvement both in time and depth domain seismic image quality and lateral continuity. Still, the coherent noise not eliminated by the pre processing sequence is boosted as well, leading to no clear gain in terms of interpretation derisking. In cross line view as well, the use of CRS enhance lateral continuity but the comparison between wider and narrower dataset shows no clear trend in terms of final quality on stack.

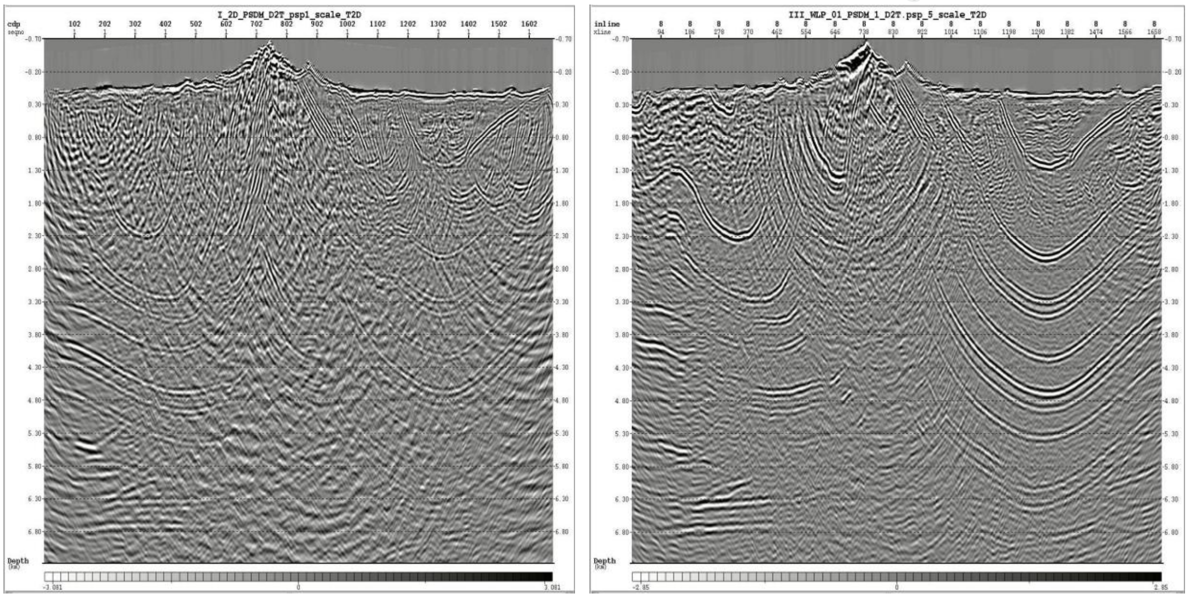


Figure 4 *PSDM comparison between 2D dataset (left) and 2DWL 960/60 dataset (right), Kirchhoff migration with true velocity model, Aperture 5km, dip limit 80°*

Conclusions

This study illustrates the importance of the modeled data on a feasibility study workflow. Indeed the conclusions we may draw are quite different from the ones coming from conventional workflow (acoustic modeling and migration with exact model). Reliable results indeed come from a realistic dataset (near surface effect, addition of pseudo random noise) and a blind processing sequence in time/depth, which balances the pitfalls of synthetic data.

The CRS algorithm was used in this study more as an interpolation tool in 3D than a denoising tool. In this case, it definitely enhances the signal to noise ratio but unfortunately coherent noise as well. Some conflicting dips observed in time and depth sections were not removed by the use of CRS. As a consequence, it appears that on these synthetic datasets, using sparse cross line interval cannot be properly mitigated by such algorithm. On the other hand, the gain in signal to noise ratio coming from swath width and cross line sampling would require in the field huge logistical effort. The tradeoff between operations logistics & cost and seismic quality shall be questioned and adapted to every terrain.

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