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3D Fullwave Modelling for On-shore Acquisition Feasibility

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Summary

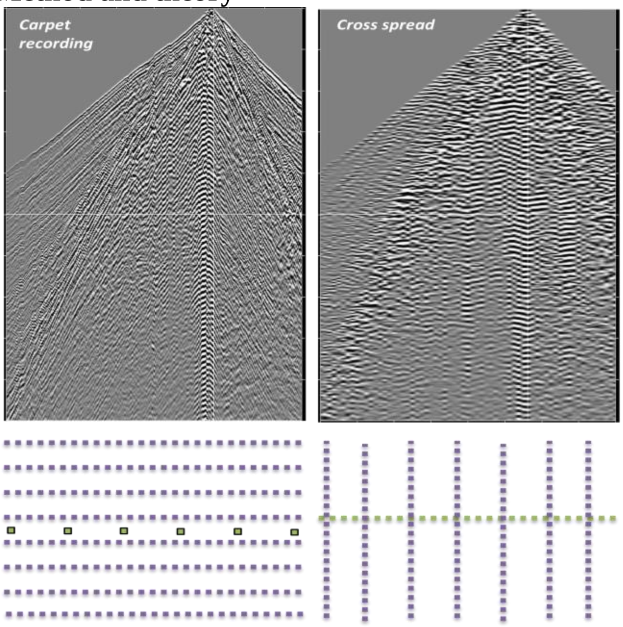
3D elastic modelling was performed to compare two acquisition designs . Blind full processing sequence was applied to ensure unbiased conclusions and final quality.

Final quality on stack sections are similar in quality for both flat and highly structured sub-surface. some major advantages of carpet recording shall be mentioned: computation cost savings for feasibility studies, the use of a coherent geophysical unit (one shot point), compared to a cross spread (an aggregate of several different shots) may lead to easier preprocessing sequence, shot points can be migrated independently, and working with shot points allow thus real time imaging, impossible with cross spread design.

Introduction

Land seismic faces several realities, going from high productivity desert acquisition, to the foothills domain with vegetation and almost no field access. These terrains shall be treated as radically different on the acquisition pattern as well (Lv & al, 2015)(Xiao & al, 2015), to optimize quality, logistics and cost. The interest of using high density full azimuth data for seismic imaging has already been demonstrated (Vermeer, 2002). This paper introduces a synthetic comparison of two acquisition patterns, with identical fold & offset (cf fig 0). It aims at proving that using nodal geometry in foothills is also valid for seismic imaging (Munoz, 2015), with the dual paradigm: sparse shooting grid and dense sensor grid, called either aerial sensing or carpet recording. The feasibility study presented has been done on two models: the SEAM II unconventional model, and a foothills model, representative of sub Andean thrust belt, built internally. The reason to perform a multi model feasibility study is due to different imaging problems in each case: lateral velocity changes, near surface complexity, steep dips.

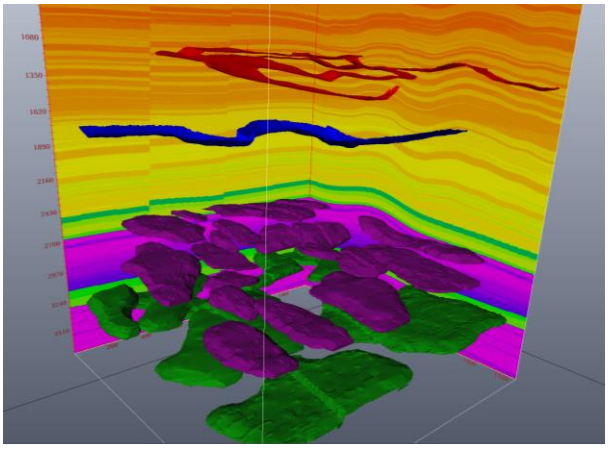
Method and theory



Classically, acoustic modelling is performed on Vp model only, and several dataset are generated, migrated with the exact velocity model and compared. This leads to anomalous high quality time or depth seismic sections and thus to a bias in minimum shot density estimation, always underestimated. This elastic study will prove (from foothills case) that the combination of detailed near surface velocity model building, elastic finite difference modelling, and full processing sequence (without exact model provided) ensures reliable results in terms of seismic design estimation and comparison.

Figure 0 *Inline view of one shot gather in carpet recording design (left) and cross spread (right), with associated pattern (below)*

SEAM II unconventional case



	Cross spread	Carpet record.	Cross Spread	Carpet record.
SI	50 m	300 m	50 m	250 m
RLI	300 m	50 m	250 m	50 m
RI	50 m	50 m	50 m	50 m
RLI	300 m	300 m	250 m	250 m
Offset max	8 km	8 km	7 km	7 km
Fold (nom)	178 (theor)	178 (theor)	196 (theor)	196 (theor)

Figure 1 *3D view of SEAM II unconventional Vp model, with main shale and sandy geobodies (left), and acquisition parameters for the two models (right, green for SEAM II, red for Andean model ; RI : Receiver Interval, RLI : Receiver Line Interval, SI : Shot Interval)*

The model itself is made of 300m thick near surface, including low velocities with layers conform to invert topography, and a sub horizontal graben made of 3 tilted blocks, with Vp varying from 2900 to more than 6000 m/s (cf fig 1). The model was build to identify the ability of different acquisition pattern to detect and measure azimuthal anisotropy in shale geobodies at 3200m depth, to correlate it with fractures main directions. In our study, the goal was limited to seismic quality comparison of two PSTM sections, including top/base reservoir continuity. The same processing sequence and migration operators have been applied to the two datasets. Processing parameters were defined on the carpet recording dataset and then apply it to the cross spread design

We chose to perform isotropic Kirchhoff PSTM and expected misfit in time/depth at reservoir level due to anisotropy parameters (ε,δ). The processing sequence defined was rather conventional, including statics computation, high amplitude noise attenuation, ground roll attenuation, and COV sorting.

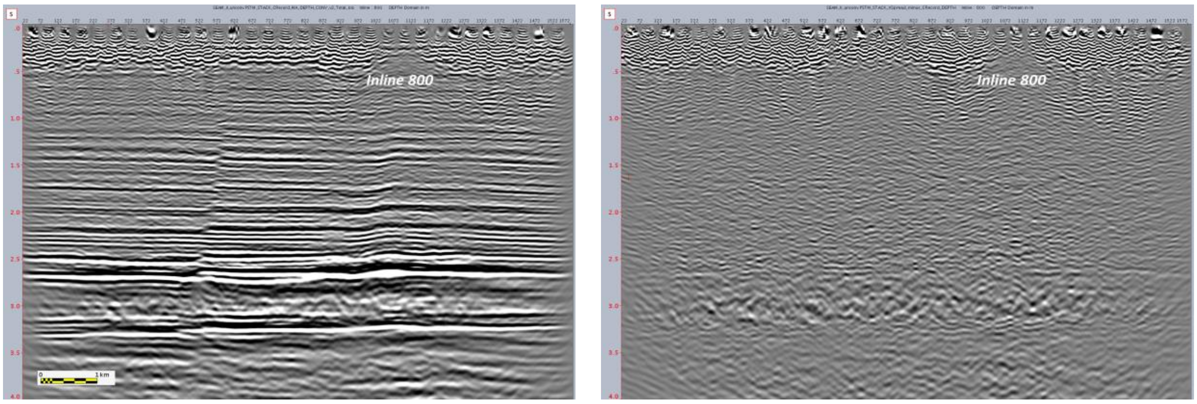


Figure 2 *PSTM section (depth converted) of carpet recording design (left), and differences with cross spread design (right)*

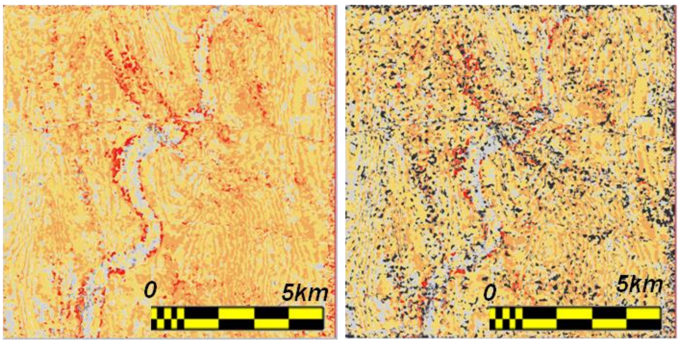


Figure 3: *Pseudo period attribute in carpet recording design (left) and cross spread (right)*

The results of the PSTM are displayed above (cf fig 2), and show good seismic quality with excellent reflectors continuity and the main structural features detectable. Still, the resolution does not go below 50 m at 4km depth, which makes the analysis of elastic parameters for shale geobodies, and even their detection, challenging. The spatial distribution of these differences has been analyzed through geostatistical tools, and shows no structure at all, ensuring almost purely random dataset, even if frequency content varies with depth. The first channel can be delineated very easily on time slice thanks to pseudo period attribute (not visible on amplitude map only), with meandering channel appearing in grayish tones. Comparable result is obtained with cross spread design, despite some speckles differences

Similar analysis has been performed on the lower shale geobodies reservoir, located at 3200m depth. The reservoirs are for most of them below seismic resolution making picking nearly impossible. Amplitude map was computed along top/base horizons and shows no correlation with the geobodies, and any other attribute gave similar results, with no delineation feasible on seismic. The main features noticeable on amplitude maps are the major normal faults existing in the model.

The conclusion drown was the following : in case of relatively unstructured earth model like the SEAM II unconventional, acquisition design at same fold but lower shot density gives identical final seismic quality at exploration scale.

The Andean foothills model

Another model, more representative of foothills area, was built to assess the possibility to use carpet recording in environment with complex topography and very low near surface velocities. This was done to mimic as much as possible real case data.

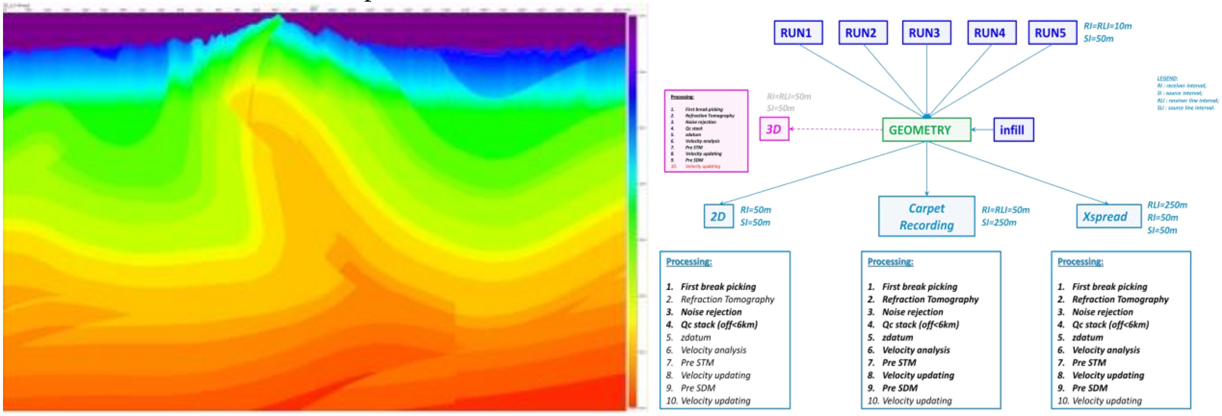


Figure 5 *Vp model (Inline 819) used for elastic modelling and processing sequence structure*

The finite difference modeling was done using elastic curvilinear modeler (Tarass, 2010), isotropic (Vp,Vs, Rho cube in input, cf fig 5) & without attenuation, using Total's HPC infrastructure. To limit computation time, only one shot line of 15km was modeled, with a shot interval of 50m, recorded on a 10m*10m grid, full spread. Decision was made to process the dataset independently at the velocity model building step. Thus, the comparison between the PSTM sections are linked to the data, but also to the processing sequence, and thus to the processing geophysicist. In particular, statics computed were different for each dataset. The ultimate step of this study included a Kirchhoff PSDM with the true model. The processing sequence was conventional (cf fig 5), including first break picking and tomography (cf fig 6), statics computation, noise rejection (high amplitude attenuation, FK filter…), velocity analysis, Kirchhoff PSTM, velocity model building in depth using refraction model, Kirchhoff PSDM and velocity update using reflection tomography.

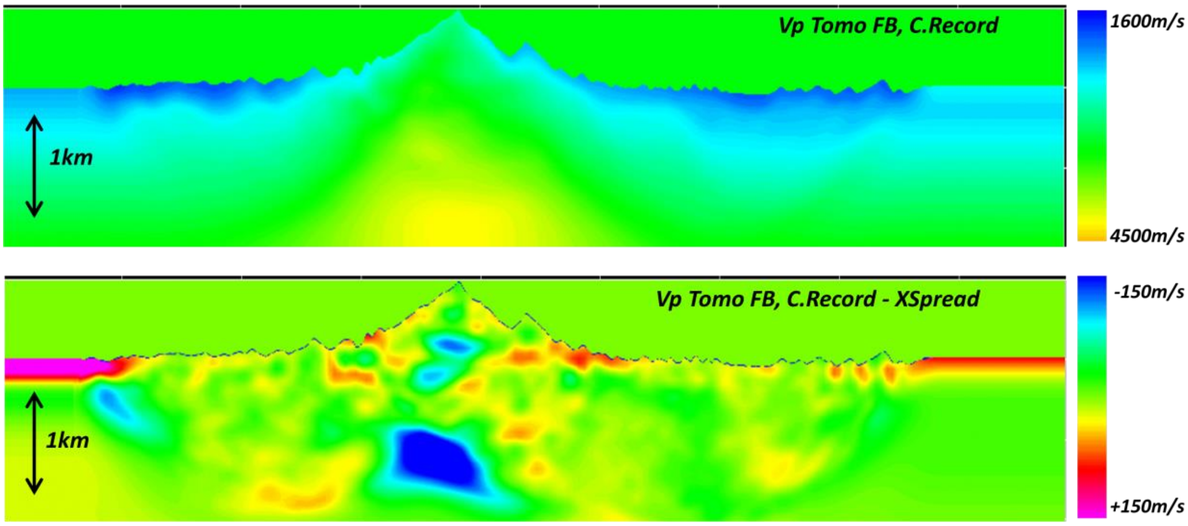


Figure 6 *Vp model from first break tomography from carpet recording data (top) and differences with cross spread dataset (down)*

The Kirchoff PSTM sections (cf fig 7) show differences between cross spread and carpet recording data. These are not in favor of one design versus the other: pros and cons are observed in both, in terms of horizon continuity & dip coherency. The KPSDM done with true velocity model show also slight differences in horizon lateral continuity, mainly located at the heart of the anticline. We note the dramatic differences of kinematics between time and depth images, related to lateral velocity variations, and also possibly to the lack of accuracy of PSTM estimated Vp model.

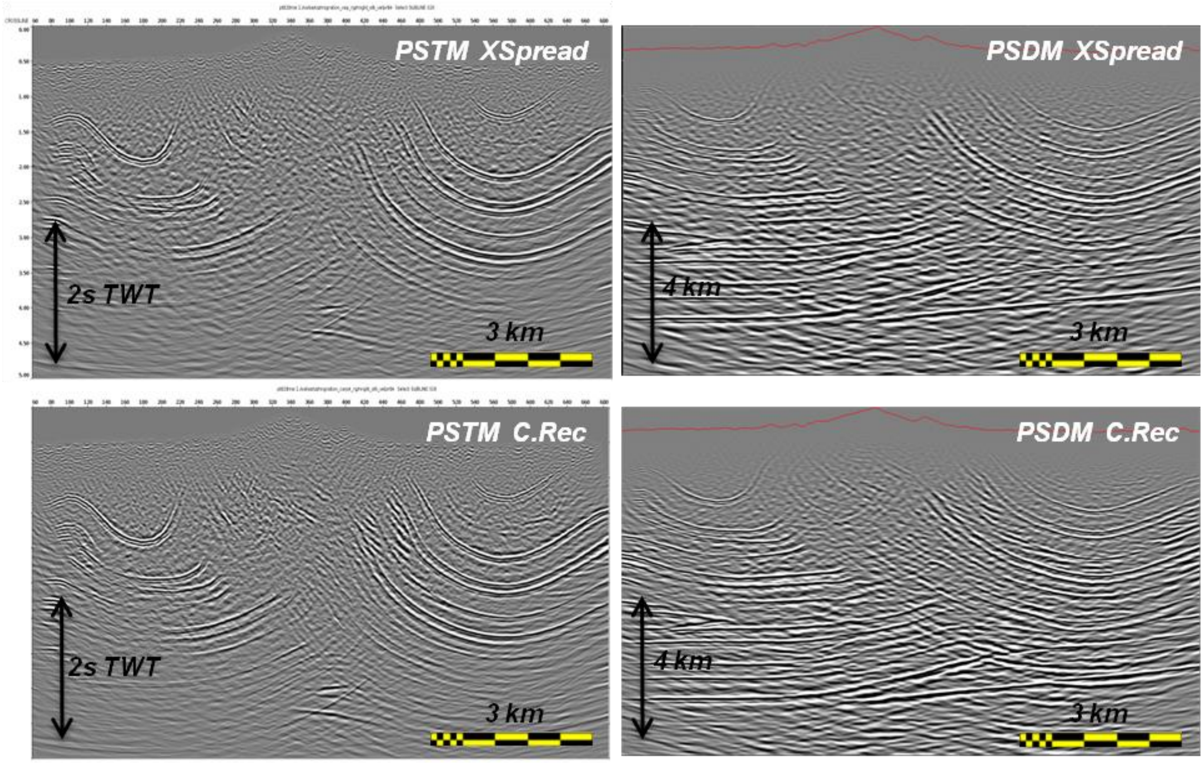


Figure 7 *PSTM section of cross spread design (top left), carpet recording (bottom left), PSDM cross spread (top right) & PSDM carpet recording (bottom right), Inline 819, aperture 4km, dip limit 80°*

Conclusions

In terms of structural interpretation, we can thus conclude that carpet recording design seems to be an interesting alternative to cross spread, delivering comparable seismic quality images, with lower shot density. This conclusion is valid for unstructured subsurface, as well as for steeply dipping foothills subsurface. Despite these similarities on seismic quality (cf fig 7), some major advantages of carpet recording shall be mentioned: computation cost savings for feasibility studies, the use of a coherent geophysical unit (one shot point), compared to a cross spread (an aggregate of several different shots) may lead to easier preprocessing sequence, shot points can be migrated independently, and working with shot points allow thus real time imaging, impossible with cross spread design.

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References

[1] H.Lv, X.Li, Z.Jiang, L.Zhang, L.Xiao, J.Wu, Y.Liang, B.Liang, M.Zhang, R.Li, F.Li, S.Yang, P.van Baaren, T.Heesom and H.Xiao [2015] Land seismic in difficult terrain and complex geology: a case study from the Jungar Basin, northwest China, First Break 33, Jan 2015

[2] F.Xiao, J.Yang, B.Liang, M.Zhang, R.Li, F.Li, H.Xiao, X.Lei, Q.Liu and T.Heesom, [2014] High-density 3D point receiver seismic acquisition and processing – a case study from the Sichuan Basin, China, First Break 32, Jan 2014

[3] Vermeer, G.J.O. [2002] 3-D Seismic Survey Design. *SEG Geophysical Reference series*, 12, 1-205

[4] Tarass [2010], Parallel large scale seismic wave propagation simulations for 3D geological media with topography

[5] Munoz & al [2015], Operational challenges of nodal 3D seismic acquisition in the sub Andean environments, *EAGE 2015*, Madrid