SBGf33899

Seismic modeling with complex geology and topography

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ABSTRACT

Complex geology, due to folding and faulting, implying in strong lateral velocity variations and the rough topographic relief are the principal constraints that may be faced in order to obtain a reliable subsurface seismic image. Several physical investigations to support acquisition parameters and processing are on demand before any new seismic acquisition in such area, in order to establish the best strategy to get a better subsurface image. To perform this strategy we got information from several sources: geology, geophysics and modeling, in the former we used finite difference acoustic and elastic wave propagation with topographic effects included and ray tracing modeling, considering isotropic or smoothly inhomogeneous media. As a result of such integration, we could investigate some acquisition parameters and processing steps which to have greater impact on seismic data quality.

INTRODUCTION

The area studied is characterized by fold and thrust belt type deformation, affecting Paleozoic and younger rocks. The sedimentary section is strongly affected by compressive tectonics. Therefore folds, faults and complex structures were observed. This tectonic style creates a very complex geologic picture to be imaged, with very steep dips (up to 80 degrees), numerous faults, contrasting elastic velocities and abrupt topographic variations. The area is plenty of peculiarities: considering previous surveys, on dip lines that crossing the rough topography the data quality on the plains and on the valleys between ridges goes from good to very good. Otherwise on the flanks and on the highs, data quality drops dramatically; on strike lines along the valleys and on ridge there are good quality that exhibit a plethora of reflectors, even at great depths. Since there are few seismic data in the area, modeling was proposed to generate several seismic image in different spacial domain where was possible to evaluate effects due to the structural complexity of the area and to support acquisition parameters design and processing strategy. We suggest that conventional acquisition parameters and seismic processing even if used PSDM can be difficult to achieve a good quality if topographic effects are treated only as conventional static corretions.

MODEL BUILDING

A seismic model with topography was generated from a structural cross section of anticline (Figure 1). This structural cross section was constructed based on surface mapping, well logs and the first seismic lines, in addition to a simplified one, all main features are depicted. The state of the art in seismic acquisition and processing are driving data acquisition to a more regular sampling of all events (considering signal and noise) in time and space. Better sampling is imperious for convenient data handling in several space-time common domains like: shot, receiver, offset, mid-point, azimuth (3D) and time domains. Inherent to topography, many constrains impede or restrict, besides a matter of budget, the best solution in acquisition/processing such as: high fold 3D surveys, areal geophone arrays, vibrators, PSDM, among other possibilities. Such constrains are even more serious considering the short experience in seismic data collecting not only in this area but in the all environments like this. We can say surely that until today this is a might question nobody has a final answer. However, such discutions, in a scenario of high geological/structural complexity are prone to give an unsatisfactory subsurface imaging, affecting data interpretability.

The Figure 2 shows a vertical ray zero-offset synthetic section simulating a perfectly depth migrated data, that has been converted back to time. The anticlinal zone is between traces 40 and 120 and targets are situated on depths between 1.000m (0,5 s) and 5.000m (2,5 s). The seismic images points out pitfalls related to time models of structural complex areas. A pull-up is observed on the deeper seismic event, generating false domic structures and is very hard to be interpreted. Dip reversal for deep horizons in the main fault footwall, the steep events could be badly sample, the apex of domic structure is poorly imaged, steep events are often splitted into pieces. Some of these imaging problems might be removed partially by using PSDM, although the results depend very much on velocity model and how the topographic effects are corrected. We believe that topographical problems and the velocity model at the most superficial layers are the principal constraints to obtain a reliable subsurface seismic image.

SEISMIC MODELING WITH TOPOGRAPHY

The Figures 3 and 4 show results of finite difference elastic modeling of vertical component in the shot domain without and with rough topographic. The Table 1 shows the parameters and references used in finite difference acoustic and elastic seismic modeling algorithms. The Figure 4 shows that, due to the rough topography and near-surface velocity variation, severe signal distorcions up to deeper target appeared.

RESULTS AND ANALYSIS

So, as a matter of seismic image in this area, we can state: pre-stack migration is mandatory for 2D or 3D data; rays that reach the target are highly affected by velocity contrasts and huge dips in upper layers. The most superficial layers and the topography exert an important role in final data quality, probably due to the scattering in line and cross line. The other kind of effort would be to get longer offsets outside the rough topography that would work like an undershooting method. Available packages for pre-stack migration, that usually work in the common offset domain, which in terms of seismic acquisition demands attention on the following issues: pre-stack migration aperture could be very different (larger!) than apertures defined for conventional (post-stack) migration; spatial sampling is done in the common offset domain; source - receiver offsets and spread length could be higher than usual; recording length such as could be higher than usual.

CONCLUSIONS

This work shows that it is important to do seismic modeling with topographic effects before seismic acquisition and processing to set up strategies aimed to an optimum seismic data analysed in complex geological model. Seismic ray-tracing, acoustic and elastic modeling and real data were analysis in the search. We verified that there is a clear dependency between seismic data quality and the processing sequence to be used in order to treate problems with velocity model in the most superficial layers and the rough topography.

REFERENCES

Cerjan, C., Kosloff, R., and Reshef, M., (1985). A nonreflecting boundary condition for discrete acoustic and elastic wave equations. Geophysics, ***50****, 705-708.*

Cunha, P., E.,M., (1997). Estratégias eficientes para migração reversa no tempo pré-empilhamento 3-D em profundidade pelo método das diferenças finitas, tese de mestrado, PPPG-UFBa.

Emerman, S.,H, and Stephen, A, R., (1982). Comment on "absorbing boundary conditions for acoustic and elastic wave equations," , by R. Clayton and B. Engquist, Bull. Seism. Soc. Am. ***73:2****, 661-665.*

Israeli, M. & Orszag, S.A. (1981). Approximation of radiation boundary conditions. Journal of computational physics, ***41****, 115-135.*

Zahradník, J., (1995). Simple elastic finite-difference scheme. Bull. Seism.Soc. Am., ***85****, 1879-1887.*

Zahradník, J., Moczo, P., and Hron, F, (1993). Testing four elastic finite-difference schemes for behaviour at discontinuities. Bull. Seism. Soc. Am., ***83****, 107-129.*

ACKNOWLEDGMENTS

We would like to thank BRASPETRO, TOTAL e ANDINA for permission to publish this work.

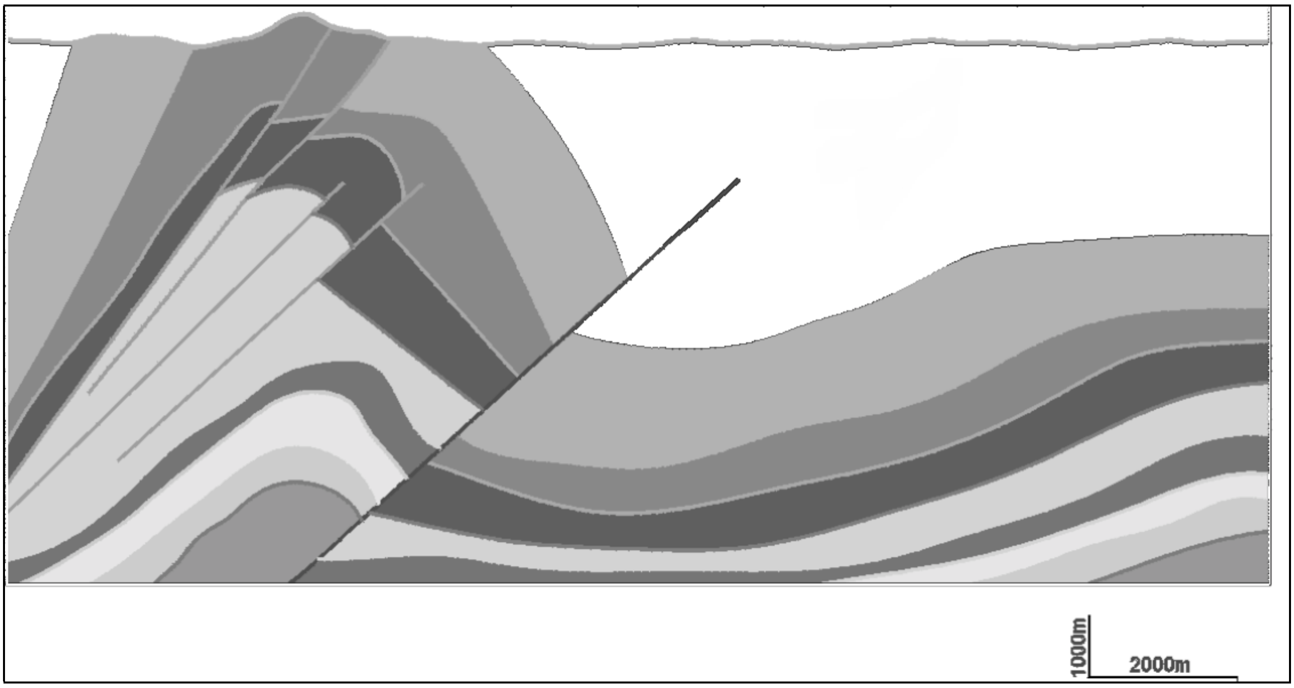


Figura 1 - Structural cross section of anticline model.

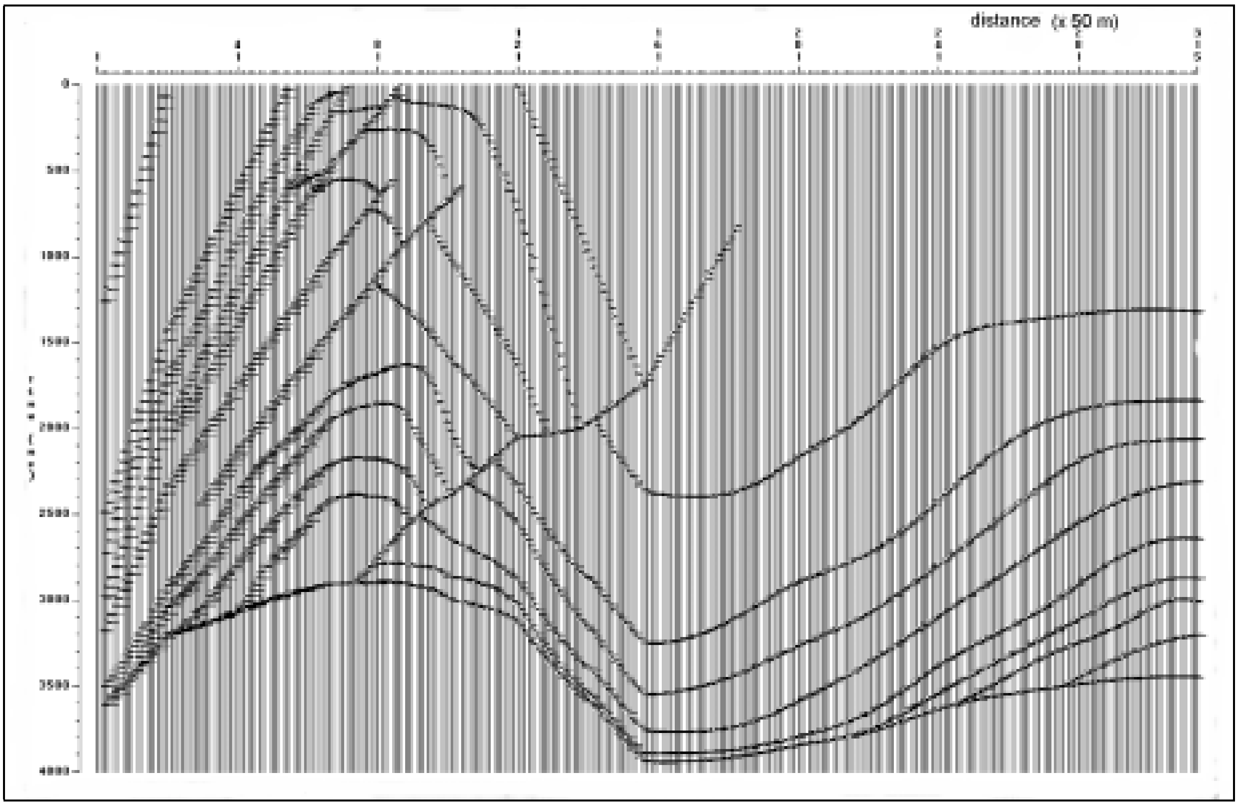
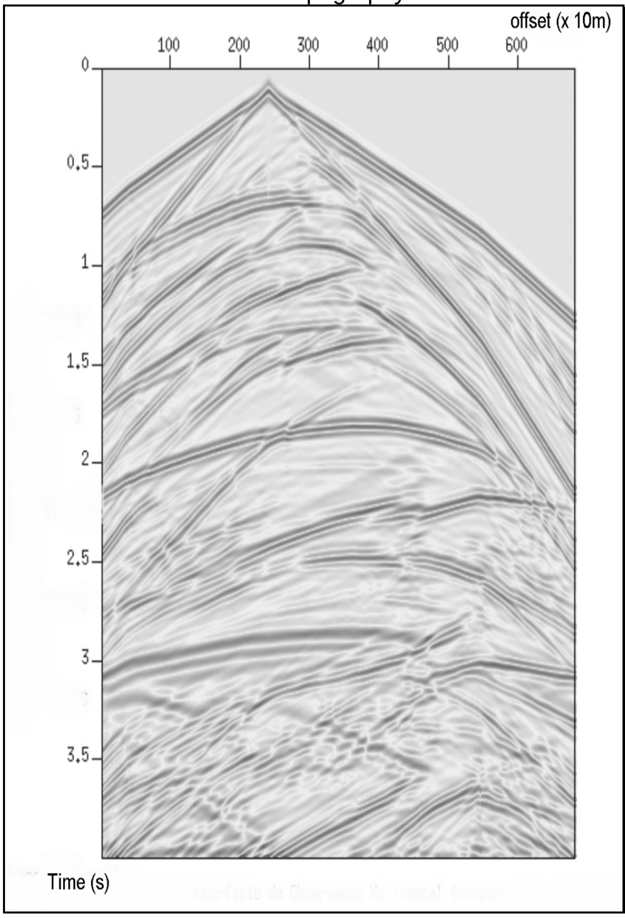
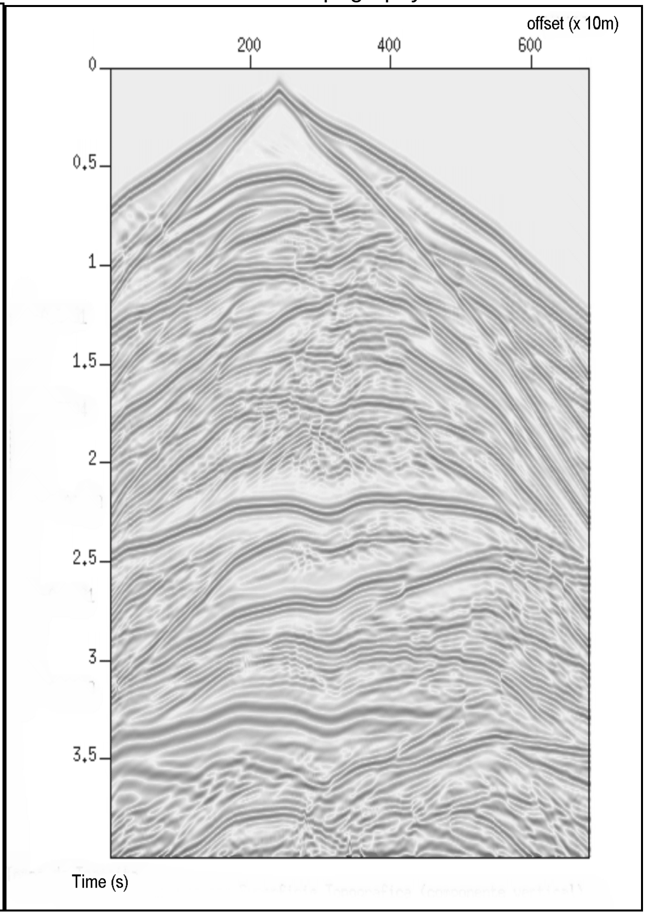


Figure 2 - A vertical ray zero-offset synthetic section simulating a perfectly depth migrated data, that has been converted back to time.

whitout topography



with topography



Figures 3 and 4 – Shots from results of finite difference elastic modeling of vertical component without and with rough topographic, respectivement.

Type of Modeling	Acoustic	Elastic
Order of approximation	$O(h^4,t^2)$	$O(h^2,t^2)$
Parameters	Vp and ρ at the grid points	λ,μ and ρ introduced as geometric average along the grid lines(Zahradník, 1995)
Topography	no	Vacuum Formalism (Zahradník, 1993)
Source term	$2_{nd.}$ derivative of Gaussian pulse (Cunha, 1997)	$2_{nd.}$ derivative of Gaussian pulse(Cunha, 1997)
Boundary conditions	Reynolds(1978) Israeli & Orszag(1981)	Emerman & Stephen Absorbing boundary(1982) Combined with Cerjan *et ali*i, 1985

Table 1 – Parameters and references used in finite difference seismic modeling algorithms.