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Stratigraphic Model-Based Seismic Inversion Guiding Stochastic Simulation of Deep Water Turbidites

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Abstract

A stochastic model comprising a truncated Gaussian field was derived from stratigraphic model-based seismic inversion volume and has been used to generate an improved 3-D earth model, which attempts to represent a turbidite succession, in terms of lithotypes, which is the reservoir of a giant oil field in deep-water (600 - 1200 m) from Campos Basin, Brazil. The goal of this 3-D reservoir characterization is derive more realistic images of the inter-well heterogeneity using integrated geophysical and geological data.

INTRODUCTION

Integration of seismic and geological data is one of the keys for the success of many 3-D earth models derived for reservoir development of turbidites giant deep water fields in Campos Basin. The purpose of this poster paper is show how the lithotypes which are used to describe turbidite successions can be derived from stochastic simulations using stratigraphic model-based inversion of seismic amplitude data.

SEISMIC INVERSION DATA GUIDING STOCHASTIC SIMULATIONS

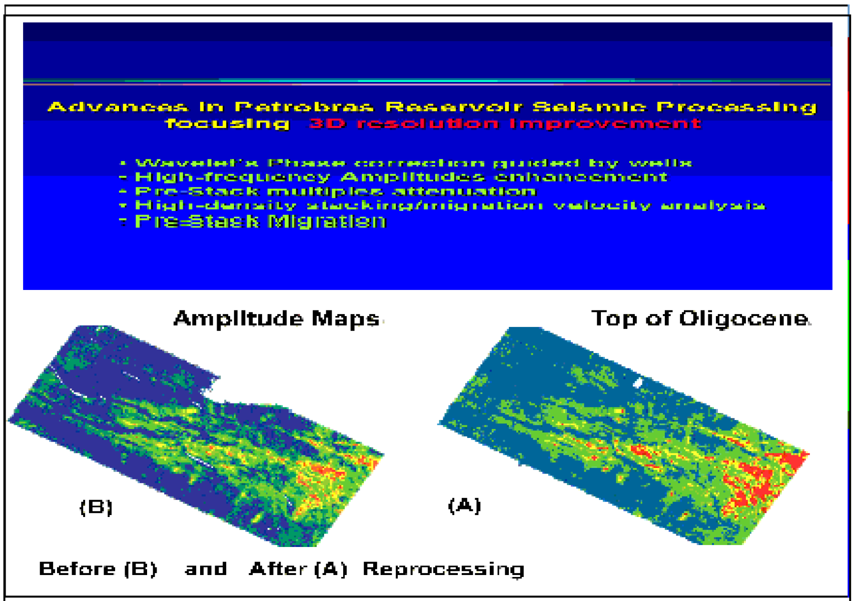
The studied reservoir is a dip-elongated Oligocene turbidite fan, NW/SE oriented, which were strongly cut by moderate to low sinuosity deep-sea channels. Reservoir fault systems have their main direction along and perpendicular to the fan orientation and are closely related to salt movement. This reservoir sandstone covers an area of 130 Km^2 , with thickness reaching 25 m. It shows average porosity of 30% and high permeability (above 1000 mD).

The seismic volume was acquired in 1986 and reprocessed in 1996. This reservoir oriented reprocessing was done to improve the amplitude recovering, the well-seismic phase deconvolution and multiple attenuation, and also to obtain a more detailed velocity field for stacking and migration. The result of this reprocessing, which enhanced the vertical seismic resolution, allowed a better understanding of either the stratigraphic and structural model for the field.

Although there is an excellent correlation between amplitudes and sand thickness and a good correspondence between time and depth, due to a detailed velocity analysis, the individualization of each high resolution stratigraphic sequence can not be done from the 3D seismic amplitudes. However, using acoustic impedances derived from constrained seismic amplitudes inversions, the correlation between the stratigraphic sequences and the seismic data is improved. The seismic resolution after inversion is controlled not only by the time sampling of logs, but also by a kind of “adjustable” seismic resolution for each stratigraphic sequence.

The stratigraphic model and the depositional elements of the turbidite system are the framework used to constrain the 3-D gridded geological model, which represents the reservoir architecture in terms of spatial distribution of the lithotypes. The stochastic model attempts to constrain 3-D earth models with 2-D seismic information related to the proportions of lithotypes. A 3-D proportion matrix is therefore required. This matrix is interpolated from the well data constrained by seismic data. The main philosophy of this stochastic method is to establish a relationship between the spatial distribution model of the lithotypes proportions and the realization of a Gaussian random function from the analyzed stratigraphic interval.

In the next pages we show the Figures that will be present in the poster section describing the seismic reprocessing and inversion for further steps of turbidite successions stochastic simulations in the deep water portion of Campos Basin.



Advances in Petrobras Reservoir Seismic Processing focusing 3D resolution improvement

- Wavelet's Phase correction guided by wells
- High-frequency Amplitudes enhancement
- Pre-Stack multiples attenuation
- High-density stacking/migration velocity analysis
- Pre-Stack Migration

Figure 1 – Recent advances in Petrobras seismic processing and their benefits when applied also to legacy data. **Remarkable differences on the limits, internal geometry and amplitude levels of turbidites before (B) and after (A) the reprocessing of 1986 data.**

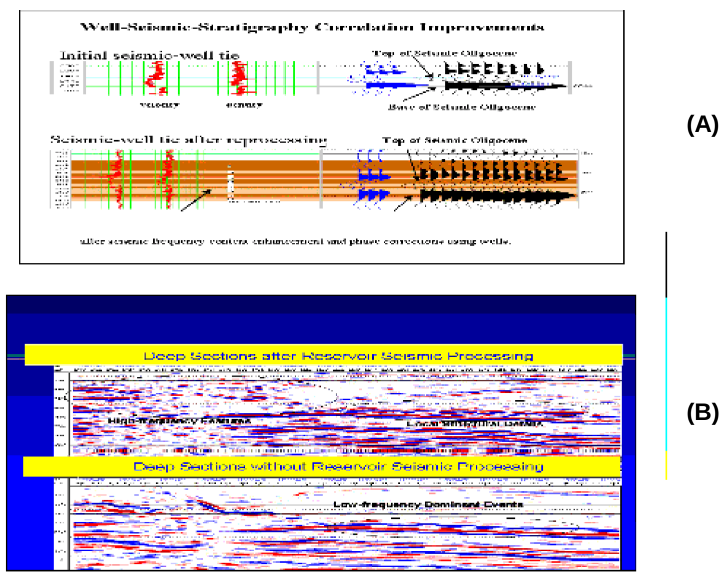


Figure 2 – Benefits from seismic reprocessing:

(A) The well-seismic tying for stratigraphic inversion is improved. After phase corrections the lithologies are better correlated with the seismic events.

(B) Some possible pitfalls in the seismic reflection interpretation are avoided by enhancement of signal frequency content. Better horizon focusing is achieved by spatial-condensed velocity analysis, multiple attenuation and time-migration before stack.

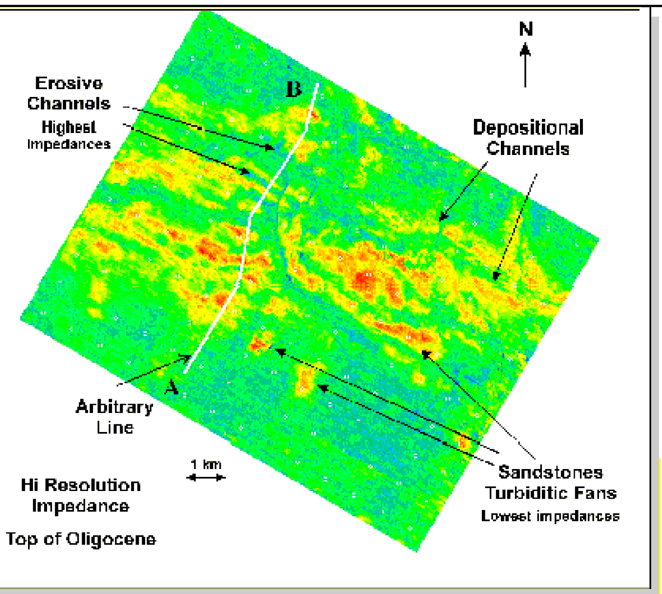


Figure 3 – Main turbidite structural features in the seismic impedance map from Oligocene top. The impedance values are derived from stratigraphic model- based seismic inversion. Depositional channels and turbidite lobes have lower values (lighter gray colors) .
The arbitrary section A-B is shown in the next Figure.

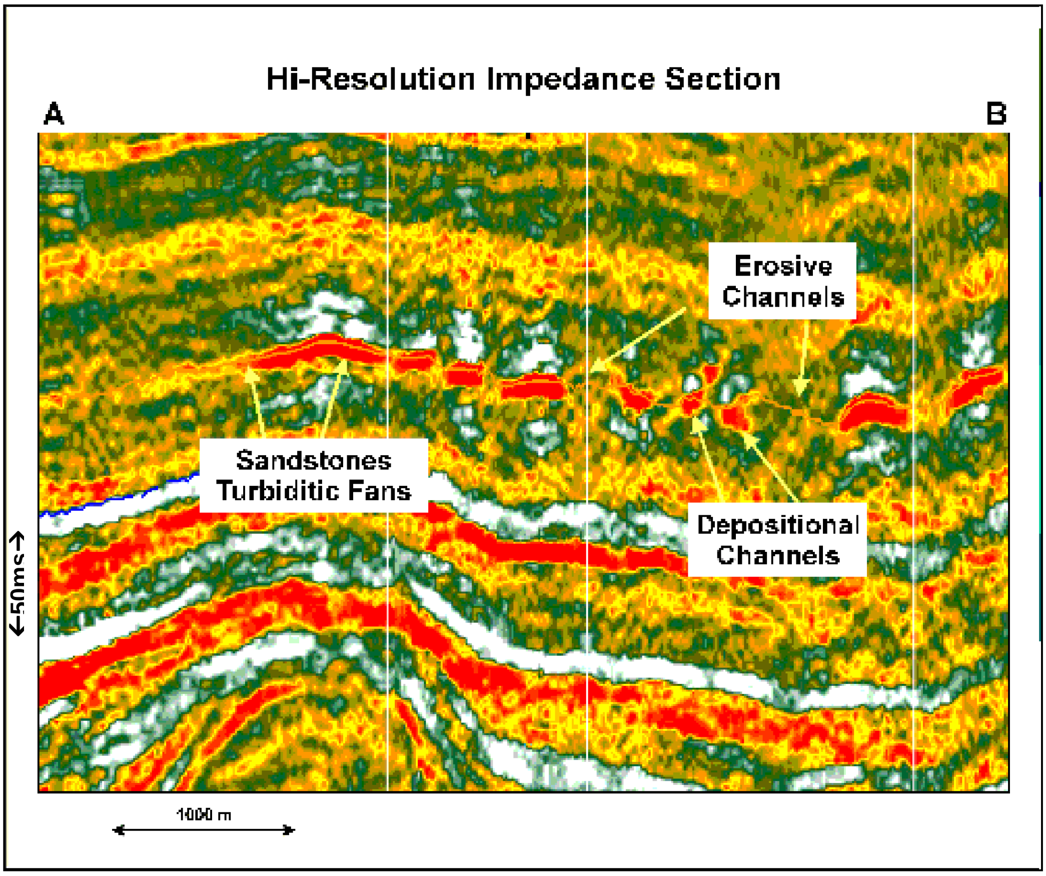


Figure 4 – Arbitrary line from 3D seismic impedance volume derived from stratigraphic model-based inversion. The lowest values are in white colors, related to turbidite lobes and depositional channels. The erosive channels appear as truncations in the continuity of these turbidites impedances.

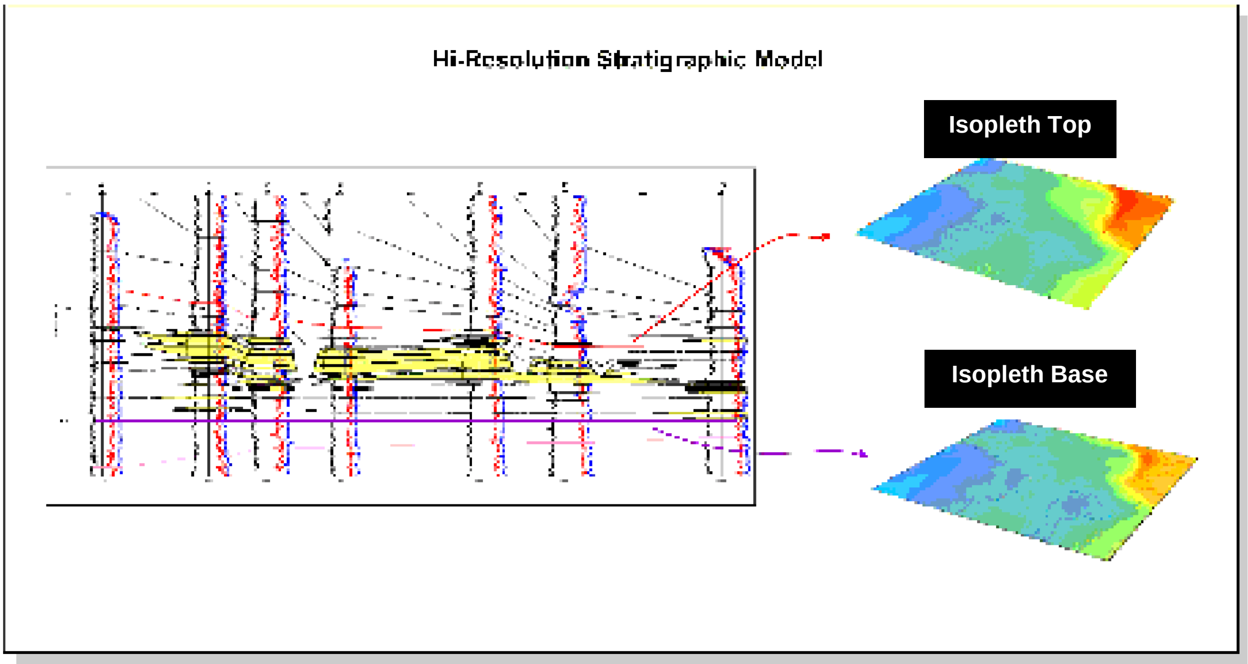


Figure 5 – A Dip oriented stratigraphic section on Mio-Oligocene reservoir in deep water portion of Campos Basin.

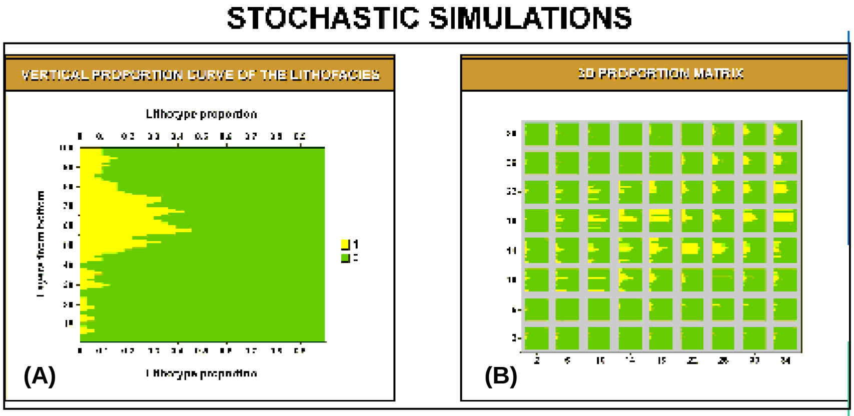


Figure 6 – (A) Vertical proportion of two lithotypes inside on the studied stratigraphic unit.

(B) 3D proportion matrix: vertical and horizontal variability of sandstone proportion are shown in ligther colors.

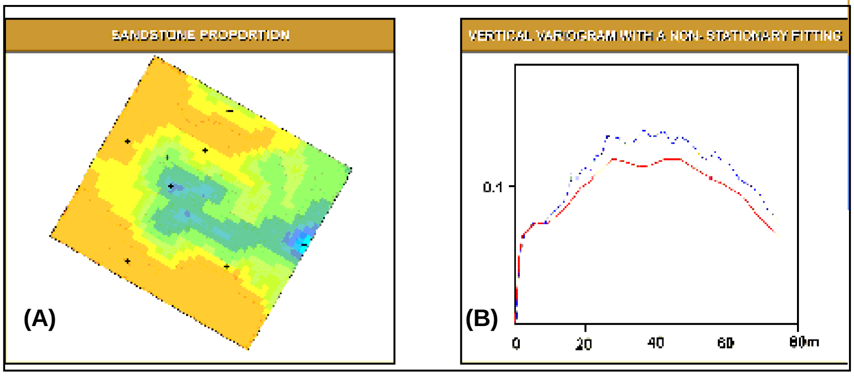


Figure 7 – (A) Kriging solution sand proportion map derived from both weel and seismic data.

(B) Raw vertical variogram and the non-stationary fitting of an indicator variable (sandstone)

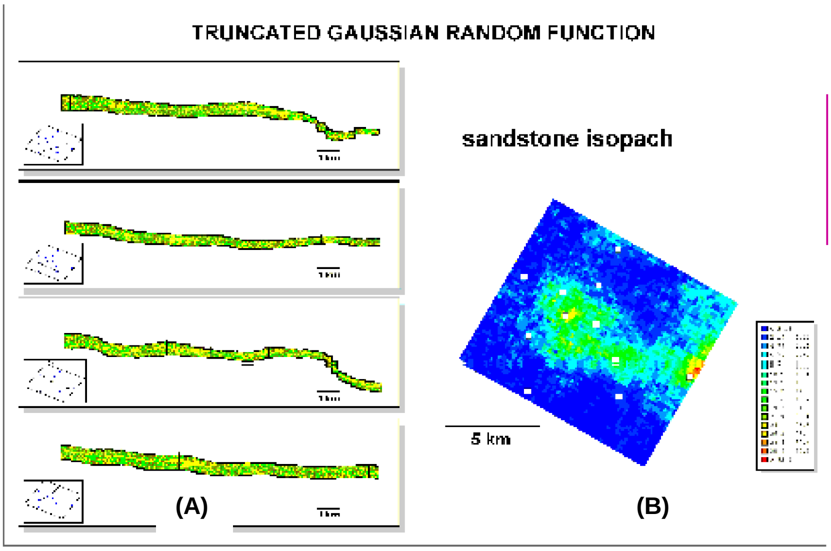


Figure 8 – (A) Geologic sections derived from a truncated Gaussian random function model

(B) Sand isopach map derived from a single realization of the truncated Gaussian function

Conclusions

Sthocastic simulations of turbidite deep water successions in Campos Basin were improved by detailing of seismic reprocessing of a 1986 data and by stratigraphic model-based inversion to guide geologic models. The well-seismic tying for inversion had more resolution and the sandbodies were better imaged from the impedance volume. The truncated Gaussian method is very flexible and it allows to take into account additional information for geological modeling. Vertical proportion curves are very useful to synthesize geological information and can be used as additional constraint on the simulation algorithym

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