A consistent reservoir modelling workflow conditioned to seismic data – a case history from the Peregrino field

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Abstract

A consistent modelling chain from time interpretation to flow simulation using an integrated approach to reservoir modelling has been utilized on the Peregrino Field in the Campos Basin outside Brazil. The consistency between the geo- and simulation models has been maintained during the modelling chain, with the same structural framework, and the same property modelling. In this study we will focus on how the seismic data is used to condition the facies probabilities in the geological model, and also on how uncertainties connected to the seismic interpretation and the seismic velocities can be represented in the workflow.

Introduction

To enable a consistent modelling chain from depth conversion to flow simulation, an integrated approach to reservoir modelling is required. The consistency between the geo- and simulation models should be maintained during the modelling chain, with the same structural framework, and the same property modelling. In addition, model updating and uncertainty modelling should also be treated as integrated processes. The basic idea is to have a model chain which is consistent, updateable and repeatable. Intuitively, integrated modelling is appealing, as it ensures a consistent chain of models from interpreted data to reserve estimates and predicted hydrocarbon production. Figure 1 shows an overview of the integrated modelling workflow. More details on the integrated workflow can be found in e.g. Zachariassen et al (2011) or Skjervheim et al. (2012).

Seismic data together with a conceptual understanding of the geology are used in the daily subsurface work on Peregrino in order to plan and position wells, targeting areas with low acoustic impedance. This strategy has proven to be largely successful, and the learnings were taken into the geomodel by conditioning the facies distribution in the geomodel on acoustic impedance data. In addition, structural uncertainties has been incorporated in the model chain by conditioning on well zonation and well picks. Through these updates, the velocity model for the depth conversion will also be updated. We will also show how uncertainties connected to the seismic interpretation and the seismic velocities can be represented in the workflow.

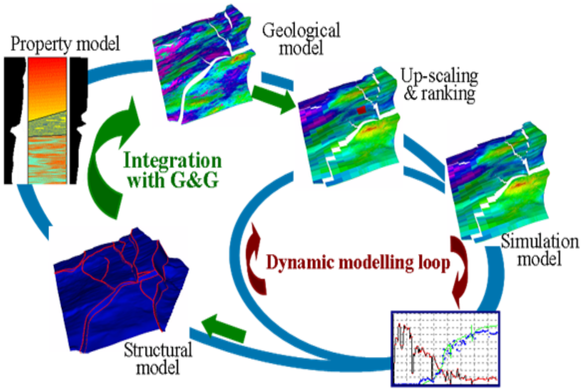


Figure 1 Overview of integrated modeling workflow

Peregrino Field

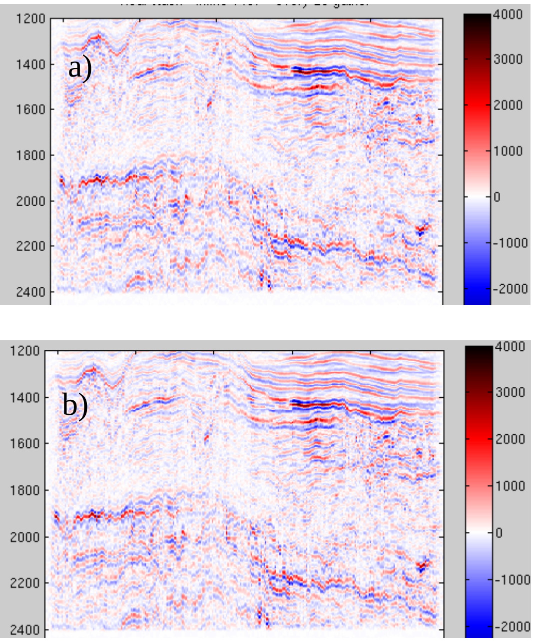
The Peregrino Field is located in Block BM-C-7, in the southernmost Campos Basin (Figure 2). The area is located 85 km southeast of the nearest coastline, approximately 100 km southeast of Macaé. The Peregrino Field was discovered in 2004, and the production started in 2011. The water depth in the area varies from 95 to 135 meters, over an area of approximately 350 km2. The reservoir depth in the field is between 2150 and 2350 meters TVD. The Peregrino Field is one of the heaviest offshore oil developments (14°API) in Brazil.

The reservoir interval is the Carapebus Fm., with good quality Cretaceous sands deposited from gravity flows in deltaic and shallow marine environments. The upper and lower part of the reservoir is divided by a 5 m thick siltstone flooding surface.

Figure 2 Location of Peregrino field

Conditioning on seismic data

A Statoil developed internal pre-stack relative AVO inversion has been performed on 3D seismic data from Peregrino. The main difference between this internal methodology and a commercial AVO inversion is that the inversion is performed on data without NMO correction. The method aims to reduce the errors caused by sub-optimal gather flatness and wavelet stretch on the far offsets. The method seems to capture the variations in elastic properties in the data in a good way, and the residuals between real seismic data (both post stack and prestack) and synthetic seismic data generated from the elastic properties are small (Figure 3).



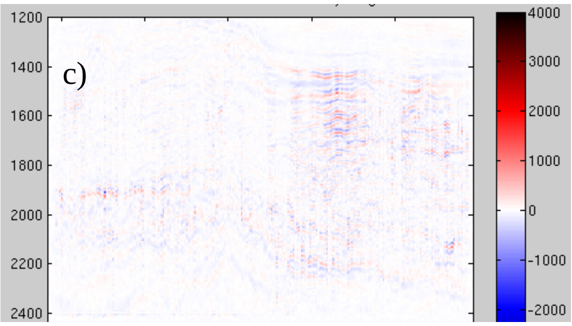


Figure 3 a) Real seismic data, b) synthetic seismic data generated from inversion results, and c) residuals between real seismic and synthetic seismic.

The prestack data on Peregrino has relatively few useable offset classes (approximately 20) due to large bin size and noisy near offsets. The resulting AI data gives a good match with the wells (Figure 4), and low residual energy. However, the quality in the Vp/Vs data is lower, partly because of multiple energy contaminating the AVO response in the data. The Vp/Vs data were therefore not used in the conditioning of the geomodel in this study.

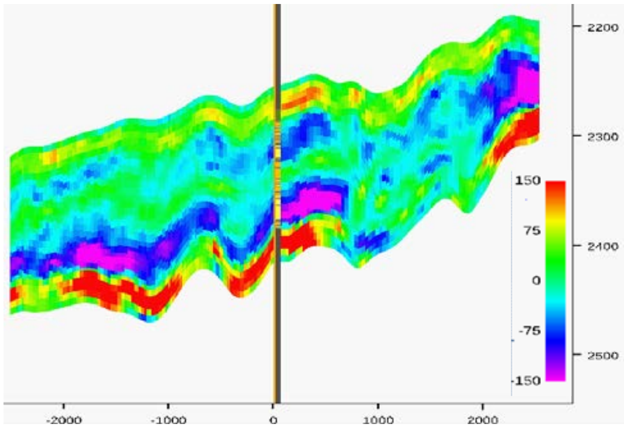


Figure 4 Well cross sections through vertical exploration well showing acoustic impedance from seismic data.

Well data was analysed to check for trends that could be exploited in the sand prediction. Facies distributions from vertical wells were correlated with acoustic impedance well logs, and also with acoustic impedance from the seismic. No easily exploitable regional trends were found in the data, but the analysis of AI vs. Porosity highlighted 2 trends in the data which appear to be spatially distributed. These trends may be a result of different provenance of the sand source input. A probability function for the relationship between acoustic impedance and facies was generated based on the well log data (**Figure 5**).

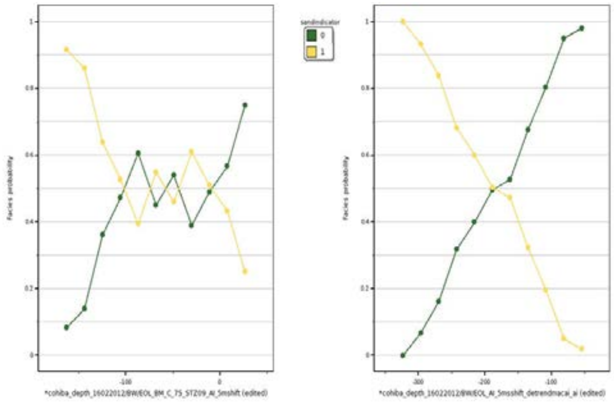


Figure 5 - Plot of facies probability from blocked logs vs. raw AI (left) and Macaé compensated AI (right)

The presence of the hard Macaé unit with a large change in impedance below the reservoir creates too low values in the inverted impedance data in the zone just above the Macaé reflector compared to what is observed in well logs. This effect was compensated for, so as not to over-predict the amount of sand at the lower part of the reservoir (**Figure 5**). The Macaé compensated AI cube showed a better match to blocked facies log from wells compared to the raw AI cube.

In general the results were fairly good and showed a good match to the wells (**Figure 6** and **Figure 7**). The match was better for the vertical or deviated wells which intersected the top Macaé than for the horizontal wells. This is due to having an extra point to aid the depth conversion, which in turn improves the positioning of the probability cube relative to the well.

The facies probability cube from inversion was then combined with various other forms of information, such as the conceptual geological model, and deep reading resistivity logs from already drilled wells to create a facies grid.

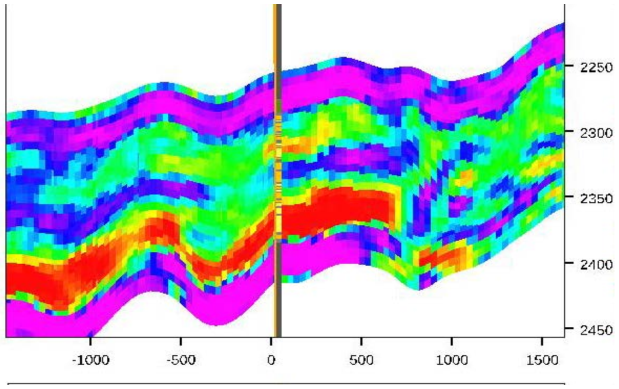


Figure 6 Vertical exploration well showing the uncompensated probability cube.

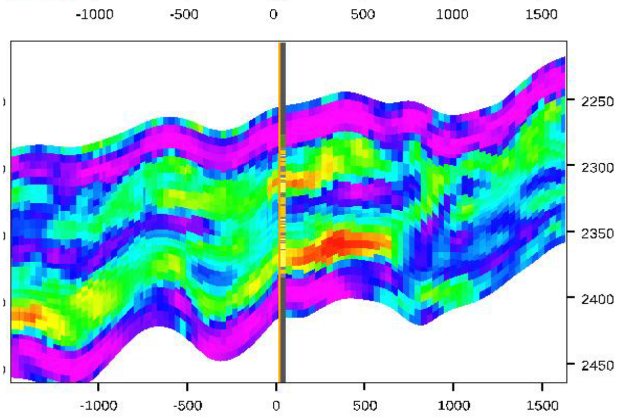


Figure 7 – Vertical exploration well showing the Macaé compensated sand probability

Uncertainty in velocity models and depth conversion

One of the other major uncertainties in the use of seismic data within the geomodel is the depth conversion, as the seismic data is in time but the well information and the geomodel are in depth. The effect of depth conversion was highlighted by the many generations of differing depth surfaces created throughout the modelling project and their effect on the well match. The Peregrino field is drilling horizontal wells with up to 2000m long horizontal sections, without drilling pilot holes. In this setting, good control of the depth conversion is of utmost importance.

As part of the geomodel workflow, the depth converted time surfaces are updated based on well picks, layer thicknesses, and zone logs (Figure 8). The depth surfaces conditioned to well information and zone logs are then used to update the depth conversion velocity model. By QC'ing the update depth maps and velocity maps, it is possible to identify areas were the seismic interpretation needs corrections or refinements. This is the case for the area with the largest changes in Figure 9, were the seismic interpretation was also updated.

This secondary depth conversion update does not replace a traditional depth conversion process. An initial velocity model is required, and the workflow is used to update the velocity model to ensure that the well data (picks and zone logs) and thickness maps are honoured in the depth conversion process. The traditional analysis performed to obtain a good initial velocity model is still required. Also, this work process requires a decent match between the initial depth converted surfaces and the well picks. If the initial mismatch is too large, we might still match the well data during this updating (depending on the specified uncertainties), but the overall depth-converted surface might be of a poor quality (rubbish in, rubbish out!).

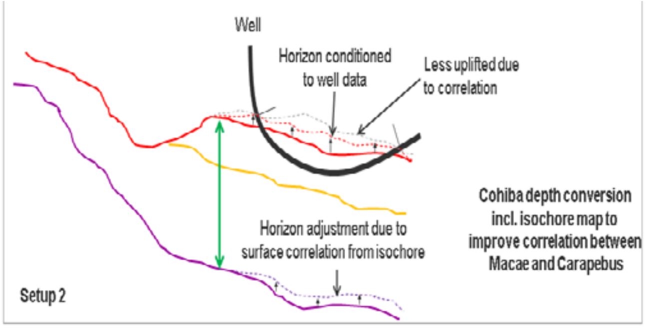


Figure 8 Illustration of conditioning the depth surfaces to well picks and zone logs.

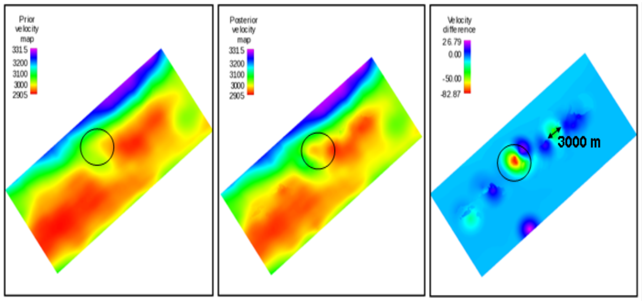


Figure 9 Example of a prior and posterior interval velocity map and their difference. The corrections needed to condition the depth surface to the well data can be clearly observed. The circle indicates the area where the largest adjustment was.

Conclusions

A consistent modelling chain from depth conversion to flow simulation using an integrated approach to reservoir modelling has been demonstrated on the Peregrino Field in the Campos Basin outside Brazil. In this study we have shown how the seismic data is used to condition the facies probabilities in the geological model, and also on how the depth conversion velocity model has been updated by conditioning to well information and zone logs.

Acknowledgements

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References

J.A. Skjervheim, X. van Lanen, D. Hulme, V. Røine Stenerud, E. Zachariassen, S. Liu, J. Hove and G. Evensen, 2012, Integrated Workflow for Consistent Model Building from Depth Conversion to Flow Simulation - North Sea Field Case, 74th EAGE Conference & Exhibition, June 2012

E. Zachariassen, J.A. Skjervheim, J.G. Vabø, I. Lunt, J. Hove and G. Evensen, 2011, Integrated Work Flow for Model Update Using Geophysical Monitoring Data, 73rd EAGE Conference & Exhibition, 2011