Benefits of a Multi-Azimuthal data to reservoir characterization: A Brazilian Pre-Salt Case.

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Abstract

The reservoir characterization of the Pre-Salt in the Santos basin presents several challenges such as the lack or often insufficient and inadequate seismic data quality to mitigate the main uncertainties identified in the reservoir process. A new seismic data of better quality was able to generate a major impact in the project, changing the conceptual model of the area, the geological model and the well positions (Producers and injectors). Another challenge presented in the project are the low permeability carbonates, laminites and spherulites. This type of reservoir presents large oil columns with excellent porosities, however, low permeability, which has been proving to be a great challenge for the generation of feasible projects in Pre-salt areas. A natural fracture modelling workflow was proposed using the new multi-azimuthal seismic data in order to identify and characterize regions with more fractures and with potential for permeability increasement.

Introduction

Successful implementation of the Pre-Salt DP&P projects in Brazilian ultra-deep waters, where huge capital investments are a major issue, depends much on the robustness and confidence of the available static and dynamic reservoir models. The first discovery of these large oil and gas reserves found along the southeastern coast of Brazil was made in 2006, and represented a new chapter in the global oil history. Since then, Petrobras has been facing major technological challenges in a broad suite of areas and disciplines.

The processes involved in the geophysical reservoir modelling has the main objective of generating a 3D models that are representative of the properties of rocks in subsurface, allowing the quantification of, for example, Gross rock volume – GRV, facies, porosity, and their associated uncertainties, which will serve as input to subsequent steps in geological modelling and numerical fluid flow simulation. These will enable the generation of probabilistic scenarios of reservoirs and oil / gas / water production curves, necessary for economic analysis for the implementation of E & P portfolio projects (Figure 1).

A common characteristic for projects in the field of delimitation and/or initial development of production is the limited availability of seismic and well data. The 3D seismic data show wide covered area over the studied reservoirs, while the wells are usually positioned sparsely, mainly considering the greater thicknesses and / or anomalous values of amplitude. It is important to point out that, even under conditions of availability of seismic data, its quality is often insufficient or inadequate to mitigate the main uncertainties identified in the reservoir characterization process.

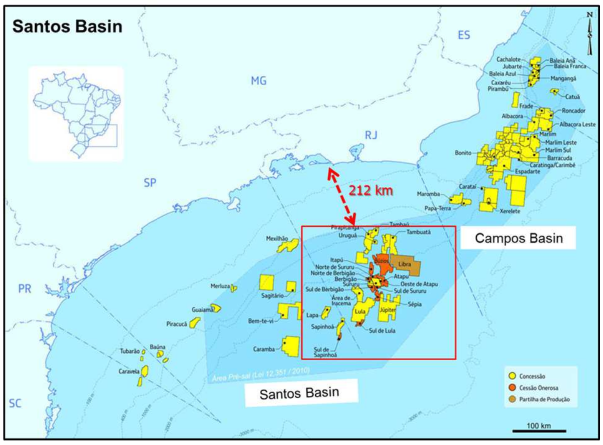

Figure 1: Location of Santos basin showing several field from Pre-Salt area.

Pre-Salt G&G Context

An important part of the Geophysical and Geological challenges in the Pre-Salt context is related to the lack or to the inadequacy of the available seismic data to meet the main reservoir characterization objectives. Ultimately, the final seismic response is strongly dependent on geological factors related to subsurface conditions, such as reservoir depths, which can reach more than 7000m, as well as the thickness and complexity of the underlying layers. The Pre-Salt overburden interval is mainly composed by a large amount of both homogeneous and heterogeneous salt layers sequences, presenting complex structures such as walls, diapirs, canopies and salt welds, of variable composition, varying from anhydrite, gypsite, tachydrite, carnallite and sylvite (Meneguin et al., 2015), with total thickness ranging from hundreds to 3000m, approximately (Figure 2). A thick marine mega-sequence overlies these salt layers, and may form mini basins controlled by the halocynesis, imposing an additional complexity to the velocity model lateral variation. The intensive use of narrow-azimuthal seismic technology in the early days of the Pre-Salt discoveries, combined with those previously mentioned intrinsic structural and stratigraphic complexities, increased the uncertainties of the static models in the early development phases, due to poor imaging.

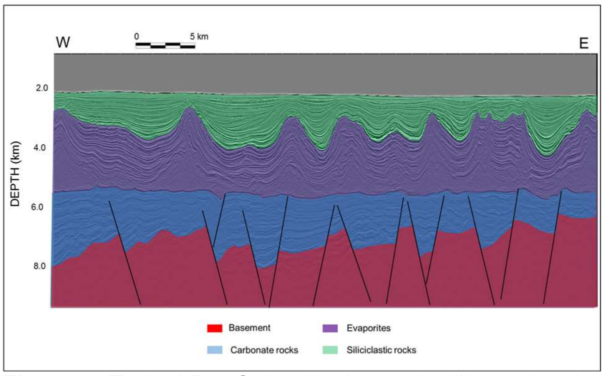

Figure 1: Typical Pre-Salt seismic section illustrating the geological complexity and salt structures.

Carbonate reservoir Case Study

The project database is composed by logs and cores from exploratory wells, and from three conventional non-dedicated narrow-azimuth seismic surveys, recorded in different calendar-times and acquired with sail-lines head of N90o, N158o and N123o respectively, and hereafter referred to as acquisitions A, B and C, cover the studied area. From ray-tracing illumination modeling studies, an opportunity for jointly processing these three seismic volumes was identified, which delivered the pre-stacked multi-azimuthal data called Tri-Azimuth, as seen in Figure 3.

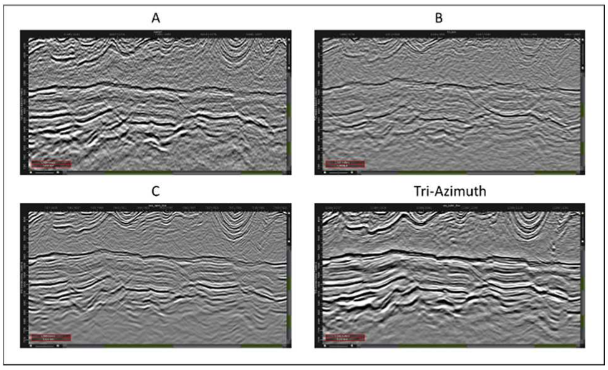

Figure 3: Depth-migrated W-E amplitude seismic sections from the studied area, where A, B, and C panels accounts for the legacy seismic data volumes, and the Tri-Azimuth panel for the resulting depth migrated merge of the previous ones.

The main reservoirs corresponds to Aptian carbonates from Barra Velha Formation, showing varying petrophysical characteristics, with high permo-porosities reservoirs identified as carbonatic mounds (Figure 4), contrasting with low energy facies mainly composed by laminites and spherulitites. The Mound facies corresponds to carbonatic growths associated to faults and to basement highs structures, showing restricted areal distribution and a chaotic seismic facies in full-stack amplitude migrated seismic sections. Low energy facies, despite its good porosities, presents very low permeabilitie. Characterizing these seismic facies is not a straightforward process, involving uncertainties that shall affect, for instance, well locations of the proposed drainage plan.

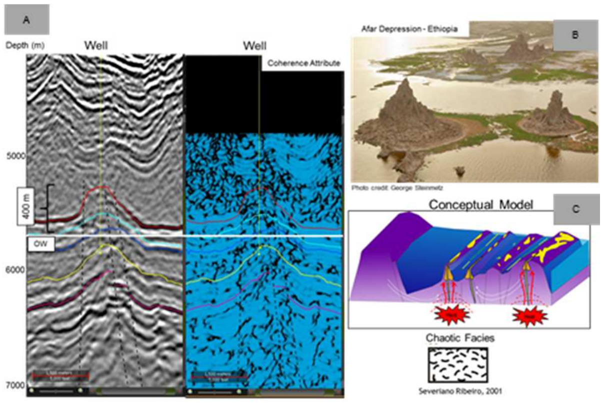

Figure 4: *A)* Seismic section showing Mound features in amplitude and coherence attributes. B) Lake abhe located in afar depression (Ethiopia) showing similar recent Mound structures. C) Conceptual model explains mound formation through fluid uprising in fault zones.

Seismic reservoir characterization modeling studies also showed that more regular illumination should contribute to the generation more realistic seismic images, enabling the interpretation of facies and structural patterns. Aiming at improving the static model of the studied area by means of an enhanced characterization of the above mentioned reservoir facies, a dedicated multi-scale and multi-disciplinary approach was developed to better describe the tectono-sedimentary evolution of the area. A synthesis of the proposed methodology is presented in Figure 5.

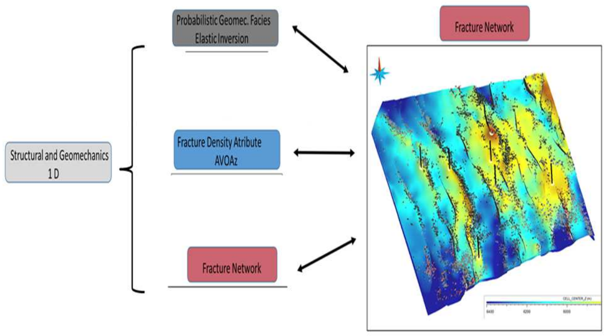

Figure 5: *Proposed multi-scale and multi-disciplinary workflow to better characterize the low permeability reservoir facies in the studied area, with the corresponding fracture model.*

Conclusions

The benefits achieved so far by the incorporation of the Tri-Azimuth data in a new conceptual static model go further beyond the simple improvement of the seismic image, as it enabled the inference of important geological elements previously masked by the low signal-to-noise (S/N) ratio due to a poor illumination. The improvement of the reservoir model was evidenced by a better detailing of the structural and stratigraphic models, resulting in a better understand of the area and well locations. An integrated fracture model, by taking data from cores, logs and seismic with distinct spatial resolution and support, opens up new perspectives to the challenging Pre-salt low permeability carbonates projects.

Acknowledgments

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