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Hybrid 4D in the Brazilian pre-salt: how low-repeatability seismic data is providing insights for evaluation new opportunities in a mature field

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Introduction

Most oil fields in Brazil's pre-salt were discovered using streamer seismic data, and only after several years of production the first Ocean Bottom Nodes (OBN) survey was acquired for 4D monitoring projects. Thus, fluid movement monitoring from early production relies on a hybrid 4D approach, using streamer as baseline and OBN as monitor.

Repeatability between surveys is key for detecting production-related changes in 4D seismic. In the stiff carbonate rocks of pre-salt reservoirs, dealing with low repeatable surveys is a big challenge. However, recent advances in seismic processing—such as Full Waveform Inversion (FWI)—have enabled the mitigation of low-repeatability effects in seismic monitoring projects.

This work presents a 4D project in a pre-salt field, where a hybrid time-lapse data provides important information to reduce ambiguity in the interpretation of the 4D seismic signal, supporting the evaluation of new opportunities.

Method and Dataset

The study area is a pre-salt carbonate reservoir in the Santos Basin, at ~5000 meters depth. It is a mature field that has been producing for over ten years.

The field was developed with streamer data, acquired in 2012. In 2021, the first OBN survey was acquired, used as the baseline for a high-repeatability 4D OBN-OBN project (4D-OBN), with the second OBN monitor survey completed in 2023.

To detect 4D signals through these hybrid data, as suggested by previous petroelastic modeling, two processing workflows were tested: 4D LSRTM and 4D FWI Imaging, with 4D FWI yielding the best results. For the 4D-OBN, LSRTM processing is ongoing.

Results and Conclusions

For the hybrid monitoring project, 4D LSRTM data allowed to identify few anomalies and was heavily affected by noise. In contrast, the image obtained through FWI offered significantly better resolution, enabling a more continuous and confident anomalies interpretation.

The hybrid 4D (FWI processed) data revealed positive anomalies in the lower portion of the reservoir and negative anomalies in the upper, associated with the replacement of oil by formation water and gas. Together with 4D-OBN, these anomaly maps are currently being used qualitatively to: (i) support field management decisions; (ii) reduce ambiguity in the interpretation of the 4D-OBN project; (iii) improve production history matching in the flow simulator; and (iv) evaluate new development opportunities by assessing gas and water risk in prospective new wells.

FWI Imaging algorithms have shown that it is possible to extract meaningful 4D insights even under low-repeatability conditions, enabling interpretation in fields where 4D seismic monitoring was not originally planned during early development. The success of this project highlights the value of having fluid movement information from the earliest stages of field production.