Submission code: PMGRBG5P67

See this and other abstracts on our website: https://home.sbgf.org.br/Pages/resumos.php

Seismic Monitoring of the Buzios Supergiant Oilfield: Challenges & Opportunities

Carlos Eduardo Borges de Salles Abreu (Petrobras), Felipe Apolonio (PETROBRAS; Petróleo Brasileiro SA), Leandro Souza (Petrobras), Eliane Born (Petrobras), Monica Costa (Petrobras)

Seismic Monitoring of the Buzios Supergiant Oilfield: Challenges & Opportunities

Abstract

Seismic monitoring has become a standard tool for optimizing reservoir management, improving well placement, and supporting infill drilling in brownfields. In Brazil, successful applications have been reported in both siliciclastic reservoirs and low-stiffness carbonates even with less repeatable seismic data. This work highlights challenges and opportunities posed by the Life of the Field Seismic (LoFS) monitoring project in Buzios field, a supergiant offshore carbonate greenfield located at the southeastern Brazilian continental margin.

Introduction

In the last twenty years, numerous seismic monitoring projects have been conducted in post-salt Tertiary heavy oil turbiditic deposits (Bruhn et al., 2017; Grochau et al., 2014; Abreu, 2008) in oilfields operated by Petrobras. Initially deemed risky due to the lower detectability of stiff carbonate reservoirs, Cruz et al. (2021) showcased the successful application of time-lapse technology in the Tupi field, revealing new opportunities for tracking gas and water fronts in pre-salt targets. The Buzios field, discovered in 2010 and declared commercially viable in 2013, presents a thick column of complex carbonate rocks containing light oil (26-30º API), which demands innovative geology and geophysics (G&G) modeling, along with advanced drilling workflows and technologies. A key objective of the Buzios field Director Plan is to maximize recovery by implementing a comprehensive data acquisition plan, using water and water-alternate-gas (WAG) injection for enhanced oil recovery (EOR), utilizing intelligent completion valves (ICVs), and executing seismic monitoring throughout the field's life.

Seismic data acquisition evolution

In most Petrobras Pre-salt Production Development & Production (PD&P) projects, depth-migrated seismic volumes from towed streamer technology have been the main dataset supporting initial reservoir models and project decisions, despite their intrinsic limitations, such as restricted frequency bandwidths and limited source-to-receiver azimuthal distributions. Additional imaging challenges were posed by complex overburden, consisting of thick salt diapirs with varying compositions, which imposed relevant uncertainties in the geophysical modeling of the complex carbonate reservoirs in the Buzios field. New seismic marine acquisition technologies for accurate sedimentary representation were requested, and the first Ocean Bottom Node (OBN) multicomponent survey was recorded from October 2018 to November 2019. Considered the largest OBN survey globally at that time, it covered a receiver area of 1,621 km² and a shot area of 2,739 km², with 1,095,540 recorded shots across 2,600 nodes, utilizing a shot interval of 25 m.

The recovery mechanism in the Buzios field is solution gas drive, supplemented by secondary recovery with water or gas through WAG injection. The drainage strategy positions producers in the reservoir's upper portions, supported by peripheral injection. Currently, six production units are installed, with five more planned by 2028, aiming for a production rate of 1.5 million bbl/d. The completion strategy includes 2 to 3 zone completions and ICV systems to enhance performance and reduce heavy workover needs.

Modeling Results and Areas of Interest for Monitoring (AIM)

The selection of the most suitable commercial seismic monitoring technology for specific oilfield characteristics involves a complex decision-making process. A multivariate analysis with interdependent parameters such as rock and fluid properties, economic analyses of production profiles, water depths, subsea layout complexity, and scheduled monitoring surveys was proposed. The goal is to identify available market options that provide the highest repeatable seismic data (Lopez et al., 2017). A key parameter in this evaluation is the expected 4D seismic signature, which is influenced by the rock-fluid system and recovery mechanisms.

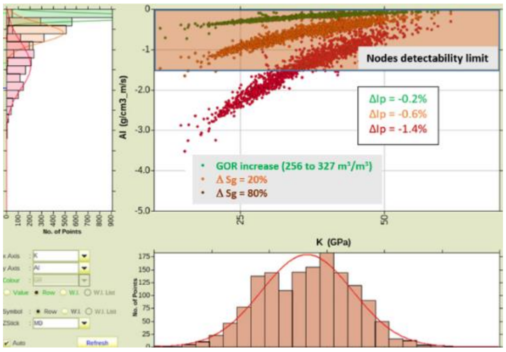

Figure 1: Petroelastic modeling results for different production scenarios of water-alternate-gas (WAG) injection strategy, considering primarily gas injection with consequent reservoir softening. Acoustic impedance (AI) values assigned as percentual variations.

Feasibility petroelastic modeling studies were conducted to simulate synthetic seismic responses under water-alternating-gas (WAG) and water injection conditions throughout the production lifecycle. The objectives of the injection program include enhancing sweeping efficiency and compensating for pore pressure decreases due to high oil production rates in the Barra Velha and Itapema formations, where a total of 454 ultrasonic wave propagation velocity measurements were taken from six wells, representing different facies with varying porosities and permeabilities. The petroelastic modeling results reveal challenges in obtaining reliable 4D signatures in the complex production scenarios of Buzios. Findings indicate intricate interactions between high-rate injected fluids and reservoir minerals. Figure 1 illustrates the difficulty of achieving accurate 4D signatures for gas saturation increases and the effects of water injection, with impedance contrasts close to the technical limits of Nodes technology (less than 1.5%).

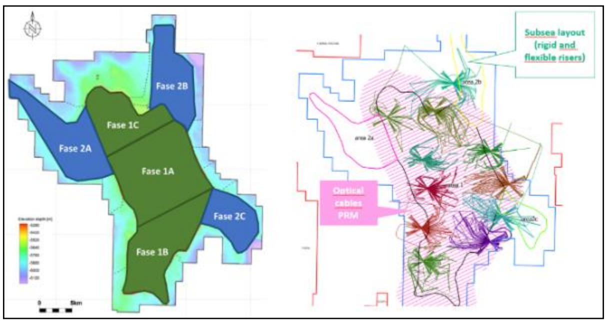

Figure 2 - (Left) Area of Interest for Monitoring (AIM) for Phase 1 (green area), and Phase 2 (blue areas); (Right) In pink, conceptual geometry for fiber optics cables PRM system deployment in Buzios field, where colored spyders represent each FPSO with its individual anchoring system.

Monitoring surveys and Value of Information (VoI)

The two primary phases shown in Figure 2 outline key priorities for reservoir LoFS monitoring in the Buzios field. Phase 01 covers an area representing 84% of the Volume of Oil In-Place (VOIP) and 89% of expected cumulative production. In early 2022, Petrobras announced a bidding process for the first seismic monitoring acquisition, which has already been recorded during the period from September 2024 to April 2025, using the same geometry and equipment as the base Nodes program to maximize repeatability. To evaluate the optimal interval for future seismic monitoring campaigns in the LoFS Buzios project and capture rapid reservoir changes from WAG cycling, an experiment was performed by redeploying sensors and reshooting over a 19 km² area in the central part of the field, following the Instantaneous 4D (i4D) concept proposed by Stammeijer et al. (2013).

Various methodologies support decision-making in Exploration and Production (E&P), including break-even analysis and the Value of Information (VoI). VoI assesses the economic benefit of additional information against its costs, helping to decide whether to invest in further data collection. In seismic monitoring, potential benefits include optimizing well placement, enhancing production rates, identifying poorly swept zones, and mitigating geomechanical risks. Dias et al. (2024) developed an in-house methodology using the VoI metric to estimate investment costs versus the benefits of seismic information, which were categorized into three groups: i) supporting new wells; ii) informing production management; and iii) geomechanical advantages, adjusted for signal-to-noise levels and acquisition timing. Figure 3 summarizes this concept.

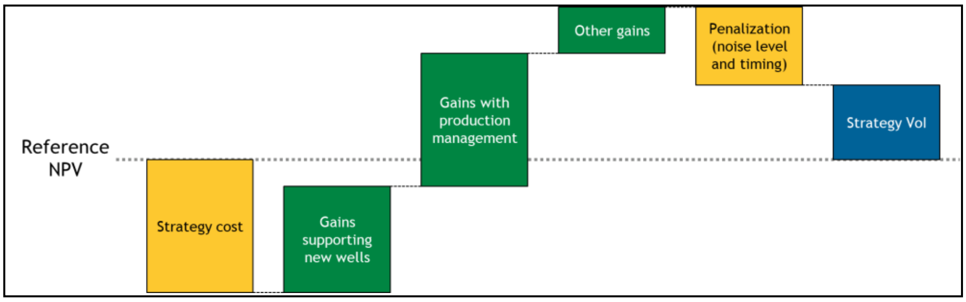

Figure 3: Waterfall graph of the proposed VoI methodology, where green bars represent the gains/benefits and yellow bars the associated cost, and blue the final value.

Challenges & Opportunities

A key challenge in the LoFS project in the Buzios field is the complex topside and subsea layout, which includes twelve production units and over 180 producer/injector wells by 2030. The water depths, ranging from 1,600 to 2,200 meters, introduce seismic repeatability constraints due to variations in ocean layer velocity. Additionally, more frequent monitoring may encounter seasonal temperature fluctuations that can further affect the 4D response. Similar challenges have been observed in Snorre PRM data (McCluskey et al., 2017) and were simulated for an Ocean Bottom Node (OBN) in the Santos Basin (Borges et al., 2022).

To enhance the chances of success for the LoFS operation, several factors need to be addressed: (i) conducting Front-end Engineering & Design studies to assess feasibility, resources, risks, costs, and timelines; (ii) implementing project phasing for timely data delivery; (iii) integrating multidisciplinary teams; (iv) utilizing the available Santos Basin Optical Network to expedite seismic data transfer; and (v) ensuring contractual flexibility for long-term goals.

The successful implementation of the LoFS project in Buzios relies on obtaining high-quality monitoring data for geology and geophysics (G&G) models, efficient processing, and rapid updates of numerical simulators, especially when using more frequent monitoring data from PRM systems. The potential benefits include opportunities for: (i) optimizing well placements; (ii) managing intelligent completion valves (ICVs); (iii) identifying infill drilling options; (iv) updating G&G models; (v) monitoring Carbon Capture, Utilization, and Storage (CCUS); and (vi) leveraging future Distributed Acoustic Sensing (DAS) technologies. By capitalizing on these opportunities, the LoFS project can enhance reservoir management, improve production efficiency, and mitigate risks related to fluid dynamics and reservoir performance.

Conclusions

The opportunities presented by the Life of Field Seismic (LoFS) project in Buzios rely on high-quality monitoring data for geology and geophysics (G&G) models. To maximize the value of this investment, efficient processing and rapid updates of geological and numerical simulation models are essential, especially with increased monitoring frequency from PRM campaigns. The benefits of LoFS projects include optimizing well placement, enhancing the performance of ICVs, identifying poorly swept zones for infill wells, and mitigating geomechanical risks through passive seismic data. The project aims to reduce model uncertainties, improve predictability of fluid arrival in production and injection scenarios, and enhance understanding of fluid pathways, thereby supporting reservoir management and minimizing health, safety, and environmental (HSE) risks.

Acknowledgments

The authors would like to thank Petrobras and its partners for granting permission to publish this work, as well as all colleagues from Buzios, GFR, AGUP, Mero, AG, TG, and CENPES for their valuable contributions and technical discussions.

References

Abreu, C.E.B.S. [2008] Time-lapse (4D) Seismic interpretation methodologies based on kriging analysis: application to the Senlac (onshore Canada) and Marlim (offshore Brazil) heavy oilfields. PhD Thesis, INPL, France.

Borges, F., Muzzette, M., Queiroz, L.F., Pereira-Dias, B., Dias, R. & Bulcão, A. [2022] Analysis of water velocity changes in time-lapse ocean bottom acquisitions - A synthetic 2D study in Santos Basin, offshore Brazil. Journal of Applied Geophysics.

Cruz, N. M., Cruz, J.M.N., Costa, M.M.M., Urasaki, E.N.A., Teixeira, L.M. and Grochau, M. H. [2021] 4D seismic applied to Pre-Salt carbonate reservoirs: challenges and results from Tupi Pilot, Santos basin. Second EAGE Online Conference on Pre-Salt Reservoir, Extended Abstract, D3-1.

Dias, R. M., Salgado, M., Da Silva, R., Borges, F., and Pereira, C. [2024] Where, When, and How to Acquire Seismic Data? a New VoI Methodology to Support Decisions. 85th EAGE Annual Conference & Exhibition. P.1 – 5.

Grochau, M.H., Benac, P.M., Alvim, L.M., Sansonowski, R.C., Pires, P.R.M., Villaudy, F. [2014] Brazilian carbonate reservoir: A successful seismic time-lapse monitoring study. The Leading Edge 2014, 33 (2): 164–170.

Lopez, J.L, Cox, B.E., Hatchell. and Wang, K. [2017] Technology Options for Low-Cost On-Demand Seismic Monitoring in Deepwater Brazil. 15th International Congress of the Brazilian Geophysical Society & EXPOGEF, Rio de Janeiro, Brazil.

McCluskey, K., Buizard. S., McCluskey. M., Zietal, R. and Moyle, N. [2021]. The Impact of Environmental and Acquisition Variations for PRM 4D Processing - Snorre Case Study. First EAGE Workshop on Practical Reservoir Monitoring. Amsterdam, The Netherlands.

Stammeijer, J.G.F., Davidson, M., Hatchell, P.J., and J.L. Lopez. 2013, Instantaneous 4D Seismic (i4D) - An Innovative Concept to Monitor Offshore Water Injector Wells. Paper presented at the International Petroleum Technology Conference, Beijing, China.