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Búzios Field 4D Seismic Processing: Initial Perspectives and Challenges

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Abstract Summary

This work addresses the initial challenges related to the time-lapse (4D) seismic monitoring of Búzios field, a super-giant oilfield located in ultra-deep waters offshore Brazil. Some of the initial 4D processing challenges, such as baseline and monitor acquisition differences, which include receivers' relays, water column effects and noise levels, are highlighted. Important salt geometry heterogeneities, as well as the spreading of several igneous bodies throughout the field also add to the complexity of seismic imaging in both 3D and 4D senses. Despite the aforementioned challenges, recent advancements in imaging technologies can unlock unprecedent 4D information accuracy, such as the application of 4D Elastic Time-Lag Full Waveform Inversion (TL-FWI). Preliminary results indicate improvements over the 3D structural interpretation based on a legacy model and indicate a robust path towards obtaining realistic 4D information.

Introduction

Búzios field, a super-giant oilfield, is considered the largest operating Pre-salt oilfield operating in ultra-deep waters of Santos basin, southeastern offshore Brazil. Producing since 2018 from 6 (six) Flooding Production Units (FPUs), Búzios has recorded the biggest Ocean Bottom Nodes (OBN) campaign during 2018-2019, assumed as the base survey for the Life of the Field Seismic Monitoring Project. The first OBN monitor survey was acquired during 2024-2025. Due to the presence of complex salt and igneous bodies, water velocity variability and an intense field operation, obtaining repeatable acquisitions becomes a challenging task. Thus, 4D seismic processing steps are fundamental for generating reliable results. The main challenges in the ongoing seismic processing to obtain suitable datasets towards reliable 4D seismic results in Búzios field and the improvements in the reprocessing of the velocity model obtained by employing state-of-the-art imaging techniques, such as Elastic TL-FWI, are described and detailed in this work.

Seismic Processing Challenges

To ensure maximum repeatability, both baseline and monitor acquisitions were conducted using the same Ocean Bottom Node (OBN) technology. This approach leveraged long offsets, full azimuthal coverage, and a higher signal-to-noise ratio. Although the surveys demonstrated good repeatability, several factors related to acquisition operations, the field environment, and geological conditions can impact the quality of the results. Due to the vast size of the Búzios field and the limitations of the node battery, multiple receiver relay operations were necessary, particularly during the baseline survey. This led to increased variability in receiver positioning and some nodes lacking full azimuthal coverage, which affected the repeatability of the acquisitions and necessitated a detailed 4D binning strategy to preserve the 4D information.

A significant difference between the baseline and monitor datasets is associated with the ambient noise levels during acquisition. The baseline was collected during a period of reduced field activity, resulting in cleaner data overall. In contrast, the monitor acquisition occurred amidst intense field operations, leading to a dataset with a higher noise level. Figure 1 illustrates a deep-window RMS map for all nodes within a specific region of the field, highlighting elevated noise levels (indicated in red) around production zones, with the monitor dataset exhibiting an overall increase in noise.

Moreover, variations in water column conditions between the acquisitions introduce additional complexities that require precise corrections to prevent contamination of the 4D information. Figure 2 presents the different water velocity profiles recorded during the baseline (a) and monitor (b) acquisitions. These discrepancies necessitate a comprehensive water column correction step during the 4D processing to avoid introducing unrealistic 4D time-shifts into the dataset.

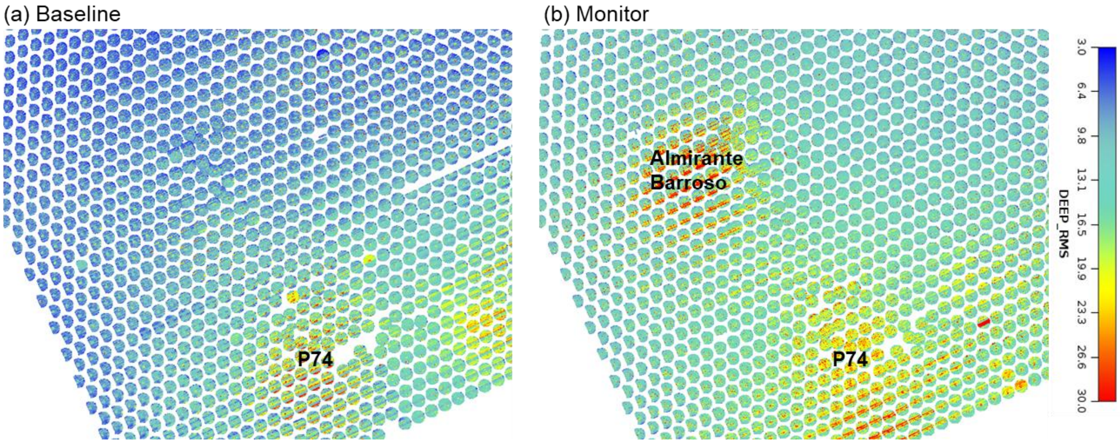

Figure 1: Deep-window RMS shrink map for (a) baseline and (b) monitor surveys.

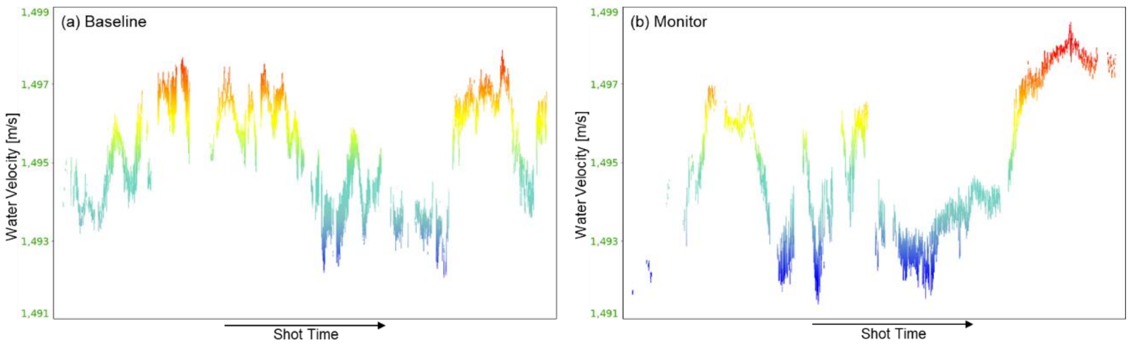

Figure 2: Water velocity value across time for (a) baseline and (b) monitor datasets.

Another complexity in the 4D processing of the Búzios field arises from its geological settings. To tackle this challenge, the baseline dataset is being utilized within the framework of Elastic Time-Lag Full Waveform Inversion (TL-FWI) for velocity model building, replacing the acoustic TL-FWI used in legacy processing. This shift allows for more accurate physical modeling during inversion. In addition to advancements in physical accuracy, computational power has also progressed significantly over the years, enabling us to run multiple iterations and utilize higher frequencies in FWI, which have proven successful in pre-salt datasets (Brando et al., 2023; Pacheco et al., 2024).

Preliminary results from applying Elastic FWI to the Búzios data demonstrate significant improvements over the legacy velocity model, particularly in the delineation of potential geological features, including enhanced boundaries of salt and igneous bodies, as illustrated in Figure 3. The arrows in Figure 3b highlight heterogeneities that are more clearly identified in the Elastic FWI velocity model. Figures 3c and 3d present overlays of well sonic data on the legacy and Elastic FWI velocity models, respectively. Notably, the Elastic FWI model exhibits a much better correlation with the well data for pre-salt velocities when compared to the legacy low-frequency model.

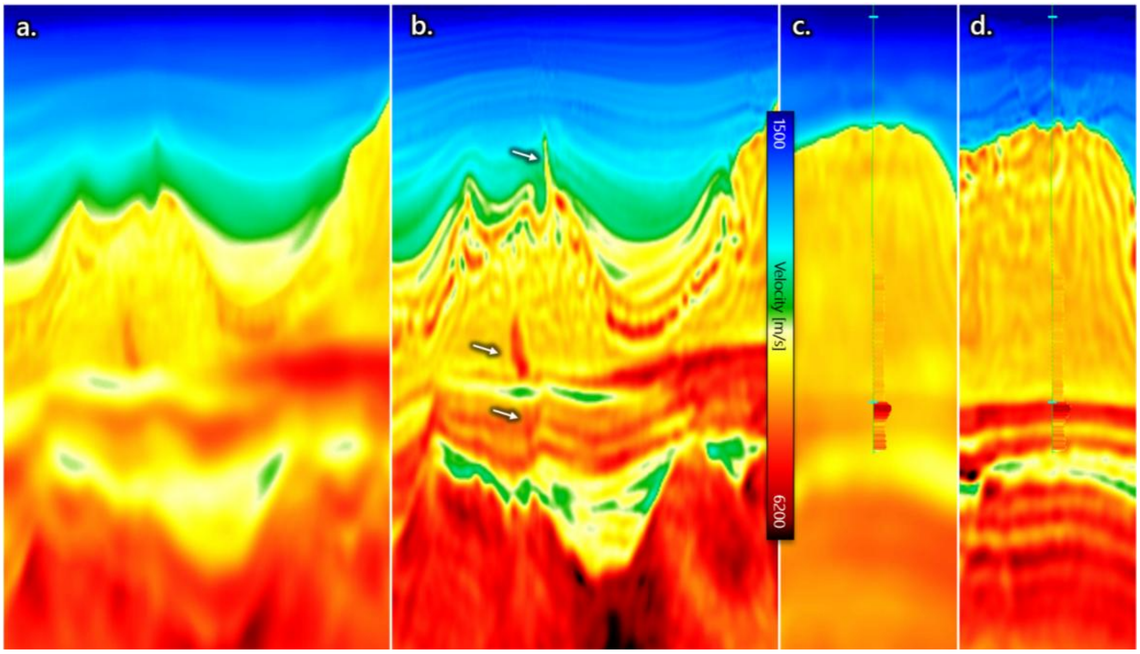

Figure 3: (a) Legacy velocity model, (b) Elastic FWI velocity model, (c) legacy velocity model with well sonic data overlay and (d) Elastic FWI velocity model with well sonic data overlay.

Conclusions

Despite seismic acquisition and environmental intrinsic variability observed when processing Búzios baseline and monitor seismic datasets, the current ongoing seismic processing aims to mitigate these issues to obtain consistent datasets to generate reliable 4D images. One of the key outcomes so far is the improved baseline velocity model obtained through Elastic FWI, which delivered enhanced geological consistency compared to legacy acoustic approach. This sets the stage for the next steps, which involve the 4D co-processing of baseline and monitor datasets that will be input for migration algorithms and 4D FWI.

Acknowledgments

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