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The Influence of Merging Cutoff Frequency on Seismic Inversion: Insights from Búzios Pre-Salt Field

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Introduction

Selecting an appropriate merging low frequency cutoff is a challenging task that requires balancing several factors: seismic data limitations, seismic residuals, lateral and vertical resolution, crossplot analysis, rock physics, and geological knowledge of the study area.

The studies were conducted on the Búzios field, a giant pre-salt oilfield located in the Santos Basin. Búzios is situated within a complex geological setting, characterized by structural highs and mounds, carbonates reservoir beneath a thick salt layer, and a complex top-salt geometry. Seismic inversion was performed using ocean bottom nodes (OBN) seismic data. The objective of this study is to demonstrate how the selection of the merging low-frequency cutoff affects seismic inversion results, both qualitatively and quantitatively.

Method and Dataset

In this analysis, different scenarios of merging low-frequency cutoff were tested, ranging from 1 Hz to 10 Hz. This approach enables a direct evaluation of the impact of the merging low-frequency cutoff selection on seismic inversion results. The seismic inversion was performed using OBN seismic data processed through least-squares reverse time migration (LSRTM) and a velocity model built with full waveform inversion (FWI). This seismic data features a high signal-to-noise ratio and good low-frequency content.
The low-frequency trend model used to constrain seismic inversion was created through well interpolation, utilizing data from more than 90 well.
The analysis focused on seismic residuals (the difference between modeled seismic data and real seismic data), as well as reflectivity, crossplots, and impedance results.

Results and Conclusions

The seismic residual results showed that for the lowest frequency tested (1 Hz), geological features were barely visible, indicating that the inversion process was able to resolve the seismic data effectively. This is the primary goal of the inversion process. Although the P-impedance (compressional impedance) values exhibited low resolution and displayed considerable differences from those expected for the region. This highlights the limitations of using inappropriate low-frequency cutoffs.
Typically, the low trend model plays a significant role in the inversion results, potentially imprinting characteristics that influence the final outputs.
Using low merging frequency cutoffs increased the contribution of the seismic data to the inversion process. However, seismic data with poor low-frequency content led to unrealistic P impedance values. Conversely, higher frequency cutoffs improved resolution but increased seismic residuals. The differences in reflectivity results across scenarios were subtle, with lateral and vertical resolution exhibiting consistent behavior across the various tests. Crossplot analysis, comparing well P- impedance values to inverted P-impedance values, demonstrated that lower merging frequencies generally resulted in weaker correlations. However, beyond a certain frequency, the correlation values stabilized and showed minimal variation.
The ideal merging cutoff frequency should provide low residuals, good resolution, and realistic P-impedance values consistent with the reservoir geology.