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Maximizing Seismic Information: FWI Imaging as an Innovative Tool to Unravel Geological Complexities of the Brazilian Pre-Salt

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Introduction

Conventional seismic imaging methods rely on the single-scattering assumption, where only primary reflections contribute to the reflectivity, neglecting the additional illumination provided by multiples. These methods also depend on a velocity model obtained through a separate workflow—such as tomography or full waveform inversion (FWI)—that focuses on recovering the low- to mid-wavenumber components governing wavefield kinematics. On the other hand, FWI imaging takes advantage of the full wavefield to recover both the velocity model and reflectivity image within a single framework. This approach updates low-, mid-, and high-wavenumber components, therefore enhancing image illumination and resolution. In this work, we demonstrate the benefits of this methodology by comparing recent FWI-based imaging results from the Brazil Santos Basin with those from traditional approaches.

Method

Seismic imaging has traditionally relied on migration techniques to create reflectivity models of subsurface structures, requiring a well-constructed velocity model and extensive preprocessing to enhance signal-to-noise ratio and focus on primary reflections. However, conventional migration faces limitations, such as challenges with multiple scattering and the potential loss of valuable wavefield data during preprocessing. Full Waveform Inversion (FWI) offers a more comprehensive approach by iteratively updating velocity and reflectivity models through the utilization of the full wavefield, including primary reflections, multiples, and diving waves. This methodology minimizes preprocessing steps, retains low-frequency signals, and extracts low-wavenumber information, enhancing resolution and accuracy. Recent advancements in FWI workflows aim to directly produce reflectivity images, streamlining the imaging process and improving structural detail and quality. FWI Imaging is especially impactful in complex geological settings, offering superior vertical and lateral resolution while accommodating multiple energy orders to provide additional subsurface illumination. This work presents case studies on FWI Imaging's effectiveness in revealing intricate subsurface details and its transformative potential in seismic exploration.

Results

The **r**esults highlight the strengths of FWI Imaging in addressing complex geological challenges and improving the overall quality of seismic interpretation. This approach has successfully resolve fine reflectors, complex fault systems, and the intricate geometry of minibasins. Besides, FWI Imaging also proved effective in accurately defining the base and top of salt, which are critical for exploration in Santos Basin, as well as intra-salt geological features. In the pre-salt section, the improved resolution and structural clarity contribute to a more comprehensive understanding of the reservoirs, enabling better characterization of potential hydrocarbon traps and their associated geological features. FWI Imaging serves as an innovative complement to conventional migration techniques, offering unparalleled vertical and lateral resolution, as well as the ability to incorporate the full wavefield data. Its application in the Santos Basin has demonstrated its capacity to reveal intricate subsurface details, advancing in geological understanding of post-salt, salt and pre-salt sections.