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## **Potential for 4D seismic detection of CO<sub>2</sub> injection in pre-salt carbonate: A 1D feasibility study using a well of the Atapu Field, Santos Basin**

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## Potential for 4D seismic detection of CO<sub>2</sub> injection in pre-salt carbonate: A 1D feasibility study using a well of the Atapu Field, Santos Basin

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With rising CO<sub>2</sub> levels in the atmosphere, oil and gas companies are seeking to reduce their CO<sub>2</sub> footprint with technologies such as CO<sub>2</sub>-Enhanced Oil Recovery (EOR) and Carbon Capture and Storage (CCS). To maximize the success of such projects while ensuring long-term security, time-lapse seismic acquisitions are crucial for reservoir monitoring, enabling the assessment of fluid dynamics resulting from injection or production. Over the last decade, Brazilian pre-salt carbonate reservoirs have emerged as candidates for 4D seismic monitoring due to their complexity and the need for improved reservoir management. Because of the high costs associated with deploying a 4D project, feasibility studies are crucial for evaluating the sensitivity of the reservoir to fluid changes and its detectability through 4D seismic monitoring. We conducted a 1D feasibility study using one well to assess the sensitivity of the Barra Velha carbonate reservoirs in the Atapu Field, pre-salt Santos Basin, to fluid changes, particularly an increase in CO<sub>2</sub> content resulting from injection. For that, we performed the reservoir properties estimation and the CO<sub>2</sub> elastic properties calculation in the reservoir conditions. We compared Batzle-Wang, Xu, and Han equations to calculate the bulk modulus (K) and density (RHO) of the CO<sub>2</sub>. The estimate obtained using Xu equations, which was similar to the one from Han, was preferred in this study, as previous works suggest that the Batzle-Wang model may be less adequate for calculating CO<sub>2</sub> properties. In well 1-BRSA-1172-RJS, we performed fluid substitution for two baseline (Baseline 1 and Baseline 2) and two monitor (WAG and CO<sub>2</sub> injection) scenarios using the Mavko equations, which are suitable for application when S-wave velocity (VS) logs are missing for the Gassmann equations. From the two injection scenarios, we found strong 4D anomalies in the acoustic impedance (IP) and P-wave velocity (VP) in the carbonate reservoir. The acoustic impedance difference ( $\Delta IP$ ) from baseline to monitor scenarios produced changes of more than 1.5%. Such  $\Delta IP$  combined with the high thickness of the formation and VP changes produced 4D anomalies detectable in the synthetics. When performing the forward modeling for both injection scenarios, the average time-shifts estimated in this well were more than 3.5 ms of delay in the base of the Barra Velha Formation. With that, we have demonstrated the potential for 4D monitoring CO<sub>2</sub> changes during CCS or EOR projects in the pre-salt.