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Direct seismic modeling of basal anhydrite that covers the Pre-Salt reservoirs in the Santos Basin: challenges, impacts and solutions

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Abstract

The salt section in the Santos Basin, the Ariri Formation in the Guaratiba Group, Aptian age, may vary from dozens of meters to more than 3 kilometers, and it lies above the Pre-Salt hydrocarbon reservoirs. Besides this thickness variation, the composition of this section presents alternances of minerals, mainly dominated by halite, also named as the background mineral, followed by minerals presenting higher velocity than halite, known as high-velocity salts (HVS), well represented by anhydrite, and fewer quantities of low-velocity salts (LVS) compared with halite, represented predominantly by carnallite, sylvite, and tachyhydrite. The salt deposition occurs in cycles due to the desiccation of brines, and the record is well known as salt stratification, which is often moved from its original position (autochthonous salt) to the present one (allochthonous salt) due to basin movements such as tectonism and sedimentary overload. An important record of this salt stratification is observed immediately above the Pre-Salt reservoir, known as the basal anhydrite, which evidences the final carbonate phase of brine evaporation and the initial phase of the sulfates and chlorides that form the whole expression of the Ariri Formation. After drilling almost 400 wells to reach the Pre-Sal reservoir in the Santos Basin, it is feasible to estimate that most wells sample this basal anhydrite measuring about 10 meters thick. This assumption is then used to estimate the top of the first reservoir moving below the mapped seismic horizon, named as base of salt, by 10 meters. However, some wells experienced distinct scenarios of this basal anhydrite, causing several problems during the operational well-drilling process, leading to an incorrect positioning of the reservoir top. To overcome this challenge, we propose a methodology to direct modeling the seismic response of this basal anhydrite. The methodology involves several key stages to assess the impact of this feature variability on seismic imaging in the Santos Basin. The stages include obtaining good correlations for compressional velocity (Vp), shear velocity (Vs), and density (ρ) for each geological domain, direct seismic modeling using full wave equation to simulate various and possible (sampled) geological scenarios, incorporating the seismic acquisition geometry and source characteristics, and finally generating synthetic seismic data for basal anhydrite evaluation, to play as a crucial information for uncertainty analysis. The results are analyzed both qualitatively and quantitatively, focusing on resolution, noise, diffractions, amplitude values, and structural positioning. This comprehensive approach allows for a detailed understanding of the seismic response of basal anhydrite and supports improved reservoir characterization and drilling strategies. Besides, the results demonstrate that typical thin basal anhydrite layers, such as those with a thickness of approximately 10 meters, fall below the limits of vertical seismic resolution, leading to potential misinterpretation of the reservoir top. However, integrated analysis of seismic thickness and amplitude has proven effective in reducing interpretational discrepancies and enhancing reservoir characterization.