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Flow Pattern Characterization Integrating 4D Seismic Inversion, Seismic Attributes and Reservoir Simulation to Optimize Production in the Jubarte Oil Field (Campos Basin, Brazil)

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The Jubarte Field is located in the northern part of the Campos Basin, approximately 77 km offshore from the coast of Espírito Santo State, Brazil. Production began in 2002 and, since then, the field has undergone several development phases, incorporating advanced recovery technologies and 4D seismic monitoring to optimize reservoir performance. At the end of 2012, Petrobras installed a deep-water optical Permanent Reservoir Monitoring (PRM) system covering part of Jubarte oil as a pilot project. This system covered approximately 9 km^2 with a fully fiber-optic, four-component (4C) sensor array. Data acquisitions were performed in 2013, 2014 and 2015. The high repeatability and excellent quality of the 3D/4D images significantly improved the understanding of flow patterns. It supported geological model updates enabling the prediction of preferential flow paths within the reservoir. In this study, detailed mapping of horizons and fault systems was performed using 3D seismic data, supported by seismic attributes such as variance, most positive curvature, and most negative curvature. These attributes were used to investigate the relations between 4D seismic anomalies and the structural framework of the field. Subsequently, the 4D anomalies were mapped and compared with a synthetic seismic volume generated through seismic inversion processes. This comparative analysis allowed a reassessment of previous assumptions about the preferential flow paths of injected water within the reservoir. Following this, an integrated interpretation stage was conducted, combining 3D/4D seismic volumes and attributes with the geological model, as well as production and injection well data, and dynamic simulation outputs. All datasets were jointly analyzed in the context of the mapped seismic anomalies. The improved understanding of true saturation changes was then used to update both the geological model and the reservoir flow simulator, enhancing predictive capabilities and model reliability. The 4D response from this reservoir enables inference of fluid movement during the production period from 2013 to 2015. Five distinct classes of amplitude difference anomalies were identified in the 4D seismic data: hardening at producing wells, hardening at non-producing wells, hardening at injector wells, softening at an injector well, and seismic noise. Pressure-related effects were not considered significant within the scope of this study. Among the structural features evaluated, some faults appear to allow fluid flow, indicating effective permeability across them, whereas others, particularly stratigraphic boundaries in the southern and western sectors, act as barriers, restricting fluid movement in those directions. The integrated analysis revealed that water propagates through the reservoir in two main patterns: cone-shaped beneath wells and fingering driven by production. This behavior is governed by a combination of structural and stratigraphic controls. 4D seismic data proved to be a powerful and indispensable tool for monitoring fluid distribution and movement within the reservoir throughout its production life. However, deriving reliable interpretations required a comprehensive and integrated methodology, combining seismic and geological modeling, seismic attribute analysis, and engineering data. This multidisciplinary approach enabled a more accurate and detailed understanding of the Jubarte reservoir's dynamic behavior.