Enhanced Imaging and Characterization of the Inyan Kara Formation in the Williston Basin: A Seismic Reprocessing and Machine Learning Approach

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Abstract

Increased saltwater disposal (SWD) activity and the management of shallow disposal reservoirs for produced water in unconventional U.S. basins pose significant operational challenges, especially in wells affected by overpressure, which require more complex well designs to ensure safe and efficient operations. Accurately predicting overpressure conditions, such as those observed in the Inyan Kara Formation within the Williston Basin of North Dakota, is essential for overcoming these challenges. The Inyan Kara Formation, a Cretaceous-age fluvial and estuarine sandstone reservoir, is characterized by its complex channel architecture and highly variable reservoir quality. Understanding these channel geometries and improving reservoir quality predictions are essential for optimizing disposal strategies and enhancing reservoir injectivity models. This study addresses these challenges through a detailed seismic reprocessing approach aimed at improving the imaging and characterization of the Inyan Kara Formation. By applying advanced processing technologies, such as wave equation refraction statics and 5D interpolation, to existing 3D seismic data, we successfully enhanced vertical and spatial resolution at the Inyan Kara level, despite the original survey's deeper target design. Results from a 50 mi^2 pilot reprocessing effort revealed significant improvements in imaging channel morphology, indicating potential for improved predictions of reservoir behavior and injectivity. Comparing the reprocessed volume to the original data highlighted both the limitations of the existing seismic survey and the considerable advancements achieved through modern techniques. These insights will inform future work on the full 328 mi^2 seismic volume, guiding reservoir management decisions and addressing overpressure risks. In parallel, ongoing efforts using machine learning are refining our understanding of the Inyan Kara's channel fill sediments. We are training supervised algorithms to correlate seismic features with well log measurements, enhancing the characterization of sand channel bodies, improving connectivity models and predicting reservoir properties such as impedance and porosity, especially in areas away from wellbore control. Additionally, geocellular modeling with electrofacies classification is being integrated to model reservoir injectivity and pressure behavior in regions lacking seismic data, using well logs, analog seismic data and core data to validate models and quantify risks. This approach, combining seismic reprocessing with advanced modeling techniques, holds broad applicability across Hess's 1,500 mi^2 3D seismic inventory and has the potential to be adapted for other basins, aiding in optimizing well planning and mitigating risks associated with shallow injection reservoirs like the Inyan Kara Formation.