Guiding Exploration and Development of the Cretaceous Shuaiba Carbonate Using Quantitative Interpretation: Success, Failure and Future

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Abstract

The Shuaiba carbonate reservoir has been a significant contributor to the oil production in the Sultanate of Oman. It was deposited during the Cretaceous age and it is overlain by the Nahr Umr shale. It consists of complex patterns formed in different environments including open marine areas, shallow marine shoals and lagoons. Such variety in depositional environments led to significant lateral and vertical rock heterogeneity and progradation geometries. Thus, understanding Shuaiba patterns and facies distribution is critical for exploration and development strategies. Seismic quantitative interpretation (QI) has been challenging for Shuaiba because of the imaging quality, mainly impacted by the presence of multiples and low P-impedance contrast. However, with the recent advancements in seismic acquisition and processing, the imaging quality of Shuaiba has been uplifted. In this study, we revive the QI of Shuaiba using multiple case studies in North Oman. The workflow includes: (1) rock physics analysis, (2) forward seismic modelling and, (3) deterministic and probabilistic inversions. The Shuaiba reservoir is generally characterized by high porosities (>15%). The rock physics analysis shows a good correlation between porosity and P-impedance, making it practical to invert for porosity using seismic data. However, the analysis also indicated that good hydrocarbon saturation is not always correlated to high porosity, limiting the use of porosity as proxy for good facies. Additionally, we analyzed the facies defined by geologists in the acoustic and elastic domains. The results show that it is challenging to separate geological facies in the P- impedance domain. Some of the facies can be separated with moderate confidence in the Vp/Vs domain. The rock physics analysis concludes that full stack inversion is only useful to invert for porosity. In contrast, separating geological facies requires AVO inversion. However, the current quality of pre-stack data is not optimal to conduct AVO inversion.

Mapping the top Shuaiba loop consistently has been challenging. It may vary from peak to zero-crossing to trough. Forward seismic modelling shows that a tuning effect may occur between the top of Shuaiba loop and the loop corresponding to the thin carbonate layer embedded within the overlain Nahr Umr shale. The tuning is obscuring the image of top Shuaiba and yielding unreliable amplitudes. These unrealistic amplitudes may translate, through seismic inversion, to wrong subsurface properties. Thus, having sufficient vertical separation between the top Shuaiba and the carbonate layer within Nahr Umr is important for the success of seismic inversion.

Considering the challenges highlighted by the rock physics analysis and the forward seismic modeling, we dropped several case studies that were technically not feasible. In contrast, for the areas where porosity is useful to define good reservoir facies, we run multiple successful deterministic and probabilistic seismic inversions. The results are being utilized to de-risk opportunities and plan new wells.
Future work will focus on producing AVO friendly pre-stack data which will allow us to invert for elastic properties, providing a better chance to separate Shuaiba facies. We had some success with AVO inversion for other deeper reservoirs. Furthermore, we are exploring the applications of Artificial Intelligence which can simultaneously incorporate multiple reservoir properties to better separate the facies.