**Characterization of Seal Potential and Distribution Using Pre-Stack Seismic Inversion:
A Field Case Study of Onshore Abu Dhabi**

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Search and Discovery Article #20489 (2020)**
Posted August 24, 2020

*Adapted from poster presentation given at 2020 AAPG Middle East Region, Geosciences Technology Workshop, 3rd Edition Carbonate Reservoirs of the Middle East, Abu Dhabi, UA, January 28-29, 2020

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**Abstract

The outputs of seismic inversion are broadly used to characterize different lithofacies with variant rock properties and to reduce the uncertainties of target reservoirs. The P-wave impedance provides the initial basis of acoustic properties from post-stack seismic data and S-wave impedance provides additional elastic properties from pre-stack seismic data.

Regional indications, such as mudlogging hydrocarbon shows, high oil saturation log, high porosity log values and production test results, have shown high prospectivity of the wide-spread shallow-water Mauddud carbonate reservoir. However, characterizing the efficiency and distribution of seal for the Mauddud reservoir is a challenge. The main objective of this study is to develop a workflow utilizing advanced geophysical techniques including rock physics analysis and seismic inversion, to understand the potential and distribution of seal above the target reservoir.

The overlying Shilaif Formation in the study area was deposited in an intrashelf basin and three zones are identified: S1 (lower part), S2 (middle part), and S3 (upper part). The bitumen-rich zone in S1 of the Lower Shilaif shows sealing potential through well log analysis and it may act as a satisfactory seal for the underlying reservoir. In an oil-bearing source rock play, total organic carbon (TOC) is a mixture of kerogen and liquid hydrocarbon. In this context, bitumen is considered a viscous, soluble hydrocarbon that is an early product of kerogen maturation. Due to its high viscosity, bitumen is less likely to migrate from the kerogen-hosted pore system and is often left behind as a residue after light oil expulsion. The well logs have shown a good indication of the existence of non-movable fluids by the large separation between the porosity from neutron density (PHIT_ND) and the porosity from nuclear magnetic resonance measurements (TCMR). The core analysis also confirmed that the non-movable fluids are with high content of bitumen. Three lithofacies can be identified from well logs: (1) Clean mudstone characterized with inorganic porosity and low total organic content (TOC), (2) Mudstone with porosity partly filled with elevated TOC, and (3) Bitumen-rich mudstone. Seismic elastic property analysis (P-impedance and velocity ratio Vp/Vs) with reservoir properties (TOC and
separation of PHIT_ND and nuclear magnetic resonance measurements) provides valuable insights to the characterization of the target seal. The clean mudstone with inorganic porosity and low TOC is characterized with high P-impedance, while the mudstone filled with movable oil is characterized with low Vp/Vs and low P-impedance, and the target bitumen-rich mudstone is characterized with high Vp/Vs and low P-impedance. Pre-stack simultaneous seismic inversion and Bayesian-based lithofacies classification were carried out to predict the distribution of target seal in study area. The results show that there is a distribution of relative low P-impedance values in the northeastern and southern parts of study area. However, high Vp/Vs values are only present in the northeastern part of the field. The target seal in S1 unit of Shilaif Formation with high TOC and non-moveable bitumen at an early maturity is most probably present in the northeast part of the study area, consistent with well logs correlation results and present-day vitrinite reflectance map.

For the first time, the integration of rock properties and seismic inversion results to predict the potential and distribution of bitumen-rich seal in S1 unit of Shilaif Formation is addressed in this study. The results obtained are valuable information to further rock physics modeling and well placement.
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1. Introduction

The proposed workflow integrates the petrophysical and rock physics analysis with pre-stack seismic inversion and Bayesian classification to characterize the seal potential and distribution (Figure 4). This workflow first involves the integration of petrophysical analysis of rock properties and pre-stack seismic inversion with, finally, Bayesian classification to characterize the seal potential and distribution. The workflow is as follows:

2. Workflow

The workflow comprises the following steps:

(a) Petrophysical and rock physics analysis

(b) Pre-stack seismic inversion

(c) Bayesian-based lithofacies classification

3. Petrophysical and Rock Physics Analysis

The rock physics analysis is performed on the basis of the following steps:

4. Pre-stack Seismic Inversion

The pre-stack seismic inversion is performed as follows:

5. Bayesian-based Lithofacies Classification

The Bayesian-based lithofacies classification is performed as follows:

6. Conclusions

The proposed workflow is applied to a field case study of Onshore ABU DHABI. The workflow integrates petrophysical and rock physics analysis with pre-stack seismic inversion and Bayesian classification to characterize the seal potential and distribution. The workflow is successful in identifying the seal potential and distribution in the study area.

7. References

Acknowledgements

The authors acknowledge the ADNOC management for permission to share the study results. We also thank the support and contribution of our colleagues from ADNOC Exploration Function.

Figure 1: Gross deposition environment (GDE) map of Mishrif/Shilaif (Abu Dhabi petroleum system portfolio study, 2018).

Figure 2: Seismic section of study area with interpreted horizons.

Figure 3: Charging and sealing theory of Mauddud (ADNOC internal study, 2019).

Figure 4: Interval average map of final most probable seal distribution.

Figure 5: Crossplots of P-impedance and Vp/Vs from seismic inversion results and well logs calculations.

Figure 6: Probability density function of lithofacies classification.

Figure 7: Interval average map of final most probable seal distribution (highlighted in red).

Figure 8: Inversion analysis panel for P-impedance and Vp/Vs synthetics (the trace at a well location is in red, and the actual log curves for that well is in blue).

Figure 9: Seismic sections used to QC the inversion outputs Zp and Vp/Vs.

Figure 10: Crossplots of P-impedance and Vp/Vs from seismic inversion results and well logs calculations.

Figure 11: Interval average map of final most probable seal distribution.

Figure 12: 2D probability density functions using lithology classification.

Figure 13: Interval average maps of final most probable seal distribution (highlighted in red).