[PS]Prediction of Carbonate Reservoirs Pore Pressure and Porosity in Onshore Abu Dhabi Using Petroleum Systems Modeling Technology*

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Abstract

Prediction of pore pressure and porosity in an unconventional resource assessment area of Abu Dhabi was performed by using petroleum systems modeling techniques, combining seismic and well data and geological knowledge to model sedimentary basin evolution. The study objective was ultimately to reconstruct basin history and key geological structures as a basis for further geomechanical and fracture prediction studies. Twelve surfaces were interpreted from seismic data and derived from isopach maps. These maps were used to construct the basin model. The model was built from the top of the surface sediment down to the Shuaiba formation. Sediment decompaction was modeled, which enabled the reconstruction of the formation structures through time. Athy's law, formulated with effective stress, was used in the forward modeling simulator for the calculation of pore pressure. Information such as formation ages, erosional events, and hiatus periods were taken into account during simulation. The evolution of porosity, pore pressure, temperature, and thermal maturity through time were simulated and calibrated to measured data. Model porosity is dependent on burial depth, weight of the overburden sediment columns, and lithology properties. Porosity calibration was achieved by adjusting the compaction curve to effective stress. Pore pressure was calibrated by adjusting lithology porosity-permeability relationships. Low-permeability lithologies result in high pore pressure. A regional Paleocene pore pressure reduction was observed, caused by substantial erosion of the Simsima formation. Generally, formation overpressure is observed at greater depth. Additionally, modeled overpressures depend on the evolution of connate water vectors over geological time; these vectors depend on multiple lithology parameters as well as the capillary entry pressure of adjacent model layers. In the Shilaif fm, overpressure zones were identified at the anticlinal structures. Interestingly, higher overpressure was observed in the shallower anticlinal structure. The simulation results provide the estimated porosity and pore pressure in the unconventional play, as well as the reconstruction of the overall basin geometry through time. The resulting models were subsequently used as the basis for further fracture prediction studies; results were ultimately consistent with faults derived from existing seismic interpretation. Model porosity, pore pressure, and predicted fractures will be used for the development of static geological and dynamic reservoir models.

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Introduction

Exploration of unconventional/tight reservoir means emphasis must be placed on understanding porosity and pressure development in highly heterogeneous sediments. Qualitative understanding of lithology, pressure and porosity distributions across a large resource area remains challenging, particularly when the source rock interval is a complex mixture of clay minerals and carbonates. Pore pressure and porosity predictions are more complex in unconventional plays where the focus is clearly on the details of the source rock interval itself.

Background

The study area is part of the Rub Al Khali basin and it is situated in the south central area of Abu Dhabi, United Arab Emirates. The study area covers the onshore area of Abu Dhabi Company for Onshore Petroleum Operations Ltd (ADCO) (Fig. 1). There are a number of producing oil fields bounding the central namely, Bab, Bu Hasa, Shah, Asab and Sahil fields.

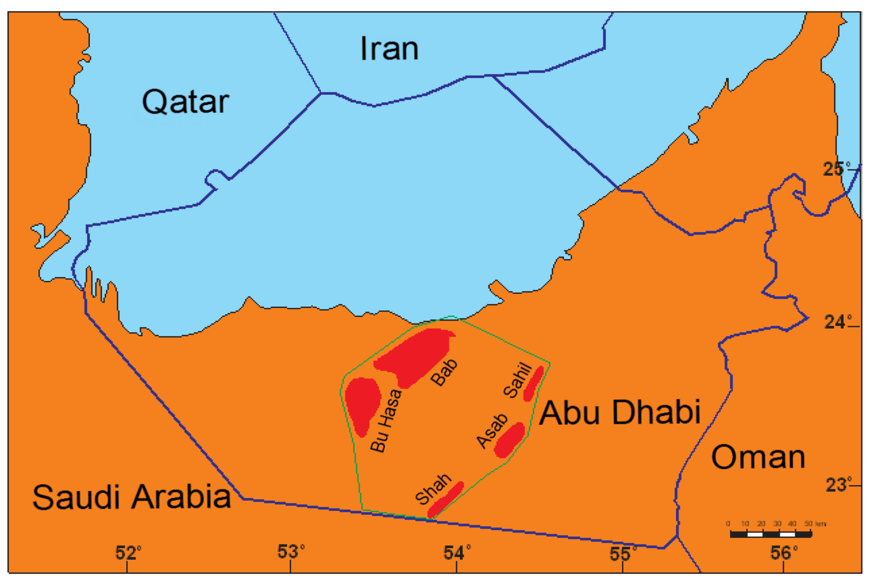


Fig. 1 – Location map of the studied area in onshore Abu Dhabi. (modified after Morad et al., 2010)

The study focused on the Shilaif formation of the Wasia group as the primary unconventional target formation. This formation was identified and considered source rock due to its organic richness with 2 % Total Organic Carbon (TOC) and Hydrogen Index (HI) of 500 mg HC/g TOC.

Aim

The study focused on the Shilaif formation of the Wasia group as the primary unconventional target formation. This formation was identified and considered source rock due to its organic richness with 2 % Total Organic Carbon (TOC) and Hydrogen Index (HI) of 500 mg HC/g TOC.

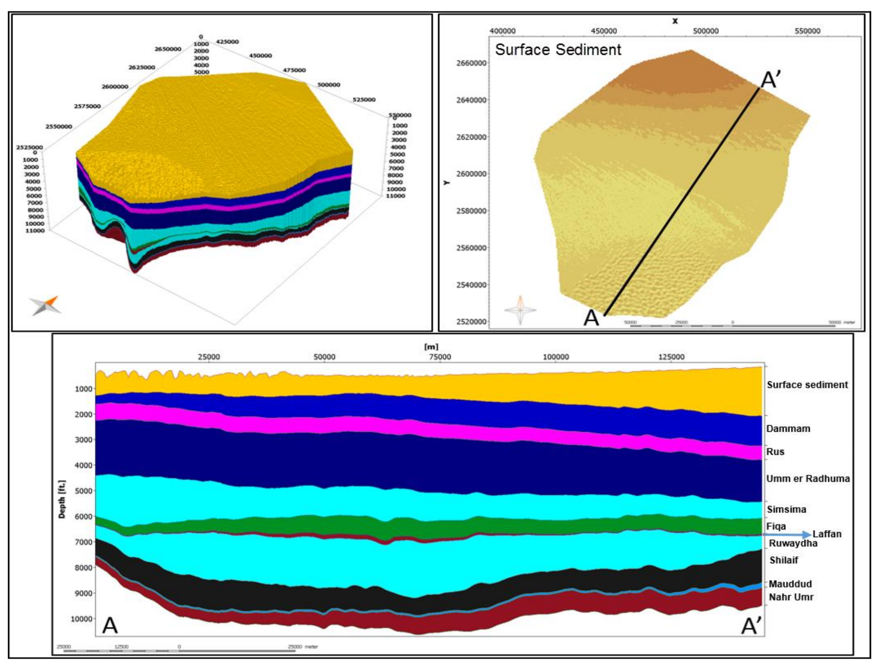
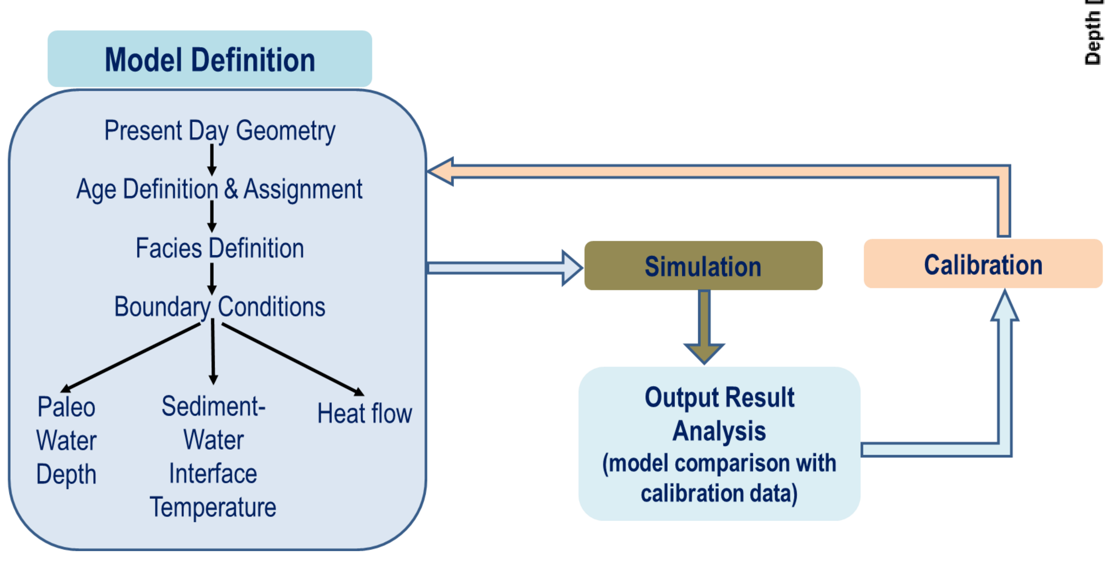


Fig. 2 – Geological structure model of the studied area (top left). The south-southwest (A)/north-northeast (A') cross section (top right) shows the geological formations in depth (bottom).

Principle of Modeling

Methodology Framework



Porosity Empirical Algorithms

- Porosity-depth relationship was first described by Athy (1930)

$$\Phi = \Phi_i e^{-kz}$$

- Porosity-effective stress relationship was described by Smith (1945)

$$\Phi = \Phi_i e^{-k\sigma_z'}$$

- Porosity-effective stress relationship to include none zero minimum porosity Hantschel and Kauerauf (2009)

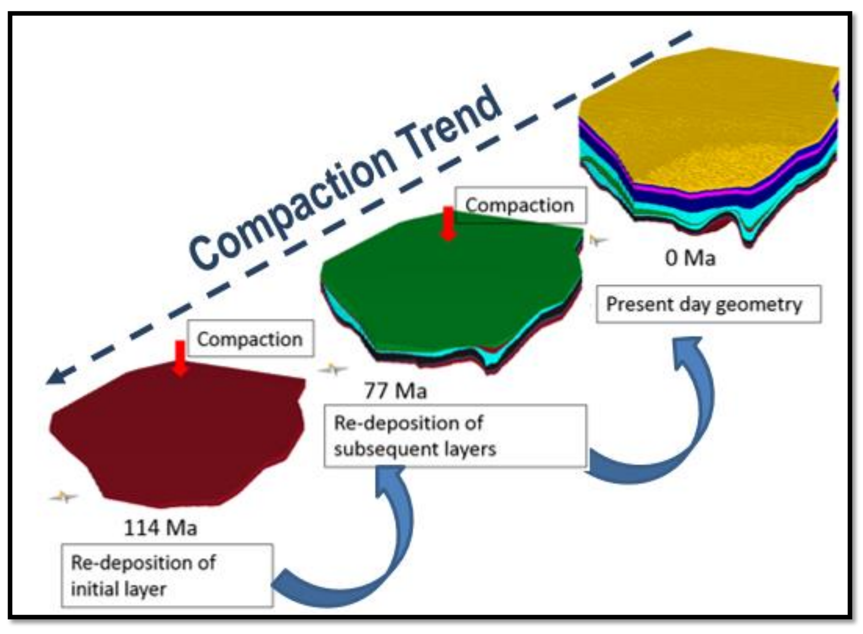
$$\Phi_\sigma = \Phi_{min} + (\Phi_i - \Phi_{min}) e^{-k\sigma'}$$

- Porosity-pressure relationship, Terzaghi (1925)

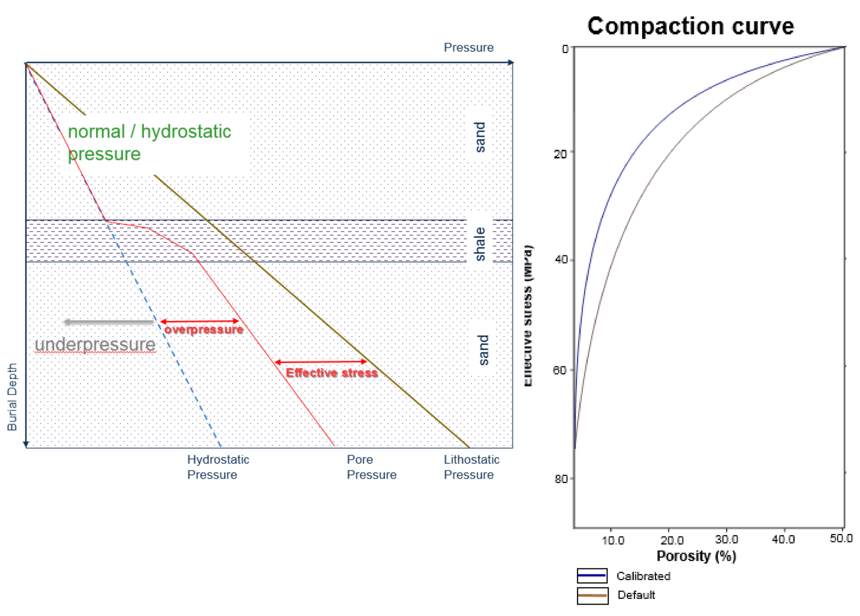
$$\sigma' = p_z - p_u$$

- Correction of compaction curves

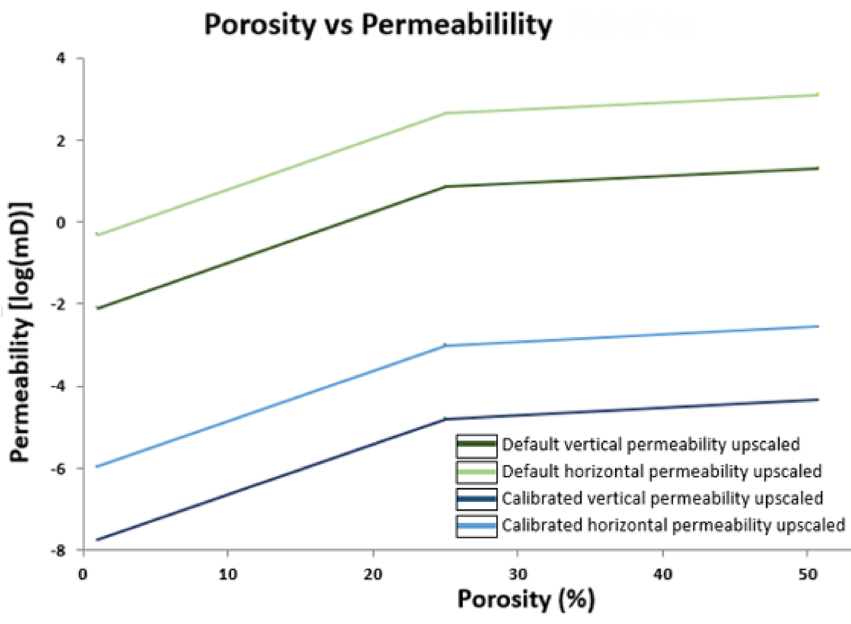
Compaction: Behind the Scene



Pore Pressure Model: Calibrated



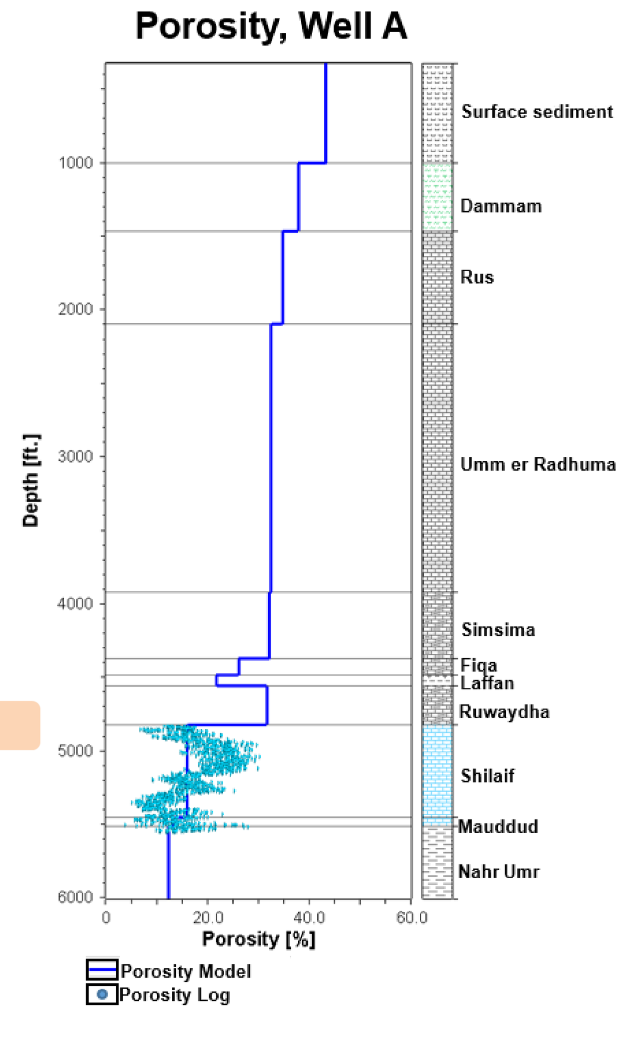
Poro-Perm Relationship



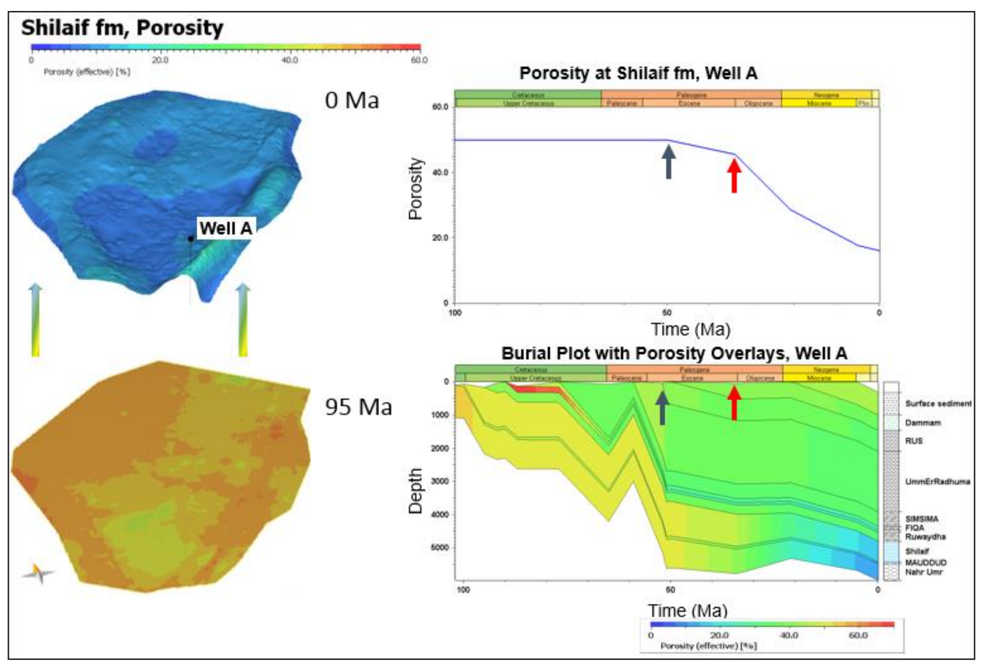
Results

- Porosity-effective stress relationship to include none zero minimum porosity Hantschel and Kauerauf (2009)

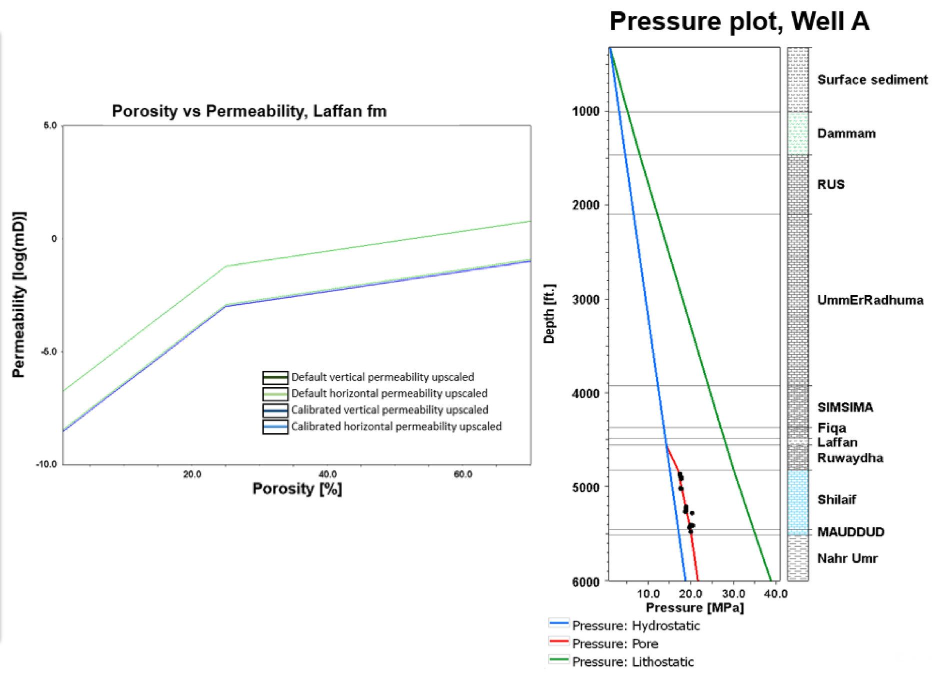
$$\Phi_\sigma = \Phi_{min} + (\Phi_i - \Phi_{min}) e^{-k\sigma'}$$



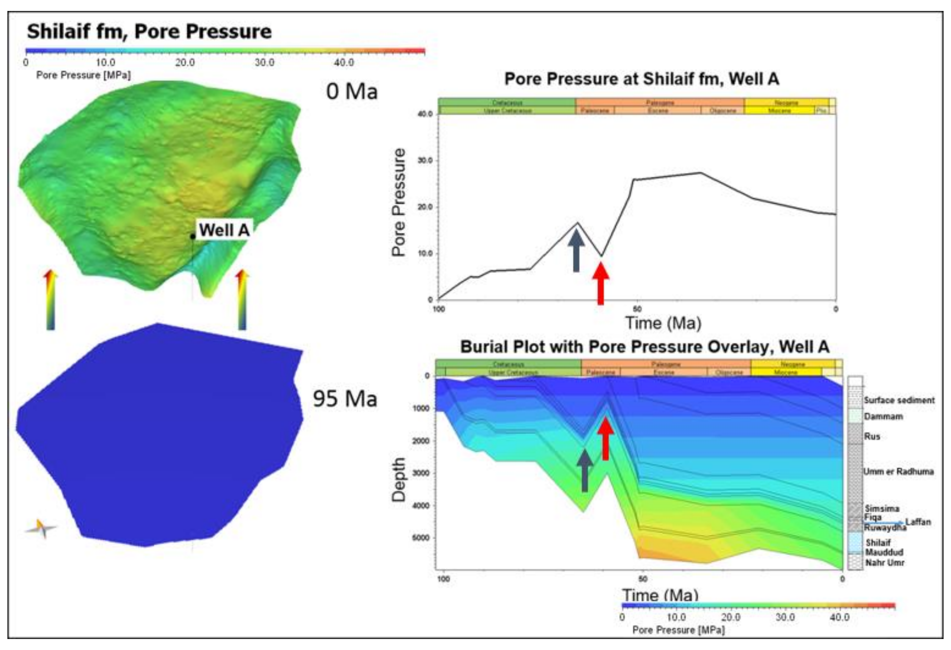
Porosity Results: Shilaif Fm



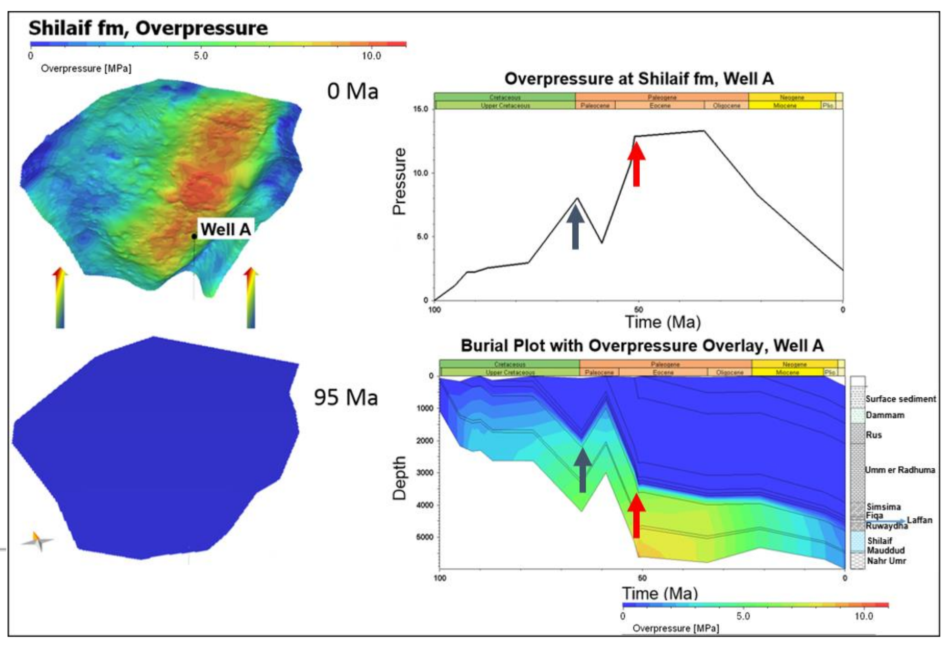
Pore Pressure Model: Calibrated



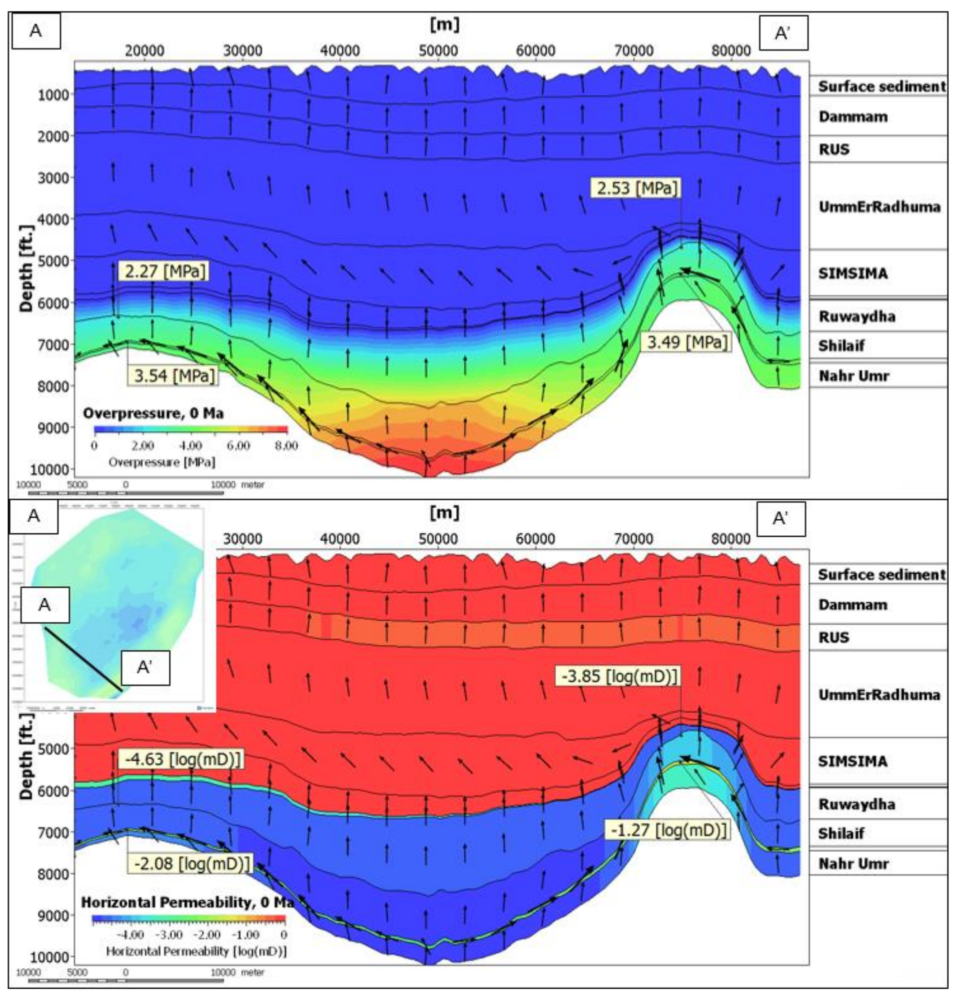
Porosity Results: Shilaif Fm



Overpressure Results: Shilaif Fm



Indicator for Fluid Flow



Conclusion

We have demonstrated that petroleum systems modeling technology can be used to predict porosity and pressure variation on an unconventional play.

Specifically, the used methodology have succeeded to:

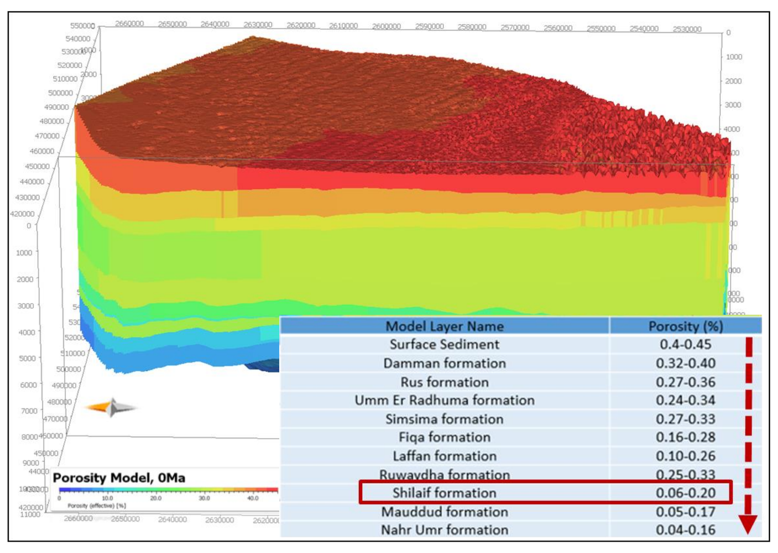
- Show a better explanation/estimation regarding the effect of overburden and the basic architecture on porosity and pressure development
- Characterize the heterogeneity of the different intervals in the model
- Predict and understand the development of dynamic pressure changes through geological time
- Quantify porosity in the interval of interest

The results show that the quality and validity of the predictions matched the limited measured well data available, but could be further improved with more data.

The model was simulated using a decompaction approach and each geological event has been taken into account.

The quality of the porosity and pressure models reveal that they are highly dependent on the lithology parameters assigned, and were validated against calibration data.

Each analysis was carried out systematically and with a considerable knowledge of the geological events, which were helpful to quantify and interpret the simulation results.



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References

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Nomenclatures

Porosity, initial	Φ_i
Porosity, maximum	Φ_{max}
Porosity, minimum	Φ_{min}
Compaction factor	k
Stress, effective	σ'
Pressure, Lithostatic	p_z
Pore Pressure	p_u