Integrating Core Data with Well Log Data for Petrophysical Rock Typing and Permeability Estimation: A Case Study of 2nd Eocene Carbonate Reservoirs in the Wafra Field Located in the Onshore Partition Zone (PZ) Between the State of Kuwait and the Kingdom of Saudi Arabia

Maryam Dawoud AlMejren AlBanwan[1], Jayanta Thakur[1], Ranjit Subudhi[1], Jamal Al-Rubaiyea[1]

[1]Kuwait Gulf Oil Company

Extended abstract

Introduction: Accurate modeling of porosity, permeability, and reservoir rock types integrated with hydraulic flow units are crucial for comprehensive reservoir characterization and modeling. These factors significantly impact the quality of reservoir models and influence well production behavior and predictive accuracy. This study emphasizes the importance of precise petrophysical rock typing (PRT) and permeability estimation for reservoir characterization. Utilizing core data from routine and special core analysis (SCAL) tests, along with well log data, this study focuses on the shallow 2nd Eocene carbonate reservoirs in the Wafra field, located in the Partitioned Zone between the State of Kuwait and the Kingdom of Saudi Arabia. The 2nd Eocene reservoir, one of the shallowest in the multi-stacked reservoirs of the Wafra field, comprises cyclic deposits capped by thick anhydrite beds that serve as a seal, separating it from the overlying 1st Eocene reservoir (Fig-1).

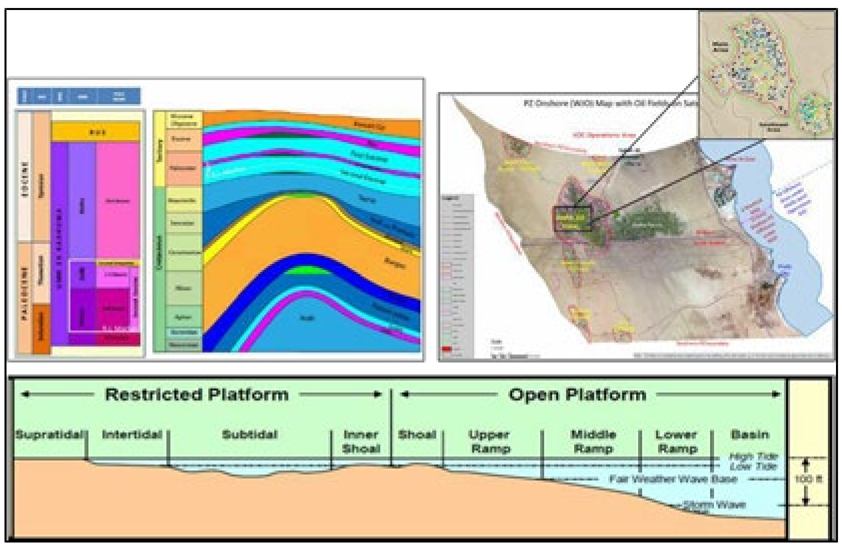

Fig 1: Location Map showing the study Area along with stratigraphy and depositional model of 2nd Eocene Reservoir.

Methodology: This study developed a methodology for rock typing based on petrophysical data, including Mercury Injection Capillary Pressure (MICP) data, well logs, and porosity-permeability relationships (Fig-2). Core data from routine and SCAL tests, along with well log data and petrographic studies, were analyzed to classify rock types using a deep learning Self-Organizing Map (SOM) technique. This approach aimed to calibrate the Reservoir Rock types (RRT) over the cored intervals and apply the same process to predict PRT in un-cored intervals. Log-derived permeability was estimated using multivariate linear regression (MLR), calibrated with core data. To follow the trends of the rock types, the regressions were defined using rock fabric (RF) as per the below equation.

$$RF = a \times \emptyset + b \times \log_{10}RT + c \times GR + d$$

(Where a, b, c and d are regression coefficients for different zones in 2nd Eocene reservoir as shown in Table- 1;
GR represents Gamma Ray, RT is true resistivity and Ø porosity)

$$Perm = 10^{[(9.8-12.084\times\log_{10}RF)+((8.67-8.3\times\log_{10}RF)\times\log_{10}\emptyset]}$$

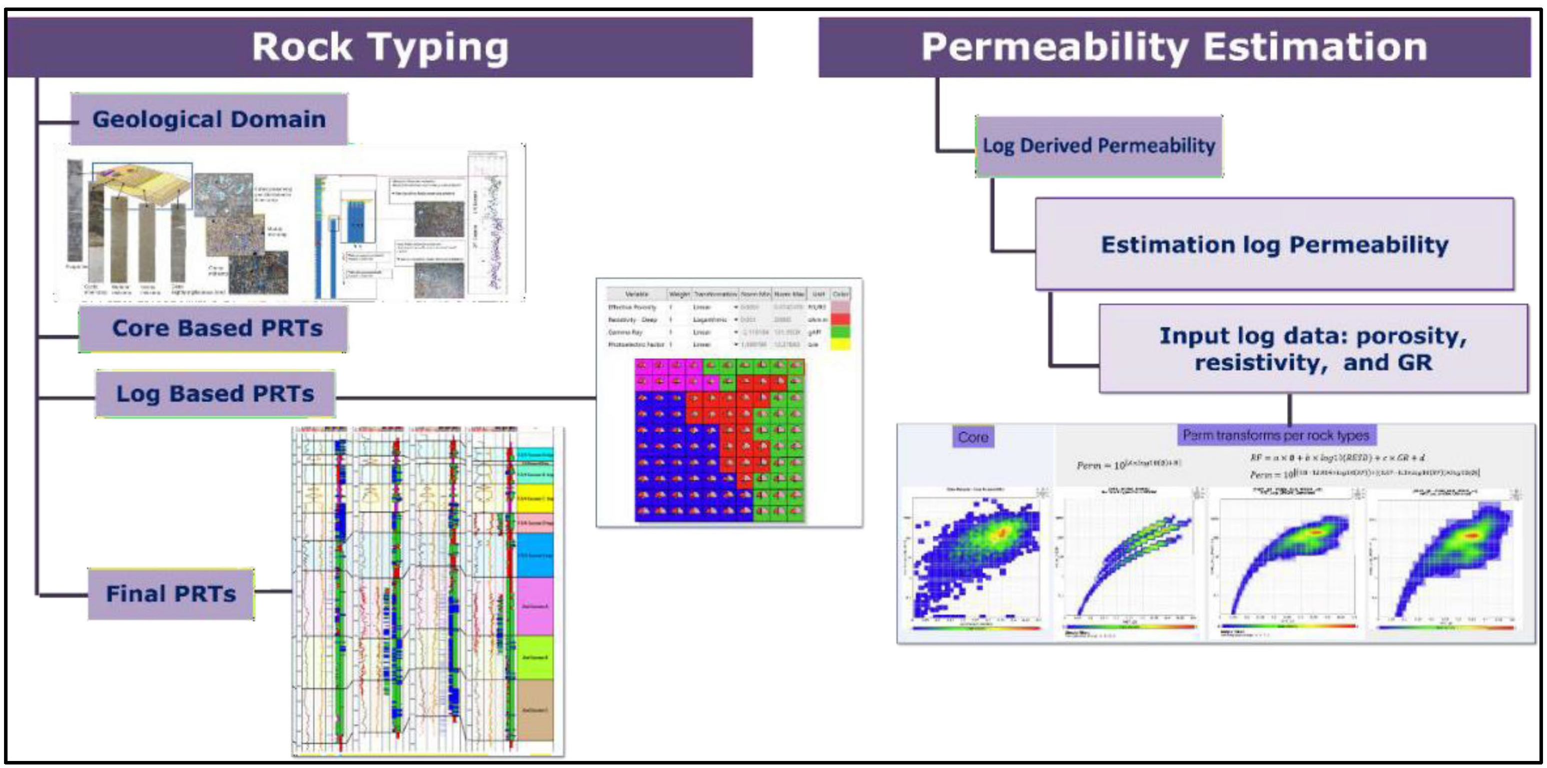

Fig 2: Study workflow

Table-1: MLR Coefficient

zones	a	b	c	d
2nd Eocene A	-1	-0.595	0.0037	3.65
2nd Eocene B	-0.705	-0.175	-0.02	3.6
2nd Eocene C	-0.207	-0.917	-0.006	3.47

Results and Discussion: The 2nd Eocene formation is characterized by an inner to mid-ramp depositional environment with limited preservation of depositional fabric, primarily altered by early to middle dolomitization and dissolution processes. Core analysis indicates that porosity and permeability are mainly influenced by crystal size due to extensive diagenesis rather than original lithofacies. Four RRT's have been defined from Lucia rock-fabric (RF) boundaries using geological features from thin sections, crystal size trends, and pore throat size distributions (Fig-3). The fifth Rock Type (RT-5) is anhydrite and considered non reservoir.

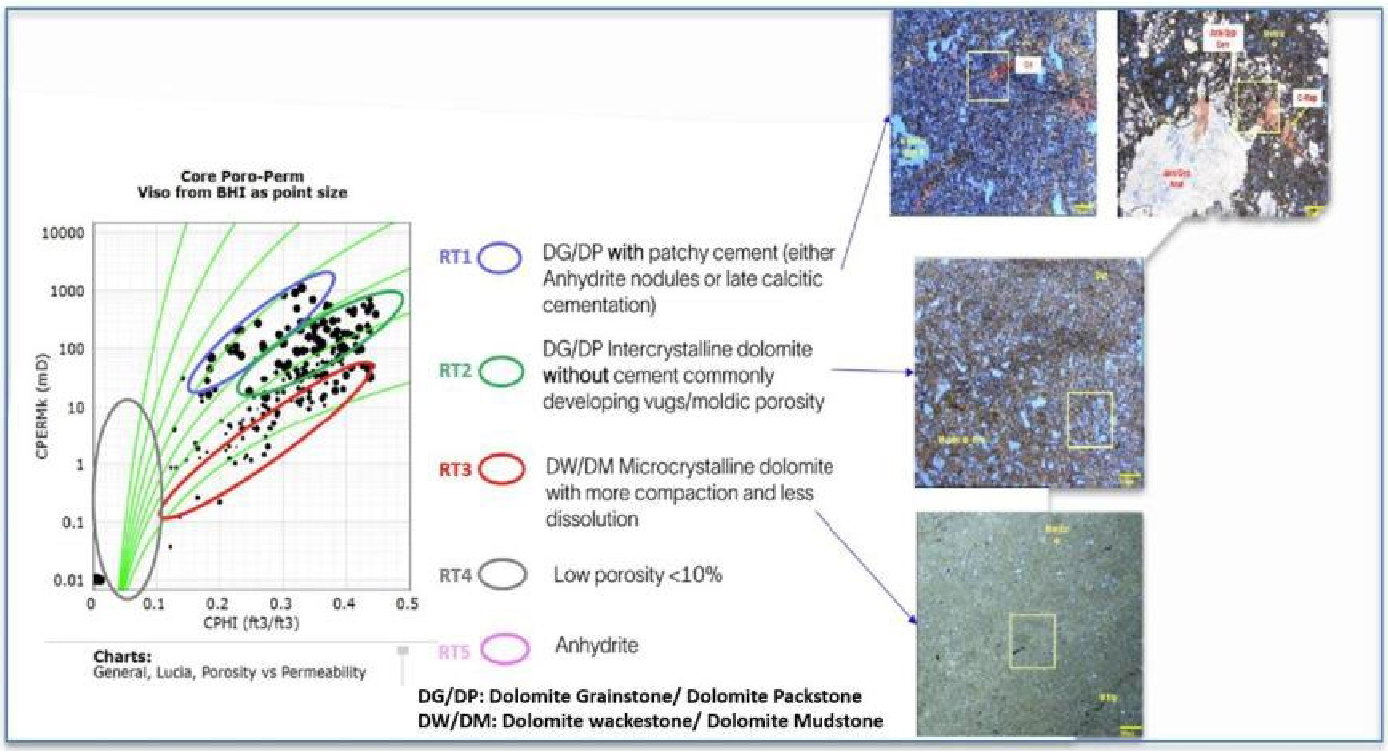

Fig 3: Rock Types classified based on Lucia rock fabric boundaries

A cross plot of porosity versus pore throat radius revealed similarities between Rock Types 1 and 2, with bi-modal pore throat distributions (Fig-4).

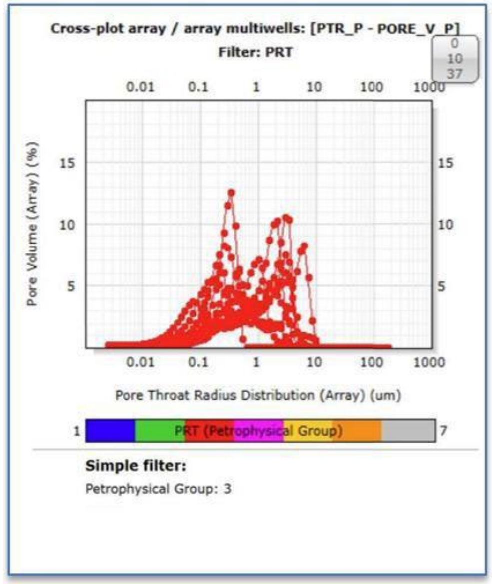

Fig 4:Cross plot between pore volume Vs. pore throat radius distribution

In log-based rock typing, porosity and resistivity emerged as key proxies. The SOM model, supervised by core-based rock types, demonstrated a good match with core-based classifications, confirming its effectiveness in predicting rock types (Fig-5).

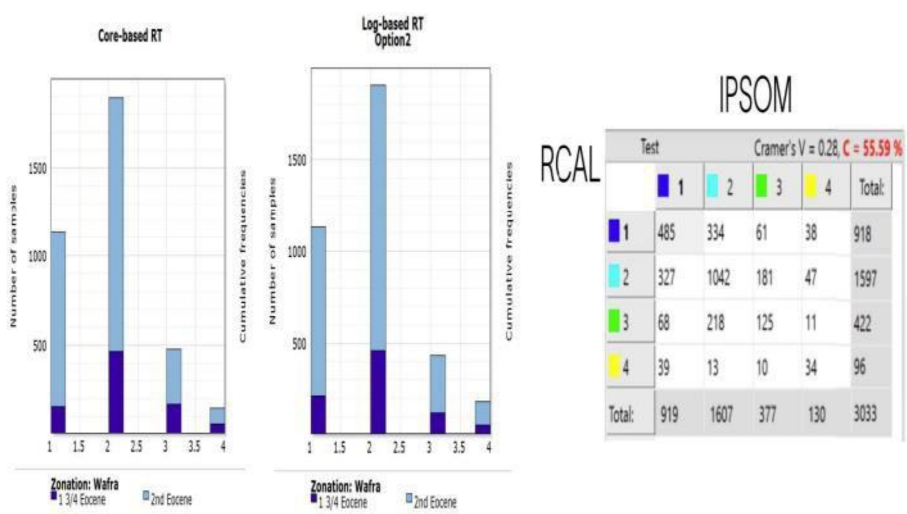

Fig 5: The core-based rock type proportion and correlation on the contingency tables.

The use of resistivity logs for permeability and rock typing is associated with the effects of fluids, as resistivity, related to connate water saturation, showed the best correlation with permeability (Fig-6)

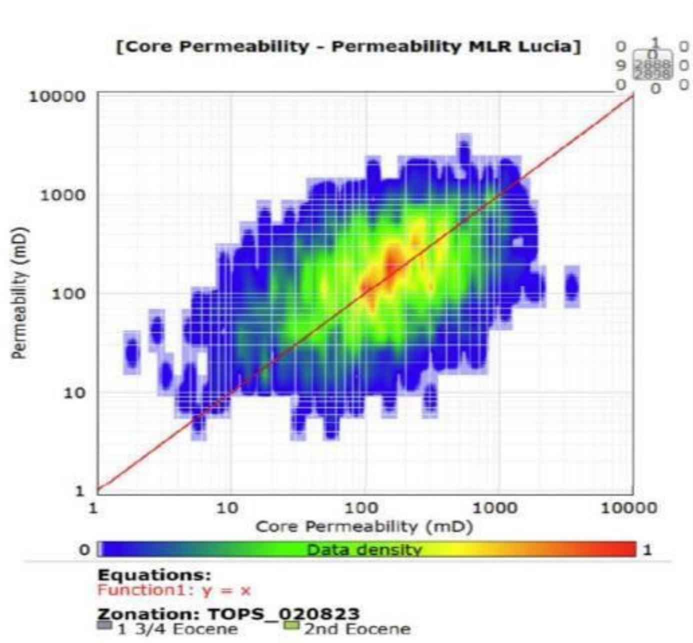

Fig 6: Core Permeability-permeability plot

Conclusion: The log derived PRT from SOM model has a better match with core-based rock type. The study shows that RT1 and RT2 has similar reservoir characteristics. The log derived permeability is showing a good match with the core data. A detailed reservoir rock typing and permeability modeling was achieved in a stepwise approach as part of full field 3-D reservoir modeling and simulation study of the 2nd Eocene reservoir in the Wafra field in PZ Area. The accurate estimation of PRT and permeability from this approach, used in the sensitivity analysis in the context of static reservoir model demonstrates that PRT significantly impacts (+/- 20%) on the estimated volume of hydrocarbon in place. This information is valuable for decision making and planning influencing the effectiveness of recovery techniques and the overall economics of the reservoir.

References:

1. Rafiq Wani and S. Khalil Al-Kabli, Kuwait Oil Co. 2005, SPE 92827, Sequence Stratigraphy and Reservoir Characterization of the 2nd Eocene Dolomite Reservoir, Wafra Field, Divided Zone, Kuwait-Saudi Arabia

2. W. Scott Meddaugh (SPE), Paul Frydl, Rachel Dvoretsky, Steve Gross, Saleh Al-Gamdi, Dennis Dull, Steve Johansen, and Gary Caldwell (Chevron), 2013, SPE 164247, The Wafra Second Eocene Heavy Oil Carbonate Reservoir, Partitioned Zone (PZ), Saudi Arabia and Kuwait: Reservoir Characterization, Modeling, and IOR/EOR Evaluation.