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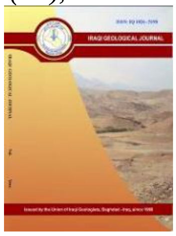

Advanced Technique of Rock Typing Characterization of Mishrif Formation, Amara Oil Field in Southern Iraq

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Abstract

Reservoir rock typing integrates geological, petrophysical, seismic, and reservoir data to identify zones with similar storage and flow capacities. Therefore, three different methods to determine the type of reservoir rocks in the Mushrif Formation of the Amara oil field. The first method represents cluster analysis, a statistical method that classifies data points based on effective porosity, clay volume, and sonic transient time from well logs or core samples. The second method is the electrical rock type, which classifies reservoir rocks based on electrical resistivity. The permeability of rock types varies due to differences in pore geometry, mineral composition, and fluid saturation. Resistivity data are usually obtained from well logs, and resistivity logs are available. The third method is the storage capacity of rocks. The focus is on the ability of rocks to store liquids, especially hydrocarbons. This method analyzes porosity, permeability, and pore size distribution data. After that, we compared the previous three methods to identify the types of rocks and determine the best method. In the first method (Cluster Analysis), three types of rocks were identified (Bad, Moderate, and Good). In the second method, electrical rock type (ERT), four types of rocks were identified (Bad, Moderate, Good, and Very good). Then, the third method (Storage Capacity) came and enhanced the results of the second method, so the second method is considered the best and most accurate method determining the types of rocks.

Keywords: Cluster analysis; Electrical rock; Storage capacity; Mishrif Formation; Rock types; Well log.

1. Introduction

Reservoir characterization is fundamental to understanding reservoir architecture and predicting and assessing reservoir performance (Baker and Awad, 2017). Porosity determines a reservoir's ability to store hydrocarbons, whereas permeability determines deliverability. The approach of reservoir characterization is to identify the quality of the reservoir. Because flow properties on geological conditions and the physics of the flow, the flow unit technique has been frequently used for pore-scale rock type classification (Alameedy et al., 2023b). By definition, rock typing is the process of dividing reservoir rocks into distinct components. These units underwent comparable diagnostic processes and were deposited in comparable surroundings (Bagci and Yildirim Akbas, 2007). Thin section microscopic investigation, well-log classification (electrofacies analysis), and reservoir data (porosity, permeability, and capillary pressure) can all be used to identify them. These zones are typically defined by their resistivity, which a material's resistance to the flow of electrical current. They are distinguished

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by a current zone indicator (commonly called CZI). Each sample falling into a particular CZI method has a set of units specified in dielectric parameters of the same electrical flow (Rezaee et al., 2008). Log data for reservoir rocks should be classified according to their permeability and porosity (Alameedy, 2012; Alameedy et al., 2023a; Al-Yaseri et al., 2013). The development of the field and discoveries are based on isolated reservoir rocks. Accurate shale mass estimates are important for quantitatively analyzing a hydrocarbon unit in any formation. Shale limits pore space and reduces permeability, thus reducing reservoir quality (Ahmed and Farman, 2023).

Many studies have been carried out to find appropriate methods to determine rock types (Tali and Farman, 2021). Statistical models provide a rigorous and systematic approach to calculating and verifying the validity of results. The porosity calculated by a statistical model is more accurate because of the records to obtain the result, and the effect of the poor hole condition and the low accuracy recording is less. Wei et al. (2023) presented a method for integrating reservoir rock and pore types based on basic measurements. Then, the FZI method was chosen to expand the rock type from mercury injection capillary pressure (MICP) data to routine core analysis (RCA) data. Accordingly, a method based on the NMR log was developed to classify the PRT from drilled to undrilled wells. The NMR log is very useful and effective in the quantitative classification of rock type and varies from the uncertainty of using traditional log data only. Sadeq et al., (2024) and Mahdi and Farman (2023) used this research as the most popular and accurate method for determining the volume of oil rocks, which is gamma rays, to calculate the volume of oil rocks. The water saturation factor can be calculated using an average parameter such as the volume of shale in sandstone reservoirs or predicted directly from core data, well logs, or seismic characteristics.

Previous studies have utilized the Cluster Analysis method to classify rock facies. Three methods were used in this research (Cluster Analysis, Electrical rock type, and storage capacity) to determine the types of rock facies, and the methods were compared with each other.

This study is concerned with interpreting and classifying the rocks of the Mushrif reservoir in Amara oil field, as well as dividing the Mushrif layer based on the quality of the rocks to know the physical properties of the Mishrif reservoir.

The Amara field lies roughly 10 km southwest of Amara City in the Missan Governorate in southeast Iraq. Amara Field is surrounded by many oil fields far from the Halfaya field, about 10 km to the northwest, 25 km from the Al-Rafedain field in the east, and 30 km from the Kumait field. The field's structure is made up of a single, semi-symmetrical anticline with an axis that trends from north to south. Its length is roughly 18 km, and its breadth is 4.5 km (Abdulmajeed et al., 2020). Eight zones made up Mishrif Reservoir in Amara Field: TZ1, MA, TZ2, MB1, TZ3, MB2, TZ4, and MC (Hasan, 2021).

Mishrif Formation is part of the Middle Cretaceous epoch, as shown in Fig.1. Its upper and lower boundaries are the Khasib and Rumaila formations, respectively (Abdulmajeed et al., 2020). Determining the quality of reservoir rocks is essential to understanding their properties. Therefore, this study used six wells to determine the lithology of the Mishrif Formation in the Amara oil field (Fig. 2).

2. Materials and Methods

Petrophysical rock classification focuses on classifying rocks based on their petrophysical characteristics, such as porosity, permeability, mineralogy, and fluid saturation. These methods are used to identify rock types with similar potential petrophysical characteristics that are useful for reservoir modeling and flow simulation (Awadh et al., 2018).

2.1. Cluster Analysis Method

Cluster analysis is a multivariate approach that seeks to split the data based on a single variable into several groups with comparable subjects in the same group. This data division is accomplished via a clustering algorithm (Awadh and Al-Yaseri, 2015). Wells log cluster analysis is a multivariate statistical technique that groups data points according to their electrofacies by comparing and contrasting their similarities and differences in the multivariate. The k-means method is one of the most used and straightforward approaches to grouping data (Al Kattan et al., 2018).

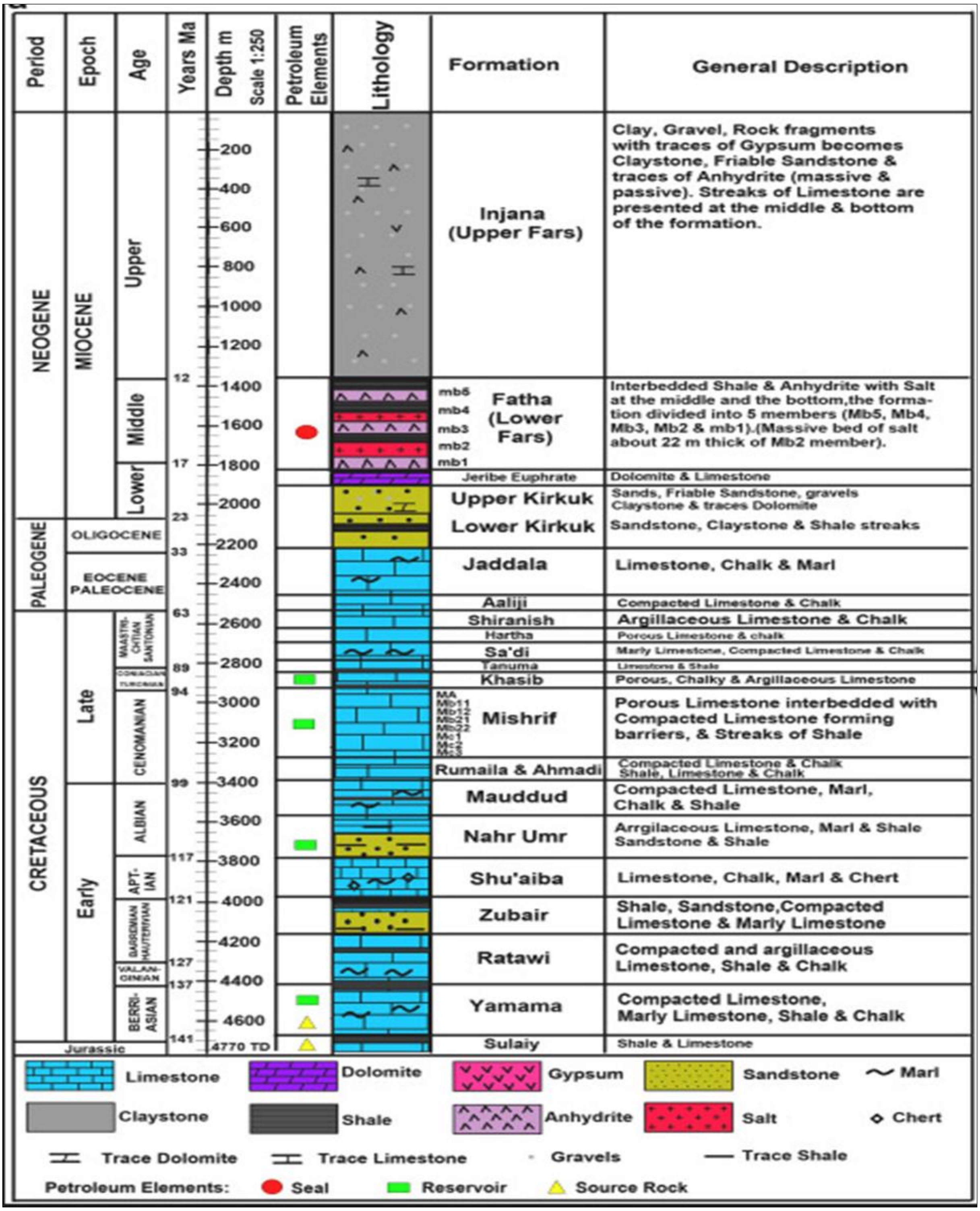

Fig .1. Amara oil field's stratigraphy column, southern Iraq (Abdulmajeed et al., 2020)

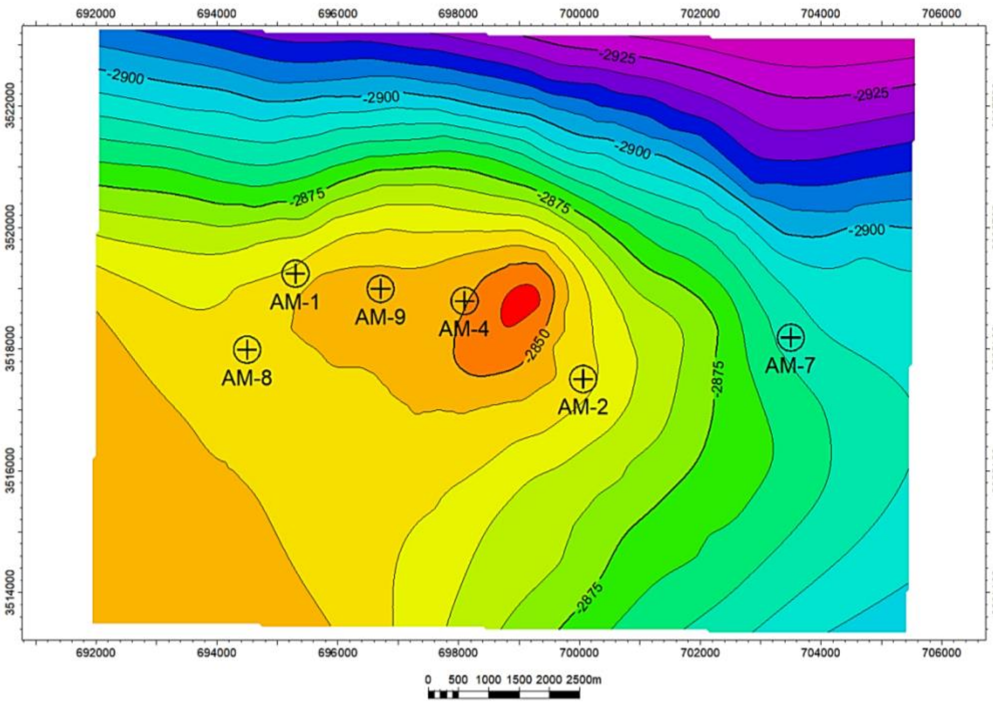

Fig. 2. Structure contour map of Mishrif Reservoir in Amara Field (Petrel 2018)

It is preferred over alternative techniques because of its effectiveness in clustering big data sets and the speed with which it converges to acceptable results in various applications (Mihai and Mocanu, 2015). This produces the desired results in the following steps:

Defining the number of clusters that will be established using k-means is the first step in assigning the group size. It was determined by the original predicted number 20 to involve the most significant quantity of different data.

- Distance Measurement (Similarity/Dissimilarity): In this stage of the k-means method, the goal is to minimize the sum of squares difference within the same cluster between the k-main centroids and the n objects of log data points. This is accomplished by using a similarity/dissimilarity matrix. Things located within the same cluster are more similar and closer to one another than objects located inside other clusters.
- Data grouping: Agglomerative (Hierarchical) cluster analysis was used to organize the data in groups by merging the related clusters and performing computations until one cluster was obtained (Doveton, 1994).

2.2. Electrical Rock Type (ERT)

Electrical flow units (EFU) are zones with comparable electrical flow characteristics. They are identified by a current zone indicator (CZI) (Rezaee et al., 2008).

$$CZI = \sqrt{\frac{\phi/_{F}}{\phi_z}} \quad (1)$$

$$\emptyset_z = \frac{\emptyset}{(1-\emptyset)} \quad (2)$$

F and Øz are fraction porosity (dimensionless), formation factor, and the pore to matrix volume ratio, abbreviated as PMR, respectively. Calculating the electrical radius indicator (ERI) involves the following steps (Rezaee et al., 2008):

$$ERI = \sqrt{(\frac{\phi}{F})} \quad (3)$$

Then,

$$CZI = \frac{\boldsymbol{ERI}}{\phi_z} \quad (4)$$

The CZI is a factor that may be used to differentiate between reservoirs that have almost identical m and n values and in which the difference in F is a function of porosity. Each CZI range has a set of units that have been suggested to have the same electrical flow parameters (Rezaee et al., 2008).

Yarmohammadi et al. (2013) used a technique based on electrical flow units for a deep sandstone reservoir at the Shah Deniz gas production. The principal reservoirs are known as Balakhani VIII and sandy packages II and III of the Fasila group. Their findings demonstrated a correlation between high reservoir quality units and high CZI zones Fig. 3.

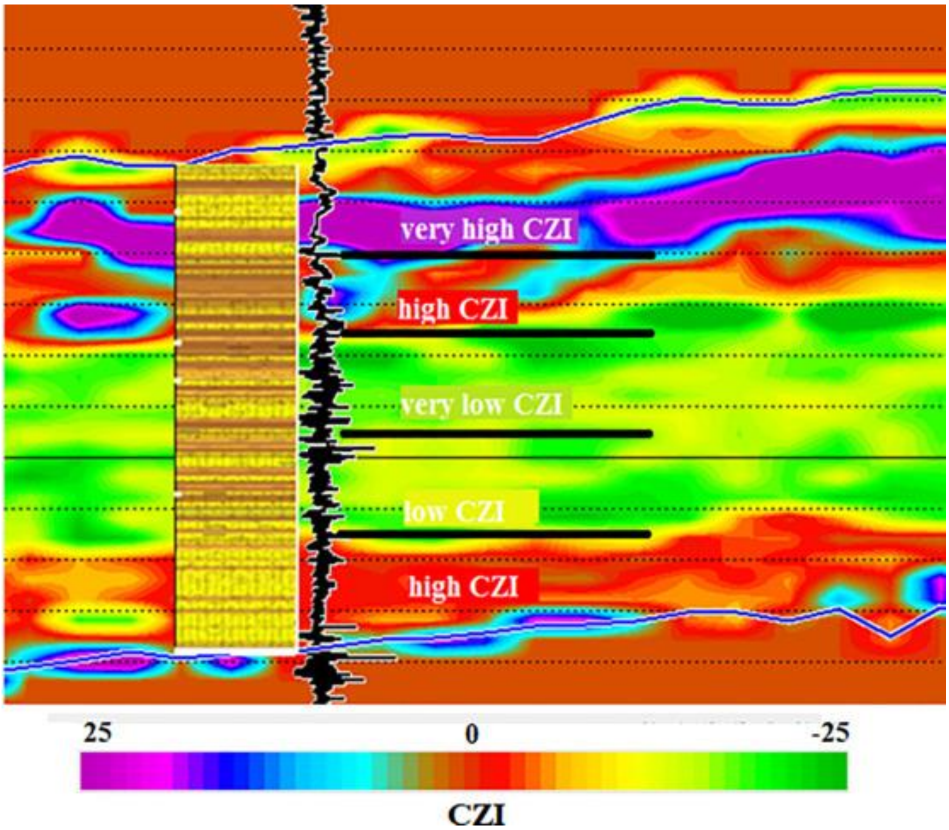

Fig. 3. A 2D section of CZI distribution correlated with a lithological column in well SDX-04, Shah Deniz gas field; Good pay sandstones correspond to high CZI values (Yarmohammadi et al., 2013)

2.3. Storage Capacity From The Lorenz Method

To utilize log analysis information, reservoir rocks should be categorized according to their permeability, porosity, wettability, and pore throat. The advancement of the field and discoveries depend on the separation of reservoir rocks. With the aid of well-logging data and logs analysis, the degree of accuracy and correctness in the separation of reservoir formations should be investigated in this study. This raises the question of whether the techniques employed to separate the reservoir rock are appropriate or if their combination aids. To accomplish this goal, the results of the classification of reservoir rocks must be obtained by processing the data from the diagrams and combining it with the findings of the core analysis. In this regard, logs are useful tools (Gomes et al., 2008; Riazi, 2018). Fig. 4 shows the drawing is divided into four hydraulic flow units based on the shape of the slope. Zone No. 1 is characterized by fast speed and a high flow capacity compared to storage capacity.

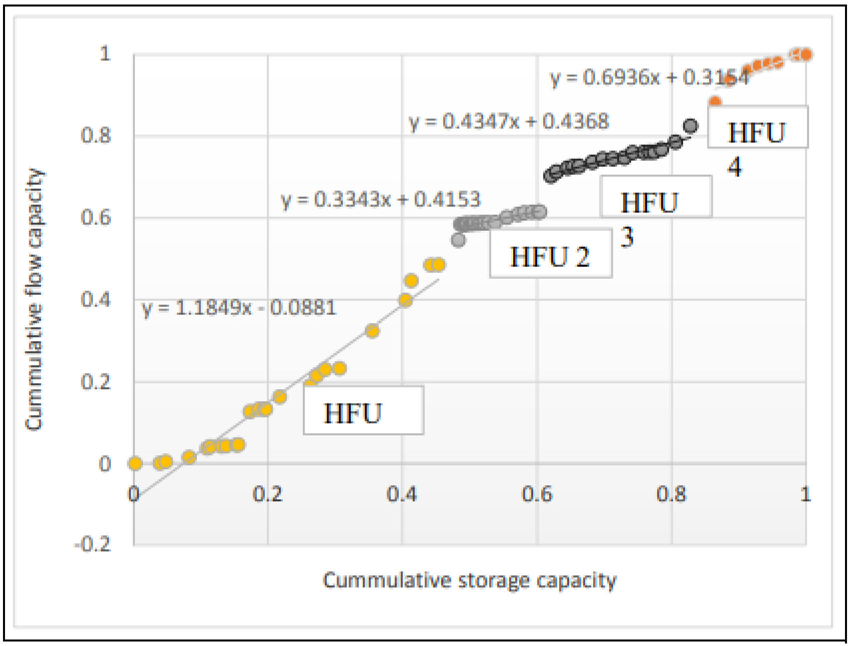

Fig.4. Determination of rock species based on storage capacity from the Lorenz Method (Gomes et al., 2008)

Zone No. 2 has a reduced flow velocity due to its low slope. Put another way, it has a poor flow capability despite having a high cumulative storage capacity. High-speed flow zones are also seen in zones 3 and 4 (Gomes et al., 2008).

The Storage capacity is calculated through the following equation:

$$Storage\ Capacity = \frac{Sum\ (\emptyset e * H)}{(Sum\ (\emptyset e * H))last} \quad (5)$$

Where: H = depth (ft), (Øe) = effective porosity, (%), Sum (Øe * H) = Add two values of Øe * H, respectively.

$$m = \frac{\Delta y}{\Delta x} \quad (6)$$

Where: m = slope between S-Capacity and Depth

3. Results and Discussion

Determining the reservoir facies is an important process for knowing the quantities of oil in the reservoir. This process depends on knowing the basic characteristics of the reservoir rocks. Porosity, water content, and volume of oil shale, in addition to acoustic records and bulk density, are the various input data used in the Interactive Petrophysics software to calculate rock facies. Below are the results of three different methods for determining rock types in the Mushrif Formation of the Amara oil field:

3.1. Cluster Analysis Method

Figure 5 displays the cluster multi-curve cross plot of the cluster analysis for the wells under study. Identified three rock types:

Rock Type-1 (Gray color): Represents the good reservoir quality rock properties. Distinguished by a high porosity fraction (20% - 35%) and a low shale volume content (about 0% - 35%).

Rock Type-2 (Yellow color): Represents the moderate reservoir quality properties. Distinguished by having a medium porosity (6% - 25%) and a high volume content of shale (40% - 70%).

Rock Type-3 (Purple color): Represents the bad reservoir quality properties. Electrofacies had low porosity (0%–20%) and a high shale volume fraction (50%–95%).

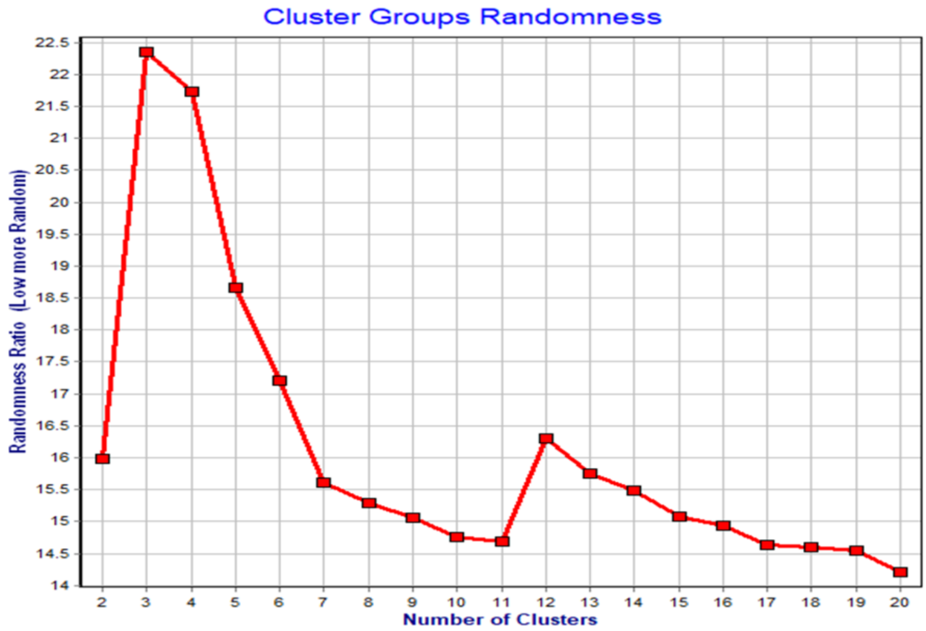

Fig.5. Cluster randomness plot analysis for six wells

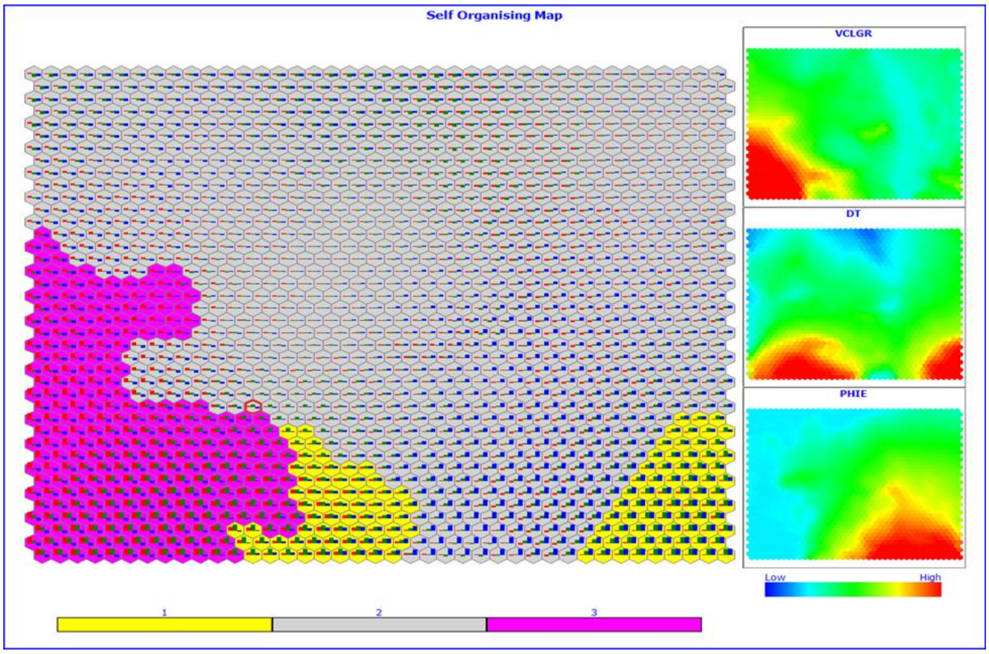

Fig.6. Hierarchical Clustering Matrix for Six Wells

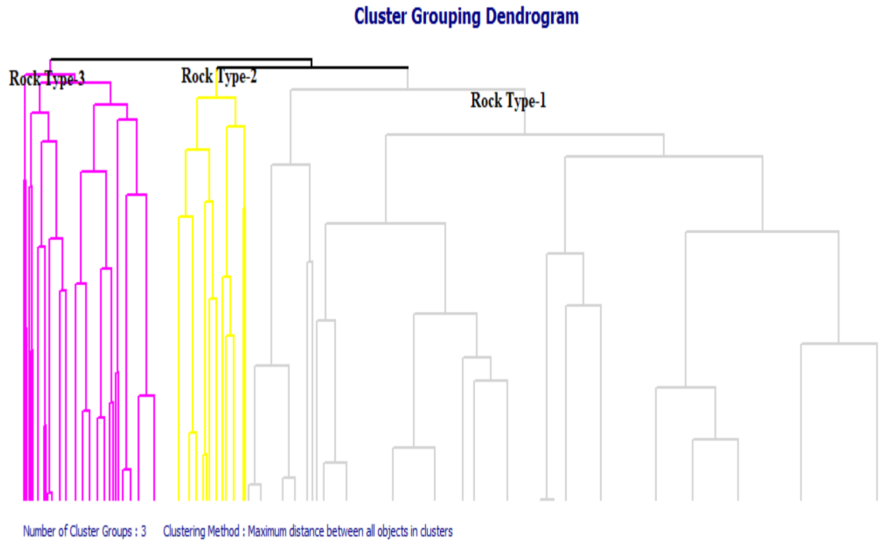

Fig.7. Dendrogram grouping tree for six wells

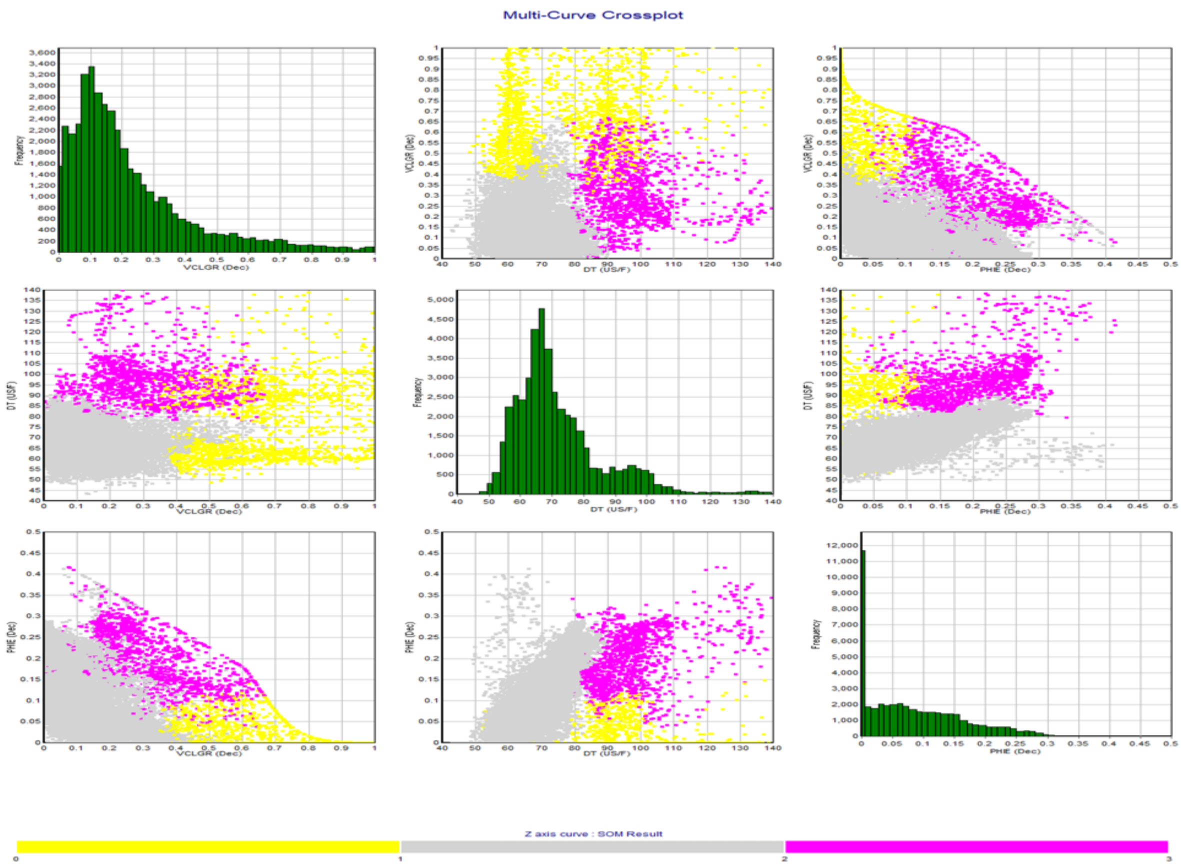

Fig.8. Cluster analysis multi-curve cross plot for six wells

3.2. Electrical Rock Type (ERT)

The electrical rock typing (ERT) method is used to determine the type of rock based on its electrical properties. It uses resistivity or conductivity measurements to classify rocks into groups or rock types. The ERT method takes advantage of the fact that different rocks exhibit electrical responses due to mineralogy, porosity, and fluid saturation differences. The ERT method depends on the rocks' actual porosity and conductivity of the fluids present in the pores. It is affected by several factors, including pore geometry, tortuosity, and cohesion. The ERT method works with FF to calculate the electrical response of the pore structure in the rock and provides a detailed understanding of the petrophysical properties of the rock.

ERT method is valuable for characterizing rocks based on their electrical properties, porosity and formation factors. This study provides new insights into the petrophysical properties of these rocks, which can be used to characterize them. However, as with any method, it must be accompanied by appropriate validation and integrated with other available data sources to ensure the accuracy of the results. Transformed the results obtained from the CZI law into whole numbers, DCZI.

- Therefore, this method is considered the best in covering all the depths of the Mishrif layer. Thus, it will give more accurate results than the cluster analysis method, which is considered a statistical method only for similar data. Fig. 9 shows the four groups of rocks found through this method, which are classified as follows: Rock Type-1: Represents the bad reservoir quality properties.
- Rock Type-2: Represents the moderate reservoir quality properties.
- Rock Type-3: Represents good reservoir quality rock properties.
- Rock Type-4: Represents the very good reservoir quality of rock properties

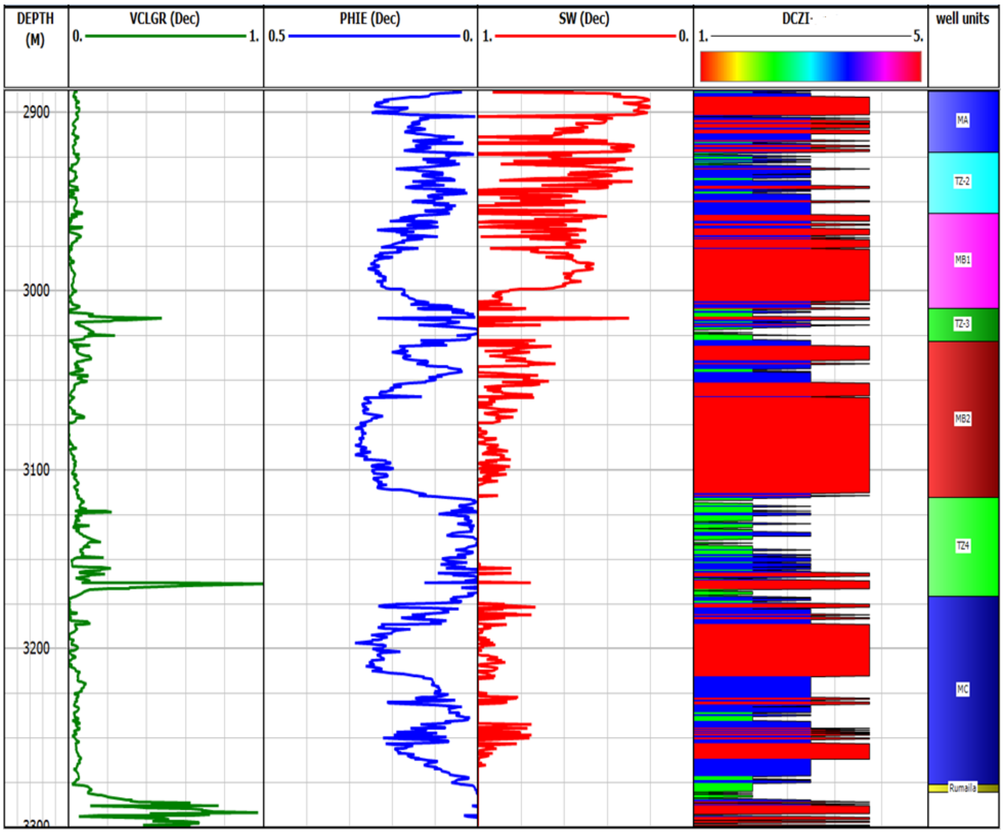

Fig.9. The current zone indicator (CZI) method

3.3. Storage Capacity From the Lorenz Method

By analyzing the Lorenz theorem, high conservation areas can be identified. These areas are typically associated with highly permeable rocks, which allow for greater drainage and storage, as shown in Fig.10.The advantage of the storage method is that it directly incorporates the actual permeability of the rock, allowing for a more accurate assessment of the fluid storage capacity of the reservoir This can be of particular advantage where possible improve hydrocarbon accumulation or flow. The slope is very important in this method; the greater the slope, the more the rock has good properties and high permeability.

It is essential to emphasize that the storage capacity must be utilized in conjunction with other reservoir characterization methods and data sources to attain a comprehensive understanding of the reservoir. Baseline data, well logs, production history, and other geological and geological data should also be considered to validate and refine the results obtained by the Lorenz method.

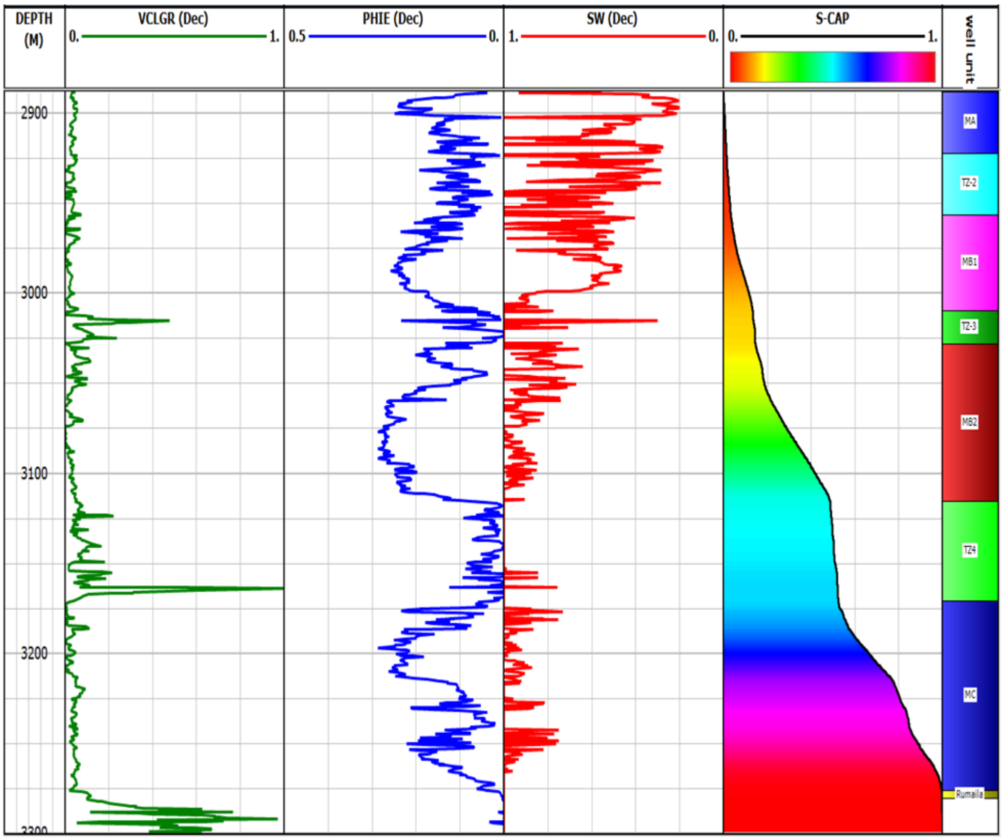

Fig.10. The s-capacity plot with $\emptyset e$

3.4. Choosing the Best Method for Rock Typing Characterization

To compare for determining rock type (cluster analysis, electrical rock type, and storage capacity), found that the cluster analysis method identified three rock types (bad, moderate, good). The DCZI method identified four rock types (bad, moderate, good, and very good), which is more accurate than the cluster analysis method. This is because the DCZI method relies on log data, which captures information from all depths of the Mishrif layer. The storage capacity method relies on the steepness of the slope, and the greater the slope, the better the quality of the rocks. This method also agrees well with the DCZI method. Fig. 11 illustrates the three methods (Cluster analysis, DCZI, and Storage capacity).

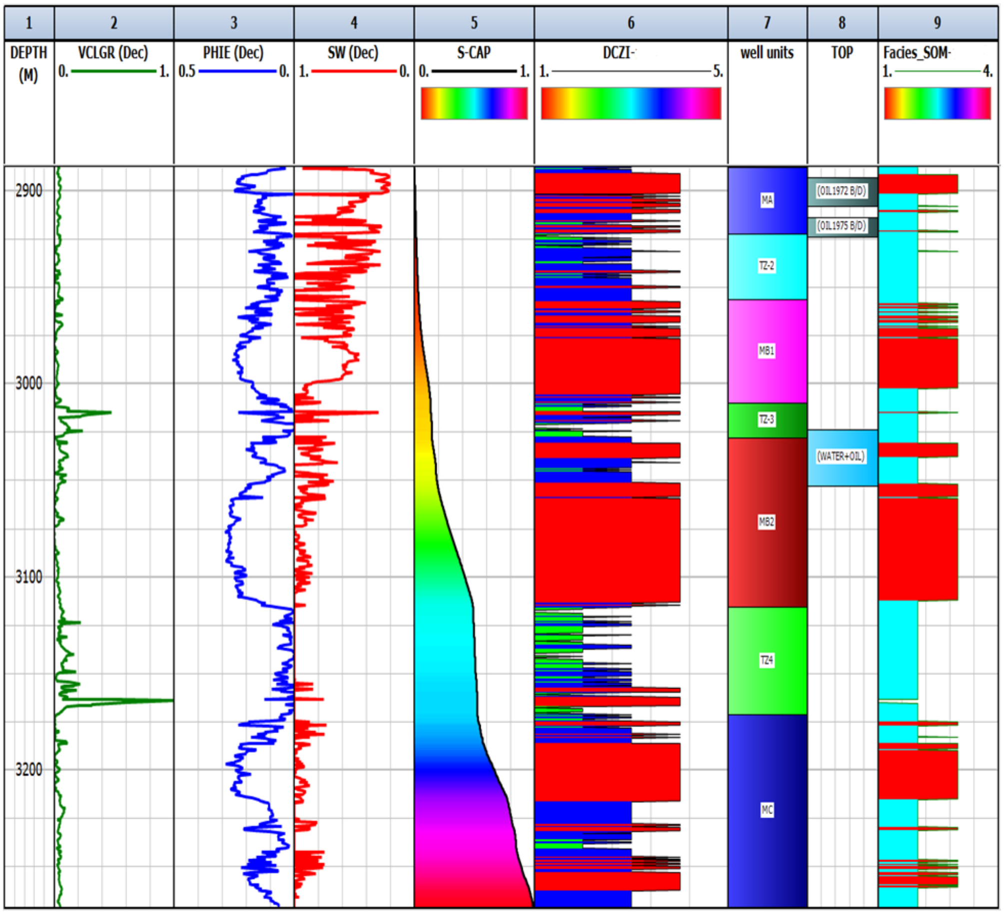

Fig.11. A comparison between the previous three methods (cluster analysis, electrical rock type, storage capacity)

4. Conclusions

The types of rocks in the Mishrif Formation of the Amara oil field were calculated in three ways (cluster analysis, electrical rock type, and storage capacity), and the results were as follows.

The first method (cluster analysis) showed three types of rocks, which are bad (1), moderate (2), and good (3). The cluster analysis method collects and analyzes data and divides similar data into groups. Through this process, rocks are classified based on the similarity of the data.

The second method (electrical rock type) showed four types of rocks, which are bad (1), moderate (2), good (3), and very-good (4). The electrical rock type method works to sense the conductivity of pores connected with high accuracy, and thus, it is more accurate in knowing the type of rocks.

The third method (Storage capacity) supported the results of the second method and enhanced its accuracy; therefore, the second method is the most successful among the three methods. The storage capacity method is the storage capacity of connected pores.

Symbols:

Symbols	Description
ERI	Electrical Radius Indicator
CZI	Current Zone Indicator
DCZI	Discrete current zone indicator
EFU	Electrical Flow Units
PHIE	Effective Porosity
VCLGR	Clay Volume from The Gamma Ray Log

DT	Sonic Transient Time
MICP	Mercury Injection Capillary Pressure
RCA	Routine Core Analysis

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