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# Rock facies classification and its effect on the estimation of original oil in place based on petrophysical properties data

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**Abstract**

The most significant function in oil exploration is determining the reservoir facies, which are based mostly on the primary features of rocks. Porosity, water saturation, and shale volume as well as sonic log and Bulk density are the types of input data utilized in Interactive Petrophysics software to compute rock facies. These data are used to create 15 clusters and four groups of rock facies. Furthermore, the accurate matching between core and well-log data is established by the neural network technique. In the current study, to evaluate the applicability of the cluster analysis approach, the result of rock facies from 29 wells derived from cluster analysis were utilized to redistribute the petrophysical properties for six units of Mishrif Formation; MA, MB11, MB12, MB21, MC1, and MC2. The precise facies modelling is constructed by using Petrel software while applying different appropriate scale-up methods. Consequently, the petrophysical properties such as porosity, water saturation and permeability are distributed within each unit depending on facies modelling. The Net to a gross parameter which has a significant impact on determining original oil in place (OIIP) also calculated and distributed using facies modelling. The facies modelling is performed to obtain an accurate estimation of OIIP. Finally, the results of the facies investigation have a significant effect on petrophysical properties and therefore affect the estimation of OIIP by 2% for the whole Mishrif Formation.

Keywords: Rock Facies, Cluster analysis, Mishrif Formation, Buzurgan oil field, Petrophysical properties, Scale up methods, Porosity, Water saturation, Permeability, Net to gross, Original oil in place
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## 1 Introduction

Well-logs are one of the most important information of underground rock data. They reveal important details on mineral strata formations, structural properties, and reservoir characterization qualities including porosity and permeability. By gathering information from many well-logs, geological layers that have identical log features may be distinguished clearly, as shown in (Fig. 1) which illustrates the lithological column of the Buzurgan oilfield. Deposited divisions recognized on this root and described from wireline logs are denoted as electro-facies or log-facies [2]. By converting diagenetic facies to well-log reactions, the well-logging development board of distinct lithology facies are presented on sound waves, correction neutron recording, density recording, gamma radiation, and actual formation

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resistivity. A set of log answers characterize facies, and core investigations establish porosity and permeability values for each lithology facies [8].

The up-scaled petrophysical models, which were independent of facies models, were based on porosity and permeability values and statistical analysis of their distribution. The distribution of lower and higher values in the petrophysical models mirrors that of the facies model. As a consequence, the modelling findings clearly show a relationship between facies type and grain size distributions in the deposit and petrophysical parameters [12]. The most essential implement in petroleum engineering, sediment logical, and depositional sub-surface of rocks types is log-facies analysis, particularly when well-logs are the basically accurate information presented. The examination of log-facies can be done manually or automatically using mathematical approaches. In oil-bearing reservoirs, multivariate cluster analysis (as the best way of data grouping) is unique as the furthermost precise and effective procedure [2].

In both detrital and carbonate rocks, the cluster analysis method is considered as the finest technique of data combination as well as a furthermost correct and effective technique in oil-bearing zone [6]. The rock types in the reservoir were identified using petrographic analysis, petrophysical data, and neural network clustering approaches. The relationship between electro-facies and geological data revealed that the reservoir quality of the chosen Formation was regulated by both sedimentary and diagenetic processes. The reservoir quality of each electro-facies was estimated using porosity, permeability, and water saturation [9]. Reservoir geology's major goal is to propose answers and use formulae to overcome complexity and heterogeneities in order to gain a better knowledge of the reservoir's characteristics.

The goal of this research is to distribute gamma rays, porosity, and water saturation into log-facies kinds. The log-facies categorization is carried out using the cluster analysis approach, which aims to discover groups of good log answers with comparable properties. This categorization is based on the unique properties of well-log readings, which reflect minerals and litho-facies within the recorded interval, and artificial segmentation of the data population. Interactive Petrophysics software was used to classify log facies in this research.

Typically, the data of core analysis from 13 cored wells were utilized to establish the petrophysical properties determination for Mishrif reservoir units. The available well-logs data (gamma ray, density, neutron, and sonic logs) from 29 wells from the north and south domes of Buzurgan oilfield were utilized to divide the Mishrif Formation into six units separated by barrier beds. This study used cluster analysis to practice determining rock facies in each unit of the Mishrif Formation in the Buzurgan oil field. The vertical variations of rock facies for the Mishrif Formation are investigated in this study using four groups of rock facies. Finally, this work aims to estimate the original oil in place depending on the rock facies effect to obtain a precise calculation.

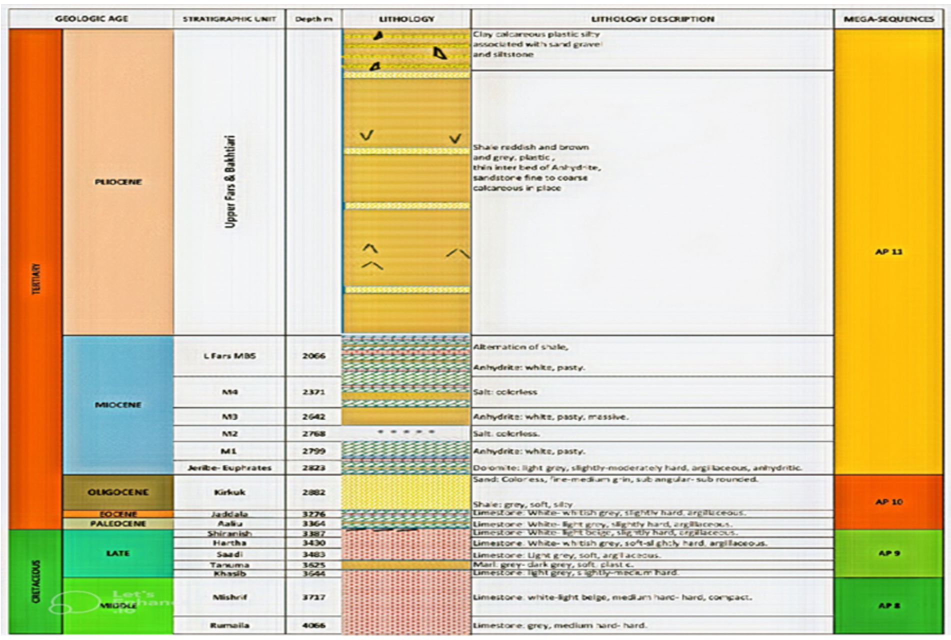


Figure 1: Lithological column of Buzurgan oilfield [2]

## 2 Area of the Study

The Buzurgan oil field is located in the south-eastern region of Iraq, close to the Iran border, 40 kilometres northeast of Buzurgan, as shown in (Fig. 2). In southern Iraq, Mishrif Formation is an important reservoir as it contains a respectable volume of hydrocarbon in place. In reality, the field's structure consists of two domes: north and south. The north dome is 16 km * 6 km in size, whereas the south dome is 23 km * 8 km in size [7]. The top of the Mishrif formation is surrounded by the Khassib Formation, while the bottom is bounded by the Rumaila Formation. The contour map of the MB21 unit which shows all 29 wells is presented in (Fig. 3).

Mishrif Formation is a diverse group of depositional organic limestone-tight carbonate reservoir which make this reservoir challenging to determine the rock types and construct a facies modelling. In addition, it is comprising layers of algal, rudist, and coral-reef limestone, topped with limonitic freshwater limestone [3]. Therefore, the formation is Cenomanian-Early Turonian in age. Overgrowing minor structural highs developed on an otherwise comparatively deeper shelf on which marine sediments of the Rumaila Formation were formed, the formation was deposited as rudest shoals and patch reefs [4].

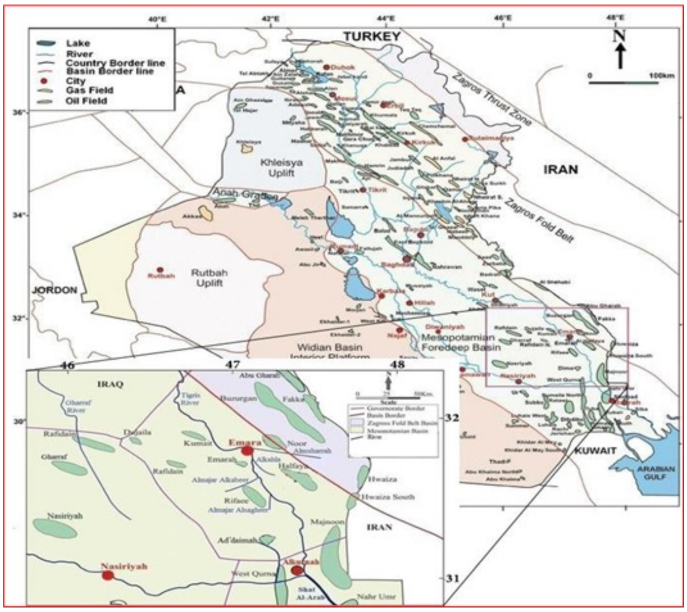


Figure 2: Location of Buzurgan oilfield in Iraq [1]

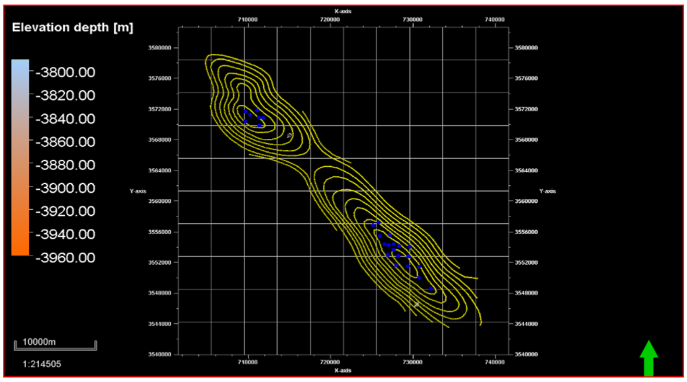


Figure 3: Contour map of MB21 unit which shows all 29 wells in north and south dome.

## 3 Units of Mishrif in the Buzurgan oil field

Types of Facies develop as a result of a mix of complicated processes present at the time of deposition and changes in the source material. Any alteration in the facies has an impact on their physical qualities and log patterns. As a result, these logs may be used to correlate comparable strata from one well to the next. To construct trustworthy cross sections and undertake regional facies investigation, accurate stratigraphic unit correlation utilizing well logs is required [2].

According to final drilling and geological reports as well as well-logs data such as gamma ray, density, acoustic, and neutron logs, Mishrif Formation in the Buzurgan oil field was split into six reservoir units separated by five barriers, as shown in (Fig. 4). MA, MB11, MB12, MB21, MC1, and MC2 were the reservoir units designated from top to bottom of the Mishrif Formation [10].

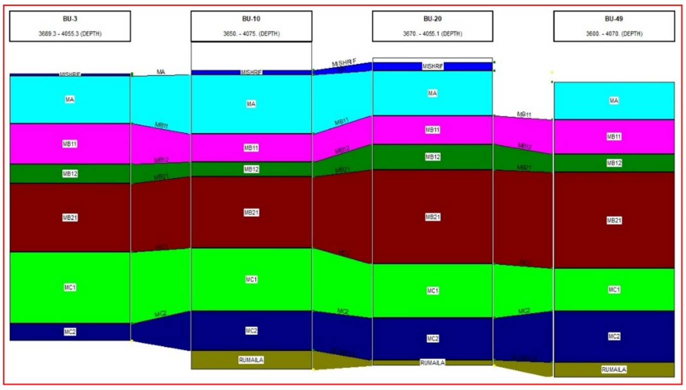


Figure 4: Depths column of Mishrif units in Buzurgan oil field

## 4 Congregation Method

The same log-facies category could have different log answers due to numerous factors that affected the well-logs data. All data are grouped in the clustering phase with a minimum distance and the highest homogeneity when statistical methods are utilized. It goes without saying that several geophysical elements might be connected to a collection of log-facies data, which scientists can then use for further in-depth analysis. In this calculation, the utilized logs are considered as values of the observations, and all log inputs are considered as observational data [11].

Till the new congregate forms contain all of the information, this operation is continued. Two clusters can be connected using a variety of methods. The cluster parts are joined using the minimum distance possible across them [11].

The grouping section is finished utilizing the Interactive Petrophysics program (IP) during two phases: Gamma-ray log, porosity, and water saturation information are first sorted in comprehensible datasets. To include every one of the material categories shown in logs, there should be enough groups. A reasonable number of nodes seems to be fifteen to twenty for the majority of large datasets. These 15 to 20 clusters must be arranged into a manageable number of geological log-facies in the second, highly labour-intensive phase. Compacting the data into different groups could be necessary for this.

### 4.1 Statistical Methodology (K-mean)

The first phase of "Facies Clustering" involves grouping the dataset into a predetermined number of groups using the K-mean analytical techniques. In order for this to function, a first approximation of the average values of every group for every source log should be generated. The predicted conditions cover the whole area of the logs since the starting presumption has an effect on the results. In K-mean grouping, a group is allocated to each input data point.

The technique seeks to minimize the summation of squared variance between each piece of information and the group average.

Each data point's summation of squared difference from each group average is calculated as part of the procedure, and the grouping with the least difference is assigned to receive the data item. After all the pieces of information were assigned to the groupings, the updated average scores for each grouping are calculated. Using the new average scores, the procedures continue reallocating the information to the groups. Up till the measured scores between repetitions stay stable, this cycle is continued. Each source log's data is first adjusted to ensure that they all have the same spectral response [2].

### 4.2 Congregation Consolidation

In IP programming, the groups are joined using one of five major clustering methods. The numerous tactics can provide quite diverse results. After subgroups are joined, the calculation of the distance is adjusted separately in every one of the available methods. Suppose that cluster "G1" was formed by the joining of groups "G2" and "G3" and that we need to determine the length among "G1" as well as another group is "G4 [2], as shown in (Fig. 5).

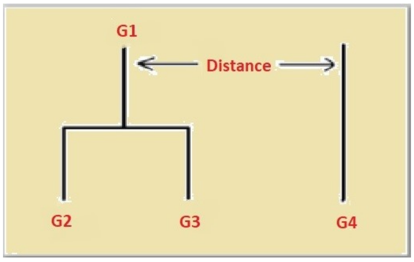


Figure 5: Grouping Distance

Here are the statistics for the various methods: The distance from G1 to G4 is equal to the total of the distances, which is the minimum distance between all grouped objects (G2 to G4 and G3 to G4). The distance between G1 and G4 is the summation of the lengths across G2 and G4 and G3 and G4, which is the total length between all objects in groupings.

Middling distance between merged groups: The connection across G1 and G4 is generally equal to the average range across all the objects that have been included in the group created by combining clusters and G4. The mean distance with both groups G1 and G4 is the normalized distance between all particles in a group; this measurement can be done around groupings G1 and G4. Reduce the distance between groups' summation of squares; groupings be constructed because this gap rises as less as feasible. The separation between the two groups would match the rise within that summation of squares if indeed the two segments got united [2].

In general, "minimum distance between all things in groups" produces long, reedy groups, whereas "longest range between all objects in groups" produces greater sphere-shaped collections. "Minimize the within-cluster sum of squares distance" and "Average distance between all items in clusters" possible to yield groups that are similar to individuals formed with "Average distance between all objects in clusters. As shown in (Fig. 6) of the dendro-gram, the defaulting methodology "Minimize the within-cluster sum of squares distance" yields respectable outcomes for excruciating the distinct log lithologies into separate groups.

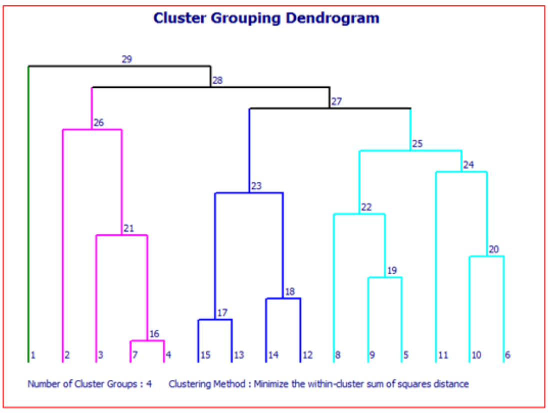


Figure 6: Cluster grouping tree Dendro-gram for Mishrif reservoir.

The data's appearance of arbitrariness for each number of collecting groupings is under management by the grouping randomness plot in (Fig. 7). The greater the rating, the less likely each category is to exist, showing that the data is more thoroughly planned.

The men width of a group level, is first determined to control the randomness, the original log data is used for this. A value of 1 is completely random, but increasing numbers are less so. The scheme is decoded by determining the minimum random numeral of groups at maximum points.

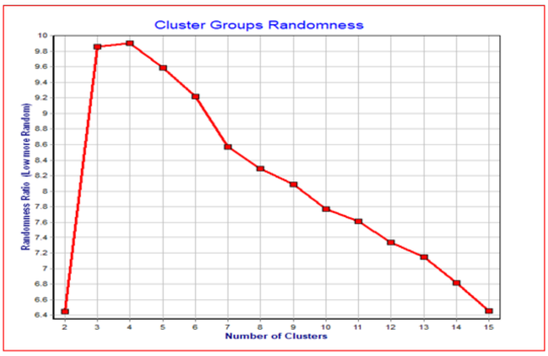


Figure 7: Cluster group randomness number for Mishrif reservoir.

### 4.3 3D Facies Modeling

The challenge in developing a scope of the study for the simulation model is to incorporate heterogeneity and suitable petrophysical elements that affect flow characteristics in petroleum reservoirs of various sizes. The comprehension of the geological modelling and the availability of training datasets are necessary for accurate stochastic log-facies models. As a result, as log-facies are frequently defined by image characteristics, the log-facies framework is also educated by the production and surroundings of sediment deposition and is used to construct reservoir characterization modelling. The objective of building models in any analysis of reservoir characterization is to approximate the spatial variation of rock types that manage fluid flow performance. However, Porosity, water saturation, shale volume, and others well logs were ready to detect rock type logs by cluster analysis method in Mishrif formation/ Buzurgan oilfield. Typically, Rock types that are treated for facies modelling are upscaling as property modelling in Petrel 2017 software using Most, Arithmetic, and Mid-point averaging methods. Consequently, these upscaling methods are effected on how the property is distributed within the grids of the geological model. As an example of Most scale-up methods, (Tables 1, 2, 3 and 4) present the porosity, water saturation, net to gross and permeability comparison results between the geological model with and without applying facies modelling for all Mishrif reservoir's units. When applying the facies modelling the settings will be applied on individual facies in the zone, whereas the setting will be applied on the entire zone when is not applied the facies modelling is. Finally, it was noted from the facies distribution plot for the MB21 unit that the rock type-3 is the most type of rock which have been distributed within this unit, as shown in (Fig. 8). In addition, the figures for other units which show the facies distribution throughout the reservoir are presented in Appendix A.

Table 1: Porosity Distribution with and without Facies Modelling

| No. | Mishrif Formation's Unit | Facies Type | With Facies | Without Facies |
|---|---|---|---|---|
| | | | Property value | Property value |
| 1 | MA | 2 | 0.076-0.116 | 0.063-0.146 |
| | | 3 | 0.063-0.146 | |
| | | 4 | - | |
| 2 | MB11 | 2 | 0.027-0.132 | 0.027-0.132 |
| | | 3 | 0.04-0.106 | |
| | | 4 | - | |
| 3 | MB12 | 2 | 0.026-0.117 | 0.026-0.148 |
| | | 3 | 0.08-0.119 | |
| | | 4 | 0.138 | |
| 4 | MB21 | 2 | 0.026-0.187 | 0.026-0.20 |
| | | 3 | 0.043-0.179 | |
| | | 4 | 0.05-0.20 | |
| 5 | MC1 | 2 | 0.016-0.162 | 0.016-0.194 |
| | | 3 | 0.067-0.181 | |
| | | 4 | 0.063-0194 | |
| 6 | MC2 | 2 | 0.031-0.127 | 0.031-0.17 |
| | | 3 | 0.069-0.17 | |
| | | 4 | 0.048-0.165 | |

Table 2: SW Distribution with and without Facies Modelling

| No. | Mishrif Formation's Unit | Facies Type | With Facies | Without Facies |
|---|---|---|---|---|
| | | | Property value | Property value |
| 1 | MA | 2 | 0.188-.99 | 0.079-1 |
| | | 3 | 0.079-1 | |
| | | 4 | - | |
| 2 | MB11 | 2 | 0.005-1 | 0-1 |
| | | 3 | 0.255-1 | |
| | | 4 | 0-1 | |
| 3 | MB12 | 2 | 0.05-1 | 0.05-1 |
| | | 3 | 0.491-1 | |
| | | 4 | 0.559-0.56 | |
| 4 | MB21 | 2 | 0.004-1 | 0.004-1 |
| | | 3 | 0.065-1 | |
| | | 4 | 0.078-1 | |
| 5 | MC1 | 2 | 0.001-1 | 0.001-1 |
| | | 3 | 0.179-0.977 | |
| | | 4 | 0.199-1 | |
| 6 | MC2 | 2 | 0.467-1 | 0.166-1 |
| | | 3 | 0.416-1 | |
| | | 4 | 0.166-1 | |

Table 3: Net to Gross Distribution with and without Facies Modelling

| No. | Mishrif Formation's Unit | Facies Type | With Facies | Without Facies |
|---|---|---|---|---|
| | | | Property value | Property value |
| 1 | MA | 2 | 0.024-0.25 | 0-566 |
| | | 3 | 0-0.566 | |
| | | 4 | - | |
| 2 | MB11 | 2 | 0-0.444 | 0-84 |
| | | 3 | 0.013-0.84 | |
| | | 4 | 0-0.2 | |
| 3 | MB12 | 2 | 0-0.28 | 0-637 |
| | | 3 | 0-0.382 | |
| | | 4 | 0.637 | |
| 4 | MB21 | 2 | 0-1 | 0-1 |
| | | 3 | 0-1 | |
| | | 4 | 0-1 | |
| 5 | MC1 | 2 | 0-1 | 0-1 |
| | | 3 | 0.113-0.552 | |
| | | 4 | 0-1 | |
| 6 | MC2 | 2 | 0-0.869 | 0-1 |
| | | 3 | 0-0.986 | |
| | | 4 | 0-1 | |

Table 4: Permeability Distribution with and without Facies Modelling

| No. | Mishrif Formation's Unit | Facies Type | With Facies | Without Facies |
|---|---|---|---|---|
| | | | Property value | Property value |
| 1 | MA | 2 | 0.32-5.02 | 0.32-11.47 |
| | | 3 | 0.409-11.47 | |
| | | 4 | - | |
| 2 | MB11 | 2 | 0.25-11.65 | 0-11.65 |
| | | 3 | 0.33-2.97 | |
| | | 4 | 0-1 | |
| 3 | MB12 | 2 | 0.24-5.79 | 0.24-10.74 |
| | | 3 | 0.51-2.65 | |
| | | 4 | 10.74 | |
| 4 | MB21 | 2 | 0.257-65.6 | 0.17-80.4 |
| | | 3 | 0.39-21.88 | |
| | | 4 | 0.17-80.4 | |
| 5 | MC1 | 2 | 0.22-74 | 0.22-60.09 |
| | | 3 | 0.489-20.64 | |
| | | 4 | 0.53-60.09 | |
| 6 | MC2 | 2 | 0.27-6.22 | 0.27-27.85 |
| | | 3 | 0.41-27.85 | |
| | | 4 | 0.37-23.97 | |

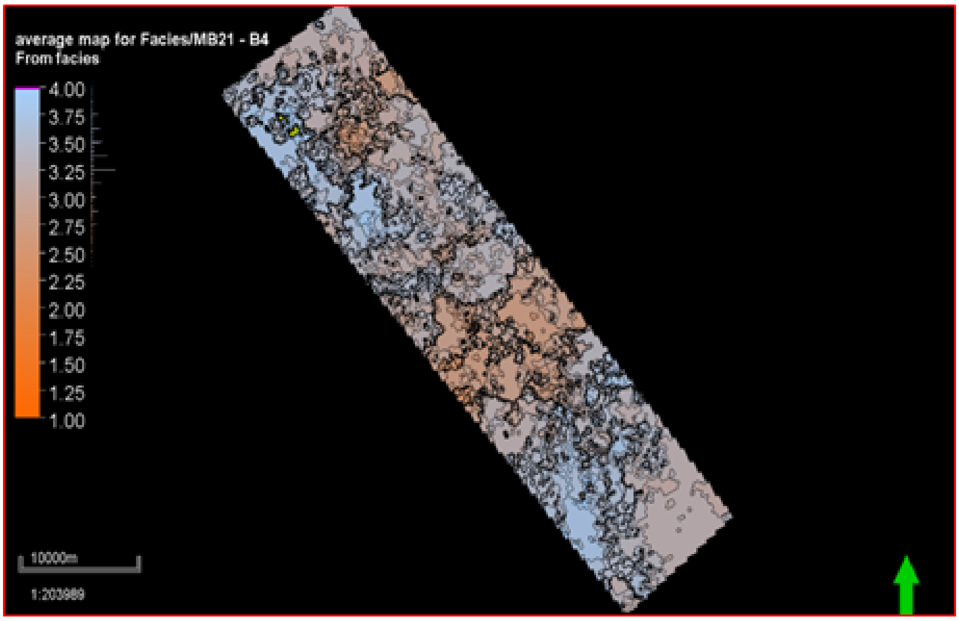


Figure 8: Average facies (Rock type) modelling for MB21 unit in Mishrif reservoir/ Buzurgan Oilfield.

## 5 Results and Discussion

Mishrif Formation is categorized into fifteen main groups in the dendrogram plot, and four types of facies were constructed depending on the input data (gamma ray log, porosity, and water saturation) utilized to generate the clusters. The mean values of gamma-ray, porosity, and water saturation define each cluster. Table 5 displays the mean values as well as other statistics of the utilized data for every cluster.

Following the categorization of the data into fifteen groups, log-facies groups were formed from these gatherings. Four groups were identified in the Mishrif Formation. Each log-facies group is described in order to identify reservoir parameters (porosity and water saturation), and each group can comprise one or more clusters. (Fig. 9) depicts histograms and cross-plots of porosity, water saturation and shale volume for Mishrif Formation groups obtained by K-means cluster analysis. Table 6 lists the characteristics of these log-facies groupings. This table illustrates that rock facies-3 and 4 are the preferred reservoir facies, but rock facies-1 and 2 are not good reservoir facies and are not preferred. In each well under investigation, the vertical distribution of rock facies with reservoir units for the Mishrif Formation is depicted in (Fig. 10).

(Table 5) shows the "Cluster Means" values as well as other data statistics for each cluster. In addition, all units are defined by reservoir facies depending on the wells investigated which have different rock facies, therefore (Table 6) presents the Attributes of Cluster groupings.

Table 5: K-Mean Clustering results

| Cluster | # | Cluster | PHI core_nnt | | Sw | | VCL | | DT | | RHOB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Points | Spread | Mean | Std Dev | . Mean | Std Dev | . Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. |
| 1 | 199 | 2.715 | 0.03228 | 0.03716 | 0.86568 | 0.2303 | 0.78882 | 0.184 | 102.26 | 15.67 | 2.2989 | 0.1304 |
| 2 | 1332 | 1.282 | 0.02508 | 0.00819 | 0.90135 | 0.1942 | 0.54847 | 0.1247 | 55.825 | 4.323 | 2.6281 | 0.06952 |
| 3 | 5542 | 0.7817 | 0.05039 | 0.01311 | 0.97425 | 0.07112 | 0.26395 | 0.05856 | 55.146 | 2.897 | 2.6486 | 0.05663 |
| 4 | 7313 | 0.5366 | 0.08055 | 0.01244 | 0.9849 | 0.05804 | 0.11017 | 0.0434 | 53.57 | 1.822 | 2.6998 | 0.03116 |
| 5 | 2385 | 1.063 | 0.08418 | 0.02019 | 0.9559 | 0.08633 | 0.23351 | 0.06871 | 65.299 | 5.16 | 2.5179 | 0.0683 |
| 6 | 2114 | 1.119 | 0.06603 | 0.01865 | 0.2952 | 0.1997 | 0.25783 | 0.06973 | 55.232 | 2.973 | 2.5964 | 0.0713 |
| 7 | 5760 | 0.6819 | 0.10181 | 0.01544 | 0.94981 | 0.09698 | 0.10161 | 0.04125 | 57.625 | 2.838 | 2.6164 | 0.0387 |
| 8 | 1523 | 1.26 | 0.08218 | 0.02452 | 0.48239 | 0.1932 | 0.41581 | 0.07997 | 67.68 | 6.058 | 2.4281 | 0.07917 |
| 9 | 2454 | 0.9458 | 0.11555 | 0.02005 | 0.47773 | 0.1451 | 0.19027 | 0.04658 | 65.305 | 3.79 | 2.4976 | 0.05715 |
| 10 | 3586 | 0.8702 | 0.11965 | 0.02015 | 0.35978 | 0.1644 | 0.09231 | 0.03813 | 53.583 | 2.973 | 2.5968 | 0.04722 |
| 11 | 1417 | 1.218 | 0.1558 | 0.02895 | 0.1525 | 0.1356 | 0.15086 | 0.07432 | 53.342 | 2.913 | 2.398 | 0.1088 |
| 12 | 3367 | 0.6942 | 0.14503 | 0.01611 | 0.44968 | 0.1182 | 0.08607 | 0.03325 | 63.207 | 2.773 | 2.5263 | 0.03592 |
| 13 | 3773 | 0.7613 | 0.16541 | 0.01453 | 0.42879 | 0.129 | 0.08854 | 0.04422 | 66.403 | 2.944 | 2.4748 | 0.04012 |
| 14 | 2886 | 0.9281 | 0.17734 | 0.01912 | 0.3507 | 0.1355 | 0.10575 | 0.06192 | 69.972 | 3.448 | 2.4 | 0.05632 |
| 15 | 3374 | 0.8758 | 0.1887 | 0.01677 | 0.27796 | 0.1368 | 0.07204 | 0.06232 | 72.352 | 3.829 | 2.3923 | 0.05514 |

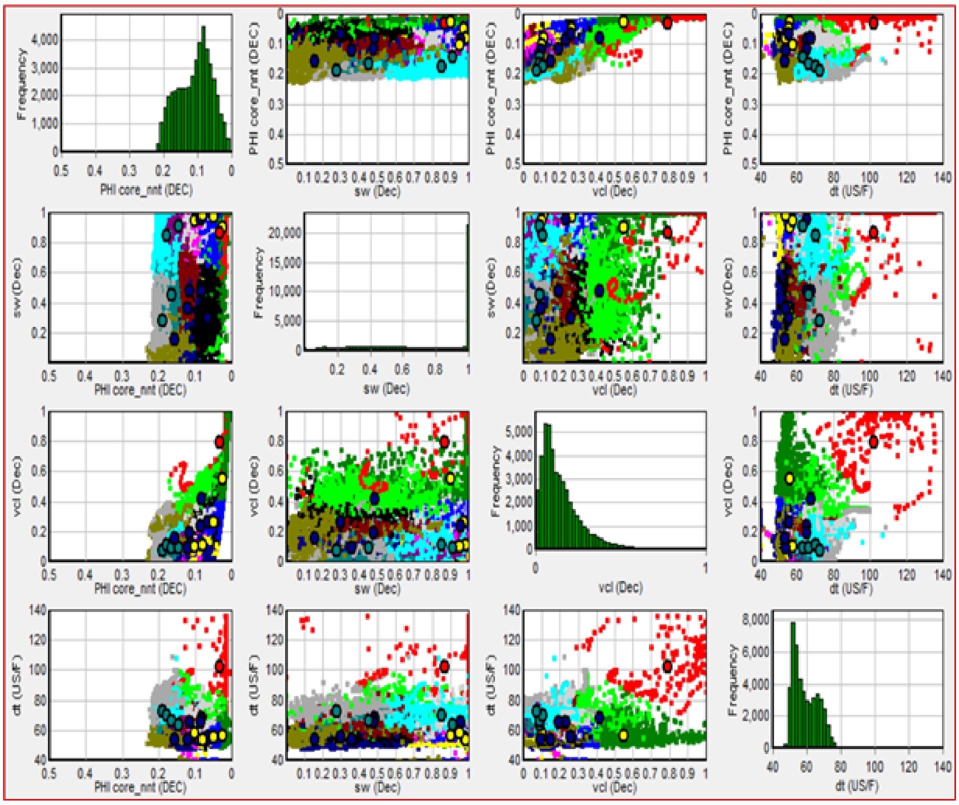


Figure 9: K-means cluster analysis crossplots and histograms between porosity, water saturation, shale volume, sonic log and bulk density for Mishrif Formation

Table 6: The Attributes of Cluster Groupings.

| Group Name | Group Sample | Clusters of Group | Description |
|---|---|---|---|
| Facies-1 | | 1 | Very high Shale volume, very low porosity, very high water saturation. |
| Facies-2 | | 2,3,4,7 | Moderate to high Shale volume, low to moderate porosity, very high water saturation. |
| Facies-3 | | 12,13,14, 15 | Low Shale volume, good porosity, moderate water saturation. |
| Facies-4 | | 5,6,8,9,10, 11 | Very low Shale volume, respectable to very respectable porosity, small to moderate water saturation. |

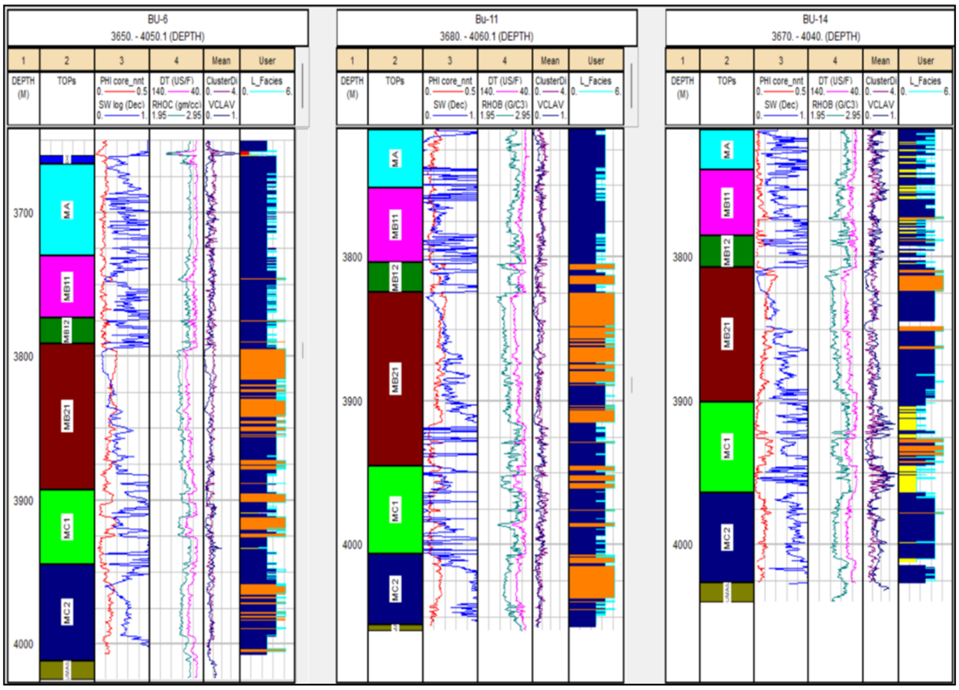


Figure 10: Mishrif Formation log-facies plot within every reservoir units.

Facies rock modelling is the most important governing element of hydrocarbon reservoirs and their crucial conditions for revealing hydrocarbon distribution and optimizing the search for good sites. However, various sedimentary facies and lithologic indicate that hydrocarbon is primarily distributed in depositional facies constituted under prolonged and reasonably strong fluid properties, characters handle the circumstances of resource and energy. In furthermore, the likelihood of finding conventional petroleum reservoir reductions as the particle size of rock formations improves [5]. Additionally, each Mishrif unit is defined by its reservoir facies, which vary based on the wells that have been explored. (Tables 7 to 9) show the proportion of each facies type for each Mishrif unit while applying different scale-up methods.

Table 7: Log-facies type's percentage for every Mishrif unit by Most of method.

| No. | Units | Facies-1 | Facies-2 | Facies-3 | Facies-4 |
|---|---|---|---|---|---|
| 1 | MA | 8% | 50% | 40% | 2% |
| 2 | MB11 | 10% | 62% | 25% | 3% |
| 3 | MB12 | 20% | 61% | 14% | 5% |
| 4 | M21 | 2% | 16% | 32% | 50% |
| 5 | MC1 | 5% | 45% | 19% | 31% |
| 6 | MC2 | 4% | 20% | 35% | 41% |

Table 8: Log-facies type's percentage for every Mishrif unit by Arithmetic method.

| No. | Units | Facies-1 | Facies-2 | Facies-3 | Facies-4 |
|---|---|---|---|---|---|
| 1 | MA | 0-1% | 30-50% | 50-70% | 0-2% |
| 2 | MB11 | 0-1% | 55-72% | 25-44% | 0-3% |
| 3 | MB12 | 0-1% | 72-82% | 14-28% | 0-5% |
| 4 | M21 | 0-1% | 13-16% | 33-42% | 45-50% |
| 5 | MC1 | 0-1% | 38-50% | 44-19% | 18-31% |
| 6 | MC2 | 0-1% | 13-20% | 39-57% | 29-41% |

Table 9: Log-facies type's percentage for every Mishrif unit by Mid-point method.

| No. | Units | Facies-1 | Facies-2 | Facies-3 | Facies-4 |
|---|---|---|---|---|---|
| 1 | MA | 0-1% | 40-51% | 25-49% | 34% |
| 2 | MB11 | 0-1% | 50-72% | 25-33% | 2-16% |
| 3 | MB12 | 0-1% | 81-86% | 8-14% | 5% |
| 4 | M21 | 0-1% | 17-19% | 33-34% | 47-50% |
| 5 | MC1 | 0-1% | 44-50% | 19-20% | 31-35% |
| 6 | MC2 | 0-1% | 19-20% | 38-40% | 40-41% |

Porosity, water saturation, net to gross and also permeability in x, y, and z directions were statistically distributed depending on every unit's facies by the Sequential Gaussian Simulation method. However, estimation of OIIP was performed by two different methods; firstly, without applying facies effect on petrophysical properties distribution and secondly, by applying facies effect on petrophysical properties distribution for all Mishrif reservoir units. Finally, the results show that the OIIP by applying the Facies modelling effect was equal to 731*106 SM3 whereas OIIP without applying of Facies modelling effect was equal to 701*106 SM3. The increase in the original volume of oil in place by using the facies modelling effect was very significant and equal to 30*106 SM3 with an increasing percentage equal to 4.28%. (Table 10) presents the OIIP calculation results for the Mishrif reservoir-Buzurgan oilfield with and without applying the Facies Modelling effect while using Most of the scale-up methods.

Table 10: OIIP for Mishrif reservoir units without and with applying Facies Modelling

| Zones | IOIP [*106 sm3] without applying Facies Modelling | IOIP [*106 sm3] with applying Facies Modelling |
|---|---|---|
| MA - B1 | 8 | 9 |
| MB11 - B2 | 52.2 | 57 |
| MB12 - B3 | 1.8 | 2 |
| MB21 - B4 | 515 | 525 |
| MC1 - B5 | 84 | 94 |
| MC2 - B6 | 40 | 44 |
| Total | 701 | 731 |

## 6 Conclusions

Different forms of data, such as well logs and regular core analysis findings, were used in this study to classify reservoir intervals of the Mishrif Formation into distinct rock types and clarify the geological model in the context of pore facies. Through the application and study of facies studies, reservoir parameters, and their influence on OIIP estimate, the following results were reached.

- In the Mishrif Formation, four rock facies types have been identified based on petrographic analyses of core and well logs. Rock Facies type-3 and 4 were found to have the best petrophysical properties in the high porosity range (14.5% to 18.8%), low to moderate water saturation range (0.27 to 0.45), and low shale volume range (0.07 to 0.10), whereas Rock Facies type-1 and 2 were found to have the worst petrophysical properties in the low porosity range (0.25% to 10.1%), high water saturation range (0.86 to 0.98), and low to high shale volume range (0.11 to 0.78) at all formation units.

- The highest rock facies type that existing in Mishrif reservoir is Rock Facies type-3, then Rock Facies type-4, Rock Facies type-2, and Rock Facies type-1, respectively.
- The good petrophysical characteristics are spread in the crest of the north and south domes, while the worst petrophysical qualities are scattered in the flank of the north and south domes. The petrophysical qualities of the MB21 and MC1 units are superior to those of the other units.
- Based on facies modelling, the porosity, water saturation, and net to gross modelling had a substantial influence on the value of OIIP, increasing from 701*106 SM3 to 731*106 SM3 with a different percentage equal to 4.28 percent.

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## Appendix A

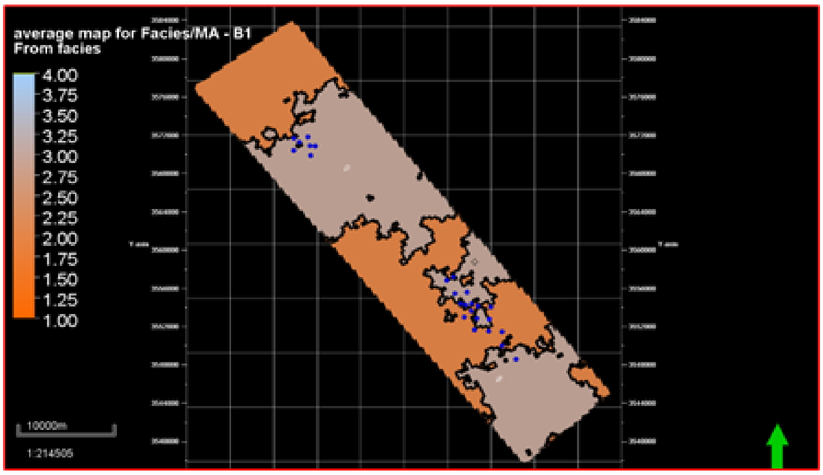


Figure A.11: Facies (Rock type) modelling for MA unit in Mishrif reservoir/ Buzurgan Oilfield.

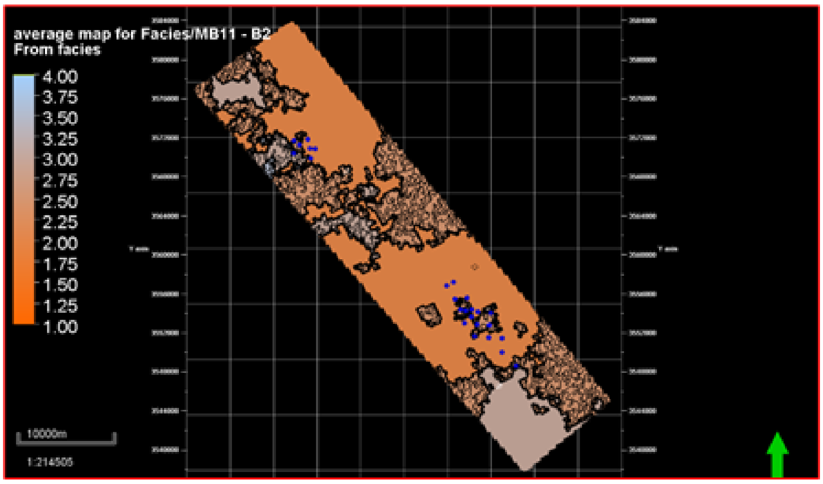


Figure A.12: Facies (Rock type) modelling for MB11 unit in Mishrif reservoir/ Buzurgan Oilfield

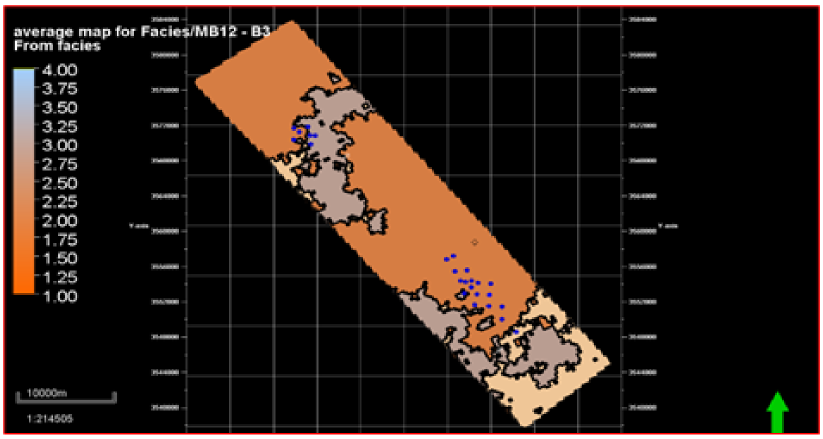


Figure A.13: Facies (Rock type) modelling for MB12 unit in Mishrif reservoir/ Buzurgan Oilfield.

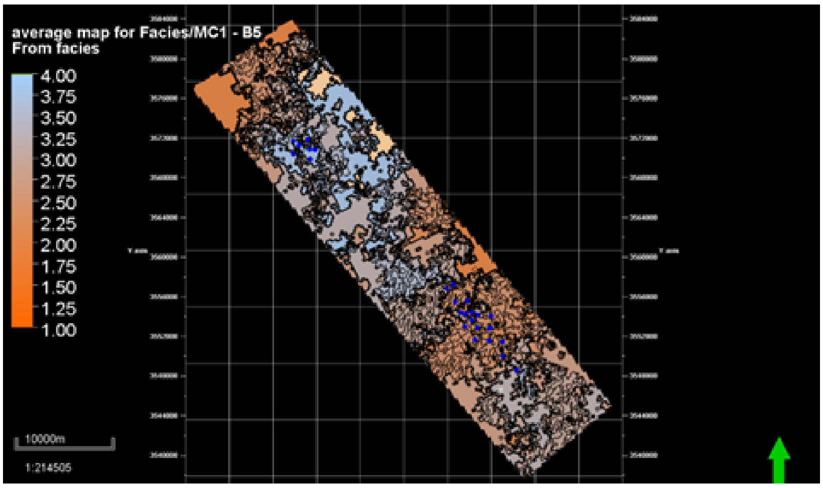


Figure A.14: Facies (Rock type) modelling for MC1 unit in Mishrif reservoir/ Buzurgan Oilfield.

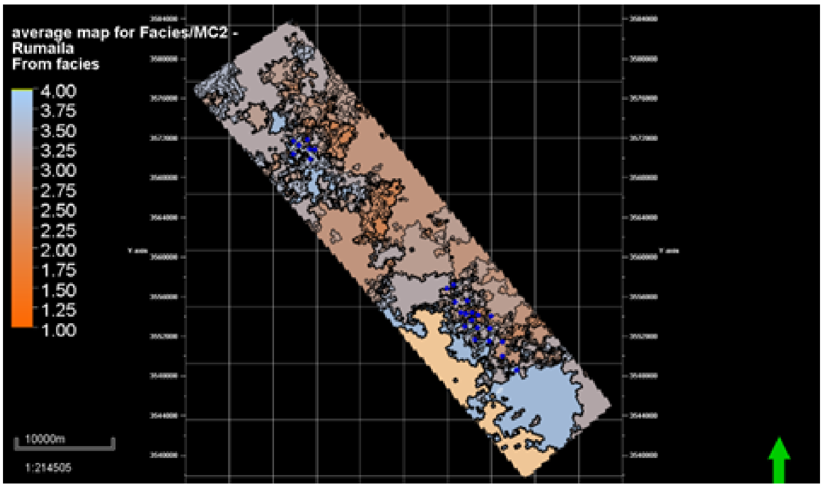


Figure A.15: Facies (Rock type) modelling for MC2 unit in Mishrif reservoir/ Buzurgan Oilfield.