Applied NMR Log Technology to Determine Reservoir Characterization and Flow Units for the Mishrif Formation in Buzurgan Field Southeast Iraq

Hiba M Shakr Al-Jinaay¹ and Moufaq F. Jaber²

¹²College of Science, University of Basrah

Email: aljinaayhiba@gmail.com

Abstract. During the past decade, the remarkable technology of nuclear magnetic resonance (NMR) logging has improved continually. Oil companies are using NMR measurements for an ever-growing number and range of applications, such as characterizing formation fluids during reservoir evaluation and assessing formation producibility. Besides the conventional well logs, to get a better understanding on flow behavior, the relationship of porosity and permeability of reservoir units, reservoir zonation and flow units were defined, three methods were used (Stratigraphic Flow Profile, Stratigraphic Modified Lorenz Plot and Flow Zone Indicator) and made anew NMR facies classification for the studied interval in seven selected oil wells (Bu-24, Bu-37, Bu-39, Bu-40, Bu-41, Bu-51, Bu-52), the results from these methods used to make the 3D modeling that give the best view of the heterogeneity in the field and led to focused on the best properties in the field in the south anticline and in the north anticline in the wells (Bu-24 and Bu-51) respectively.

Key words: NMR, conventional logs, zonation, flow units, modeling.

1. Introduction

More than one direction has been deals with in the recent study including analyses, classification and modeling. The basic topic deals with is the NMR log tools in addition to the conventional logs; which tested and applied in the study area which has been chosen in Buzurgan oil field in the Mishrif Fm. by selecting wells in the north dome and others in the south dome. Many essential objectives include this study, starting with the petrophysics, reservoir characterization, NMR facies classification, the correlation between the conventional logs data versus the NMR logs data, the hydraulic flow units divisions and finally the heterogeneity modeling for the Mishrif Formation.

By constructing a work plan of NMR logs (Combinaible Magnetic Resonance) and conventional log data (Compact Gamma, Compact Dual Laterolog Sonde, Compact Dual Neutron, Compact Microlaterolog, Compact Photo Electric absorption Density Log and Compact Sonic Sonde) the results achieved supported by cooperation and help from China National Offshore Oil Corporation Limited (CNOOC), China Oilfield Services Limited (COSL) and Weatherford Limited to determine the NMR logs analyses that led to put a five Nuclear Magnetic Resonance Facies founded in the study
area in vary distribution in the study wells, as anew facies classification depending on the NMR logs, while the open hole analyses which done by using PETRO Log program show the complex lithology for the Mishrif Formation in the seven selected oil wells.

The correlations between the NMR logs and conventional logs data has been done statistically between the values of permeability, effective porosity and total porosity, led to determine the favorite formulas for transformation between these logs. The flow units' determination done by using three methods: Stratigraphic Flow Profile (into approximately eleven flow units), Stratigraphic Modified Lorenzo Plot (into approximately eleven flow units) and Flow Zone Index (into approximately ten flow units) to makes the reservoir facies modeling in a shape of three dimension diagram that reflected the high heterogeneity in the Mishrif Formation in the Buzurgan oil field depending on the three basic principles (Reservoir Quality Index, Flow Capacity and Nuclear magnetic resonance permeability). When making the comparison between the classifications methods that applied in this study, the preference of each method differed from one to another depending on the objective used for.

Finally, six 3D diagrams proposed to show the heterogeneity models for more than one concept view, but in the all models, the well Bu-24 show the combined best properties between the rest study wells, that located in the southern of the south dome, then followed by the well Bu-51 in the north dome, and the rest wells show vary in its properties along the field.

2. Geological Setting

The Buzurgan oil field is located southeast of Iraq in Missan province. Buzurgan is placed near the border of Iraq-Iran, about 40 km Northeast of Amara city and 300 km Southeast of Baghdad city. The structure, which is composed of two domes extended along a NW-SE direction (Nasser, 2018). In figures (1, 2 and 3) the studied wells (Bu-24, Bu-37, Bu-39, Bu-40, and Bu-41) in the south dome while (Bu-51, Bu-52) in the north dome (CNOOC, 2015). The lower Mishrif Formation boundary considered a conformable surface of Rumaila Formation, while at the boundary with the Khassib Formation represented the truncation at the top by an unconformity surface. (Aqrawi et al., 2010).

Figure (1): Location of Study Area (after Hakimi and Najaf, 2016)
Figure (2): The development well layout map for MB21 sub-zone in north dome of Buzurgan oilfield (after CNOOC, 2015)
3. Available Data and Work Procedures

For achieving the aims of this study, a plan of work was put for the conjunction this research and in methodology based essentially on NMR logs data coupled with conventional logs data in the figure (4) as following: Part One: organizing data for use, including many steps for preparation and proceed. Part Two: use the data for targets.

4. NMR Facies and Rock Typing

After complete well logging operations by using NMR log technique and obtained the logging results with doing the necessary processing steps to have the final measurement parameters, it was observed there is vary in well logging response along the study formation for extend interval in the table (1) for the wells (Bu-24, B u-37, B u-39, B u-40, B u-41, B u-51, B u-52).

| Well no. | Top(m) | Bottom(m) | Thickness(m) |
|----------|--------|-----------|--------------|
| Bu-24    | 3690   | 4050      | 360          |
| Bu-37    | 3684   | 3985      | 301          |
| Bu-39    | 3684   | 4049      | 365          |
| Bu-40    | 3690   | 4037      | 347          |
| Bu-41    | 3690   | 4060      | 370          |
| Bu-51    | 3701   | 4041      | 340          |
| Bu-52    | 3711   | 4100      | 389          |

Figure (3): The development well layout map for MB21 sub-zone in south dome of Buzurgan oilfield (after CNOOC, 2015)
Part One: Organizing Data for Use

1. Wells Selection and Data
2. Quality Check
3. Data Grouping
   a. Conventional Logs
   b. NMR Logs

Above Steps for Preparation

Bottom Steps Necessary to Proceed
4. Open Hole Analyses (OHA)
5. NMR Analyses (NMRA)

Part Two: Use the Data for Targets

1. NMR Facies
2. Conventional Logs and NMR
3. Conventional Logs and NMR Correlation
   a. Stratigraphic Modified Lorenzo Plot (SMLP)
   b. Stratigraphic Flow Profile (SFP)
   c. Flow Zone Index

Histogram Approach
Log-Log Plot Approach

4. Hydraulic Flow Units Determination
   a. Stratigraphic Modified Lorenzo Plot (SMLP)
   b. Stratigraphic Flow Profile (SFP)
   c. Flow Zone Index

5. Hydraulic Flow Units Modeling
6. Properties Heterogeneity in the field

Figure (4): Schematic Diagram Show the General Research Methodology
Implementation a statistical approach to analyze this parameters led to found five different groups characterize by various ranges of specifications can classified as NMR facies (table 2) which appear clearly in figure (6) where permeability vs effective porosity cross-plot for different NMR facies (Bu-39) representative by NMR log response.

Depending on the permeability in the Fig. (5), the NMR facies were divided into five classes denoted in the table (2) and grade from number one to number five, from the best properties (colored with red) to the worst (colored with gray) and this led to classifying the rest properties of the NMR. The relation in the Fig. (6) between the K and Ø can considered a base to obtained the five NMR facies that found in the study wells and can distinguish these facies as significant imprint, for example, in Fig. (6) in the well Bu-39 found the five NMR facies. While NMR facies lake in well Bu-37.

Table (2): NMR facies classification with their characteristics

| NMR F No. | Statics | K SDR | K COA | Øf | BFV | BVCL | BVCP | T2 | FFI | Øe |
|-----------|---------|-------|-------|----|-----|------|------|----|-----|----|
| NMRF1     | Average | 43    | 0.16  | 0.05 | 0.01 | 0.04  | 178  | 0.12 | 0.15 |
| NMRF2     | Min-M.  | 10-129| 0.03-0.5 | 0.0003-0. | 0-0.1 | 0-0.52 | 17-19 | 0-0. | 0.03-0.52 |
| NMRF3     | Average | 0.5   | 0.01  | 0.12 | 0.1  | 0.02  | 0.0002-0. | 12-19 | 0-0. | 0.03-0.31 |
| NMRF4     | Min-M.  | 0.1-1.1| 0.03-0.3 | 0.002-0.3 | 0-0.01 | 0.0002-0. | 5-708 | 0-0. | 0.02-0.23 |
| NMRF5     | Average | 0.05  | 0.008 | 0.08 | 0.07 | 0.02  | 0.005-0. | 27  | 0-0. | 0.06 |
| Min-M.    | 0.02-0.1| 0-0.0 | 0.03-0.1 | 0.02-0.16 | 0-0.1 | 0.01-0.13 | 6-88 | 0-0. | 0.03-0.13 |
| Average   | 0.004  | 0.000 | 0.05  | 0.02  | 0.03  | 0.007-0. | 1-62 | 0-0. | 0.0003-0. |

Well Buzurgan 39 (Bu-39) was taken as example to make and explain the NMR facies classification as shown in table (6), in which mentioned the detail for each parameter in form of ranges (min-max) in addition to summarized in averages for this parameters alone for the five NMR facies. The distribution of this facies along the Mishrif formation in this well started with NMRF4 at the top then NMRF5 then to NMRF2 at depth (3825-3900) m and at the bottom NMRF1 at depth (3990-4030) m.

Figure 5): rock permeability ranges (after Gargin, 1986)
5. Conventional and NMR Logs Results Correlations and Transformations

In order to make the correlations and the transformations between the conventional logs and the NMR logs, must at first step finished the open hole analyses and the NMR analyses, then, makes the correlation test between the common basic parameters to show all the correlations and focused on the best correlations. The best correlations led to best transformations formula that can suggested, as in table(3). The capability to estimate formation permeability is one of the premier benefits of nuclear magnetic resonance (NMR) logging and remains the most consequential application. NMR logging does not give direct and constant measurement of permeability; to some extent, a formation-permeability estimate, or index, is computed from the spectral-porosity measurements using permeability models that are based on a combination of empirical and theoretical relationships with mentioned to some important notes(Kenyon, et al., 1988; Bryant, et al., 1993; Chang, et al., 1997 ; Babadagli, and Al-Salmi, 2004).

Available conventional wire lines logs for this work including DT, ρ_b, Ø_N, R_T, PEF, GR, and Caliper. Caliper log was firstly used to identify bad hole intervals where standoff is higher than 1.5 inches in 8.5″ hole. The intervals which have bad hole removed to avoid the non-good reads. Photoelectric factor (PEF) is a litho-log which determines composition of reservoir rocks. NMR logs have no lithology dependency. So that, the Photoelectric log was not important to use as an input data. Gamma ray (GR) considered as a shale indicator. In this study, four conventional well logs, including sonic log (DT), bulk density (ρ_b), neutron porosity (Ø_N), and resistivity log(RT) were chosen as inputs. These are known appropriate input logs having logical relationship with outputs, because the first three logs are porosity logs and the last one is attributed to fluid flow pass (tortuosity) (Asoodeh, 2013).

Fig.(7) shows the logical dependency of chosen traditional wire lines information with nuclear magnetic resonance log parameters using the concept of correlation coefficient. In all wells there is a strong correlations (colored with blue), moderate correlations (colored with pink) and weak correlations(colored with red)

![Image of Figure 6: Permeability vs Effective Porosity Cross-Plot for different NMR Facies (Bu39)]
Figure (7): Correlations in well Bu-39
6. Flow Units Determination

The fundamental of petrophysics and its relation with hydraulic flow units were documented well in modern time and mentioned from Amaefule et al., 1993; Gunter et al., 1997a; Al-Ajmi and Holditch, 2000; Yasin et al., 2001; Aguilera and Aguilera, 2002; Tiab and Donaldson, 2004; Perez et al., 2005; Taslimi et al., 2008; Rahimpour-Bonab et al., 2012. In this study, three methods have been done to determine the hydraulic flow units: (Stratigraphic Flow Profile, Stratigraphic Modified Lorenzo Plot, Flow Zone Indicator):

6.1 Stratigraphic Flow Profile (SFP)

The reservoir volume can subdivide into bodies geologically by the flow units and helping in modeling of reservoir in addition to flow simulation (Bhattacharya et al., 2008). Depended on many essential elements the flow profile was constructing to determine the flow units for the study wells. This flow profile is the foundation that compares flow units from different techniques to develop a three dimensional flow unit reservoir models. The essential elements are: 1. Gamma ray-GR (API), 2. Permeability (md) from NMR log (SDR and COAT) and conventional logs, 3. Total porosity (pu) from NMR log and conventional logs, 4. Effective porosity (pu) from NMR log and conventional logs, 5. Reservoir Quality Index (RQI). NMR log data was taken to calculate mean hydraulic radius (MHR) as a base to define the reservoir quality index (Dhar, 2006) and (Rastegarnia et al., 2017) given in equation (1):

\[ \text{RQI} = 0.0314\sqrt{K/\Phi} \]  

(1)

Where: RQI: reservoir quality index (µm), K: permeability (md), \( \Phi \): porosity (fraction).

6. Flow Capacity- FC (%) The flow capacity is a function of permeability (md) corresponding to the thickness (m) in percentage formula (%) (Gunter et al., 1997a and 1997b). In this study, used permeability from NMR log (SDR and COAT) by applying equation (2).

\[ K_h = K_1 (h_1-h_0), K_2 (h_2-h_1), \ldots, K_n(h_n-h_{n-1}) \]  

(2)

7. Storage Capacity- SC (%), is a function of porosity (pu) corresponding to the thickness (m) in percentage formula (%), and used porosity from NMR log and conventional logs by applying equation (3).

\[ \Phi_h = \Phi_1 (h_1-h_0), \Phi_2 (h_2-h_1), \ldots, \Phi_n(h_n-h_{n-1}) \]  

(3)

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**Table 3:** Transformations Formulas with strong correlations

| Well N | Formula | Variables | \( x \) | \( y \) | Correlation |
|--------|---------|-----------|---|---|----------|
| 1      | \( y = 0.0356x + 0.16 \) | Logk con | \( \Phi \) | \( \Phi \) | 0.8 |
| 2      | \( y = 0.0373x + 0.11 \) | Logk con | \( \Phi \) | \( \Phi \) | 0.96 |
| Bu-3   | \( y = 0.7053x + 0.61 \) | LogkCOAT & LogkSDR | \( \Phi \) | \( \Phi \) | 0.8 |
| 4      | \( y = 0.7715x + 0.02 \) | \( \Phi \) NMR | \( \Phi \) NMR | 0.76 |
| 5      | \( y = 0.8223x - 0.023 \) | \( \Phi \) con | \( \Phi \) con | 0.75 |
Figure (8): SFP for Bu-39
6.2 Stratigraphic Modified Lorenz Plot (SMLP)

Bhattacharya et al., 2008; Rahimpour-Bonab et al., 2012; 2014 Gunter et al., (1997a; 1997b) showed a graphical way to limiting the flow units depending on the Petrophysics of rock, types of pore, flow capacity and storage capacity (Kh) and (Øh) and reservoir procedure speed (K/Ø). A Stratigraphic Modified Lorenz Plot (SMLP) was generated using cumulative flow capacity (Khcum) and cumulative storage capacity (Øhcum).

The values of cumulative flow capacity and storage capacity were determined using Equations (4 and 5). (Rahimpour-Bonab et al., 2012; Gunter et al., 1997a):

\[
K_{hcum} = K_1 \left( h_1 - h_0 \right) / K_{Total} + K_2 \left( h_2 - h_1 \right) / K_{Total} + \ldots + K_n \left( h_n - h_1 \right) / K_{Total} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)
\]

\[
\Omega_{hcum} = \Omega_1 \left( h_1 - h_0 \right) / \Omega_{Total} + \Omega_2 \left( h_2 - h_1 \right) / \Omega_{Total} + \ldots + \Omega_n \left( h_n - h_1 \right) / \Omega_{Total} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)
\]

Where: K: permeability (md), h: thickness (m), Ø: porosity (fraction).

The break or inflection points revealed the number of preliminary flow units in the SMLP. The shapes of this curve indicate a predictable flow performance of the reservoir, the shape of the curve can be divided to four segments (Momta et al., 2015). (i) Normal Flow Units (NFU): with approximately equal values of the storage and flow capacities. (ii) Super Permeable Units (SPU) or Speed Zone Units (SZU): with high flow and low storage capacities and steep slopes in the SMLP. (iii) Baffle Units (Bar. U): low flow and high storage, which is can indicated the zone that control formation fluid movement. (iv) Barrier Units (Bar. U): units having very low permeability or impermeable (no have) flow capacity and storage capacity. The slope of the SMLP is very low (no slope) for such units.

To construct the SMLP we need the permeability value, from the NMR log we can obtain two values for the permeability (SDR and COAT), that resulted two forms for the SMLP for each study well and that presented in table (4) the Summary of SMLP units classification. As example of SMLP shape in Fig. (9 and 10).

| Wells | Flow Units No. | NMR Model | Flow Unit Characterization |
|------|----------------|-----------|---------------------------|
| BU-24 | 11 | SDR | NFU | 1, 8, 9 | 1, 8, 9 | 2, 4, 5, 6 | 3, 10, 11 | Bar. U |
|      |     | COAT | SPU | 7 | 3 | 2, 4, 5, 6 | 3, 10, 11 | Bar. U |
| BU-39 | 10 | SDR | NFU | 5, 6 | 5, 6 | 1, 2, 9 | 4, 7, 8, 10 | Bar. U |
|      |     | COAT | SPU | 3 | 5 | 2, 3, 4, 7 | 1, 8, 9, 10 | Bar. U |
| BU-40 | 11 | SDR | NFU | 7 | 8 | 1, 2, 3, 4, 5, 6, 10 | 9, 11 | Bar. U |
|      |     | COAT | SPU | 5, 6, 9 | 5, 6, 9 | 3, 4, 8, 10 | 1, 2, 7, 11 | Bar. U |
| BU-41 | 11 | SDR | NFU | 1 | 5, 6, 9 | 8 | 2, 3, 4, 7, 10, 11 | Bar. U |
|      |     | COAT | SPU | 8 | 6, 8, 9 | 3, 4, 5, 7 | 1, 2, 10, 11 | Bar. U |
| BU-51 | 10 | SDR | NFU | 9 | 7 | 1, 2, 3, 4, 5, 6, 7 | 8, 9, 10 | Bar. U |
|      |     | COAT | SPU | 7 | 5, 6, 9 | 2, 3, 5, 6 | 1, 8, 10 | Bar. U |
| BU-52 | 10 | SDR | NFU | 9 | 1, 2, 3 | 4, 5, 6, 7, 8 | 5, 10 | Bar. U |
|      |     | COAT | SPU | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | 5, 7, 8, 10 | Bar. U |

Table(4): Summary of SMLP units classification
Figure (9): SMLP for Bu-39 using $\phi_{hexam(%)}/\phi_{hexam(%)}$

Figure (10): SMLP for Bu-39 using $K_{coat(nd)}$
6.3 Hydraulic Flow Zone Index (FZI)

Flow Zone Index represent the dividing value of reservoir quality index (RQI) by normalized porosity ($\bar{\phi}$). RQI regarded as an approximation of average hydraulic radius in reservoir rock and a key for hydraulic units and correlates between porosity and permeability (Tiab and Donaldson, 2004). Flow Zone Index can regarded as a function for the pore type, tortuosity based on sedimentation model and diagenesis effect (Porras et al., 1999). Conventional open hole log interpretation can provide the answer of different lotho-volume and its thickness but cannot address the issue of free fluid porosity, permeability (flow capacity) and HFU can be determined by making use of rock quality index, void ratio and FZI (Equations 6 to 8) which also relate to the mean hydraulic radius (Abed, 2014; Forest et al., 2014).

Where Flow Zone Index (µm), rocks with same type will have similar FZI values and on alog-log plot of RQI vs $\bar{\phi}$, samples that lie on the same strait line constitute ahydraulic unit. It was demonstrated that this technique is applicable to both carbonate and clastic reservoirs (Ameafule et al., 1993). As in Fi.11.

6.3.1 Histogram Approach

This statistical approach show the frequency histogram for the log FZI value which classified the data to groups with its frequencies, then show the limits of every class, in which will be clear the classification of the units. The histogram method put an essential way to clear the number of hydraulic flow units founding in a carbonates reservoirs with a heterogeneity. Since Flow Zone Index considered as an indirect way of permeability, a method of the histogram to the log FZI would show numbers of the normal distributions corresponding to “n” numbers of HFU’s. First, the FZI values were calculated by equation 7. Then a histogram plot for FZI value is constructed. The number of HFU’s corresponds to the number of normal distributions in the histogram plot of Log FZI. A new FZI is determined to represent each HFU using averaging the FZIs within the same HFU.

6.3.2 Log-Log Plot Approach

A plot of RQI vs. $\bar{\phi}$ in a form of strait line is making. Intersection of this strait line in $\bar{\phi}$z equals to one which product flow zone index. Samples which are on strait line happen to have similar properties and so contribute to make flow unit. Strait lines with slop of unity are firstly expected for non-shale formation while larger slopes identifying shale formations. Rock with detrital material has porus stratification, filling and fine grains generally; therefore, they indicate low amounts of FZI (Ameafule et al., 1993).

\[
\bar{\phi} = \frac{\phi}{1-\phi} \quad \text{......................................... (6)}
\]

\[
\text{FZI} = \frac{\text{RQI}}{\bar{\phi}} \quad \text{......................................... (7)}
\]

\[
\log \text{RQI} = \log \text{FZI} + \log \bar{\phi} \quad \text{......................................... (8)}
\]
### Log FZI for Total Values for Bu-39

| HFU No. | Low limit | High limit | Frequency |
|---------|-----------|------------|-----------|
| 1       | -2        | -1.665     | 8         |
| 2       | -1.665    | -1.330     | 23        |
| 3       | -1.330    | -0.995     | 90        |
| 4       | -0.995    | -0.661     | 189       |
| 5       | -0.661    | -0.326     | 566       |
| 6       | -0.326    | 0.008      | 649       |
| 7       | 0.008     | 0.342      | 785       |
| 8       | 0.342     | 0.677      | 853       |
| 9       | 0.677     | 1.012      | 48        |
| 10      | 1.012     | 1.346      | 13        |

**Histogram of Log FZI for Bu-39**

**Figure (11):** FZI for Bu-39
7. Preference between methods

The preference of each method differed from one to another depending on the objective used for it, that is meaning; when needing to define the characteristics of the reservoir in general form and need prediction the boundaries, we can use the SFP method, while if the main target was the knowledge about the storage and compared it with the flow, then we can applying the SMLP method, but determined the predominant properties and classified it, in this state, the best way is FZI method. In case we want to combine all these targets the best way is using NMRF method and with more details can support it with another statistical way such as the histogram method.

8. Reservoir characterization heterogeneity in the field

Reservoir characterization researchers beginning investigate the quantification of various heterogeneities, and the heterogeneity concept depending on the researcher description (Frykman 2001; Jennings & Lucia 2003; Pranter et al., 2005; Westphal et al., 2004). Carbonate reservoirs are well documented for their complex internal structure (Akbar et al., 1995; Kennedy 2002; Lucia 1995; Moore 2001). The variation within carbonates is generally related to the numerous ways in which carbonate grains and matrix coexist, carbonates are known for being chemically unstable and undergoing substantial alteration, e.g. dissolution and dolomitization (Akbar et al., 1995). So that will use three methods in this study to show the heterogeneity in the field:

8.1 Reservoir Quality Index (RQI)

The mean hydraulic radius in the form of RQI is the essential principle in the two models, used to show the difference in, and this difference appear between (SDR and COAT) permeability as shown in Figs.(12 and 13).

Figure (12): Heterogeneity model depending on the best RQI (resulted from KSDR) for the field.

Indeed, the detection of heterogeneities is often dependent upon the manner of examination and on the technology used, there are many log indicators for reservoir heterogeneity, however they do not generally reveal the type of heterogeneity present (Nurmi et al., 1990).
Figure (13): Heterogeneity model depending on the best RQI (resulted from KCOAT) for the field.

Therefore, the dissimilarity clear in the two models because the SDR permeability model applying formula of T2 mean, while the COAT permeability model applying formula of free fluid.

8.2 Flow Capacity (FC)

The different depths and volumes of investigation cause problems when investigating heterogeneous carbonate reservoirs (Kennedy 2002). Boya-Ferrero et al., (2004) therefore show that integrated studies of all petrophysical and geological data will provide the key to understanding heterogeneous fractured carbonate field. The flow capacity that show the best flow properties in a field can reflected the heterogeneity when using more than one single well for this purpose, and this display in Fig.(14 and 15).

In the Fig.(14 and 15) show the heterogeneity along the field when applying the flow capacity concept, most problems in carbonate reservoir exploration are concerned with the large variation in porosity systems and permeability encountered, fifteen different types of carbonate porosity systems are documented in the literature (Lucia 1995; Moore 2001), and often two or more porosity systems exist in a single carbonate reservoir. In carbonates porosity will often increase as sorting decreases; the opposite effect is seen in clastic rocks. Carbonate porosities are complicated further by the fact that a carbonate initially has a high porosity which it will lose gradually over time (Lucia 2000).
8.3 Nuclear Magnetic Resonance Permeability (NMRP)
Lithological variation can also be documented by changes in the facies, this facies variation generally occurs on a larger scale than that of mineralogy alone, as in the MB21 member (3818m-3914m) limestone: light brown, slightly hard, porous, good oil show while (3914m-3926m) limestone: white, slightly hard, compact. Limestone: Light brown, slightly hard, porous. Heterogeneities in carbonate sedimentary facies may be defined by changes in grain characteristics (e.g. size, shape, and sorting), fossil content (including trace fossils / bioturbation), and structures such as bedding, cross-bedding, grading, water-escape features, and ripples. The way in which one facies passes laterally into another can be gradual (graded), abrupt or be seen as inter-stratified mixing of the two (Nichols 2001; Tucker and Wright 1990).
In Fig.(16 and 17) show the heterogeneity models for the field when using the SDR permeability and COAT permeability as a guide concepts in the field. Two other features common to carbonates which may introduce or increase heterogeneity are fractures and stylolites. Stylolites form by pressure solution during compaction of the carbonate sediment; fine-grained insoluble residues become concentrated along what appear to be irregular planes of discontinuity (Akbar et al., 1995; Nichols 2001; Tucker and Wright 1990).

The fine-grain residue within stylolites is commonly different to the surrounding rock with a different mineralogy and/or porosity. Fractures are generally irregular and cut across pre-existing fabrics. They commonly occur in carbonates because of tectonic deformation, slumping or dissolution collapse (Tucker and Wright 1990). It is most common that fractures remain open, acting as strong porosity and permeability enhancers (Aguilera 2004).

Because of depositional heterogeneities that resulting from the deposition factors and the effects of boundaries from sequences on the reservoir quality, each study area shows distinct combinations of geometric pay zones (Mahdi et al., 2013).

The high initial oil rate producers usually located on the shoal core in MB21, the large outflow is from the top of MB21 while, the supply rate is slow on the lower section because of the vertical heterogeneous in MB21 and the fractures seem to mostly occur on the southern parts of the south dome. (CNOOC, 2015)

In general view on the all heterogeneity models, the well Bu-24 show the combined best properties between the rest study wells, that located in the southern of the south dome, then followed by the well Bu-51 in the north dome, and the rest wells show vary in its properties along the field.

9. Conclusions

A new NMR facies classification was constructed depending on this study, that show five classes for NMR facies which makes it easy to anyone interest in this field to understand the NMR log behavior and interpreted it in quick look manner. Depending on the log analyses that including NMR log analyses and open hole analyses, the best properties in all studded wells concentrated in the unit MB21. In the equation logk= a+bØ, the correlations of kcon. With Øe con. better than with ØT con. Than led to applied Øe in the equation for more accurate results. Improving the flow properties in the strong correlations between Øe and ØT that founded in some of studied wells. The relation between Log kCOAT and Øe, NMR can led to use the value of kCOAT as an indicator to the effective porosity, while these relation not found with KSDR. The highest value of FZI between the studied wells were in the wells Bu-51 and Bu-52 equal to (30 and 29.3)sequentially, with same number of flow units(8). The super permeable units founded with more presence in the well Bu-52, in spite of using two different formulas for calculating the permeability (SDR and COAT). The best SFP was for wells

Figure (17): Heterogeneity model depending on the best permeability (KSDR) for the field.
Bu-24 and Bu-52 that shows the different properties and focused on the interval with good extent of flow capacity, compared with the rest wells. Depending on the comparison between the four methods for determined the flow units (NMRF, SMLP, SFP and FZI) The preference of each method varies according to the objective used for. Despite of the high heterogeneity in the formation, but in general view on the all heterogeneity models, the well Bu-24 show the combined pest properties between the rest study wells, that located in the southern of the south dome, then followed by the well Bu-51 in the north dome, and the rest wells show vary in its properties along the field. Based on results of (SMLP) method, it was understood that wells (Bu-24, Bu-40 and Bu-41) include eleven flow units and wells (Bu-39, Bu-51and Bu-52) has ten flow-units. According to slopes, it seems that the Speed Zone Units more available in wells (Bu-40, Bu-41 and Bu-52) than in the rest wells, have the best reservoir quality.

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