3D geological model of Nahr Umr /Ratawi oil field in Basra.

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Abstract. The study includes building a 3-D geological model, which involves get the Petrophysical properties as (porosity, permeability and water saturation). Effective Porosity, water saturation results from log interpretation process and permeability from special correlation using core data and log data. Clay volume can be calculated by six ways using IP software v3.5 the best way was by using gamma Ray. Also, Water Resistivity, flushed zone saturation and bulk volume analysis determined through geological study. Lithology determined in several ways using M-N matrix Identification, Density-Neutron and Sonic-Neutron cross plots. The cut off values are determined by Using EHC (Equivalent Hydraulic Unit) method. The full grid of the model was 454308 cells. Layering of units depend on the importance of these units and scale up had done using several methods depend on property (Arithmetic for porosity and water saturation and geometric for permeability). Petrophysical properties distributed using Gaussian statistical approach. Original oil in place calculated for Nahr Umr which equal to 460 m3.

1. Introduction
Ratawi oil field was discovered by the Iraqi oil company and the first exploration well drilled in 1948, at depth 3868 m. In 1972 another exploration well, Rt-2 was drilled to depth 3020 m. Ratawi oil field located at 70 km from Basra city and 12 Km in parallel to north Rumaila field [1] (Figure 1). Nahr Umr formation first discovered by Glynn Jones 1948 in Nahr Umr field where the thickness of formation reaches to 360m and in the south of Baghdad reach to 160 m while in Ratawi filed between (200-240m) which in deposited in Cretaceous era with shale sand rocks and thin sand layer in upper part with some clastic rocks. The log interpretation process includes Environmental correction, Estimate the petrophysical properties, fluid resistivity determination, lithology, Archie Parameter and net pay, net to gross determination. In the middle part of the layer consist of layers of sand rocks and shale rocks respectively and followed by the thick layer of sand stone rocks In the bottom of Nahr Umr totally consist of thick sand rocks and one third of upper part of this section consist of layers of sand and shale rocks respectively[2].There are no fault in the Ratawi which may effect on the compartments [3], thirty one wells were drilled in Ratawi Oil Field, just 14 wells were penetrate Nahr Umr formation as well as 8 wells (Rt-4,Rt-16,Rt-17,Rt-18,Rt-20,Rt-21,Rt-22 and Rt-24) were have las files. These las files have been imported to IP software v3.5 (Interactive Petrophysics) in order to get interpretation as shown (Figure 2).
2. Environmental correction and Clay Volume

Many charts available to correct the logs like Baker Hughes, Halliburton, Schumberger…. etc. Schumberger charts were used to this purpose. Environmental correction was used in order to bring back log into the standard condition. The input data beside the log needed for Gamma Ray, Mud weight and Top, Bottom of each well, density mud weigh. Resistivity logs need temperature curve, hole diameter, mud filtrate resistivity, mud resistivity and temperature of each them. (Figures 3&4) these figures show the correction for density, resistivity curves, gamma ray and Neutron respectively [4]. Clay volume can be calculated by six ways using IP software which include gamma Ray, neutron, resistivity, SP, density neutron and sonic neutron as shown (Figure 5).
Figure 3. Environmental correction of Resistivity.

Figure 4. Correction of gamma ray and density
3. Effective porosity and Lithology

Effective porosity [5], depend on the clay volume as expressed below:

\[ \phi_e = \phi_t (1 - V_s) \]  \hspace{1cm} (1)

Lithology can be determined from different method using IP software such as density neutron cross plot, Neutron sonic cross plot, M-N Mineralogy Identification plot equations (2 & 3) can be used to estimate M and N and Matrix Identification (MID) involve estimate apparent matrix density (\( \rho_{ma} \)) and apparent transit time of rock matrix (\( \Delta t_{ma} \)) as in equations (4 & 5). Lithology of Nahr Umr as mentioned in introduction section composed mainly of sand stone and shale with minor amount of limestone which located mainly in upper part of formation. As shown in (Figures 6,7,8&9).

\[ M = \frac{\Delta \rho}{\rho - \rho_{ma}} \times 0.01 \]  \hspace{1cm} (2)

\[ N = \frac{\rho - \rho_{ma}}{\rho_{ma}} \]  \hspace{1cm} (3)

\[ \Delta t_{ma} = \frac{\Delta \rho_a - \Delta \rho f \rho t}{1 - \phi_t} \]  \hspace{1cm} (4)

\[ \rho_m = \frac{\mu_t - \mu_{tf}}{1 - \phi_t} \]  \hspace{1cm} (5)
Figure 6. Sonic Neutron cross plot.

Figure 7. Neutron-density cross plot.
Figure 8. M/N cross plot

Figure 9. Matrix density vs. transit time plot.

4. Water resistivity ($R_w$) determination

$R_w$ is an important factor to estimate water saturation besides the Archie parameter. Rabanit 1952 proposed a method to calculate water Resistivity. First, must calculate $R_w$ at 75 °F depending on the Salinity concentration then determine the water resistivity in reservoir temperature [5], (Table 1).
Archie Parameter (a, m and n) is necessary to determine water saturation, so that picket plot used for this purpose. By assuming that a=1 and n=2 and By Knowing the Rw values the m (cementation factor) will be determined, (Figure 10) and (Table 2).

Table 1. Rw and Rmf for each well

| Wells | BHT (F°) | Rmf @MT | Rw @ BHT |
|-------|----------|---------|----------|
| RT-4  | 176.5    | 0.52    | 0.019589 |
| RT-16 | 177.8612 | 0.32    | 0.01944  |
| RT-17 | 178.682  | 0.177   | 0.019356 |
| RT-18 | 176.936  | 0.165   | 0.0195   |
| RT-20 | 163.4    | 0.22    | 0.02109  |
| RT-21 | 168.8    | 0.22    | 0.02044  |
| Rt-22 | 165      | 0.18    | 0.0209   |
| RT-24 | 174.2    | 0.1     | 0.01983  |

5. Archie Parameter

Archie Parameter (a, m and n) is necessary to determine water saturation, so that picket plot used for this purpose. By assuming that a=1 and n=2 and By Knowing the Rw values the m (cementation factor) will be determined, (Figure 10) and (Table 2).

Table 2: Archie parameters for different wells.

| Wells | a  | m  | n  |
|-------|----|----|----|
| Rt-4  | 1  | 1.98 | 2  |
| Rt-16 | 1  | 1.94 | 2  |
| Rt-17 | 1  | 1.95 | 2  |
| Rt-18 | 1  | 1.92 | 2  |
| Rt-20 | 1  | 1.95 | 2  |
| Rt-21 | 1  | 1.93 | 2  |
| Rt-22 | 1  | 1.98 | 2  |
| Rt-24 | 1  | 1.98 | 2  |

6. Fluid saturation determination

There many equations to determine the water saturation one of the most equation was Archie, besides this equation there are many equations like Simandoux, Indonesian and Indonesian. Archie can calculate water saturation for clean zones depend on the effective porosity(\(\phi_e\)), water resistivity (Rw), true resistivity (Rt) and Archie parameter (m, n, a) [6].

\[
S_W = \left( \frac{R_M}{R_R \phi_e^m} \right)^\frac{1}{n}
\] (8)

\[
S_X = \left( \frac{R_M}{R_R \phi_e^m} \right)^\frac{1}{n}
\] (9)

Residual oil saturation (\(S_o\)) and movable oil saturation (\(S_m\)) [7] can be determined as:
\[ S = [\varphi (1 - S_h)] \]  
\[ S_{hr} = \varphi (S_x - S_W) \]

Indonesian equation was used to estimate water saturation for this study because the high shale percent in the Nahr Umr formation [8] as shown below:

\[
S_W = \left[ \frac{1}{\frac{V_{sh}}{K_{sh}} - \frac{V_{sh}}{K_{sh}} + \varphi (1 - \beta) \varphi} \right]^{\frac{1}{R}} 
\]

7. Bulk volume Analysis

In porosity track BVWSXO (Black line) which represent the bulk volume of porosity in flushed zone filled with water as shown in eq.13, BVW (red line) which is bulk volume of porosity in true zone filled with water as shown in eq.13, where area between them represent the movable hydrocarbon and the area between effective porosity (\(\varphi_e\)) and BVW represent the total hydrocarbon. Through this study the result that the percentage of shale in NU-A and NU-B equal to 45% and 44% respectively while \(V_{sh}\) in NU-C and NU-D equal to 28%, (Figure 11).

\[ B_l = \varphi_e \times S_x \]  
\[ B_l = \varphi_e \times S_W \]
8. Cutoff parameters

There many ways to determine the cutoff values one of these methods was EHC (equivalent hydraulic column) method, eq. 14, where this method depend on multiple values of water saturation like (Sw>40%, Sw>50, Sw>60%, Sw>70% and Sw>80%). Porosity and water saturation cutoff were determined (Figure 12 and Figure 13). So, the criteria of Nahr Umr will be porosity >8%, water saturation <70%, permeability>0.1 md and shale cutoff <0.3.

\[ E = (1 - S_w) \times \phi_a \times \sum h_i \]  

(15)
Figure 13. Water saturation cut off Nahr Umr formation.

9. Permeability calculation
Permeability can be predicted using core data in order to create correlation use to convert the log porosity to core porosity for the rest wells as in eq. 16, (Figure 14) show the relation between the porosity log and porosity core for Rt-4. The core porosity that result from this correlation can be used in eq.17 which result by draw between core permeability and core porosity for Rt-4 in order to get permeability as (Figure 15).

\[ \phi_c = 0.8731 \phi_{lt} + 0.01 \]  \hspace{1cm} (16)

\[ K_{core} = 0.0005 \ e^{62.8 \phi_{core}} \]  \hspace{1cm} (17)
10. Geological modeling and petrophysical properties distribution

Geological model has been built using Petrel software 2015.1 and by input multiple data that need as well head (where well head must be imported to know the position of the well path as well as the measured depth), well tops (represent a peck point along the well path), well logs (represent the CPI, Net to Gross, shale volume…..etc.), and contour map. Use simple grid to define the structural of the model by define the dimension of grids (X=250, Y=250 and Z=4.218). The structural contour map of NU-B depened for this model (Figure 16), so based on this map other maps were constructed, (Figure
17). The skeleton of this model represents the framework which represent the first step of 3D the model, where the Top, Bottom and middle of this skeleton represented in (Figure 18). Layering process used to split the important zones into several layers depending on the importance of these zones. Where NU-A split into 15 NU-B into 20, NU-C into 10 layers and NU-D into 1 layer. In order to get average value of properties to each cell need to make scale up. There are many ways to make scale up such as arithmetic, harmonic, geometric …. etc. [9]. The total number of cells reach to 454308 cells (68 cells in I direction, 131 in the y-direction with 51 number of layers). The Porosity, permeability and water saturation was distributed throughout the model using Gaussian statistical approach [10]. Porosity result from IP v 3.5 as a result of interpretation process. Porosity maximum and minimum of the model was (0.074 to 0.195, 0.071 to 0.259, 0.132 to 0.259,0.099 to 0.256) for NU-A, NU-B, NU-C, NU-D respectively. Water saturation model was used distribute the water saturation that have been gotten from well logs interpretation for four layers mentioned previously as (0.2539 to 1, 0.0872 to 1, 0.01 to 1 and 0.855 to 1). Permeability was supported from porosity-permeability correlation, where permeability model was construct based on the maximum and minimum of NU-A was from 0.00033666 to 6561.55, NU-B from 0.00024531 to 162.18 md, NU-C from 0.00085822 to 7256.9 md and NU-D was 0.00024531 to 1218.53 md, shown (Figure 19,20,21).

11. Original oil in place

Water oil contact was determined for Nahr Umr formation from the comparison between the water saturation and depth of well log data where the water oil contact was -2729 m, (Table 3), (Figure 22). Original oil in place has been calculated for Nahr Umr which was 2893.31 MMBBL using Petrel software 2015.1. where NU-B has the biggest reserve (1257 MMBBL) and for NU-A equal to (1062.97 MMBBL), while oil in place in NU-C equal to 572.37 MMBBL.

![Figure 16. structural Map of NU-B formation.](image-url)
Figure 17. Map surfaces of Nahr Umr formations.

Figure 18. Structural skeleton of Nahr Umr formation.
Figure 19. Porosity Model of Nahr Umr formation.

Figure 20. Water saturation Model of Nahr Umr. formation

Table 3: Oil water contact values of different wells of different wells

| Well name | OWC (meter) |
|-----------|-------------|
| Rt-16     | -2725.6     |
| Rt-17     | -2718.9     |
| Rt-18     | -2720.39    |
| Rt-20     | -2730.3     |
| Rt-21     | -2743.03    |
| Rt-22     | -2729       |
| Rt-24     | -2730.42    |
| Rt-4      | -2735.3     |
Figure 21 Permeability model of Nahr Umr.

Figure 22. O.W.C determined with depth for different wells

12. Conclusions
Nahr Umr can be divided into four units depending on the composition of each unit. NU-A have large percentage shale about 45% so little perforations recommended in this Unit. NU-B has a biggest oil reserve where NU-B and NU-C represent main reservoir of Nahr Umr. Depending on all sections that mentioned in lithology the main composition of hole formation is sandstone and secondary from shale. EHC method was used to determine the cutoff values. The relation between porosity log and porosity
core give $R^2=0.6224$ while the relation between the porosity core and permeability core give $0.8742$ $R^2$. Indonesian equation was used for water saturation calculation. Porosity, water saturation and permeability models have been built using statistical Sequential Gaussian simulation method.

**Nomenclature**

$a$: tortuosity factor;  
CSP: Concentration of salinity ppm;  
n: Saturation exponent.  
m: Cementation factor.  
$\phi_e$: Effective porosity.  
$\phi_{nt}$: apparent total porosity fraction which can be determined by appropriate neutron density;  
$K$: Permeability, md.;  
$S_w$: Water saturation;  
$S_{so}$: Invaded zone saturation;  
BVW: Bulk volume of porosity filled with water;  
$R_t$: True Resistivity ohm-m.;  
$R_w$: Water Resistivity ohm-m.;  
$R_{mf}$: Mud filtrate Resistivity ohm-m.;  
$R_{sh}$: shale Resistivity ohm-m.;  
$R_{W75}$: Formation Water Resistivity @ 75°F;  
$R_{Win}$: Water Resistivity at formation temperature;  
BVWSXO: Bulk volume of porosity in flushed zone filled with water;  
$S_w$: Water saturation;  
$S_{or}$: Residual oil saturation;  
$T_f$: Formation temperature, °F;  
$\rho_{ma}$: apparent matrix density.  
$t_{ma}$: apparent transit time of rock matrix.  
$t_r$: 189 usec/ft;  
$V_{sh}$: Shale volume.

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