Reservoir characterization, Facies distribution, and sequence stratigraphy of Mishrif Formation in a selected oilfield, South of Iraq.

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Abstract. Mishrif Formation is considered the most important between the reservoir formations in the south of Iraq because of its geographic extent. The facies were predicted in Ratawi oilfield from wireline logs that divided Mishrif Formation into two main reservoirs separated by a barrier member. So the formation is almost cupped with shale intervals in both contacts of Rumaila Formations in the bottom and Khasib Formations in the top. While the reservoir characteristics were calculated using the log set in terms of petrophysical properties. The reservoir characteristics destroy and decrease to the south of Ratawi area because of the abundance the facies of the deep marine environments. Furthermore, it was predicted that Mishrif Formation has good reservoir characteristics to the other directions, especially to the east, contrary to the previous expectations.

Keywords. Mishrif Formation, Reservoir characterization, Sequence stratigraphy.

1. Introduction

One of these giant formations in Iraq was the Middle - Cenomanian – Early - Turonian Mishrif Formation, that is supposed to be the most important between the reservoir formations in the south of Iraq (and the Arabian peninsula) due to its significant properties [1, 2]. This formation characterized by continuous geographic extension makes it the second economic reservoir after Zubair Formation. [3] initially defined the formation as a thick carbonate interval in the depths (2,195 to 2,371 m) at well Zb-3 in Zubair oilfield.

Mishrif Formation is composed of multi-story [4] thick carbonates [5] deposited on a wide flattened shelf. This shelf extended from shallow restricted lagoon environments to the open marine and deep platform [3] provided by a major Eustatic sea-level rise, which started in the Middle Cenomanian [6].

This setting was common in the Mesopotamian Basin of Iraq and the neighboring countries [7, 8].
Figure 1. Columnar section of well Rt-3 illustrates the generalized stratigraphic secessions of Ratawi oilfield.

Mishrif Formation overlies the oligosteginal Rumaila Formation with a conformable and gradational contact of the same period of deposition [3, 9]. Whilst, the upper boundary is unconformable with the U. - Turonian–Coniacian Khasib Formation that deposited in transgressive and deep basin environments in the study area and most parts of Iraq, Figure 1. It should be noted that Mishrif Formation is overlaid by a conformable Turonian Kifl Formation due to progressively wedging out to the southern parts of Iraq due to Intra Turonian erosion or because of non-deposition [10].

Mishrif Formation consists dominantly of carbonate rocks with Foraminiferal, Algal, and Rudists facies that reveal neritic and shallow marine environments, except for the occurrence of green Algae which indicates a relatively deep environments.
2. Geological Setting

Tectonically, Ratawi oilfield is placed over the structure of the Jurassic Salt Basin that locates above the tectonic system of the Infra-Cambrian Salt Basin in the Stable Shelf, Fig. 2. [11]. The oilfield of interests is located in the Zubair subzone which is a part of the Mesopotamian zone, which the later a part of the unstable shelf, southern Iraq [12, 13, 14].

It is a structural dome with NS dominant direction, Fig. 3. The gentle dip may hide a steeper dip of the structural flanks of the deformable Gotnia anhydrite [15, 16, 17].

The detailed log analyses, seismic mapping, and stratigraphic correlations indicate that this Shelf-type of anticline express pulses evidence of structural growths belongs to Neocomian, Albian, Turonian and Palaeocene-Oligocene periods. These structural growths depict the multiple reservoirs of the giant oil fields of the Arabian Shelf and precisely southern parts of Iraq [18, 19, 20, 21].

Figure 2. The study area in southern Iraq illustrates (A) Ratawi oilfield location and (B) the wells that examined this study.
3. Material and Methods

In order to convert the two-way time map to a depth map, the average velocity map is constructed and to know the seismic average velocity distribution over the study area. The source of information on average velocities are well sonic log and check shot from the available well that drilled in the study area on the one hand and velocities derived from seismic reflection data on the other [22]. Velocities that obtain form wells not enough to represent the lateral variation and distribution of the velocity of the study area and velocities that derived from seismic data will be unreliable, therefore; it may necessary to rely primarily on available well velocity data. From the sonic log and check shot, the average velocity of Mishrif Formation can be deduced. The depth conversion carried out via multiply two-way time with average velocity to arrive at a certain depth to construct a depth map of Mishrif formation.

Seven (7) wells used to utilize the data from Mishrif formation in the Ratawi field. The collected data were coordinates, tops and bottom contacts, and total depth of the wells. The log sets of the wells Rt-5 and 7 debugged in "didger software" to convert the hard copy of the logs into digital data. Then the resulted LAS file exported to "petrel software" to start the next step of reservoir analyses. These analyses indicate primary and total porosity (secondary porosity is undisputed), the shale volume, formation factor, and all other reservoir characterization. The environments and facies were also predicted from these logs [23]. As well as, the effective porosity and litho-facies distribution within the formation were indicated along with the Mishrif Formation in Ratawi structure.

4. Facies association and sequence analysis

The wells, in Ratawi oilfield, are selected depending on the available data of logs, core, and thin sections. Four facies associations including the inner ramp, middle ramp, outer ramp and basin of a mud-dominated carbonate ramp can be distinguished in the area of interest. The upper part from the formation (approximately 11-18 m) is Mudstone to Wakestone facies [24] and [25]. This facies represents the cup rock (CI) of the formation and comprises from detrital, conglomeratic, intraclasts of micrite embedded in sparite and microsparite matrix. This interval begins hard, tight, and becomes soft in the lower parts and highly porous contains solutions cavities and fractures.
The next interval was mainly Mudstone contains dismicrite, buff, hard, with cavities and randomly oriented fractures. Thin laminae of black shale in the lower part of this interval which its thickness was about 16 m in the Ratawi oilfield. The lower part of this facies comprises Grey, light grey beige in the lower part of this facies, very hard, slightly argillaceous poorly porous to compact with thin laminae and parts of shale. Dolomite bed developed in thin intervals in thin layers not exceeding the 0.5 m. This interval represents the main upper mishrif reservoir (MA) as divided by the Iraqi oil company.

Below this interval, the main barrier (CII) is located between the upper and lower reservoir intervals of Mishrif Formation. This interval represents the alternation of shale and massive limestone with about 6 m thickness. The shale is black, hard, calcareous, and pyritic, while the limestone is black, hard, shaly, and highly compacted. The facies of this interval were mainly shaly, massive Mudstone – Wakestone.

The lower Mishrif Formation (MB) about 44 m composed mainly from fossiliferous Mudstone to Wakestone facies. It may be divided into two parts, the upper comprises of micritic and spars biomicrite, porous, contain Algae, Globegrinidae, and highly porous with small fractures and cavities in the middle part. While the lower part contains biomicrite, brown - dark brown, soft, highly porous, contains large Forams, Corals, Rudists, Rotalidae, with some dense micrite intercalations.

The lowermost interval is about 20 m compose of micrite, light grey to buff, very massive limestone, with numerous large conduit-like cavities and fractures.

The proposed sequence succession starts with relative sea-level rise in the Mishrif platform over shoals of patches reef and Rudist biostrome of the paleo-structures of the pre-Mishrif shelf. This phase extended to the maximum flooding surface of the deposition of the shale barrier interval (CII). The fluctuation in this phase creates multi-environments from deep to the open marine sediment, while the shoals were rare in the Ratawi area. The main shoals of Mishrif Formation were to the E, NE, and SE in the shallower parts, while the Ratawi sector was relatively deeper. This fact interprets the thinning in Mishrif Formation in the area of study and SW area, while it is thicker toward the E, NE, and SE due to the shedding in the High-stand system tract. The next regression phase resumes the shallow environments, which represented by shoals and lagoon facies. Those facies include mainly fossiliferous, bioclastic, and lithoclastic Wakestone to Packstone, whilst the Grainstone and Boundstone were rare. The sequence boundary in the final Low-stand system tract appears as significant cavities and fractures in the upper part of the Mishrif Formation. This sequence boundary may be elongated due to the highly effected diageneses in this interval.

The last transgression phase led to the final maximum flooding surface that deposited the cup rock (CI) of the giant reservoir. The two sequence boundaries in the Mishrif Formation act as conduits to the solution to change the chemical composition of the rock as well as diageneses.

5. Results and discussions
Mishrif Formation was deposited in a ramp-like or rimmed shelf setting. The facies distributed in four dominant environments, which they lagoon, Shoals, inner and outer ramp environments. In Ratawi oilfield, the formation has characterized by relatively deeper environments.

Primarily, the lithology cross plots were achieved to each significant interval in the formation and the expected lithology distributed as shown in Figure 4. The main and significant shale intervals in the Mishrif Formation are represented by the upper unconformable contact with Khasib Formation, the barrier member within the formation, and the lower part that conformably contact with Rumaila Formation. These intervals characterize the seal rocks, while the reservoirs (mA and nB) were capped between them.

The facies distribution throughout the formation was predicted using the Petrel software. As shown in figures 5A and B, the shale and/or shaly carbonate facies located at the upper and lower parts of Mishrif Formation. The barrier bed significantly occurred in all sections in the Mishrif intervals, as indicated from the log set. While this bed disappears to the south of study area and merge with shaly intervals of the upper contact. This wedging out may continue to the south of Iraq due to the shallowing of the basin.
Figure 4. N-S section binding the wells Rt-5 and Rt-7, shows the subdivisions of Mishrif Formation, the Shale ratio, and the water saturation.

Figure 5.A. N-S section illustrates the carbonate-shale distribution within the Mishrif Formation.
Figure 5.B. E-W section illustrates the carbonate-shale distribution within the Mishrif Formation.

Moreover, the effective porosity was detected from wireline logs using the standard porosity equations from sonic and density logs. The suitable corrections to the borehole diameter and drilling fluid type were made. The equations forwarded to the Petrel software to calculate the effective porosity along the Mishrif Formation. As illustrated in figures 6 A and B, the effective porosity (PHIE) reduces in the shale intervals, while it increases in the reservoir intervals especially in the mB bed or generally lower interval of Mishrif Formation below the barrier bed. However, the effective porosity decrease in the ends of the Ratawi field structure due to the relatively deep environments represented by mud-supported facies of the deep open marine environments [26]. In the reservoir member mA, the PHIE ranged from 9 – 16%, while in mB, ranged between 16 to 21 %.

From the above results, this research indicates that the properties of the reservoir intervals of Mishrif Formation saliently decrease toward the southern parts of Iraq. While there is an acceptable prospect to increase reservoir characteristics toward the north, east and west toward the borders of Zubair subzone.

Figure 6.A. N-S section illustrates the effective porosity along with the formation.
Figure 6.B. E-W section illustrates the effective porosity along with the formation.

Figure 7. Composite log of Mishrif Formation illustrate the mail logs of GR, DT, NPHI, RHOB, and effective porosity PHIE along with the studied interval.

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