Microfacies and Diageneses Associated Mishrif Formation in X Oilfield Southeast Iraq

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Abstract
The fractal fifteen thin section showed that the deposition of the Mishrif Formation is gradual upwards. It was deposited in a period that suffered from several marine fluctuations. It began as a cycle of marine retreat that led to the sedimentation of reefs, followed by a short-term marine advance, and then a widespread marine retreat that led to the emergence of sedimentary facies and various Rudist assemblies. Through scrutiny and analysis of the slides, the presence of five main facies (basin facies, slope facies, shallow open marine, shoal, and rudist biostrom environment) was observed. The results showed that the morphological processes re-crystallization, decomposition and dolomitization have the greatest role in improving the porosity, in addition to that the Rudist biostrom and shoal facies environment have good reservoir properties in units MA, MB2 and MB2. The modulation processes affecting the development of the reservoir properties of the different units were identified, with an indication of the severity of their impact and their role in the growth and destruction of porous systems. These processes are micritization, dissolution, dolomitization, cementation, recrystallization, stylolitization, and compaction.

Keywords: Facies; Diageneses; Oil Field; Mishrif Formation; Iraq

1. Introduction

The Mishrif Formation is in gradational contact with the underlying Rumaila Formation, although the Khasib Formation is unconformably overlain (Al-Dabbas et al., 2010). The Cenomanian–Turonian sedimentary succession in the south Iraq oil fields, which includes Ahmadi, Rumaila, Mishrif, and Khasib formations, has been subjected to a high-resolution reservoir-scale genetic sequence stratigraphic study using genetic sequences at the reservoir scale. Based on the Arabian Plate chronosequence stratigraphic context, the south Iraqi Albian – Cenomanian – Turonian succession of 2nd-order depositional supersequence has been analyzed. Three main chrono-markers (the maximum flooding surface, MFS-K100 of the upper shale member of the Nahr Umr Formation, MFS-K140 of the upper Mishrif carbonates, and MFS-K150 of the lower Khasib (Awadeesian et al., 2018). The stratigraphic column consequently was split into twenty stratigraphic intervals (zones): four zones in Tanuma, five zones in Khasib and eleven zones in the Mishrif Formation.

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The bottom section of the Mishrif Formation is the principal reservoir in the stratigraphic column as well established, although the difficulty lies in the debate concerning the number of productive units and their stratigraphic intervals (Al-Mimar et al., 2018) (Fig.1). The Mishrif Formation is the deposit in a carbonate platform ramp system, with dispersed patch reefs and shoals developing along the ramp margin and on the platform top, regionally, from Jurassic to Early Cretaceous, South Iraq was at the west gentle slope of the deepest water area (Fig.2). It is distinguished by the predominance of skeletal grains (bioclasts) such as foraminifera, rudist, calcareous algae and other skeletal grains such as mollusk shell fragments containing Chondrodonta and Echinoderms, whereas non-skeletal grains such as Peloids and ooids are less prevalent.

According to the petrography examination of the Mishrif Formation, fossils predominate in the formation; four families of these fossils are identified: Oligosteginids, Alveolinids, Dicyclina, and Miliolids. Microfacies that pertain to the Mishrif Formation may be found and used to develop a sedimentary model (Al-Ali et al., 2019). The Mishrif Formation is a large reservoir in the Halfaya Oilfield and one of the most important carbonate reservoirs in central and southeastern Iraq (Al-Baldawi, 2020) performed a research in which they calculated the velocity deviation log for the Mishrif carbonate reservoir in two wells in the Halfaya oil fields (HF-1 and HF-2) by translating porosity-log data into a synthetic velocity log using a time-average equation. A velocity-deviation log, which is derived by combining a sonic log with a neutron-porosity or density log, offers a method for acquiring downhole data about the primary pore types in carbonates. These data may be utilized to monitor the dispersion of diagenetic processes downhole as well as their influence on secondary porosity trends. A total of seven diagenetic processes were identified in the Mishrif Formation, each of which had both positive and negative effects on the reservoir quality; dissolution and neomorphism (recrystallization) had highly positive effects on the reservoir quality by increasing porosity and permeability and, as a result, leading to an improvement in the quality of the reservoir. Cementation, micritization, and compaction had detrimental impacts on the reservoir by lowering porosity and permeability, which resulted in a decrease in the overall quality of the reservoir. Other processes, such as dolomitization and authigenic minerals (pyrite), did not have a significant influence on the quality of the reservoir (Chafeet et al., 2020).

Within the Mishrif succession, microfacies study revealed the presence of six major Paleoenvironments: basin, slope, shoal, Rudist biostrome, rear shoal and lagoon (Nasser, 2021). It is the continuous deposition of shallow marine carbonates. Iraq's most prolific period contains over 80% of the country's oil reserves. Three reservoir units make up the formation (MA,MB,MC). The MB unit is divided into two secondary units (MB1 and MB2), while the MC unit is also divided into two secondary units (MC1 and MC2) (Fadel and Nasser, 2021). It is the largest important carbonate reservoir in southeast Iraq, with 32 structures containing oil (Kareem et al., 2021). Halfaya oil field is one of them. This study aims to determine the microfacies of the formation with a statement of the effect of the various modification processes on the petrophysical properties of the reservoir units.
Fig. 1. Cretaceous stratigraphic column of Halfaya oilfield (M. O. C, 2013).

Fig. 2. Regional Facies Distribution (M. O. C, 2013).
2. Location of the Study Area

X Oilfield is a huge oilfield in southern Iraq (Fig. 3), roughly 400 kilometres from Baghdad, with bioclastic limestone as the principal producing zone. It emerges as a large and moderate long-axis anticline with NW-SE tendencies in the foredeep region of the southern Mesopotamian Basin, formed during Neogene Zagros orogenic migration (Aqrawi et al., 2010).

**Fig. 3.** (a) The location of a study area in Iraq and its regional structure (Al-Juboury, 2009); (b) Enlarged of a study area in a.
3. Materials and Methods

Facies analysis and Diageneses of the Mishrif Formation were analyzed using more than 30 thin section of cutting sample from X and 20 thin sections provided by M.O.C (Missan Oil Company), and the facies discovered in this study were traced vertically using various logs (Fig.4). The classification used in this study is the Dunham classification (1962) (Dunham, 1962) modified by (Embry and Klovan, 1972) for its ease of application on the facies of the study area and for its usefulness in showing different types of tissues depending on the clay or granular support.

![Fig.4. The succession of facies association and log response for Mishrif Formation at X.A well](image-url)
4. Facies Association

In the Mishrif succession, five facies associations have been identified: basin facies, slope facies, shallow open marine, rudist, and shoal biostrom as the following. The figure below shown the study area from these facies.

4.1. Facies Associated (Basin Facies Environment)

It consists of the Planktonic Foraminiferal Lime Mudstone microfacies such as Globigerina and Oligostegina, as well as the microfacies of the Planktonic Foraminiferal Wackestone – Packstone microfacies Oligostegina, in addition to some pieces of mollusk shells and broken echinoderms, and through the study of the rocky slides of the facies sequence. The presence of facies in this environment was observed at the base of the formation and near its cusp, which indicates a deep and calm environment characterized by the control of Macarit filling the voids at the base and the compartments inside the fossils. It was also possible to observe a small number of benthic foraminifera such as Milolid in addition to Ostracod, Brachopod and its presence with the Planktonic foraminifera. (Plate 1A).

4.2. Facies Associated (Slop Facies Environment)

It includes the upper and lower slope facies, the lower part of which is located within the environment of the deep platform or the external deep sidewalk, while the upper part of it is located within the environment of the shallow open platform, and the size of the structural granules increases from the bottom to the top of the slope. The lower part consists of Lime Wackestone microfacies and sometimes Mudston or Packstone microfacies with fine skeletal grains with some dimples, Planktonic foraminifera, and spongy thorns (Plate 1B&C), while the upper part consists of wackys limestone and sometimes Packstone with coarse skeletal grains containing shellfish-type mollusks (Rhodesian crumbs). Cephalopods, some echinoderms, ostracods, and shells from fossilized shells. The upper part also has some large benthic foraminifera such as the (Praelveolina and Dicyclina) this benthic foraminifera may live in the back-reef (Plate 1C).

4.3. Facies Associated (Shallow Open Marine Environment)

Through the study of the rock segments and the response of the probes to them, it was found that the microfacies of this environment were concentrated in the central region of the formation and contain facies of Lime Wackestone – Packstone, Lime Mudstone – Wackestone, bioclastic Lime Wackestone, and Packstone – Grainstone. This microfacies is characterized by its containment of Planktonic foraminifera like (Oligosteginids, Globotruncanca, Hedberyella washitensis) (Plate 1D). These foraminifera decrease as we move upwards, and in contrast the benthic foraminifera, whose proportion increases as we move upward and includes Dicyclina schlumbergeri, Pseudolituitella reicheli, Pseudotextularia, Praevalveolina, Spiropiectammina, Milolid, Nezzazata, Textularia. It also includes many organic detritus of algae, echinoderms, mollusks, corals and ostracodes, and many boilies of different sizes. These microfacies all refer to the shallow marine environment with high water currents (Wilson, 2012).

4.4. Facies Associated (Shoal Facies Environment)

They include microfacies of Packstone – Grainstone microfacies distinguished by their high content of mollusks, mainly Rudist nuts, oyster shells, parts of coral, and echinoderms, with a few benthic foraminifera such as Milolid, Nezzazata, Dicyclina, Chrysalida, etc. In addition to the presence of some boils. The facies of fords overlap with the facies of the Rudists (Plate 1D &E), and it is difficult
to distinguish or define the boundaries between these two facies sometimes. The microfacies of this environment were characterized by porosity and high permeability, and their deposits are in a high water energy environment (Sadooni and Aqrawi, 2000).

4.5. Facies Associated (Rudist Biostrome Environment)

Grainstone and Packstone – Grainstone microfacies consisting mainly of Rudisian nuts or containing a high abundance. The medulla and a few of the benthic foraminifera such as (Miliolid, Nezzazata, Dicyclina, Chrysaldina, Pseudolituonella). This facies appeared in the middle and upper parts of the studied sections. This facies refers to a high-energy environment characterized by permeability and high porosity, and these reservoir characteristics decrease towards areas behind the reefs and areas near the lagoon as a result of the increase in the carbonate clay materials present in them. It was noted that the rudist of this facies did not exist in its complete form, but rather in the form of nuts of large and irregular shells, (Plate 1F) which indicates that it was deposited in or close to the growth site (Reulet, 1982). It was possible to distinguish the standard microfacies 11. Within the divisions of Wilson (Wilson, 1975).

5. Diagenetic Processes

Several diagenetic processes influenced on Mishrif Formation at three distinct stages: marine, near-surface, and deep burial. Micritization, Cementation, Leaching (dissolution), Dolomitization, and Compaction are the most prevalent diagenetic characteristics seen in the studied sections (50 thin section). The most effective diagenetic processes are dissolution and dolomitization.

5.1. Micritization

Micritized skeleton fragments are abundant in Mishrif Formation's bioclastic wackestones and packstones microfacies. Skeletal grains were micritized shortly after deposition, which is an early diagenetic event (Aqrawi et al., 1998), (Plate 2A&B).

5.2. Dissolution

Dissolution occurs when a rock-water system is out of balance. In this situation, the water is undersaturated in CaCO₃. Meteoric water, for example, dissolves CaCO₃ until the rocks and water reach saturation equilibrium (Ahr, 2008). After mineral stabilization, dissolution can happen at any point during the carbonate sequence's burial history (Moore et al., 2004). Non-fabric-selective dissolving, in which the emerging pores cut through all fabric constituents, including matrix, cement, and grains, is the most common symptom (Moore, 2004). Dissolution impacts all types of deposits and is a common diagenetic process. Porosity in carbonate rocks is formed as a result of this process. Primary porosity and secondary porosity are the two main types of porosity based on the time of formation. The Mishrif Formation is one of southern Iraq's most important reservoirs because dissolution is responsible for producing secondary porosity such as moldic, channel, fracture, and vuggy porosity, as well as strengthening previous interpartical and/or intrapartical primary porosity (Plate 2D).

5.3. Dolomitization

It is a method of converting limestone or its precursor sediment to dolomite by replacing the original CaCO₃ with magnesium carbonate under Mg-containing water. Porosity rises gradually in the early phases of dolomitization of limestone but rises quickly as the amount of dolomite increases. The dissolution of accompanying calcite creates intercrystalline porosity, and the dolomite exhibits a sucrosic
structure formed of equally-sized rhombohedra at this stage (Flügel, 2004). (Plate 2E) In carbonate rocks, there were various types of dolomite texture.

5.4. Cementation

Cementation is a diagenetic process that sparsy calcite fills porosities and voids during deposition by filling the interpartical porosity or after deposition by filling dissolution porosities or fractures and joints caused by compaction. In the Mishrif Formation carbonates in a study area, two forms of cements have been identified. Syntaxial rim cement It thrives in shallow open marine deposits and shoals with a high energy level. Echinoderms do not have a rim cementation in lower energy deposits with rich micrite (Mason and Moore, 1975). This type of cement was discovered as syntaxial growth of calcite particles on echinoderm fragments, indicating that it was an early fresh water phreatic cement, and Granular (Blocky) Cement Granular calcite cement occludes extensive pores, vugs, and fractures in various facies and is characterized by large subhedral crystals with no discernible growth direction. Granular (blocky) cement forms as a result of meteoric influence during late diagenesis (Flügel, 2004). The crystals' huge size and clear appearance reflect their gradual crystallization in saturated solution, which occurred late in the diagenetic history (Plate 2F & Plate 3A, B).

5.5. Recrystallization

Recrystallization is a method of altering crystal shape without affecting mineral composition significantly (Ahr, 2008). Because many of its original elements are extremely reactive and unstable, carbonates are more prone to modification than other rocks (Folk, 1981). Some of the formations defined by the transition of micrite to microsparite were affected by this process (Plate 3B & C).

5.6. Stylolitization

Stylolites are the result of pressure solution, which involved solution around points of contact between grains in response to pressure, types two and three have been observed in the Mishrif in the current study. The stylolitic joints are abundant in shallow open marine deposits (wackstones with abundant micrite); however, they have not been observed or have been seen in shoal and rudist biostrom deposits grainstones or packstones microfacies (Plate 3D).

5.7. Compaction

The Mishrif Formation's dominance of mud-supported fabrics, combined with a thick overburden, resulted in considerable compaction. Mudstones and wackestones can include fragments of large skeleton grains. Compaction of muddy calcareous sediments starts immediately after deposition and increases as the overburden accumulates (Plate 3E, F).
Plate 1. (A) Hedbergella sp., calcisphere and ostrocoda in planktonic wackestone (MB2, X.A Well, 3015-3020 m, X10); (B) sponge spicules and som fragment (MC, X.B Well, 3160-3165, X10); (C) Benthic foraminifera (Tabrana bingstani) with calcisphere and sponge spicules in bioclastic foraminifral wackestone (MC, X.C Well 3106 m, X10); (D) Rudist affected to dissolution in rudistone (MC, X.C Well, 3150-3152 m, X40); (E) Different shapes of rudist (MC, X.C Well, 3084 m, X40); (F) Gastropod shell (MC X.C Well, 3086) (100x)
Plate 2. (A) Compaction and pressure solution (stylolization), (MB2 X.A Well, 2975-2980m) XPL; (B) Dolostone, dolomitization diagenesis, (MC X.A Well, 3120-3125m) XPL; (C) Solution diagenesis, (MB2 X.B Well, 3090-3095m) XPL; (D) Solution diagenesis, (MC X.D Well, 3206m) XPL; (E) Dolomitization diagenesis, (MB2 X.E Well, 3070-3072m) XPL; (F) Bocky calcite cement (MB2, X.F Well, 3325 40 x).
Plate 3. A) Blocky cement (MB1, X.E Well, 2962-2964m, X40); (B) Recrystallization of blocky cement, (MB2 X.F Well, 3325m), XPL; (C) Recrystallization of micrite to sparite, (MB1 X.E Well 3950-3952m), XPL; (D) Stylolite with dolomite (MB1 X.E Well, 2942-2944m, X10); (E) Compaction and pressure solution (stylolization), (MB2 X.A Well, 2975-2980m) XPL; (F) Compaction and pressure solution (stylolization), (MC, X.E Well, 3114-3116m) XPL.

6. Discussion

The thin section available for the Mishrif Formation have been studied. Where the study is one of the important means used in the study of the delicate rocky components and to define the basic components of the rocks and the diagenesis processes prevailing in them and thus give a picture of the facies nature of the rocks and the geological events that have passed through them and their sedimentary environment. And based on previous studies and using the Dunham classification system (Dunham, 1962) modified by (Embry and Klovan, 1972) in determining the dipositional fabric and describing the rock components, and thus the rocky facies and their types were identified, as well as the diageneses processes were identified.
7. Conclusions

Microfacies analyzes of the Mishrif Formation were studied through thin sections and different Logs, distinguished the presence of five main paleoenvironments, basin facies, slope facies, shallow open marine, shoal facies, rudist biostrom facies. Carbonate rocks are considered highly effected by the diagensis process Many diagensis process have been diagnosed as follows:- micritization, dissolution, dolomitization, cementation, recrystallization, stylolitization and compaction). Recrystallization and dolomitization dissolution are the most effective diagensis processes. These processes had influential role in multiplying and type increasing microfacies especially at the reservoir units MB1 and MB2.

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