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FACTORS CONTROLLING SANDSTONE RESERVOIR PROPERTIES OF CRETACEOUS NAHR UMR FORMATION IN HALFAYA OILFIELD, IRAQ

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Abstract: Based on core observation and casting thin section identification, combined with physical properties, scanning electron microscopy, X-ray diffraction analysis, mercury intrusion experiment, etc., the physical properties and controlling factors of sandstone reservoirs in the Cretaceous Nahr Umr Formation in Halfaya Oilfield, Iraq were discussed.. The results show that the tidal-controlled delta facies sandstone reservoirs in the B member of the Cretaceous Nahr Umr Formation in the Halfaya Oilfield have the physical properties of medium pores and medium permeability. The pore types are mainly intergranular pores and dissolution pores, and the pore throats vary greatly. Strong homogeneity; the controlling factors of reservoir physical properties include sedimentation and diagenesis. Sedimentation affects the type of pore space and pore structure. Reservoirs with good physical properties are developed in areas with strong hydrodynamic conditions and good rock component structure characteristics. In the reservoir, diagenesis has significantly modified the physical properties of the reservoir. The compaction and cementation have caused a large number of pores to be filled. The authigenic minerals and clay minerals not only reduce the pore space, but also cause the pore throat to be blocked and the physical properties to deteriorate., and the secondary pores produced by dissolution improve the physical properties of the reservoir; the best quality reservoirs are developed in the cross-bedding sandstone of tidal-controlled distributary channel facies, which have large particle size, good sorting, high relative content of quartz, The characteristics of low clay mineral content, low cement content, well-developed pores, and large pore throat radius correspond to medium-high porosity and high permeability, which is the focus of reservoir characterization and modeling in the study area.
Keywords: Sandstone reservoir; Physical properties; Controlling factors; Tidal-controlled delta; Nahr Umr Formation; Cretaceous; Halfaya Oilfield; Iraq

1 INTRODUCTION

At present, domestic and foreign scholars' research on Cretaceous reservoirs in Iraq mainly focuses on its classification, genesis, diagenesis, reservoir quality, physical properties, pore structure and influence on reservoir development characteristics, etc.[1-12]. Among them, the research objects of domestic scholars mainly focus on typical oil fields in Iraq, such as Rumaila, Halfaya and Al-Ahdab, and the research content focuses on porous carbonate reservoirs, while the research on sandstone reservoirs in Iraq is relatively scarce. [13－17]. The Nahr Umr Formation is the main sandstone reservoir in Iraq[18-22]. Foreign scholars began to explore the reservoir in 1949[23]. The deposits are mainly medium and fine-grained sandstone and mud shale[24-25]. The sedimentary thickness of the Nahr Umr Formation varies with the structural position, mainly 100-200m[26]. The depositional environment of the Nahr Umr Formation is a typical marine-continental transitional environment, with tidal-controlled delta and shallow coastal sandstone deposits developed at the same time, and the physical properties of the reservoirs are medium porosity, medium and high permeability[27-28]. However, the current research shows that the porosity and permeability of different types of reservoirs in the Nahr Umr Formation are significantly different, showing strong heterogeneity[29], and the porosity-permeability relationship does not follow a single linear relationship, which affects the permeability of non-cored wells. Rate characterization poses challenges, causing uncertainty in reservoir physical property prediction and exacerbating difficulties in subsequent infill well deployment. In order to solve the above problems, it is necessary to clarify the controlling factors of the sandstone reservoir physical properties of the Nahr Umr Formation, introduce reservoir parameters that control the porosity-permeability relationship of the reservoir to finely characterize the physical properties of the reservoir, and reduce the uncertainty of reservoir quality characterization. Based on the experimental data of coring well cores and related reservoir parameters in the Halfaya Oilfield, Iraq, this paper analyzes the sedimentary microfacies, petrological characteristics, clay mineral content, diagenesis, and microscopic pore structure characteristics of the Halfaya Oilfield in Iraq. The control factors of the physical properties of the tidal-controlled delta facies sandstone reservoirs in the Cretaceous Nahr Umr Formation were studied in order to provide reliable geological basis for the heterogeneity characterization and 3D geological modeling of the reservoirs, and further guide the subsequent adjustment of development plans.

1.1 Regional Geological Situation

Halfaya Oilfield is located in Missan Province in southeastern Iraq, 400km away from Baghdad, the capital of Iraq. It is a giant oilfield with bioclastic limestone as the main production layer. Structurally, it is located in the foredeep belt in the southern part of the Mesopotamia Basin, with a NW-SE broad and gentle long-axis anticline as a whole, and was formed during the Neogene Zagros Orogeny. The basement is composed of Precambrian crystalline metamorphic rocks, Lower Cambrian metamorphic rocks and pyroclastic rocks. Since the Cambrian, southeast Iraq has been on the northern margin of the ancient Gondwana continent for a long time, and mainly developed platform-type deposits; the Cretaceous tectonic activities were generally weak, mainly developing shallow marine shelf carbonate rocks, especially large-scale biological deposits. Detrital limestone[22]; 7 sets of oil-bearing formations developed vertically, the main oil-producing formations are the limestone reservoirs of the Cretaceous Mishrif Formation, followed by the sandstones of the Neogene Jeribe Formation, the Paleogene Upper Kirkuk Formation and the Cretaceous Nahr Umr Formation Reservoir (Fig. 1). Among them, Jeribe Formation and Upper Kirkuk Formation are a set of development strata, referred to as JK strata. The sum of production of the three sets of oil producing layers in Mishrif formation, JK formation and Nahr Umr formation exceeds 90% of the total production of the oilfield. The paleogeomorphology of the NahrUmr Formation during the sedimentary period was a wide and gentle slope high in the west and low in the east. The provenance came from the denudation area on the west side of the study area. The sandstone gradually became thinner from west to east and transitioned to carbonate rock. Its overall thickness was about 250 m, of which The sandstone section (B section of Nahr Umr Formation) is 40~70m thick. The B member of the Nahr Umr Formation deposited in the early Nahr Umr Formation in the Halfaya Oilfield belongs to the tidal-controlled delta facies fine-grained clastic rock deposits (Fig. 1). Neritic carbonate platform limestone developed[23]. At present, a total of 46 wells have encountered Nahr Umr Formation formations in the study area. Among them, Well A1 has continuously taken cores from the sandstone of the B member of Nahr Umr Formation, and completed reservoir physical properties, mercury injection experiments, casting thin-section observations under microscope, and particle size analysis., X-ray diffraction analysis and other reservoir core laboratory experiments. The figure is quoted from literature [24] with some modifications.

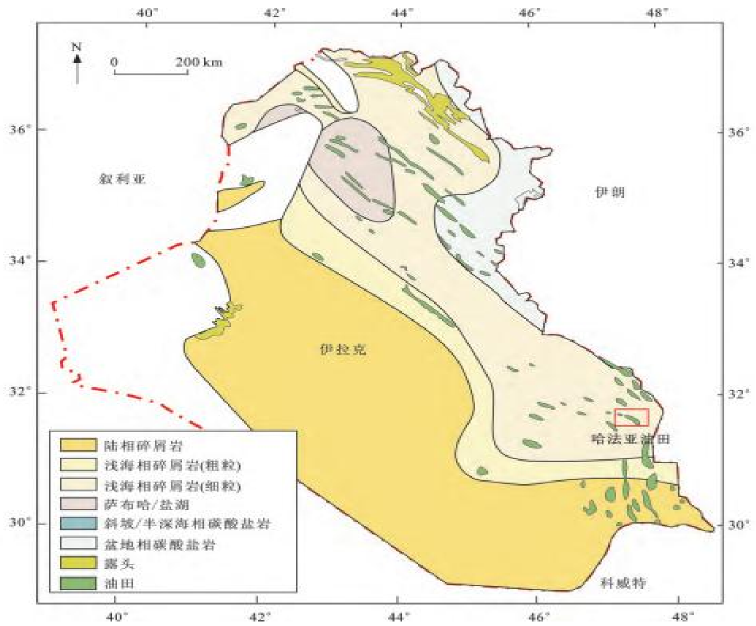


Fig. 1 Regional sedimentary background of Cretaceous Nahr Umr Formation in Halfaya Oilfield, Iraq

2 SEDIMENTARY ENVIRONMENT AND RESERVOIR LITHOFACIES DIVISION

According to the study of regional sedimentary background, the composite depositional environment of tidal-controlled delta facies and shallow littoral-facies clastic rocks in the Cretaceous Nahr Umr Formation of the Halfaya Oilfield in Iraq was determined [30]; Rock composition, structure, structure and vertical evolution sequence, and confirm its logging facies signs. A total of 13 types of lithofacies were identified in the study area, and 6 types of sedimentary microfacies were classified. On this basis, 4 types of main reservoir rocks were determined by combining the oil-bearing occurrence and production dynamics of cores (Table 1). Among them, the division scheme of sedimentary facies and sedimentary-corresponding lithofacies combination mainly refers to the tidal-controlled delta facies model and sedimentary facies combination of Dalrymple et al. [31-32] and the shallow littoral facies clastic rock depositional model of Bergman et al. [33].

The core of the Nahr Umr Formation in the Halfaya Oilfield contains a lithological sequence of pebbled sandstone-sandstone-argilly sandstone-silty mudstone (Msl)-mudstone (Ms), which can be subdivided into 13 types according to grain size and structure characteristics. The types of lithofacies are pebbled sandstone, massive sandstone (SMI), parallel bedding sandstone, low angle cross bedding sandstone, cross bedding sandstone (Sxl), wavy bedding sandstone (Sfl), bioturbation sandstone (Sb), bioturbated argillaceous sandstone (Sba), bioturbated cross bedding argillaceous sandstone (Sclb), bioturbated sandy mudstone (Msb), horizontally bedding silty mudstone (Msltl), massive mudstone and horizontal bedding manage mudstone. Among them, cross-bedding sandstone, wavy bedding sandstone, bioturbation argillaceous sandstone, and bioturbation cross-bedding argillaceous sandstone are thicker, and the oil-bearing occurrences of cores generally reach the level of oil immersion-oil saturation, which are the main rocks in the reservoir. phase type. According to lithological characteristics, lithofacies combination relationship and corresponding well logging response, six sedimentary microfacies types were identified: tidal-controlled distributary channel, mouth bar, inter-bay, near-shore, transition zone and off-shore shallow sea.

Table 1 Classification of lithofacies, sedimentary microfacies and reservoir rocks of Nahr Umr Formation

Lithofacies	Sedimentary microfacies type	Reservoir rocks	Oily occurrence	Perforation section meter oil production intensity / (t · m－1 · d－1)
pebbled sandstone			oil free	
parallel bedding sandstone	tidal control distributary channel		Enriched with oil — oil immersion	120~200
undulating bedding sandstone		undulating bedding sandstone	Oily — rich in oil	
cross bedding sandstone		cross bedding sandstone	Oily — rich in oil	
low angle cross bedding sandstone				
massive sandstone	Linbin		oil stains - oil stains	
bioturbation sandstone		bioturbated argillaceous sandstone	oil immersion - oil spots	15~40
bioturbated argillaceous sandstone	transition zone		Oil Stains - No Oil	
bioturbated cross-bedding argillaceous sandstone	Mouth bar	bioturbated cross-bedding argillaceous sandstone	oil immersion	50~90
Silty mudstone	Jianwan, Binwai Shallow Sea		oil free	
mudstone			oil free	

Based on comprehensive lithofacies description and sedimentary microfacies core-logging facies characteristics, combined with the occurrence of core oil and the production situation of the corresponding perforation section, 4 Types of main reservoir rocks (Table 1). According to oil occurrence and oil production intensity per meter of perforation interval, the order of reservoir lithofacies from good to poor is: tidal-controlled distributary channel facies cross-bedding sandstone, tidal-controlled distributary channel facies wavy bedding sandstone, and mouth bar facies bioturbation cross-bed argillaceous sandstone and bioturbated argillaceous sandstone of coastal facies.

3 RESERVOIR PHYSICAL PROPERTIES AND THEIR CONTROLLING FACTORS

Focusing on drilling and coring, based on core observation, comprehensive physical properties, casting thin-section observation, X-ray diffraction analysis, particle size analysis and mercury intrusion experiment results, the controlling factors of reservoir physical properties are analyzed, and the sedimentary microstructure is mainly discussed. Facies, petrological characteristics, clay mineral content, diagenesis and microscopic pore structure characteristics control the reservoir physical properties.

3.1 Sedimentary Microfacies

The physical parameters of the reservoir are derived from the core laboratory experiments. The porosity and permeability of the core are measured by conventional physical property experiments, the porosity is measured by the helium method, and the permeability is measured by the pulse method. The core samples are standard embolism rock samples, the sampling depth is 3646.90~3693.08m, and the total number of samples is 103. The experimental results show that the sample porosity is 1.70%~23.34%, with an average of 14.44%; the permeability is (0.078~2 604.544)×10-3 μm2, with an average of 379.794× 10-3 μm2.
According to the sedimentary environment and reservoir lithofacies division results, the sedimentary microfacies of Cretaceous Nahr Umr Formation B member in Halfaya Oilfield can be divided into six types: tidal-controlled distributary channel, inter-bay, mouth bar, nearshore, transition zone, and offshore shallow sea. deposited microphase. Putting the physical property analysis results of core samples of different sedimentary microfacies into the scatter plot, the results show that: the tidal-controlled distributary channel facies has the characteristics of high porosity and high permeability, and has the best physical properties; the coastal facies has medium-high porosity, medium-low The mouth bar facies has the characteristics of medium porosity and low permeability, followed by physical properties; the interbay facies and transition zone have the characteristics of medium and low porosity and low ultra-low permeability, and the offshore neritic facies has the characteristics of low porosity and low permeability, and the physical properties are the worst. ⑤ Offshore neritic facies. The hydrodynamic conditions are weak, and the sampling lithology is dominated by

silty mudstone with low porosity and low permeability. It should be pointed out that since the object of this study is sandstone reservoirs, the mudstone developed in the offshore neritic facies was not involved, so the core test sampling points of the offshore neritic facies only partly reflect the physical properties of the sedimentary microfacies.

3.2 Petrological Features

According to the results of depositional environment and reservoir lithofacies classification, the main reservoir rocks of the Cretaceous Nahr Umr Formation in Halfaya Oilfield include 4 types. The observation results of thin sections of typical samples show that: ① Tidal-controlled distributary channel facies. Sufficient source supply, strong hydrodynamic force, under the reciprocating erosion of rivers and tides, the rock particle size is larger, the particle sorting is better, the content of clay minerals is low, and the mineral type is mainly quartz, supported by particles and cemented. The effect is relatively weak, therefore, the physical properties are the best among all sedimentary microfacies; ②The coastal facies. Inferior to the tidal-controlled distributary channel facies, due to less terrigenous supply, the content of clay minerals is relatively low, but the content of carbonate rocks in the coastal facies increases, the content of carbonate rock cements increases, and the later dissolution, resulting in its Physical properties of medium -high porosity and medium-low permeability; ③ Mouth bar facies has relatively sufficient source supply, strong fluvial action and weak tidal action, rock grain size and sorting are slightly worse than tidal-controlled distributary channel facies, Due to sufficient terrigenous supply and relatively high content of clay minerals, and because it is far away from the depositional environment of carbonate rocks, the content of cement in carbonate rocks is lower than that of the adjacent facies, so that it has the physical characteristics of mesopores and low permeability;④ The interbay facies and the transition zone have less terrigenous supply, weak hydrodynamic force, and small rock grain size. Among them, the interbay facies is mainly controlled by fluvial processes, and the content of clay minerals is high. As a result, its physical properties deteriorate, the transition zone is mainly close to the marine sedimentary environment, and the content of carbonate rock cement is relatively high, resulting in its physical properties being tidal-controlled distributary channel facies cross-bedding sandstone, tidal-controlled distributary channel facies wavy bedding sandstone, Estuary bar facies bioturbation cross bedding argillaceous sandstone, and coastal facies bioturbation argillaceous sandstone. The controlling effect of petrological characteristics on reservoir physical properties discussed in this study mainly includes three aspects: lithofacies type, mineral composition and grain size.

3.2.1 Lithofacies type

Putting the test results of physical properties of core samples of different lithofacies into the scatter plot, the results show that: cross-bedding sandstone and wavy bedding sandstone have the characteristics of high porosity and high permeability, and have the best physical properties; bioturbation cross-bedding sandstone The argillaceous sandstone has the characteristics of medium porosity and medium permeability, followed by physical properties; the bioturbation argillaceous sandstone has the characteristics of medium-low porosity and low permeability, and the physical properties are the worst. Because lithofacies are closely related to sedimentary microfacies, the controlling effect on reservoir physical properties is also consistent. Cross-bedding sandstone and wavy bedding sandstone are mainly developed in tidal-controlled distributary channel facies, in which the hydrodynamic conditions for the development of cross-bedding sandstone are slightly stronger than those of wavy bedding sandstone, and their physical properties are better; bioturbation cross-bedding argillaceous sandstone is mainly Developed in the mouth bar facies, the hydrodynamic condition is weaker than that of cross-bedding sandstone and wavy bedding sandstone, the grain size is finer, and the sorting becomes worse due to bioturbation, and its physical properties are worse than that of cross-bedding sandstone and wavy bedding sandstone ; The bioturbation argillaceous sandstone is mainly developed in the coastal facies, with the weakest hydrodynamic conditions, the finest grain size, high clay mineral content, and the deposition location is closer to the shallow sea, and the carbonate rock cement content increases significantly. Among the above four types of reservoir rocks, the bioturbation argillaceous sandstone has the worst physical properties.

3.2.2 Mineral components

According to the X-ray diffraction whole-rock mineral composition analysis, the quartz content (volume fraction, the same below) in the mineral composition is 9.46% ~ 97.15% (78.94% on average), and the potassium feldspar is 0%. ~4.06% (average 0.37%), plagioclase 0%~0.47% (average less than 0.01%), calcite 0%~8.2% (average 0.24 %), dolomite/iron dolomite is 0%~23.06% (2.53% on average), siderite is 0%~61.11% (3.69% on average), pyrite is 0%~11.78% (average 1.60%), anhydrite 0%~0.61% (average 0.13%).

3.2.3 Granularity

The results of particle size analysis show that mineral particles with a particle size of 45-1 000 μm account for more than 95% of the total mineral particles; the median particle size is 108.81-223.67 μm, and the φ value is 2.16-3.20, which belongs to fine sand Range; the sorting coefficient is 0.38~1.15, the sorting is medium-good; the skewness of the particle size distribution is -0.18~0.13, and the particle size distribution is relatively concentrated.

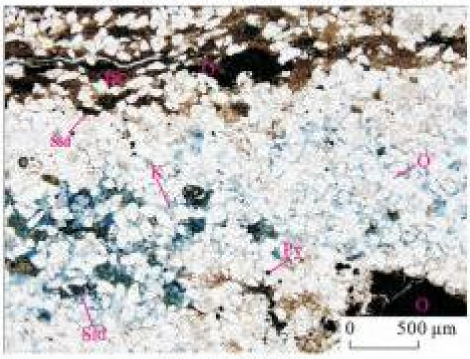
It can be seen from the median particle size-permeability scatter diagram of the core that the median particle size has an obvious positive correlation with permeability, and the permeability increases with the increase of the median particle size. According to the different clay mineral content of each core sample, it can be further divided into two regions: when the clay mineral content is low (<5%), the data distribution of the median particle size and permeability is more concentrated, and the correlation is better ; When the content of clay minerals is high (>5%), the data distribution of the median particle size and permeability is scattered, and the correlation is slightly worse. In addition, at the same median particle size, a higher content of clay minerals also leads to a decrease in permeability.

It is dominated by bioturbation argillaceous sandstone and bioturbation cross bedding argillaceous sandstone. Bioturbation affects the original deposition, resulting in changes in reservoir physical properties[34]. The relative quartz content of the core reflects the strength of hydrodynamic forces during deposition: the relative quartz content of cross-bedding sandstone and wave-bedding sandstone is high, combined with cast thin sections, the mineral grains of these two types of sandstones are relatively poor in sorting and rounding. Well, it represents high compositional maturity and high structural maturity, indicating that the depositional environment of these two types of sandstones has strong hydrodynamic forces, which have a favorable impact on physical properties; The relative content is also high, but the mineral particle sorting and rounding of these two types of sandstones are poor. This high compositional maturity and low structural maturity indicate that the sedimentary hydrodynamic conditions of these two types of sandstones are relatively weak. The impact of this effect has resulted in a decrease in the permeability of some samples; the sedimentary environment corresponding to the silty mudstone has the weakest hydrodynamic force, the smallest relative content of quartz, and the worst reservoir physical properties.

3.3 Clay Mineral Content

According to the results of X-ray diffraction clay mineral experiment, the clay mineral content is 1.69%~49.07%, with an average of 11.8%. Among the clay minerals, the relative content of illite is 0%-22.2%, with an average of 6.7%; the relative content of kaolinite is 24.1%-100.0%, with an average of 70.3%; chlorite The relative content ranges from 0% to 59.2%, with an average of 12.2%; the smectites are all transformed into illite-smectite mixed layers, with a relative content of 0% to 59.5%, with an average of 10.8%. Putting the data of clay mineral content and permeability in the core into the scatter plot [Fig. 2(a)], the results show that: when the clay mineral content is less than 20%, there is a significant negative correlation between the clay mineral content and the permeability, that is, with As the content of clay minerals increases, the permeability decreases. When the clay mineral content is greater than 20% [the circled part in Fig. 2(a)], the relationship between clay mineral content and permeability changes. This part of the data includes cores from offshore neritic facies, interbay facies and some transitional zones. Observation of casting thin sections [Fig. 2(b)] shows that this type of core shows obvious microscopic heterogeneity[35], although its clay mineral content is relatively high, but it is not evenly distributed in the pores. Instead, they are concentrated in certain positions in the field of view, and a large number of pores can still be seen in the parts with less clay mineral content, which causes the relationship between the reservoir physical properties and clay mineral content of such cores to deviate.

(a) 岩芯黏土矿物含量-渗透率散点图



(b) 典型铸体薄片A

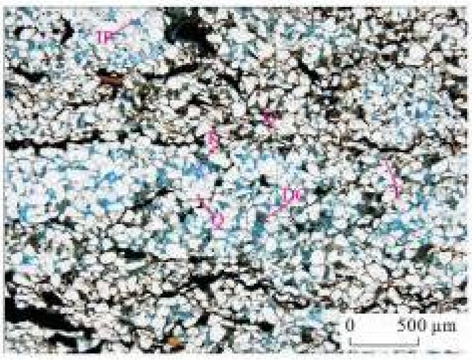


Fig. 2 Clay mineral content-permeability scatter diagram of different sedimentary microfacies cores and photos of typical casting thin sections

3.4 Diagenesis

Diagenesis controls the evolution and distribution of reservoir physical properties. According to the results of cast thin section observation and scanning electron microscope experiment, the Cretaceous Nahr Umr Formation reservoir in Halfaya Oilfield, Iraq has experienced various diagenesis. Starting from the controlling effect on reservoir physical properties, diagenesis is divided into pore-destructive and pore-constructive effects. Among them, the diagenetic effects that are destructive to the core pores mainly include compaction, authigenic pyrite, kaolinite, authigenic siderite, quartz enlargement and andolomite cementation. The constructive diagenetic effect on core pores mainly includes the retention and dissolution of primary intergranular pores.

3.4.1 Compaction

The burial depth of the reservoir is 3 600–3 800 m, and the compaction lasted from the burial to the middle diagenetic stage, and the reservoir experienced strong compaction, showing that the particle contact relationship is mainly line contact, and the particles are arranged closely. Significantly reduced primary intergranular pores. However, in the Nahr Umr Formation B member reservoir, due to high quartz content, better particle sorting, less plastic argillaceous matrix, and higher rock composition and structure maturity, the anti-compaction ability is stronger., still retain a part of the intergranular pores.

3.4.2 Authigenic minerals

The casting thin section and scanning electron microscope can observe the general phenomenon of quartz secondary enlargement. The pore space makes the particle contact relationship closer; at the same time, it can be observed that authigenic pyrite and siderite are distributed between the particles, The porosity is reduced, and some pore throats are blocked, reducing the physical properties of the reservoir. Combined with X-ray diffraction analysis of clay minerals, kaolinite accounts for the vast majority of clay mineral content, and reservoir sensitivity experiments show that kaolinite is mainly velocity-sensitive. Other mineral sensitivities are not significant, which also shows that kaolinite in clay minerals controls the physical properties.

3.4.3 Cementation

The type of cement in the reservoir is relatively single, mainly composed of iron dolomite cement in carbonate rock cement. With the development of the diagenetic stage, anodolomite cementation appeared in large numbers. In the sandstone samples of shallow littoral facies, iron dolomite cements are common; these cements fill the pore space in large quantities, and cause the pore throats to shrink obviously, making the physical properties of the reservoir worse[36].

3.4.4 Dissolution

Observing the pore types, it can be found that a large number of dissolution pores are developed, and organic matter is distributed between the pores. Carry out dissolution and generate secondary pores; provide a constructive effect on the preservation and improvement of reservoir physical properties during the diagenesis process.

3.5 Microscopic Pore Structure Characteristics

The mercury injection test results show that the median pore-throat radius of the core is 0.004-16.616 μm, and the capillary pressure curve is dominated by low displacement pressure, good sorting, and coarse skewness. Putting the core median pore throat radius and permeability data into the scatter plot, the results show that the core median pore throat radius and permeability have a significant positive correlation, which is in line with Poiseuille's law and Darcy's law The formula [37-38] launched by Lianli. Sedimentary microfacies, petrological characteristics, clay mineral content, and diagenesis control the reservoir physical properties. It can be known that the tidal-controlled distributary channel facies has strong hydrodynamics, large grain size, grain support structure, low clay mineral content, and weak cementation. The pore-throat radius is the largest and the physical properties are the best; the sedimentary environment of the coastal facies and estuary bar facies has strong hydrodynamic force, large particle size, particle support structure, low clay mineral content, and weak cementation, making the pore-throat radius larger. Good physical properties; the sedimentary environment of transition zone, interbay facies and off-shore neritic facies has weak hydrodynamic force, small particle size, matrix support structure, high content of clay minerals, and strong cementation, resulting in small pore throat radius and physical properties. poor.

Combining the mercury injection capillary pressure curves of the four types of reservoir rocks, it can be seen that: tidal-controlled distributary channel facies cross-bedding sandstone has the characteristics of well-sorted pore throats, coarse skewness, and optimal pore structure; The pore-throat sorting of undulating bedding sandstone in channel facies is medium-good, medium-coarse, and the heterogeneity of pore structure is stronger than that of cross-bedding sandstone, and the pore structure is better; Throat sorting is medium-poor, medium-fine skewness, pore structure heterogeneity is stronger, and pore structure is medium-poor; the bioturbation argillaceous sandstone in the coastal facies has poor pore throat sorting and fine skewness, and the pore structure is in the The worst among the four types of reservoir rocks. The pore structure characteristics of the four types of reservoir rocks directly control the physical properties, and the quality of the pore structure has a significant correlation with the physical properties.

4 CONCLUSION

(1) The tidal-controlled delta facies sandstone reservoirs in the B member of the Cretaceous Nahr Umr Formation in the Halfaya Oilfield, Iraq, are generally characterized by medium porosity and medium permeability. Sedimentary microfacies, petrological characteristics, clay mineral content, diagenesis and microscopic pore structure All play a different degree of control on the physical properties of the reservoir. Among them, the sedimentation represented by sedimentary microfacies affects the type of pore space and pore structure, and the reservoirs with better physical properties develop in the reservoirs with stronger hydrodynamic conditions and better structural characteristics of rock components. Diagenesis has played a significant role in reforming the physical properties of the reservoir. Compaction

and cementation have caused a large amount of original pores to be filled. The secondary porosity produced by this process improves the physical properties of the reservoir.
(2) The highest-quality reservoirs are developed in cross-bedding sandstones of tidal-controlled distributary channel facies. Under the effect of two-way flow in the tidal-controlled delta, this type of reservoir has the characteristics of large particle size, good sorting, high relative content of quartz, low content of clay minerals, low content of cement, well-developed pores, and large pore-throat radius. The physical properties are medium-high porosity and high permeability, which is the most important object in reservoir research.
(3) The correlation diagrams of various reservoir parameters and physical properties have different numbers of outliers that do not match the overall trend. Combined with the geological characteristics of the study area, it is considered that the geological factor of such outliers is usually the strong microscopic heterogeneity of the reservoir. The main reason for the microscopic heterogeneity is that under the sedimentary background of tidal delta facies, the dual effects of rivers and tides lead to uneven distribution of clay minerals, and the composition of interstitial materials at different depositional locations changes in the transitional environment between land and sea. Layers are modified by bioturbation. The geological origin of these outliers is also closely related to the main controlling factor of reservoir physical properties—sedimentary microfacies.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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