The sedimentary control factors for the cretaceous Mishrif and the tertiary Asmari carbonate reservoirs in southern east Iraq

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Abstract. There are three essential geological factors which interact and restrict each other’s: sedimentation, diagenesis and tectonism, that control the development and evolution of carbonate reservoirs. Regard to karst carbonate reservoir, karstification plays a key role in the formation of carbonate reservoirs by the formation of dissolution pore system; The tectonic movement exposes or upthrow the strata and provides the conditions for karstification. The fractures generated by them can overwhelmingly improve the seepage capacity of carbonate rocks and promote the occurrence of karstification. This paper mainly discuss how sedimentary factors control the development and evolution of carbonate reservoirs in cretaceous Mishrif and tertiary Asmari formations in east southern Iraq.

1. Introduction

The reservoir of cretaceous Mishrif and the tertiary Asmari formation were mainly bioclastic shoal carbonate reservoir or dolomite, and micrite bioclastic limestone or dolomite, which sediment in high energy environment.

The micrite bioclastic limestone or dolomite in open sub-tidal or restricted sea environment not only have the biological characteristics of pure and brittle quality, furthermore, there are massive primary pores in early time and it is easy to break and dissolution in later stage, which is the foundation for reservoir superimposition and reformation.

Core observation also indicates that the development of reservoir rocks has distinct face-controlling characteristics, mainly in grainstone (grain-shoal faces) or dissolve micrite bioclastic limestone. The sedimentary pattern and micro topography changes of cretaceous Mishrif and the tertiary Asmari reservoir controls the favourable zone of the bioclastic shoal play, and indirectly affects the development and distribution of the reservoirs. Due to the studied area connected with continent, and influence of sea level ecstatic, during the sedimentary period and after the sedimentary period, the frequent exposure made hyper gene dissolution happened, the meteoric water on the limestone or dolomite leaching and dissolution, is the key origin of face-controlled karst reservoir. The tectonic fissure have little effect on porosity, but it dramatically improve the permeability of Asmari dolomite.
2. Early research understanding
Many studies[1] have indicated that sedimentation is one of the main factors for reservoir development, especially the continent-connected carbonate platform also controlled by changes in the palaeogeographic pattern result of tectonic activity, Micro topography fluctuation, marine transgression and regression, change of paleo-climate cycle, water medium properties and etc. On the one hand, these sedimentary differentiation made the reservoir early differentiated. On a special condition, the final reservoir characteristics can be decided by reservoir early differentiation. On the other hand, sedimentation is the material basis for diagenesis. Only pure, thicker and coarse-textured carbonates is conducive to diagenetic transformation in the later period. All these factors above controlled the reservoir development, distribution and reservoir quality.

3. Inherited sub water uplift control the development of favourable reservoir facies
To elaborate the formation development and evolution of the continent connected carbonate platform of cretaceous Mishrif and the tertiary Asmari reservoir, we need to start with the view of reservoir dynamic evolution, thoroughly analysed the reservoir development mechanism, and accurately predict the vertical and horizontal distribution of target reservoirs.

Controlled by Alps movement, the Abu Ghirab, Fauqi and Burgan structure is ready and control the depositional framework of the area [2]. It especially controlled the development and distribution trend of interior platform point reef or point bar. As formal study indicated, the developmental cycle is upward shallower sequence of its middle and late stage, mainly constructed on the hard bottom of bioclastic beach. Analogue with the growth environment of modern oysters, it is indicated that the most favourable constructed environment is the high energy zone around average sea level, which located in the high energy environment of upper subtidal zone and the lower intertidal zone. The rudist development closely related to micro geomorphology, only during the period of relative sea level decline, the highland of micro geomorphology could preferential located around the band of high energy which adjacent to the average sea level, and because of the fast building of rudist, which making the characteristic of highland of micro geomorphology more obvious. Therefore, we can use the thickness of reef shoal complex which was form within isochronous geological body to approximate characterize the change of sedimentary period geomorphology. As studied, the distribution of Rumaila rudist shoal is a certain degree of coincide with the present structure. It reveals that the sedimentary period geomorphology of cretaceous Mishrif formation also is a highland. Or to say that during the period of Mishrif, the Rumaila structure is already has a prototype and continuously controlled the depositional pattern of the area.

4. There exists secondary geomorphic differentiation inside inheriting underwater highland, and cause the reservoir a certain degree of lateral heterogeneity
According to the distribution characteristics of the thickness of Drain1 (a high perm zone from MB2\(1\) (Mishrif B2\(1\) sublayer), its thickening area overall distribute along tectonic direction, but there exist a reservoir thickness change at the structure high. For example, there exist several thickening area like BU-27, BU-6~BU-13 and BU-20 well area in the Burgan south. The micro geomorphic highland is favourable area for reef shoal complex. Core observation indicates that it is easy developing pore type reservoir due to the influence of karst overlap transformation. In relatively lower land, which mainly characteristic of bioclastic shoal, possibly develop cretaceous pore type reservoirs due to the influence of karst water.

5. Four levels sea level change control the Mishrif reef, bank dolomite and Asmari relatively pure dolomite, which all having a distinct hierarchy
Core observations from 3 wells and two zonation indicates that the Mishrif reef, bank and Asmari relatively pure dolomite, all having a distinct hierarchy, which mainly were formed in the middle and late stage of four stage sea level change cycle. In layer MB2\(2\) of well BU-22 in Burzurgan Oil field, the reef and beach facies mainly developed in the late stage, while the argillaceous bio limestone and
biological micrite developed in the early and middle stage. The reef and beach facies of MB2\(^1\) were mainly developed in 3 high perm belts of drain1, drain2 and drain3, and the others were open subtidal deposit. But for Asmari formation, due to the control of the environment, wave depth of wave base surface is shorter. As a whole, sedimentary datum was located below the wave base surface. Only during the regressive period, the local highland can nearby the wave base. There is a better exchange of sea water that beneficial to biological growth, and formed relatively pure biological micritic dolomite and micritic biological dolomite, which provide material basis for later karst reconstruction (for example AGCS-24 middle to late stage).

6. Different lithofacies control the changes in the type of reservoir space and the effectiveness of the reservoir

Core observation shows that in Mishrif reef and beach facies and Asmari formation, there are a great diversity of reservoir space type from different lithologies. It is indicated that the sedimentary environment not only controlled the reservoir development, but also controlled the reservoir space type from different lithology faces. The pore throat structure change of different lithology reservoir controlled the effectiveness of the reservoir.

6.1. Rudist facies are mainly cavern type reservoir and have good connectivity

Core observation indicates that rudist limestone developed small dissolution hole, which was form by interframe pore, masking hole and coelom pore (Fig.1). The origin of the cave is relatively isolated, Therefore seldom was filled by karst formed dissociated carbonate sand; But among rudist, mostly was filled by bioclastic limestone, which reservoir mainly is intergranular dissolution hole with good connectivity, and formed drain1 high permeability zone, that easy charged by liquid hydrocarbon.

6.2. The shoal subfacies were mainly intergranular corrosion pore and intragranular hole

For bioclastic shoal subfacies, due to it was formed in the high land above the wave base, and clean up very clean, well developed intergranular pore, also see biological coelom pore(Fig.1~2). Because of the good connectivity of intergranular pore, these reservoirs mostly formed high permeability layer, which has a distinct oil show on the core. As analysis before, this kind of reservoir was mainly control by sea level change. The 3 high perm zone of Drian1, Drain2 and Drain3 of the main produce layer MB2\(^1\) which mainly were formed in the middle and late stage of four stage sea level change cycle, mainly is rudist grainstone facies. But due to the ups and downs of the micro geomorphology, the 3 high perm zones relatively lower finished that the relative increase in biological biostrome, inner granular pore and cavity whole proportion relatively increase and made its permeability decreased.
A) See intergranular corrosion vugs, 3921m. Well Bu-22

B) See intergranular corrosion vugs and organism pore, oil bearing, 3915.4-3915.8m, Well Bu-22

**Figure 2. Intergranular pore and intragranular pore in bioclastic limestone**

A) Bioclastic limestone, 3929.5m, Drain2m, Well Bu-22

B) Matrix, intergranular corrosion vugs 3929.5m, Drain1, Well Bu-22

C) Mixed fillings inside piebald corrosion vugs; Drain1, well Bu-22

**Figure 3. Intergranular pore and intragranular pore in bioclastic limestone**

Due to the exposure of karst of late MB21 and a good intergranular pore connectivity, Karst water is flowing in the shape of overflow in intergranular pore, which could make this rock reconstructed by atmospheric fresh water and formed chalking. In the meantime expended intergranular pore to intergranular corrosion vugs or followed channels, and was filled by dissociative carbonate sand and fine-grained insoluble residue, but the reservoir space type were intragranular dissolution formed by intergranular corrosion vugs and karst (Fig.3 ~ 4).
6.3. Open subtidal subfaces mainly are argillaceous bio-limestone and biological micrite with intragranular dissolution pore and matrix dissolution pore

6.4. The lithology of the granophyre oil bearing system of open subtidal subfacies have a great difference compared with the matrix which indicate that it possible a late genesis

For open sub-tidal subfacies mainly are argillaceous bio-limestone and biological micrite, although the log interpretation and core observation indicates a large amount of matrix pore and which reservoir space are mainly intragranular dissolved pore and coelom pore (Fig. 5). But oil bearing granophyre is obviously grainstone, which distinguished from low energy environmental sediments, hinting possible a late genesis (Fig. 7). From the oiliness of granophyre and matrix, granophyre is mainly intergranular dissolution hole with better pore connectivity. The Infiltration system is superior and above the OWC and oil saturated. But for matrix, mostly are independent intragranular dissolution pore and coelom pore with bad connectivity which not good for the filling of liquid hydrocarbon. Core observation indicates besides Drain1, Drain2, Drain3 of Mishrif MB21 zone, mostly are low energy sub-tidal deposition, mainly variegated oil saturated. All of this hint that for this kind of sedimentary environment, the reservoir effectiveness need to be re-evaluated or the cut offs of the effective reservoir need to be further classified and evaluated according to the reservoir space type and pore throat structure.
A) Micritic bioclastic limestone, piebald oil show, 3927-3927.25m, well Bu-22  
B) Micritic bioclastic limestone, intragranular dissolution and mold pore, piebald oil show oil show, 3924.3m, well Bu-22

Figure 5. Reservoir spaces and oiliness differences of micritic bioclastic limestone matrix and piebald system

A) Piebald filled with spar calcarenite,  
B) bioclastic micritic limestone, matrix oil-bearing, 3912.5m, well Bu-22  
dissoluted pore, none oil, 3912.5m, well Bu-22

Figure 6 Lithology, reservoir spaces and oiliness differences of open subtidal deposition Matrix and piebald system

6.5. The reservoir space of Asmari zone A of detrital tidal flat is intergranular pore. (Fig.7)

Figure 7. Oil-bearing core of tidal flat facies elastic rock in Asmari zone A
6.6. Semi restricted lagoon micritic bioclastic limestone of Asmari zone A is mainly intergranular dissolved pore. The oiliness of matrix and dissolving fillings oiliness are quite different. (Fig. 8)

Figure 8. Lithology and oiliness differences of Asmari B1 zone micritic bioclastic limestone and bioclastic micritic limestone matrix, channels and piebald system

6.7. Micritic bioclastic dolomite matrix and variegated storage space of semi restricted lagoon of Asmari B layer have a distinct difference on oiliness. The Khaki dolomite powder of grain shoal facies is mainly intercrystalline dissolution pore and intergranular dissolution pore. There are two kinds of Asmari B reservoirs: one is the Khaki dolomite powder of grain shoal facies (Fig. 9), the other is oil-bearing variegated storage space which matrix lithology is grey green micritic bioclastic dolomite that developed intragranular dissolution pore and coelom pore, and have bad connectivity. It is a kind of invalid reservoir for liquid hydrocarbon. The variegate part is mainly bioclastic dolomite, mainly developed intergranular dissolution pore, with good permeability and oil-bearing core (Fig. 10).

Figure 9. Khaki bioclastic dolomite powder, developed intergranular dissolution pore and intergranular pore, 3120.3m, FQCS-28

Figure 10. Lithology, reservoir space and oiliness differences of grey green micritic bioclastic dolomite and piebald granular dolomite
7. Conclusion
There are two unconformities caused by quasi contemporaneous period weathering crust karstification in Mid-Cretaceous Mishrif Formation of Missan oilfields. The lithology and sedimentary characteristics of the unconformity surface are obviously different, where the upper is argillaceous limestone, and the lower is bioclastic rudist limestone. There exist many dissolved fractures and caves in the rudist limestone, some of them are filled by the product of early continental diagenesis and exposed to the vadose zone in the environment. The development of dissolution under the surface reflects the geospatial structure; the unconformity of bioclastic limestone unconformity shows no light in cathodoluminescence, a few orange light scattered around the crystal edge, which indicates a characteristics of atmospheric fresh water influence; the carbon and oxygen isotopes analyses also demonstrate that the unconformity was influenced by atmospheric fresh water invasion.

Local tectonism and global sea-level change are the key factors for the karstification of Mid-cretaceous Mishrif and Tertiary Asmari formation in Missan oilfield.

The genetic model of karstification in Mid-cretaceous Mishrif and Tertiary Asmari formation of Missan oilfield is as follows: In the early stage of sedimentation, the sediments were mainly fine grained micritic limestone with the influence of large-scale transgression, and in the middle and late stages, they were affected by local tectonism, vertical growth of grain-shoal facies and sea level decline, which lead to the exposure of the platform above the sea water, and which accepted the dissolution of atmospheric fresh water and then formed karst unconformity surface.

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