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The Diagenesis Influence of Feixianguan Formation on Reservoir Pore Evolution in Dawan Area

XIONG JINHONG[1,2*], XING XIANG[3], CHEN CEN[4] AND ZHANG YUEQIAO[5]

[1]*Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China*

[2]*School of Earth and Space Sciences, Peking University, Beijing 100871*

[3]*Development and Reform Commission, Enshi Tujia and Miao Autonomous Prefecture, Hubei 401331;*

[4]*Chongqing University of Science & Technology, Chongqing 401331;*

[5]*School of Earth Sciences and Engineering, Nanjing University, Nanjing 210023, China*

Email: *278031772@qq.com, 172231975@qq.com; 22023927@qq.com; 2273876296@qq.com*

Abstract: *Diagenesis and pore evolution characteristics of Feixianguan Formation in Dawan gas reservoir were fully studied based on the microscopic-analysis on casting thin sections, scanning electricity mirror and core analyzing materials. The results showed that the mainly diagenesis types of carbonate reservoir in Feixianguan Formation are as follows: dolomitization, compaction, cementation, filling, dissolution, recrystallization diagenesis, etc. According to comprehensive analysis of diagenetic features, reservoir rocks are mainly formed in sedimentary facies belt of Oolitic beach facies at platform margin, which has a strong wave action with following characteristics: Oolitic grain-refining dolomite and sand cutting grain-refining dolomite are the mainly rock types, with large particles diameter, high level of dolomitization and well-medium sorted, but strong diagenesis. In submarine and syngenetic stages, porosity drop rapidly because of compaction and the calcite cementation. During this stage, the primary pores reduce greatly, although mixed water dolomitization and meteoric fresh water dissolution can form secondary pores; in shallow burial stage, the pores are drastically reduced under the compaction and cementation; the later period of dissolution can form secondary dissolution pore, thus there are enormous contributions to the increase of porosity.*

Key Words: *Dawan area, Feixianguan Formation, Diagenesis, Pore evolution*

1. Introduction

Dawan area is located in northwest Puguang Gasfield, which in structure locates in northeast of east Sichuan broken-and-fold belt, next to the watershed structure in the west and whereas the Puguang structure in the east [1]. The proved gas bearing area is 56.50km2, and natural gas geological reserves is 1282.31×108m3, which had been reported for three times. Dawan area is one of the major blocks for increasing reserves in further development stage of Puguang Gasfield, its formation of Feixianguan mainly developed platform edge facies, while the high-quality reservoirs are mainly distributed in upper part of the second segment. The pore types and pore textures have a controlling mechanism on reservoir property, which the intercrystalline dissolution pores and residual Oolitic dissolution pores have better reservoir capacity.

The average porosity and permeability of carbonate reservoir in Feixianguan Formation is 8.02% and 112.5×10-3μm2 respeetively, it belongs to middle-low porosity and medium permeability reservoir according to the division standard [2].

The diagenesis influence on reservoir development is great, it contributes to very complex microscopic features and evolution process of reservoir. For further study of carbonate reservoir heterogeneity of Feixianguan Formation in Dawan area, we used methods of fluorescence thin sections, casting thin sections, pressured-mercury testing and image analysis, combining with research on reservoir microscopic features characteristics and diagenesis, through these works, the reservoir pore evolution characteristics and process were analyed in this paper.

2. Reservoir micro-characteristics

2.1 Reservoir space types

Reservoir space types and size mainly affect on reservoir porosity, which influence the effectiveness and permeability of reservoir by its shape and connectivity status [3]. Two types of reservoir space are mainly developed in the study area, pores and fractures (Tab.1), especially the pores [4].

All types of pores which formed by dissolution are called dissolution pores, they are excellent storage space of oil and gas of Feixianguan Formation. Types of dissolution pores are abundant, including intercrystalline dissolution pore, intergranular dissolution pore, intragranular dissolution pore, Oolitic pore and karst cave etc. According to slice observation of coring well Dawan 1 and Dawan 102, we found that intercrystalline dissolution pores and intergranular dissolution pores are enormous, which generally developed in crystal dolomite, residual Oolitic dolomite (Fig.1, and Fig.2).

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Tab. 1 *Statistics of reservoir space types of Feixianguan Formation in Dawan area*

Reservoir space types			Characteristics	Frequency	Main lithology
Pore	Dissolution pore	Intercrystalline dissolution pore	Formed by the dissolution of intercrystalline pore	High	Residual Oolitic, sand cutting dolomite and crystal dolomite
		Intergranular dissolution pore	Formed by the dissolution of intergranule fillings	High	Residual Oolitic, sand cutting dolomite
		Intragranular dissolution pore	Formed by the dissolution of granule interior	Low	Residual Oolitic dolomite
		Oolitic pore	Formed by the dissolution of the whole granular	Medium	Residual Oolitic dolomite
		Karst cave	Formed by dissolution or pores which is more than 2mm	Medium	Dolomite
	Intercrystalline pore		Pores between crystals	Medium	Residual Oolitic, sand cutting dolomite and crystal dolomite
Crack	Suture		Zigzag, almost or half filled by asphalt	Low	
	Crack(fracture)		Mainly microcrack, partly filled by asphalt	Medium	

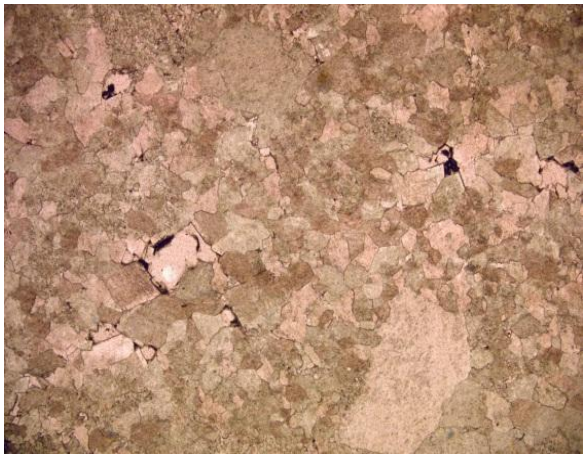

Fig.1 *Crystal dolomite (Dawan 1 well, T1f2)*

Fig.2 *Residual Oolitic dolomite* (*Dawan 102 well, T1f2*)

1.2. Pore throat characteristics

According to pore throat classification standard of carbonate reservoir in Sichuan Basin [6] (Tab.2), combined with other parameters, especially the parameters of mercury intrusion analysis, such as the percentage of throat radius which is more than 0.075μm, and throat radius of saturation mid value (Rc50), the pore throat size of Feixianguan Formation reservoir was classificated by using the above methods.

Tab.2 *Pore throat classification standard of carbonate reservoir in Sichuan Basin*

Pore classification	Class mean aperture (%)	Throat classification	Rc50(μm)
Large pore	>60	Wide throat	>1.0
Medium pore	30-60	Medium throat	1-0.303
Fine pore	10-30	Narrow throat	0.303-0.022
Micropore	<10	Microthroat	<0.022

The pore textures of Feixianguan Formation reservoir in Dawan area is medium to preferable, but due to the strong recrystallization, abundant intercrystalline pores, intercrystalline dissolution pores, dissolution pores and carst caves were formed, with good connectivity [7]. The statistical data of pore throat combination types showed that the reservoir mainly developed large pore wide throat, large pore medium throat, large pore narrow throat, medium pore medium throat, medium pore narrow throat and medium pore microthroat (Fig.3), of which medium pore narrow throat is dominated, large pore wide throat and large pore medium throat is secondary, account for 76% in all.

2. The main diagenesis

Feixianguan Formation in Dawan area has experienced complex diagenesis environment evolution and diagenesis stage change after deposition, the periods are as follows: dolomitization, compaction and pressure solution, calcite cementation, multi-stages dissolution, filling and recrystallization etc [8]. The reservoir was formed by many diagenesis, of which compaction and pressure

solution, calcite cementation, multi-stages dissolution are dominated.

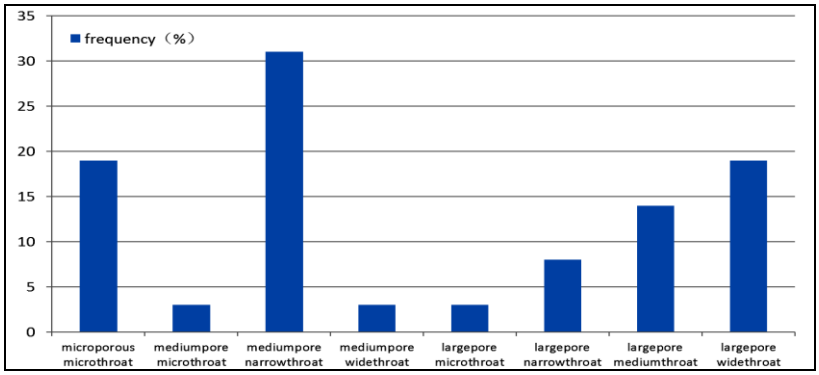

Fig.3 *Frequency histogram of pore throat combination types of Feixianguan Formation reservoir*

2.1 Dissolution

Dissolution is one of key factors for development of major blocks of Feixianguan Formation in Dawan area, reservoir mainly developed in lithology of dissolution Oolitic dolomite, dissolution dolarenite and dissolution reef dolomite etc. Dissolution has constructive significance for pore enlargement, therefore, detailed research on dissolution type and mechanism is helpful for guidance of how the dissolution effect on pore development. Based on the micro-characteristics of casting thin sections, there are two stages of dissolution in Feixianguan Formation in Dawan area, one is syngenetic dissolution, the other one is burial dissolution.

During Feixianguan Formation deposition period, the Oolitic beach in platform margin exposed, by the leaching of atmospheric freshwater, the first period of dissolution had happened. Atmospheric freshwater selectively dissolved rocks, such as Oolitic, biological particles and aragonites, high Mg calcite, unstable mineral etc. This mainly formed inner Oolitic dissolution pores (Fig.4) and Oolitic pores [9].

The second period which called burial dissolution is violent, including mainly dissolution of sulfate, carbondioxide and organic acid. And organic acid in strata is an important factor for the formation of secondary pores[10], it dissolved cements which produced in cementation, enlarged all kinds of pores, and formed a large number of new or secondary pores (Fig.5), part of the pores were filled or half-filled by dolomite crystals, asphalt and asphalt membrane.

Fig.4 *Oolitic dissolution pores (Maoba4 well, T1f2)*

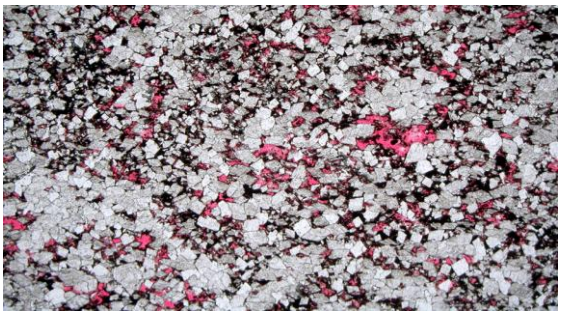

Fig.5 *Intercrystalline dissolution pores (Maoba4 well, T1f1)*

2.2 Compaction

Compaction is destructive diagenesis which can reduce pore volume between particles and lead to poor physical property. During the process, compaction changed particles contact styles from discrete state to point-line contact, thus destructed reservoir space, decreased pore volume and even disappeared. Compaction of Feixianguan Formation reservoir in Dawan area is in shallow buried stage and medium-deep buried stage, especially intense in shallow buried stage. Through microscopic observations, Oolitics mosaic or deformation affected by extrusion (Fig.6). Chemical compaction in medium-deep buried stage usually happened after formation of the second generation cement.

2.3 Cementation

Cementation bonds loose carbonate grain and mineral to consolidation and fossilization, it is a cavity filling that the primary pore or sedimentary pore are filled by chemical precipitated material [11]. There are two stages of cementation in Feixianguan Formation reservoir, the early submarine cementation and shallow buried cementation, these are the main factors of prosity reduction. The early submarine cementation act in sea undercurrent belt, here the fibrous dolomite crystal and columnar dolomite crystal grow around particle margin, form ctenoid rim, with fine-grained cement and mainly powder-fine crystal (Fig.7). During shallow buried stage, supersaturated calcium carbonate solution flow from upper to lower, generate

calcite, the calcite which formed after fibrous and columnar calcite show powder crystal and fill in primary intergranular pore.

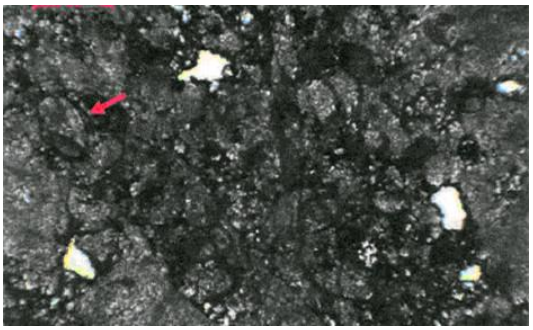

Fig.6 *Compaction deformation (Dawan503-2H well, T1f1)*

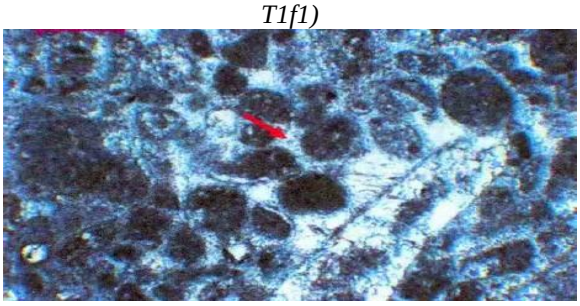

Fig.7 *Calcite cementation (Dawan503-2H well, T1f1)*

3. Pore evolution characteristic

The main reservoir space in study area is pore, the pore is mainly secondary pore (intergranular dissolution pore, intragranular dissolution pore, intercrystalline dissolution pore), which formed by diagenesis. The pore evolution stage and characteristic is influenced by diagenesis environment and sequence, according to the stage change of diagenesis environment (Fig.8), the pore evolution characteristic of Feixianguan Formation reservoir in Dawan area is described as follows: Submarine diagenesis stage: Before cemention of carbonate sediments in study area, that is the early submarine diagenesis stage, after the dolomitization, micritization and crystallization in syngenetic-parasyngenetic stage occurred, sediments in beach-core are characterized by coarse grain size and well sorted, its primary porosity is 30～40%, while sediments in beach-edge are characterized by fine grain size and poor sorted, its primary porosity is 10～20%. Subsequently, the fibrous and ctenoid cementation of the first generation in submarine happened, which makes the primary porosity reduced by 5～10%, the residual porosity of beach-core is 28～36%, and the residual porosity of beach-edge is 9～18%.

Syngenetic exposure stage: After submarine diagenesis stage, the relative sea level has the tendency of descending, half-consolidated rocks of local beach facies are exposed or nearly exposed, and the rocks are in seepage belt, the atmospheric freshwater flows from upper to lower, infiltrats the particles from above downward [12], accompany dissolution and washing and fragmentation of rocks which caused by wave, from the above, some Oolitic pores and intragranular dissolution pores are formed, in this stage, the pores can be increased by 2～10% ; However, leaching of atmospheric water is limited to the top particle beach, the lower part is preserved for the reason that it can hardly been dissolved, thus, geopetal structure is formed, which has limited influence scope.

Shallow buried stage: Along with increasing above sediments and buried depth, Feixianguan Formation reservoir is in Shallow buried stage, this is also the stage of rapid decrease of pores, because that the mainly diagenesis are compaction and cementation. In this stage, the second generation cement is the most influential diagenesis for pore evolution, which causes the pores of Feixianguan Formation reservoir reduced by 20～25%, only 2～4% of isolated residual intergranular pores and intercrystalline pores are preserved, this is the main cause of porosity reduction in this stage. Because of beach-edge is thin, and diagenesis fluid affected greatly, residual intergranular pores can hardly be preserved, reservoir rocks became tight. In late shallow buried stage, with the increase of buried depth, temperature and pressure rises, reservoir rocks experienced weak recrystallization, some intercrystalline pores were formed, which leads to about 10% of the pores were increased.

Medium-deep buried stage: After Feixianguan Formation reservoir entered into medium-deep buried stage, under the influence of the second period of dissolution, the pores gradually developed. The reason is that Permian source rocks in Dawan area began to generate hydrocarbon in late Trias, and it reached the peak in mid-Jurassic, moreover, Carbon Dioxide, Organic Acid and Sulfate which generated by Hydrogen Sulfide and Oxygen enrichment groundwater, this can cause dissolution, and finally increase pore space. Meanwhile, after the evolution entered into Yanshan Period, part of Dawan area developed fractures because of tectonic movement, Sulfate and Carbon Dioxide can easily migrate into reservoir along the cracks, and pores were formed due to the dissolution. Moreover, in Jurassic Period, with the increase of buried depth, temperature and pressure rises, reservoir rocks experienced recrystallization, various acids can enter into reservoir though intercrystalline pores, this helps to enlarge scale of dissolution. In this stage, maximum porosity of reservoir is raised up to about 20%, the average porosity is 8%. The pore space are filled with asphalts in dry gas stage, it shows that there are residual asphalt on macropore edge, underfill, with a slight decline in effective porosity [13].

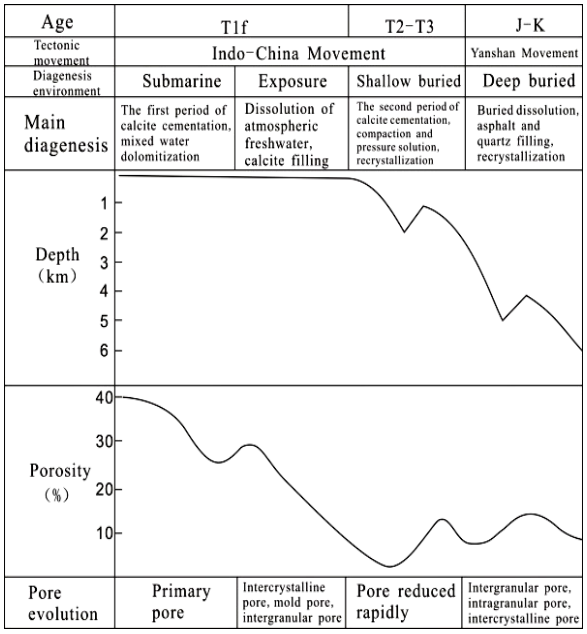

Fig.8 *Diagenesis influence of Feixianguan Formation on reservoir pore evolution in Dawan area*

4. Conclusions

(1)Based on casting thin sections, mercury injection and core analyzing, micro-characteristics of reservoir were studied. The analysis shows that the reservoir space type of Feixianguan Formation reservoir in Dawan area are mainly pores, and fractures are minor; the lithology is mainly composed of oolite, residual Oolitic dolomite, crystal dolomite and dolarenite; and the main pore throat combination types are medium pore narrow throat.

(2)Feixianguan Formation reservoir in Dawan area has experienced various diagenesis, such as dolomitization, compaction and pressure solution, calcite cementation, multi-stages dissolution, filling and recrystallization etc. Among them, dissolution, compaction and cementation are the major diagenesis. However, different types of diagenesis have different effects on reservoir development and pore evolution.

(3)Under the influence of constructive type diagenesis and destructive type diagenesis,the pore evolution of Feixianguan Formation reservoir in Dawan area mainly experienced these stages, the processes are as follows: from primary to secondary, from high to low, then gradually increase. According to the division of diagenesis environment, compaction and cementation caused primary pore rapidly reduce to disappear, and porosity drops sharply in submarine stage and syngenetic exposure stage. While in this stage, syngenetic dissolution has improved rock structure, laying a foundation for buried dissolution. Meanwhile, in medium-deep buried stage, buried dissolution, fracture development and recrystallization has increased pore space, but the filling has reduced a portion of pore, however, the porosity has increased as a whole.

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