ISSN: 2688-8645

Reservoir Characterization of Chang 6 Member in Jiyuan Area, Ordos Basin

Yihan Shi, Ke Wang

Xi'an Shiyou University, Xi'an Shaanxi, 710065 China

Abstract

The Chang 6 section in Jiyuan area of Ordos Basin is a key formation for exploration of low permeability sandstone lithology reservoirs. In this study, the reservoir characteristics and low permeability genesis were systematically revealed by means of core analysis, thin section identification and mercury pressure experiment. The results show that the reservoir is dominated by feldspathic sandstone with low porosity and extra low permeability; the pores are dominated by primary intergranular pores and the pore throat structure is poor. The main causes of low permeability include: (1) fine-grained sedimentary background with dual sources; (2) sharp reduction of pore space due to strong compaction and multi-phase cementation; and (3) limited pore enlargement by dissolution. Sedimentation-rock formation coupling analysis shows that the main sand zone of the submerged diversion channel is a favorable reservoir zone, and future exploration should focus on the weak rock formation zone. This study provides geological basis for the efficient development of Chang 6 reservoir in Jiyuan area.

Keywords

Ordos Basin; Jiyuan Area; Chang 6 Member Reservoir; Low Permeability Sandstone; Petrological Characteristics; Pore Structure; Diagenesis.

1. Introduction

The Ordos Basin, as an important Craton composite sedimentary basin at the western edge of the North China Platform, is a rectangle spreading in a near-north-south direction, with a lateral span of about 400 kilometers and a longitudinal extension of about 340 kilometers, covering a total area of 370,000 square kilometers, and it is the second largest sedimentary basin in China in terms of area (Fig. 1). The Ordos Basin has remarkable geographic features, bounded by the Luliang Mountains in the east, adjacent to the Table Mountain-Helan Mountain-Liupan Mountain tectonic belt in the west, extending to the northern foothills of the Qinling Mountains in the south, and bordering the southern slopes of the Yinshan Mountains in the north. In terms of tectonic zoning, based on the nature of the basement, the present-day tectonic pattern and the regional characteristics, it can be divided into six major tectonic units, including the Yimeng uplift, the Weibei uplift, the Jinxi flexural fold belt, the Yishan slope, the Tianhuan depression, and the western margin thrust belt[1-2]. The area is located in the west-central part of the Ordos Basin, the main part of which is in the west-central part of the monoclinic tectonic belt in northern Shaanxi, and administratively belongs to Wuqi and Dingbian counties in Shaanxi Province. The study area spans two tectonic units, the Yishan gentle monocline and the Tianhuan depression, and the western part of the study area is adjacent to the western margin of the retrograde thrusting tectonic belt. The overall tectonic structure of the area is a monoclinic structure tilted to the west, with low amplitude nasal backslope locally, and the stratigraphy of the area is gentle. This area is an important sand-rich area in the basin, and is also one of the key areas for oil and gas resource exploration. As a key exploration layer, the

Chang 6 oil formation group of the Triassic Extension Group in Jiyuan area of the Ordos Basin develops low-permeability sandstone lithology reservoirs with remarkable resource potential. Exploration practice shows that the reservoirs of Chang6 section have strong non-homogeneity and complex oil layer distribution pattern, but 3 control blocks and 10 potential blocks (total area over 1000 km^2) have been found, which confirms that it has a large exploration prospect. At present, through the systematic study of reservoir characteristics, the classification and evaluation of low-permeability reservoirs and the selection of favorable zones are of great significance in realizing the efficient development of resources. As an area with low exploration level in the basin, the systematic exploration of the Chang 6-section reservoirs in this area will provide a new resource replacement area for the increase of oil and gas production in the Ordos Basin. Therefore, the author has carried out an in-depth study on the reservoir characteristics of the Chang 6 section of the Yanchang Formation in this area by participating in the research work and combining the research results of the previous researchers.

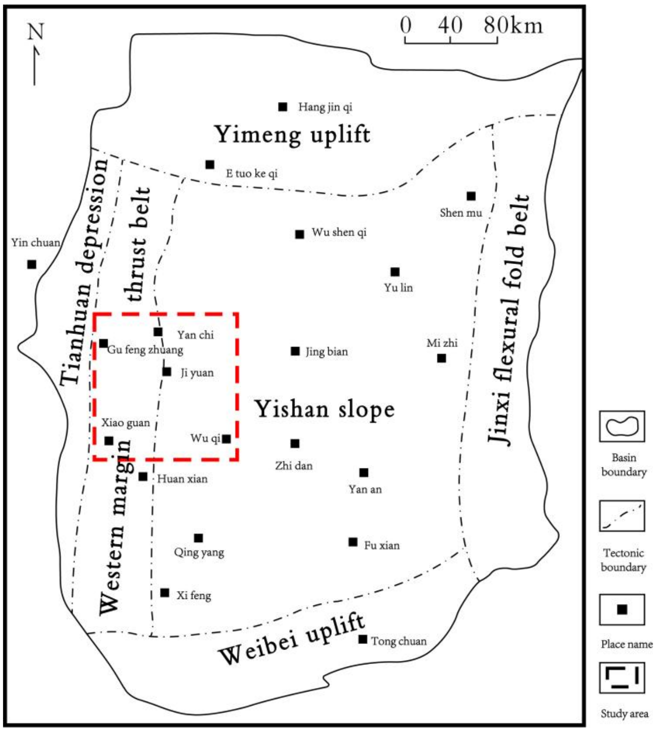

Fig 1. Tectonic position of the Jiyuan area

2. Reservoir Characterization

2.1. Petrological Characteristics of Reservoir

2.1.1. Rock Type and Clastic Composition

According to the core observation and lithological analysis, the sandstone of Chang6 oil formation in the study area is mainly composed of feldspathic sandstone and fine-grained feldspathic sandstone, followed by feldspathic clastic sandstone, which can be clearly seen in Table 1, the content of feldspar in the clastic composition of the sandstone is between 13.9% and 65.8%, with an average content of 44.5%, which occupies the largest proportion, and the content of quartz accounts for about 27.4% to 76.8%, with an average content of 29.8%. The average content of quartz is about 27.4% to 76.8%, with an average content of 29.8%, and that of rock chips is the least, with an average content of about 19.6%. The average content is about 19.6%. The rock chips are mainly metamorphic rock chips and igneous rock chips, and the content of sedimentary rock chips is the lowest. Other clastic mica content is the highest, with an average content of 7.2%.

Table 1. Statistics on the fractions and average content of clasts in the Chang 6 layers in the Jiyuan area.

Layer/ Source	Quartz (%)	Feldspar (%)	Rock debris (%)				Mica (%)
			Igneous rock	Metamorphic rock	Sedimentary rock	Total	
Chang 6	44.5	29.8	6.8	10.3	2.5	19.6	7.2

2.1.2. Characteristics of Filler

Fillers between clastic grains include heterogeneous bases and cemented materials, which differ in their nature, genesis, and the role they play in the rock. From Table 2 and Fig.2, it is clear that the average content of filling material in the sandstone reservoirs of the Chang 6 Group in the study area is 12.7%, which is relatively high, with iron calcite dominating with a content of 3.6%, followed by kaolinite and chlorite accounting for the largest proportion, which account for 2.8% and 3.2%, respectively, and siliceous and hydromica accounting for about equal proportions, and there are some individual dolomite and calcite filling material developed, and the content of cement is dominant, and the content of detrital groups is low. The main type is carbonate minerals.

Table 2. Statistics on the material sources and average contents of fillers in the Chang 6-layer sandstone reservoirs in the Jiyuan area

Layer/ Source	Fill material content (%)							Total
	Iron calcite	Kaolinite	Chlorite	Siliceous	Hydrous Mica	Calcite	Dolomite	
Chang 6	3.6	2.8	3.2	1.2	1.5	0.3	0.1	12.7

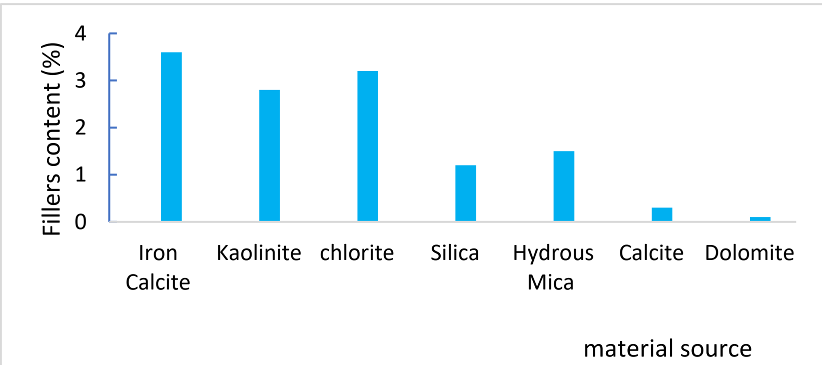

Fig 2. Statistical diagram of the source and average content of fill material in the Chang 6-layer sandstone reservoirs in the Jiyuan area.

2.2. Reservoir Physical Characteristics

2.2.1. Porosity

According to the statistical analysis of the physical property data of 8459 cast thin sections in the Chang 6 section (Table 3 and Figure 3), the porosity of sandstone is 23.6% at maximum, 1.2% at minimum, and 10.4% on average. The frequency histogram distribution has an obvious single-peak distribution, in which low porosity less than 8% accounts for 24.4%, medium porosity (8-12%) accounts for 41.9%, and high porosity (Φ>12%) accounts for 33.7%;

ISSN: 2688-8645

2.2.2. Permeability

The maximum permeability was 21.8 × 10^{-3} μm^2, the minimum was 0.01 × 10^{-3} μm^2, and the average was 0.58 × 10^{-3} μm^2(Fig.4), and the permeability in (0.01~ 0.10) × 10^{-3}μm^2 accounted for 30.6%, and permeability in (0.1~1) × 10^{-3}μm^{2}accounted for 60.3%. According to the classification criteria of reservoirs in domestic studies (Table 4), the Chang 6 sandstone in Jiyuan area is mainly an ultra-low permeability layer and secondly an extra-low permeability layer. The permeability frequency distribution map reflects that the permeability values have a large range of variation, strong non-homogeneity, and large differences in permeability values, indicating that the non-homogeneity of the gas reservoir is more serious both vertically and horizontally, and the differences are especially prominent horizontally, which is the fundamental reason for the differences in production capacity of wells and sand groups. In summary, the physical characteristics of this section are mainly medium-low porosity, low permeability and strong non-homogeneity.

Table 3. Pore and seepage statistics of Chang 6 oil layer group in the Jiyuan area

Layer	Porosity (%)		Permeability (×10^{-3} μm^2)		Number of samples
	Interval value	Mean value	Interval value	Mean value	
Chang 6	1.2-23.6	10.4	0.01-21.8	0.58	8459

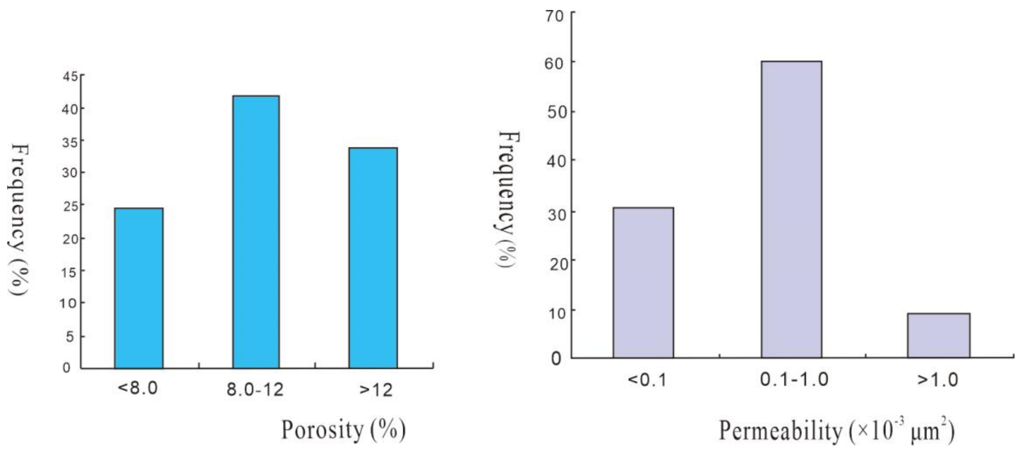

Fig 3. Histogram of porosity and permeability frequency of Chang 6 oil formation group in the Jiyuan area

Table 4. Comprehensive classification and evaluation table of low permeability oil formations in China (Li Daopin, 1997)

Level		Permeability (-10^{-3} μm^2)	Characteristic parameters				Cast pore parameters		
			Discharge drive pressure (MPa)	Median radius (μm)	Mainstream throat radius (μm)	Driving pressure (MPa)	Pore diameter (μm)	Throat radius (μm)	Dissolved pore (%)
I	Low permeability layer	50-10	0.2362	0.6134	2.4714	0.5-3.5	40-20	4.0-2.0	70
II	Extra low permeability layer	10-1.0	0.375	0.2056	1.5309	3.0-10.0	40-20	2.0-1.0	39.43
III	Ultra-low permeability layer	1.0-0.1	2.272	0.1173	0.11	10.0-16.0	40-20	2.0-1.0	59.36
IV	Dense layer	0.1-0.01	5.554	0.062		16.0-28.0	20-4	1.0-0.025	
V	Super Dense Layer	0.01-0.001	>6.0	<0.062		>28.0	4-0.05	1.0-0.025	

2.2.3. Characterization of Pore-permeability Relationship

Porosity is an indicator of reservoir storage capacity, while permeability reflects fluid flow capacity. From the plotted porosity-permeability relationship graph (Figure 4), it is revealed that the porosity and permeability of the Chang 6 formation group in the study area show an exponential relationship ($Y=0.0103e^{0.2822x}$, R=0.687, R^2=0.4727), indicating that an increase in porosity significantly enhances the permeability, but a moderate correlation reflects that the reservoir is affected by the development of fractures or diagenesis such as dissolution and cementation, and is highly non-homogeneous influence, and strong non-homogeneity. The high porosity (20%~25%) may originate from dissolution or sparse sandstone, while the low permeability section (permeability benchmark R^2= 0.4727), may be affected by strong compaction or siliceous/calcareous cementation, resulting in a reduction of primary porosity. The Chang6 of the Extension Formation is a typical low-permeability-extra-low-permeability reservoir, and the reason for the high permeability of some samples in the figure may be due to the tectonics, development of diagenetic fractures, and non-homogeneity of the reservoir.

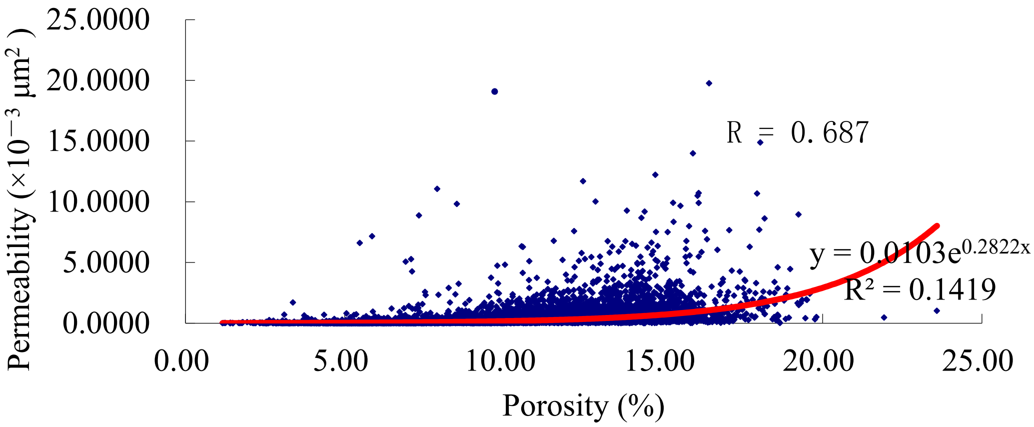

Fig 4. Relationship between porosity and permeability of Chang6 oil formation in Jiyuan area.

2.3. Types of Reservoir Pore Structure

2.3.1. Pore Type

Pore types include primary pores and secondary pores that grow secondary to dissolution in the process of rock formation. The common secondary pores in the study area include six types of pores: intergranular pores, feldspathic pores, clastic pores, intercrystalline pores, intergranular pores, and microcracks.

2.3.1.1 Primary Pore Space

Primary pores in the study area are mainly intergranular pores. Intergranular pores refer to the remaining pore space between mineral particles after the pore space caused by mechanical compaction is removed and occupied by the filler or the pore space is reduced due to extrusion and deformation. This pore type is the most important pore space morphology of the Chang6 oil formation group in the study area, and the development content accounts for a relatively large proportion of its pore state is mostly irregular, irregular distribution, non-homogeneous and strong.

2.3.1.2 Secondary Pore Space

The secondary pore in the study area mainly develops dissolution pore, the dissolution pore is the regeneration pore formed by feldspar, rock debris and other unstable components through the dissolution in the buried rock, including feldspar dissolution pore, rock debris dissolution

ISSN: 2688-8645

pore and intergranular dissolution pore, with high porosity, which is often the effective storage space of the reservoir.

2.3.1.3 Microfracture

Reservoirs subject to diagenesis or tectonic movement will lead to the development of cracks, micro-fractures can provide a certain transport channel for fluids, which can improve the circulation, and improve the seepage capacity of the reservoir to a large extent in a sizable number of cases. The reservoirs in the study area have fewer cracks and lower content.

2.3.2. Types and Characteristics of Pore Throats

The influence of pore throats on the seepage capacity of the reservoir is greater than that of pore spaces, and pore throats usually consist of multiple pore connections. Mercury pressure method is the most commonly used method to study the characteristics of pore throats in reservoirs. The main pore size parameters affecting the porosity and permeability of the reservoir are analyzed through the experimental data, and the distribution and connectivity of the pore throats are finally determined. The analysis of the results of MIP test shows that (Table 5).

The discharge and driving pressure of the Chang 6 oil formation group in the study area ranges from 0.45-3.29MPa, with an average discharge and driving pressure of 1.45Mpa; the median radius of the roaring channel ranges from 0.03-0.38μm, with an average value of 0.19μm; the median pressure ranges from 1.59-15.68MPa, with an average value of 6.12Mpa; and the range of the mercury withdrawal efficiency is 25.82-52.64%, with an average of 31.83%. The average value was 6.12Mpa; the mercury removal efficiency ranged from 25.82 to 52.64%, with an average of 31.83%; the sorting coefficient ranged from 1.08 to 3.65, with an average value of 2.81, with a medium deviation of the sorting property. Combined with the experimental data of mercury pressure and the analysis of thin section data, it can be confirmed that the reservoir in the study area is characterized by low permeability-ultra-low permeability, with small pore throat radius and uneven distribution of throat size, strong non-homogeneity of pore structure and poor connectivity, which can easily lead to the reduction of the efficiency of fluid seepage.

Table 5. Characteristic parameters of pressurized mercury in Chang6 oil formation in Jiyuan area of Ordos Basin

		Porosity/%	Sorting coefficient	Mercury withdrawal efficiency/%	Median pressure/MPa	Discharge pressure/MPa
Chang 6 oil formation group	Minimum value	1.2	1.08	25.8	1.59	0.45
	Maximum	23.6	3.65	52.6	15.68	3.29
	Mean	10.4	2.81	31.83	6.12	1.45

3. Reservoir Sand Body and Physical Properties Distribution

The Chang 6 phase is mainly subphase deposition at the front edge of the delta. The main sedimentary microfacies include submerged diversion channels, estuarine dams, and diversion bays, etc., and the microfacies of submerged breakwater fans and submerged natural dykes are locally developed [3]. Seven major sand zones are developed from west to east in the long section 6 of the study area. In the northeastern part of Jiyuan area, the terrain is flat, the river is strong, and the supply of material sources is sufficient. The river enters the submerged area and continues to carry the land source material to the shallow lake in the form of submerged diversion channels, resulting in the continuous accumulation of submerged diversion channels and the truncation and overtopping of many submerged diversion channels, thus forming the superimposed submerged diversion channel sand body. The superimposed submerged diversion channel sand body is widely distributed in the area and is the main storage sand body, followed by dam sand bodies such as submerged diversion channel sand body and estuarine sand. The sand body spreads near north-south direction, superposes each other vertically and connects horizontally[4]. The length of extension in the area is 50km-80km, the lateral width is 6km-12km, and the thickness of a single sand body is generally 10m-20m. The physical properties of the reservoirs of the long section 6 in Jiyuan area are strongly non-homogeneous. The distribution of the physical parameters in the plane has the following characteristics: the low value area is generally distributed in the form of a strip in a near north-south direction, and the relatively high value area also shows a more obvious strip. Comparison with the thickness contour distribution map of the sand body reveals that it is closely related to the physical properties[5]: the distribution of porosity and permeability is generally similar to that of the sand body, but the relatively highly porous and highly permeable reservoirs are mainly located in the areas where the river channels converge. The distribution of physical parameters in the longitudinal direction has the tendency that the deeper the burial depth, the smaller the porosity and permeability.

4. Analysis of the Main Controlling Factors of Low Permeability of Sand Body

4.1. Depositional Environment and Physical Source Conditions

Sedimentary environment plays an important role in controlling the development of reservoirs. The good or bad storage conditions of the reservoir and the later diagenetic evolution are obviously related to the sediment type and depositional environment. Ordos Basin is one of the large-scale terrestrial sedimentary basins in the middle and Cenozoic era in the east of China, and Jiyuan area is located in the northwest of the central part of the basin, which belongs to the lagoonal deltaic and shallow lagoonal sedimentation. The reservoir of Chang 6 oil formation group in the study area is a set of gray and gray-white sandstone interbedded with black and gray-black mudstone assemblage, which is sedimentarily stable, with stratigraphic thickness ranging from 70 m to 125 m. The reservoir is mainly controlled by the northeast and northwest sources, the northeast source of which is from the Yinshan Paleocontinent, with the sand body spreading related to the Anbian deltaic system, and the host rock is dominated by the volcanic and metamorphic rocks, which is characterized by the clastic assemblage with high feldspars and low clasts; and the northwest source of which is from the Alaska Paleocontinent, with the high feldspars and low clasts. The northwestern source is from the Alxa Paleoland, characterized by high feldspars and high clasts. The sand body is influenced by the deltaic system of Huaxian, and the parent rocks are mainly metamorphic rocks (such as gneiss) and sedimentary rocks, and quartzite and siliceous rock fragments are common in the rock fragments. The rock and mineral fractions in the two source areas are basically the same, with little difference in the content of filler material, and the fractions are basically the same. The same fine-grained characteristics and similar rock types of the two sedimentary source areas of the Chang6 oil formation in the Jiyuan area determine that the reservoirs in the study area are dense and characterized by low porosity and ultra-low permeability. The high content of feldspars and clasts provides a material basis for the late evolution of rock formation.

Within the same sediment source, sand bodies in different depositional locations have obvious differences in composition, structure, grain size, sorting and thickness of sedimentary debris due to differences in sedimentary hydrodynamics, which have a greater impact on the reservoir storage performance, and the type of sedimentary phase and depositional environment also have a greater impact on the distribution of reservoirs. The sedimentary microphase of the Chang6 oil formation in Jiyuan area mainly includes the underwater diversion channel, diversion interbay and estuarine dam. The main sand zone of the underwater diversion channel has better sorting and rounding than the side and flank of the channel, and the content of plastic rock debris and clay heterogeneous base is relatively less, which is favorable to the preservation of primary porosity, and the original porosity is correspondingly larger, with better permeability. The favorable storage sand body in the study area is dominated by the main sand belt of the submerged diversion channel; the permeability of the river channel sides and flanks becomes poorer while the thickness of the sand body becomes thinner; and the interbay of the diversion channel is mainly deposited with marl and mudstone, which is almost impermeable.

4.2. Rock-forming Role

According to the observation of the core of the core section in the study area and the identification of common thin section and cast thin section, combined with the scanning electron microscope, cathodoluminescence and X-diffraction analysis of clay minerals, the characteristics of petrogenesis in the area are analyzed, and it is believed that the main petrogenetic effects affecting the study section are compaction, cementation and dissolution, which directly determine the advantages and disadvantages of the physical properties of the reservoirs.

4.2.1. Compaction

Compaction is divided into mechanical compaction and dissolution. Compaction is often the main factor leading to the deterioration of physical properties of sandstone reservoirs. Observed by ordinary thin section, the compaction of the Chang 6 sandstone in the study area is generally strong, and the clastic particles are mainly in line contact with some concave-convex contact, indicating that the compaction is stronger. Water drainage, tight arrangement of clastic particles, reduction of pore volume, decrease of porosity, and deterioration of permeability occurred in the sediments under the gravity of the overlying strata (Figure 5). The long axis of the clastic particles exhibits a tendency to compact and orient, and the rigid clastic quartz and feldspar particles can be seen to fracture and microfracture under cathodoluminescence. In addition, quartz compression solubilization can be observed under the microscope, with concave-convex contacts between quartz grains (Figure 6).

4.2.2. Cementation

In the clastic rocks of the purpose-built section in the study area, cementation can have a variety of mineral compositions, but mainly carbonate, siliceous and authigenic clay minerals.

Siliceous cementation Siliceous cementation is commonly developed in this area, with an average content of about 1% of the total rock, and the degree of its development is related to the fraction of clastic fractions and the content of heterogeneous bases. In sandstones with high quartz detritus content and low clay heterogeneous base content, quartz secondary plus is more developed. Quartz secondary large edge tends to be equal thickness ring edge wrapped clastic quartz particles, most of the continuous growth. There is also part of the authigenic quartz growth in the intergranular or dissolution holes, the formation of smaller autogenous microcrystals along the pore wall growth (Figure 7). The siliceous nature of quartz secondary enlargement and authigenic quartz partly originates from the dissolution of feldspar and the conversion of kaolinite to illite, and partly may be the result of the pressure solubilization and re-precipitation of quartz itself. The secondary increase of quartz not only reduces the pore space, but also makes the pore-throat structure of the reservoir more complicated, resulting in a great reduction of the seepage capacity of the fluid; the appearance of authigenic quartz occupies a large amount of pore space, so that the porosity of the reservoir is greatly reduced.

Carbonate cementation is a prevalent type of cementation in the clastic rocks of the Chang 6 reservoir in the study area, mainly in the form of intergranular cementation, accounted for or secondary pore fillers, commonly microcrystalline, crystalline grains or continuous crystals, with the composition of calcite, ferric calcite, and ferric dolomite. Iron-free calcite shows up as an orange-yellow color under cathodoluminescence and crystallizes early (Figure 8). Iron-bearing calcite is generally speckled to fill the intergranular space and is darker under cathodoluminescence. According to the carbonate collodion composition and generation order changes can be divided into early and late two phases, early formation of pore-filling calcite not only inhibit the compaction of the reservoir, but also to prevent the entry of foreign collodion.

In the late stage, carbonate cement was dissolved by organic acid, which greatly increased the pore volume of the reservoir and improved the physical properties of the reservoir. However, the calcite cementation formed in the early stage of diagenesis and the iron calcite and iron dolomite formed in the late stage of diagenesis are very serious to the damage of the reservoir in the study area, which is also an important reason leading to the dense and low permeability of the reservoir.

Autogenous clay mineral cementation Autogenous clay mineral cementation is present in almost all sandstones. Clay mineral production can be categorized into three types, including pore-lining, pore-filling, and pore-throat lapping. The authigenic clay minerals in the Chang 6 reservoir in the study area are mainly kaolinite and chlorite. The authigenic kaolinite has the highest relative clay mineral content, is mostly filled between clastic particles, and is observed as a flake, book page, or worm-like aggregate by electron microscopy (Figure 9). A part of kaolinite altered from feldspar also exists in the sandstones in the area, and such kaolinite crystals are tightly packed with minimal inter-crystalline pores. Kaolinite occupies the reservoir space, and it affects the seepage capacity of the reservoir; however, the presence of kaolinite tends to form a large number of good intergranular pores, which has a positive effect on the improvement of reservoir physical properties.

There are two main forms of chlorite cement: one is the early pore-lining chlorite, which is mostly a blade-like aggregate distributed in a ring along the clastic particles to form a thin-film type of cement (Figure 10), and this clay ring edge uniformly wraps around the outside of the clastic particles, impeding the contact between the clastic particles and the pore water, which reduces the sedimentation of the other cements, and prevents the co-axial growth of the quartz, feldspar, and other particles. It has a protective effect on the pore space and its structure of the sandstone reservoir of the extension group; however, the formation of chlorite clay film also greatly narrowed the pore space and throat of the sandstone. The other is the late pore filling chlorite, in the form of blades filled in the intergranular pores (Figure 11).

4.2.3. Dissolution

Occasionally seen in the study area clastic components of different degrees of dissolution, such as feldspar particles of dissolution: some along the deconstructive joints or bicrystalline joints strongly dissolved (Figure 12), and some particles or collodion all dissolved into the casting holes. The occurrence of dissolution of mineral particles is conducive to increasing the storage space, but the ability to improve the storage capacity of the work area is limited.

It is known through the study of the rock-forming role of the study area that, due to the high content of plastic clastic particles in the study area, after being subjected to compaction, it is very easy to deform or fill in between the pores in the form of pseudohybrid bases, which makes the physical properties of the reservoir deteriorate, and this is one of the important reasons for the poor physical properties of the area. The chlorite formed in the late stage is filled in the primary intergranular pores in the form of blades, which reduces the radius of pores and throats; the cementing effect of carbonates is an important reason for the poor physical properties of the reservoir and the enhancement of non-homogeneity.

ISSN: 2688-8645

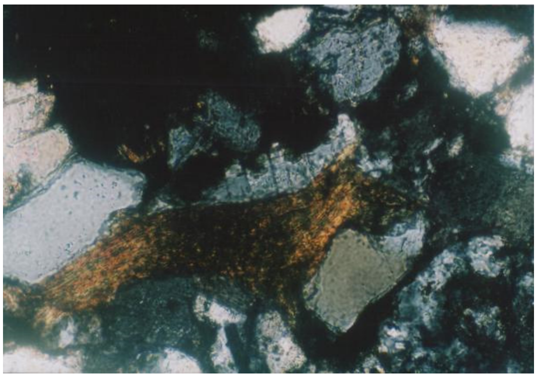

Fig 5. Plastic deformation of plastic grains (200×)

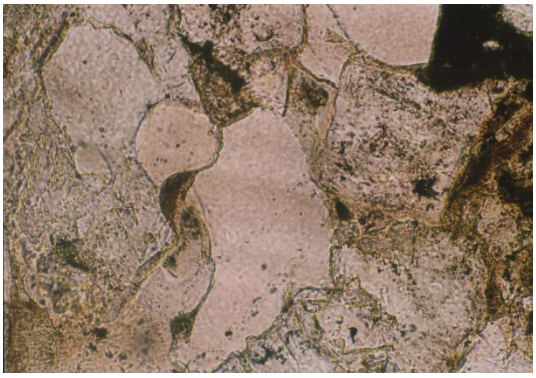

Fig 6. Concave-convex contact between quartz grains (200×)

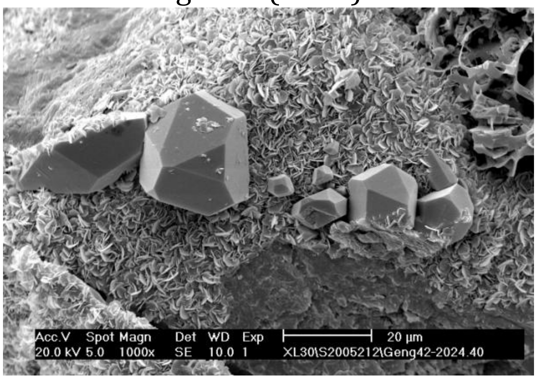

Fig 7. Authigenic quartz microcrystals

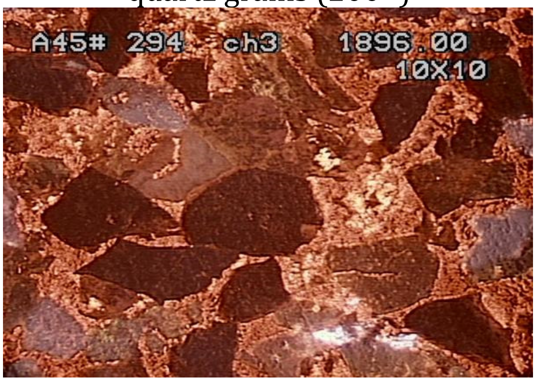

Fig 8. Iron-free calcite filling between detrital grains

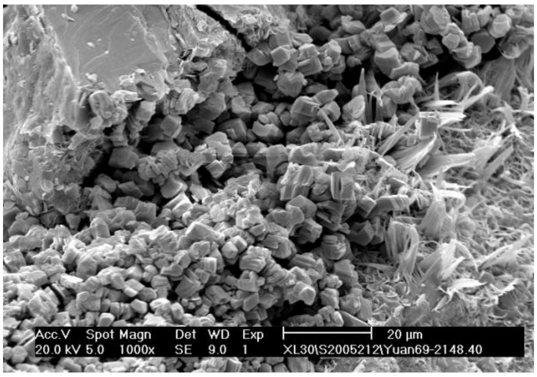

Fig 9. Worm-like authigenic kaolinite (1000×)

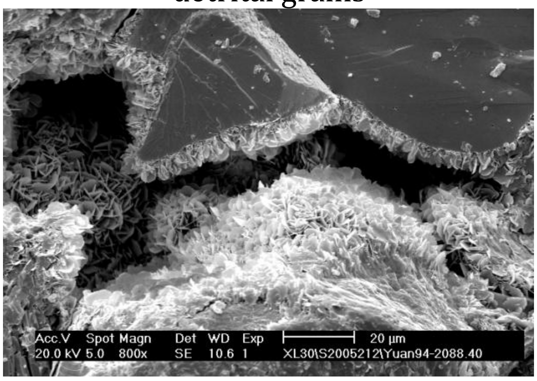

Fig 10. Chlorite ring rims on the surface of clastic grains (800×)

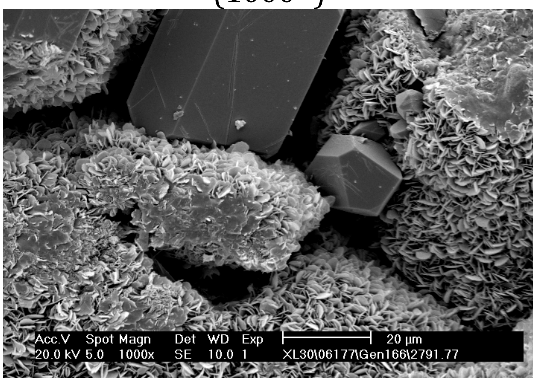

Fig 11. Pore throat filled with chlorite and authigenic quartz

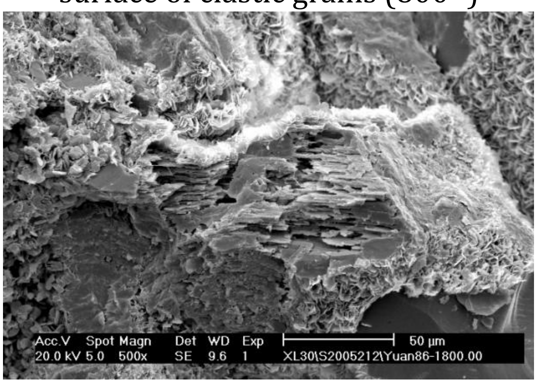

Fig 12. Dissolution of feldspar along a detrital suture (500×)

The Chang 6 section reservoir is usually the product of favorable sedimentary phase and diagenetic action superimposed on each other, and a comprehensive study of it can effectively determine the favorable reservoir area and layer section.

The reservoirs in this area have various types of diagenesis, among which compaction, cementation and dissolution are the most important, and play a decisive role in the physical characteristics and pore evolution of sandstone reservoirs. The above study shows that the fine grain size of sediments, compaction and cementation are the main causes of low permeability in the reservoirs of the Extension Formation, and the dissolution and erosion have increased the porosity of sandstones. Inspired by this result, the next step should be to carry out the study of diagenetic phases on this basis, and to find those areas with a lower degree of diagenetic evolution as the key zones for exploration.

5. Conclusion

(1) The sandstones of Chang6 oil formation in the study area are mainly dominated by feldspathic feldspathic sandstone and fine-grained feldspathic sandstone, followed by feldspathic feldspathic sandstone, and the gap-filling materials are abundant; the physical properties show that the formation is strongly non-homogeneous and low porosity (the average value of porosity is 10.4%, and the average value of permeability is 0.58×10^{-3} μm^2), and the pore throat is poorly structured (the median radius of howl channel is 0.19 μm, and the efficiency of mercury retreat is 31.83%), which is an ultra-low permeability reservoir.), which is the dominant type of ultra-low permeability reservoir. The pores are dominated by primary intergranular pores, secondary dissolution pores (feldspar/rock debris dissolution pores) are locally developed, and microfractures are scarce.

(2) The physical non-homogeneity of the Chang6 reservoir in Jiyuan area is extremely strong, and its physical distribution characteristics are mainly influenced by the distribution characteristics of the sand body. The sand body spreads in the north-south direction, is vertically stacked on top of each other, and is horizontally connected. The length of the sand body extends from 50km to 80km, the lateral width is from 6km to 12km, and the thickness of a single sand body is generally from 10m to 20m. The relatively highly porous and highly permeable reservoirs are mainly distributed in the areas where the river channels converge.

(3) The main controlling factors for the low permeability of the sand body mainly include the depositional environment and diagenesis. In Jiyuan area, fine-grained sediments are supplied by the ancient land of Northeast Yinshan and the ancient double source of Northwest Alashan, and the sand body of the underwater diversion channel is the optimal storage phase zone, but the overall grain size is on the fine side. At the same time, strong compaction led to the line-convex contact of clastic particles, and the primary pore space was greatly reduced; the presence of siliceous, carbonate, and clay minerals in cementation further damaged the pore space: quartz secondary increase and late iron calcite/iron dolomite hypocrystalline cementation significantly reduced the pore infiltration; the chlorite ring edge (and the pore filling blocked the throat; and the solvation locally increased the pore space, but the improvement was limited.

References

[1] HE zixin. Evolution and Petroleum Resources of the Ordos Basin [M]. Beijing: Petroleum Industry Press, 2003: 95-105.

[2] GAO jianbo, PANG xiongqi, WANG zhixin, et al. Low permeability characteristics and main controlling factors of oil-bearing property in clastic reservoirs of Chang-6 Formation, Jiyuan area, Ordos Basin [J]. Journal of China University of Petroleum, 2007, 31(1): 6-9.

[3] WANG feng, WANG duoyun, GAO mingshu, et al. Microfacies associations and characteristics of the Triassic Yanchang Formation delta front in Jiyuan area, Ordos Basin [J]. Acta Sedimentologica Sinica, 2005, 23(2): 218-224.

[4] NI xinfeng, CHEN hongde, TIAN jingchun, et al. Relationship between sequence stacking patterns and genetic types of sandbodies in Chang-6 oil reservoir group, Hujianshan-Jiyuan area [J]. Journal of Oil and Gas Technology, 2006, 28(4): 176-179.

[5] LI qi, LIU jiaduo, DONG wei, et al. Distribution characteristics of physical property parameters in Es_2 reservoir of Tong 61 fault block, Dongying depression [J]. Journal of Mineralogy and Petrology, 1998, 18(1): 40-46.