Study on diagenesis and diagenetic evolution of reservoir in Wuercxun depression

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Abstract. Wuercxun depression is one of the main oil-bearing depressions in the middle of the Hailar District Basin with high exploration degree. With the deepening of exploration degree, the pore structure and distribution law of tight reservoir in trough are not clear. In this paper, through the combination of quantitative and qualitative, micro and macro, following the idea of “phenomenon characterization, essence exploration, law summary”, the diagenesis analysis and diagenetic evolution of tight reservoirs are studied to find areas with relatively good reservoir properties in the depression, which provides theoretical basis for tight reservoir exploration. Diagenesis controls the formation, evolution and distribution of the reservoir. The diagenesis of the reservoir in this area mainly includes compaction, cementation and dissolution, thus forming five kinds of secondary dissolution pores (intergranular dissolution pore, feldspar and debris dissolution pore, mold pore, interstitial dissolution pore and dissolution fracture). Vertically, the physical properties of the reservoir are generally poor, but the reservoir is well developed locally. The reservoir is well developed at 1300-1900m and 2300-2700m in Wuercxun depression.

1. Introduction

Wuercxun depression is one of the main oil-bearing depressions in Hailaer basin, with an area of 1850 km² and great resource potential. At present, the remaining targets are mostly concentrated in the trough and surrounding areas, and there are some problems such as the reservoir is relatively dense, and the pore structure and distribution law are not clear. On the other hand, a large number of sedimentological studies show that sedimentary facies control the spatial distribution and original physical properties of reservoirs, while diagenesis determines the final physical properties of reservoirs. In general, the diagenetic strength of the reservoir increases with the increase of burial depth, and the porosity and permeability of the reservoir decrease continuously until it loses its industrial value. Therefore, through the combination of quantitative and qualitative, micro and macro, following the idea of "phenomenon characterization, essence exploration, law summary", the diagenesis analysis and diagenetic evolution research of tight reservoirs can find relatively good reservoir physical properties in the depression, and provide theoretical basis for the exploration of tight reservoir.

2. Diagenesis analysis

The types of diagenesis were determined based on the core observation of 77 samples from 21 wells in Wuercxun depression and the observation and description of 154 castings and fluorescent thin-section
microscope, as well as the data of 40 times Argon Ion polishing-scanning electron microscopy. The types of diagenesis in this area include compaction, cementation and dissolution.

2.1. Compaction
Compaction means that under the pressure of overlying sediments or strata, the sediments continuously discharge water, reduce porosity and volume, and consolidate the sediments. In addition to the characteristics of the sediment itself (such as grain size, composition and water content), the factors controlling compaction are also affected by pressure. Compaction will continue as long as external pressure exists. The formation pressure increases with the depth of the sediment or the thickness of the overlying strata, so the degree of compaction increases with the depth. Compaction is mainly manifested by the close accumulation of crystal chips, glass chips and rock chips and the deformation of plastic particles, from non directional arrangement to directional arrangement. Compaction in this area is mainly affected by sediment and formation pressure\(^\text{[1]}\).

2.2. Cementation
Cementation generally refers to the consolidation of sedimentary clasts by materials between particles, including not only the cementation of new minerals formed by chemical precipitation, but also the consolidation of sedimentary clasts by compaction, dehydration and adsorption of matrix or heterogene. The main types of cementation in Wuerxun depression are calcite cementation, quartz cementation, feldspar cementation and clay cementation.

Calcite cementation is also called calcareous cementation, because calcium carbonate solution precipitates in pores to form calcite, which makes clastic particles connect and consolidate. Calcite consists of pore filling and intergranular structure. In the thin section with intercalated calcite cement, the clastic particles are in point line contact, and some particles even float in the calcite cement, indicating that the intercalated calcite cement formed earlier. Pore filled calcite is generally formed after strong compaction, and its formation time is later than that of crystal embedded calcite. Calcite tends to metasomatize clastic particles in varying degrees, and even form pseudo clastic particles when it is strong. Calcite selective cementation is often developed near bedding planes and fractures, and distributed in tuberculous and layered forms. The early calcite cementation suffered from the late selective dissolution, resulting in the uneven distribution of dissolution pores, and finally formed the "porphyritic" oil-bearing characteristics.

Quartz cementation, also known as siliceous cementation, is formed by the precipitation of silica or the dissolution and precipitation of quartizes in the pores. The structures of quartz cements in Wuerxun depression include: bar structure and crystalline granular structure, continuous crystal structure, secondary enlarged structure, point contact cementation and concave convex contact cementation. The siliceous cementation of point contact and concave convex contact is very common in this area, which indicates that mechanical compaction is weak. The secondary enlarged edge structure is widely developed in Wuerxun depression. The comb like structure and crystalline granular structure often develop together in a pore or fracture, forming two cementation generations. The comb like quartz appears earlier, close to the surface of the particle, and grows vertically to its surface. The crystalline granular structure is the second generation, which develops in the center of the pore, and the particle ratio in the center is higher. The particles around it are slightly larger.

Feldspar cementation is formed by the precipitation or recrystallization of feldspar material in the pores, which is only developed in some areas and drilling wells in this area. The structure of feldspar cements in Wuerxun depression includes secondary enlargement structure, intergranular structure and interwoven structure in pores. The secondary enlarged structure often grows close to the edge of the grain, and the light property is basically the same. Feldspar cements with intergranular structure are often developed near or at the edge of the eroded feldspar particles, connecting the eroded feldspar particles with other particles. The interweaved structure of feldspar cement is mostly neutral plagioclase with card twin. Some of the crystals grow along the edge of the particles and also perpendicular to the surface of the particles, forming a triangular framework in the middle of the pores.
Under the scanning electron microscope, authigenic K-feldspar and albite grains filled in tuff pores are common, and the source of feldspar matter is also complex. On the one hand, it comes from the dissolution of feldspar debris, felsic tuff matter and other minerals and rock debris containing felsic chemical composition, and on the other hand, it comes from deep hydrothermal solution. The crystallization of feldspar needs higher temperature, so the late diagenesis or hydrothermal rise is necessary.

Clay cementation refers to the cementation of clay minerals (such as kaolinite, chlorite, illite, illite and smectite) in the diagenetic process of clastic sediments. A small part of the clay minerals in Wuerxun depression are primary clay, which are deposited together with clastic particles as miscellaneous base components. However, most of them are formed by the transformation of volcanic ash during diagenesis and belong to new minerals. Most of the rock types in this area are tuff, tuff, tuffaceous sandstone and tuffaceous conglomerate. Most of the sedimentary materials are newly formed pyroclastic. There are few products of terrigenous weathering, so the primary clay is relatively less\[^2\] \[^3\].

The kaolinite aggregate is filled in the pore space, which is hexagonal plate-like aggregate, and a small amount is vermicular. Most of kaolinite grows on microcrystalline quartz, which indicates that the formation of kaolinite is later than microcrystalline quartz. Under scanning electron microscope, chlorite is linear and its occurrence is pore filling. When there are both chlorite and dispersed microcrystalline quartz in the pores, microcrystalline quartz grows on or wrapped with chlorite, which indicates that microcrystalline quartz is formed later than chlorite. Authigenic illite is bridging. The edge curling part of the adherent clay minerals is authigenic illite, which indicates that part of illite is transformed from adherent clay minerals. Under scanning electron microscope, some of them are well crystalline flakes filled in the pores. The mixed layer is honeycombed on the surface of the particles, and the edge is transitional with the attached clay minerals, which may be formed by the transformation of the attached clay minerals. Chlorite and authigenic quartz crystallites are located on the honeycomb like smectite, indicating that they formed later than smectite.

2.3. Dissolution
The exhalation and hydrothermal process of volcanic eruption often lead to the alteration of clastic particles, which is often limited to a single clastic particle, indicating its unique geological experience. Common alterations include chloritization of dark minerals in volcanic debris and porphyry kaolinite aggregates (possibly pore filling) in volcanic debris. This alteration occurred before burial. Through the observation of cast thin section and SEM, the dissolution of feldspar is the most common. In general, the edge is first dissolved into irregular shapes such as harbor shape, arc shape and tooth shape. Feldspar crystal chips, glass chips and tuffaceous fillers are the main corrosion and dissolution materials, from local dissolution and diffuse dissolution to the formation of residual dissolution and even mold holes. Under the thin section, there is spherical volcanic dust, which is completely
dissolved except for the crust. The cladding consists of microcrystalline quartz formed by the devitrification of volcanic dust.

3. Diagenetic evolution

Based on the initial porosity, image analysis data and thin section identification data, the remaining primary porosity, the porosity and secondary porosity reduced by compaction are calculated. The remaining primary porosity is also generally 1800m, and the porosity reduced by compaction is also roughly 1800m buried depth. The secondary porosity appears peak at 1800-2000m, with the maximum secondary porosity reaching 23%, and then it will rapidly decrease to about 7%. The depth section of the thin section of the copper portmiao formation is 1805.33-2287.15m. Although the content of cement in the deep section is relatively low, it always exists. It shows that the reduction of initial porosity in the depth section is mainly compaction and the next is cementation. The remaining initial porosity of Nantun Formation is about 10% in 1200m-1850m well section, and compaction is the main factor for the reduction of initial porosity; in 1850m-2335m well section, the remaining initial porosity is less than 5%, and the initial porosity reduction is contributed by compaction and cementation; in 2335m-2395m well section, the remaining initial porosity is about 8% - 10%, and compaction is the main reason for the reduction of initial porosity.

Through diagenesis (dissolution, mechanical compaction and cementation), five kinds of secondary dissolution pores (intergranular dissolution pore, feldspar and debris dissolution pore, mold pore, interstitial dissolution pore and dissolution fracture) were formed. Vertically, the overall reservoir physical properties are poor, but the local reservoir is well developed, and dissolution is the key to improve the reservoir physical properties. The reservoirs developed well in Wuerxun depression at 1300-1900m and 2300-2700m (Fig. 2).

![Figure 2. Variation relation between porosity and depth in Wuerxun depression.](image)

References

[1] LI Lingling, LIU Jianying, WANG Yongchao. (2019) Diagenesis and main controlling factors of high quality reservoirs of Nantun Formation in Beizhong sub-sag, Hailar Basin. Global Geology, 38: 774–780.
[2] HE Songlin, LI Junhui. (2020) Microstructure characterization of tight sandstone reservoirs in the Nantun Formation of Wuexun and Beier Depresses in Hailaer Basin, Inner Mongolia. Mineral Exploration, 11: 417–426.

[3] WANG Cheng, ZHANG Anda. (2019) Reservoir characteristics and pore evolution of Wuexun-Beier Sag in Hailar Basin. Petroleum Geology & Oilfield Development in Daqing, 38: 151–159.

[4] Zhang Hongxing. (2013) Research on the characteristics of reservoir of the 2nd member of Nantun formation in South Wuexun sub-sag of Wuexun depression. Progress in Exploration Geophysics, 3: 5–9.

[5] Xiao Yanyan, Xu Han. (2012) Characteristics of Secondary Porosity of Nantun Formation and Genetic Analysis of Wuexun Depression. Value Engineering, 19: 316–317.