Study on characteristics of tight oil reservoir in Ansai Area of Ordos Basin – take the Chang 6 section of Ordos Basin as an example

Binchi Zhang,¹,² Ma Lin,¹,³ and Guo-wen Liu²

¹School of Earth Sciences, Northeast Petroleum University, Daqing, China; ²Heilongjiang Oil and Gas Reservoir Forming Mechanism and Resource Evaluation Key Laboratory, Northeast Petroleum University, Daqing, China; ³Daqing Oilfield Engineering Co.Ltd, Daqing, China; ⁴Key Laboratory of Petroleum Resources and Exploration Technology of Ministry of Education, School of Earth Sciences, Yangtze University, Wuhan, Hubei, China

ABSTRACT

In order to understand the exploration and development potential of tight oil in the oil field exploration and development stage, the reservoir characteristics of Chang 6 oil formation in Ansai area of Ordos Basin were studied. In this paper, the reservoir characteristics are studied by using a series of experimental data, such as cast sheet, cathodoluminescence, electron probe, conventional mercury injection, constant rate mercury injection experiment, scanning electron microscope, etc. The results show that the lithologic characteristics of Chang 6 reservoir group in Ansai area are mainly feldspathic sandstone, belonging to 64.57%, followed by feldspar sandstone accounting for 31.36%, the sum of the two accounting for 95.93%. Pores are most developed in Ansai area, and the interstitial materials are mainly chlorite, kaolinite and illite. Primary intergranular pores are mainly developed in this area. Besides primary intergranular pores, there are some feldspar dissolved pores in Ansai region. There are many laumontite dissolved pores in this region. The reservoir type in Ansai region is "low porosity and ultra low permeability", but the Chang 6 member reservoir in Ansai region is very well characterized by "low porosity and ultra low permeability".

Introduction

Ordos is the second largest sedimentary basin in China, is also the earliest to exploration and development of large contains "one of the oil and gas basin" and Ansai area located in Yishan Slope, filling, day ring depression in the west to the east is the jin west flexure belt, 'northern uplift for this block dense reservoir Chang6 reservoir group, including porosity in 10% 15% absolute value in the Chang6 reservoir belongs to low porosity (H. He et al., 2019; W. Cui et al., 2019; M. Wang et al., 2015; Y. Bai et al., 2013), and the permeability of <1 × 10⁻³μm², Ansai area belongs to the scope of type Ila (0.5 ~ 1.0)/x 10⁻³ μm². Tight oil has low porosity and low permeability in this area due to its wide distribution is characterized by no single well in the industry, but the oil field can be developed in the current technology. It is a kind of unconventional oil resource with a high degree of exploitation (J. Zhao et al., 2012 & Jia et al., 2012). Tectonic is a term used to describe the formation of the earth’s crust and refers to the factors or problems that affect the surface to shift. It aids in the identification of the consequences of such changes in tectonic regions. Plate tectonics is the huge displacement of the Earth’s crust that causes faults underneath the crust, which are commonly found in marine interior spaces. The Pacific and Antarctic Layers are some of the widest, with diameters ranging from a few hundreds to thousands of miles. Due to the complicated tectonic evolution of the Ordos basin, the Craton basin was formed after the superposition of the prototype basins in different periods (D. Jing et al., 2012). Ansai area is mainly composed of arkose, followed by feldspar sandstone, the influence of sedimentation, clastic particles in Ansai district is wonderful, the water flushing, clastic particles absolute content high, the quartz 30.09% lower clastic particles in Ansai area, high feldspar content of 52.59%, 17.32% cuttings content is lower because the clastic particles composition content by sedimentary environment influence is not obvious, mainly by the provenance rocks and late diagenetic transformation and the influence of (B. Li, 2006; W. Feng, 2009; T. Fan et al., 2010) (Figure 1). Diagenetic mechanisms are essential for the onset of coal, gas, oil, and “thermal treatment” ores, as well as exerting a significant influence on shallow groundwater quality and porous accumulation. Depositional features are subatomic structures which emerge from the source rock’s diagenetic alteration. Concretions, cone-in-cone frameworks, precious gemstones, adhesion molecules strings, restriction elements, sand particles, and enzyme catalysis are the most common...
diagenetic entities. Due to the great influence of diagenesis in the sedimentary period, the reservoir in Ansai period has already had a very good space. The Chang 6 oil formation in this period has all been densified, and Chang 6 oil layer is also one of the most important oil-producing reservoirs in this period.

**Reservoir petrology characteristics**

In the Chang 6 reservoir mainly feldspar sandstone, feldspathic lithic sandstone and lithic arkose, feldspathic sandstone (64.6%), followed by lithic arkose accounted for 31.36%, and 1.48% feldspar lithic sandstone and lithic sandstone accounts for 2.59% of the proportion of the overall reservoir (Figure 2), Ansai block debris is given priority to with is metamorphic rock debris, relative content (68.86%), followed by magmatic rock debris, accounted for 27.83%, metamorphic rock cuttings with high metamorphic rock debris content in the highest, accounted for 21.83%, magmatic rock cuttings to erupt rock cuttings in the highest, accounted for 17.74% (Figure 3). Cuttings have a good reflection on the source rock, and diagenesis also affects and controls the reservoir and is also useful for clay generation (Yu et al., 2008). However, the source and flow length of river control delta in the Ansai region was seriously scour by water, with high absolute content of debris grains, 30.09% quartz, 52.59% feldspar and 17.32% cuttings. The Chang 6 Member oil fracking is found inside the Ordos Basin’s Yanchang Area, which dates from the middle to late Triassic. The oil shale is 28-m thick on average, with a surface area of about 30,000 km² and a Ladinian period. It has a boundary – layer design and is mostly brown-black to black in colour. In the basin, multi-layered transitional tuff has formed, that might have aided in the production of shale oil.

The component content of detrital particles was not significantly affected by the sedimentary environment, mainly due to the influence of parent rocks and late diagenesis in the provenance area (Table 1). Quartz, feldspar and cuttings absolute maximum concentration values were 60%, 66%, 33.7%, content of quartz, feldspar and cuttings absolute value, minimum value is 12.3%, 16.7% and 2.1%, respectively, the average value of quartz, feldspar, 26.10% and 45.63%, respectively, total cuttings 15.02% absolute content amounted to 86.75%, the relative contents of quartz, feldspar and cuttings were 69.16%, 76.08%, 38.85%, the minimum value of 14.18%, 19.28% and 2.42%, respectively (Table 1). After feldspar, quartz is the second most prevalent element throughout the Earth’s surface. Almost all acidic magmatic, metamorphic, and depositional rocks contain it. In silica-rich felsic rocks including granites, granodiorites, and
rhyolites, it is a necessary element. Feldspars seem to be the most common mineral community in the Earth’s surface, owing to their ability to shape under a broad range of conditions and pressures in magmas, metamorphic, and depositional ecosystems. Chang 6 in Ansai area is mainly composed of clay minerals and carbonate cement. It can be seen that the content of quartz and feldspar is high. Any non-metallic material
with such an epidermis (non-crystalline) sparkle that splits on separate smooth surfaces is referred to as spar. Feldspar is a term used to refer to a broad number of minerals. In reality, it’s a term that’s applied to every material that contains system aluminum, oxygen, and silicone elements, as well as an addition. The crystalline structure of all materials in this category will be the same. Just 9 of the roughly 20 recognized representatives of the Feldspar community are popular. Plagioclase and alkali feldspar are the two main forms of feldspar.

X-ray diffraction is a process wherein the molecules of a crystal trigger a constructive interference of the signals contained in an incident light of X-rays due to their uniform spacing. The crystal's radioactive wings behave on the X-rays in same way as a randomly ruled jarring does this on a light beam. X-rays are used to determine the geometry or form of a substance. The elastically scattered X-rays through materials with long – distance ordering is the basis for XRD strategies. The signature X-ray transmittance in use for crystalline evaluation is generated by these strengthened scattering X-rays. By microscopically thin-section observation and X-ray diffraction analysis (Figure 4), such as development of Chang 6 reservoir in Ansai clay mineral cement and clay cement and the main of kaolinite and chlorite, illite, authigenic clay mineral, Ansai area accounted for 50%, the clay mineral cement effect is the main cement, Chang 6 reservoir in Ansai mainly chlorite, relative content was 37.49%, mainly illustrates the chlorite Ansai area is the main cement (Table 2). Carbonate cementation is also a common sandstone reservoir in the Chang 6 reservoir in Ansai area, because the development of carbonate cementation occupies the pores and narrates or fills the throat, thus reducing the porosity and permeability of the rock and making the reservoir less physical. The carbonate cementation mainly consists of siderite, calcite, iron calcite, dolomite and iron dolomite. As the burial depth increases, the order of cementation changes from early to late in the diagenetic period, and the cementation sequence also changes relatively to siderite, calcite, iron calcite, dolomite and iron dolomite. Calcite is embedded in the intergranular pores with coarse crystals (Fig. A and Fig. B). The process of mineral matter (cements)

| Region/Sample number | Composition | absolute content% | relative content% |
|----------------------|-------------|-------------------|------------------|
| Ansai/810 Block      | Quartz      | 60                | 26.10            |
|                      | feldspar    | 66                | 45.63            |
|                      | cuttings    | 33.7              | 15.02            |

Table 1. Statistical Table Chang 6 of Rock Debris Content in Ansai Area.

| Region/Sample number | Type of cement | Clay minerals | Carbonate cementation | Siliceous cementation | Authigenic cementation |
|----------------------|----------------|---------------|-----------------------|-----------------------|------------------------|
| Ansai Chang6         | Kaolinite      | 0.29          | 0.56                  | 0.33                  | 0.05                   |
|                      | Illite         | 1.01          | 1.95                  | 0.33                  | 0.05                   |
|                      | Chlorite       | 4.33          | 0.35                  | 0.33                  | 0.05                   |

Table 2. Content of Chang 6 Cements in Ansai Area.
precipitating in openings within sedimentary rocks or stones is known as cementite. Cementation occurs place in the open inter – granular or intragranular spaces between within or throughout grains, as well as substantial penalties like vugs, holes, and cracks. Since the concrete hardens so quickly, human objects from just a few years earlier are often discovered solidified into the coastal stone. In addition, dolomite and iron dolomite have small grains and are filled in the intergranular pores or metasomatism calcite. In Wells ning 153 and xin 105, they are generally filled in the intergranular pores sporadically (Fig. C and Fig. D).

In the case of siliceous cementation, some studies have suggested that the siliceous cementation temperature in the sedimentary basin was formed under the condition of 60–145°C, indicating that siliceous cementation could occur in either the early or late diagenetic stage (Wu et al., 2016 & Zhong et al., 2013) [12-13]. Quartz secondary enhanced siliceous cementation accounted for 0.21%, and a circle of black line (Fig. E and Fig. F) appeared on the side of quartz enhanced grain, which was typical in Wells hu 216 and ning 153 in Anse area. It precipitates around the edge of the quartz grain, grows, and quartz secondary enlarges the common coarser channel facies sandstone (Shi et al., 2003). Due to the absolute content of turbidity zeolite of 1.33%, the cementation of turbidity zeolite is a very important diagnosis in Chang 6 reservoir in Anse area. Due to the electron probe analysis of turbidity zeolites, it was found that the composition of the dissolved turbidity zeolites and the turbidity zeolites filling the primary intergranular pores were not significantly different, indicating that the composition of the turbidity zeolites formed in the early and late period had little change (Table 3).

**Characteristics of reservoir micro pore structure**

According to core physical property analysis, the porosity of Chang 6 reservoir is 9.81%~11.25%, with an average of about 10% (Figure 3), and the permeability is 0.31 ~ 1.55 md. In an area, the mean face rate of saichang 6 reservoirs is 5.79%, with the most developed pores. Physical properties of oak sapling cores, uninterrupted sections of separated processors, and core connectors removed from split processors were all evaluated. Prior to multi detector path calculation, the liners of stone centers were broken and the designed duration of an entire core was calculated. Residual intergranular pore absolute value is 3.7%, the relative value of 63.90%, intergranular dissolved pore absolute value was 0.1%, 1.73%, relative feldspar dissolved pore absolute value of 0.63%, 10.88%, relative lithic dissolved hole by 0.26%, 4.49%, relative zeolite solution pores absolute value 0.53%, 9.15%, relative intercrystalline micropore absolute value 0.32%, 5.53%, relative carbonate solution pores by 0.01%, 0.17%, relative microcracks absolute value 0.24%, 4.15%, relative and Anse area oily laumontite dissolution pores, Account for 9.15% of the relative face percentage. For geothermal energy reservoir analysis, microscopic pore structure and water supply are essential and indispensable criteria. Other important parameters, such as conductivity and flow power, are tightly linked to their measurement and understanding. Micropores make up a large portion of the overall pore size. The adsorbent pores are by far the most important contributors to the measured power surface. Physical properties of oak sapling cores, uninterrupted sections of separated processors, and core connectors removed from split processors were all evaluated. Prior to multi detector path calculation, the liners of stone centres were broken and the designed duration of an entire core was calculated.

**Types and characteristics of reservoir pores**

**Pore morphology and distribution characteristics**

According to the data, such as image analysis research, Anse area average-specific surface area and pore shape factor and sorting coefficient and average coefficient of Anse area the smallest, it illustrates the Anse area of uniform pore shape, pore boundaries clear under the casting thin sections, this is because the Anse district primary intergranular pore is the main pore type, content is very high (Table 5), and sorting coefficient of separation is good at 46.73%. The Trask function is more suitable for accurately representing well-sorted mudstone. The sorting coefficient is being used to determine liquid size distribution

**Table 3.** Electron Probe Analysis Results of Turbidite with Different Occurrence in Chang 6 Reservoir in Anse Area.

| Block well | Depth/m | Horizon | Na₂O | MgO | Al₂O₃ | SiO₂ | K₂O | CaO | TiO₂ | MnO | FeO |
|------------|---------|---------|------|-----|-------|------|-----|-----|-----|-----|-----|
| Anse       |         |         |      |     |       |      |     |     |     |     |     |
| GAO20      | 1802.63 | Chang6 | 0.069| 0.044| 20.514| 59.287| 0.182| 9.727| 0.021| 0.000| 0.420|
| GAO61      | 1415.25 | Chang6 | 0.252| 0.057| 17.731| 57.243| 0.000| 9.214| 0.030| 0.000| 0.091|
| XIN72      | 1760.88 | Chang6 | 0.013| 0.091| 23.120| 46.009| 0.001| 9.925| 0.085| 0.055| 0.322|
| XIN92      | 1822.20 | Chang6 | 0.047| 0.009| 20.336| 58.008| 0.020| 10.137| 0.000| 0.131| 0.155|
| LIAN39     | 1327.55 | Chang6 | 0.011| 0.000| 15.931| 60.091| 0.034| 10.110| 0.001| 0.071| 0.156|
| XING211    | 1452.16 | Chang6 | 0.109| 0.035| 20.111| 54.464| 0.071| 9.966| 0.021| 0.059| 0.415|
| YANG74     | 1918.67 | Chang6 | 0.134| 0.041| 18.473| 55.174| 0.066| 9.875| 0.011| 0.221| 0.399|
| GENG280    | 2561.45 | Chang6 | 0.212| 0.050| 19.908| 55.221| 0.071| 9.807| 0.022| 0.121| 0.420|
homogeneity, that is mainly associated to complex sediment circumstances. During a manufacturing process, the Average coefficient shows the amount of primary driver required to move the difficulty of obtaining sources out of the tank. It can be seen from Figure 5 that the porosity content in Ansai area is 10%–15%, and the permeability in $1 \times 10^{-3}$ m$^2$ reservoir is classified as low-porosity and ultra-low permeability. The permeability distribution characteristics of the 6-long sand body are similar to the porosity. It can be seen that the Chang 6 sandstone reservoir in the Ansai area has very good reservoir and sand body development (Table 4). With the increase of depth, the porosity changes in Ansai area, and the average porosity decreases gradually, mainly distributed in hongjingzi – xinzhuang – baoziwan – tiebian city – wu cangbao area.

**Features of larynx**

Transect throat is a common type in Ansai area. It was found by scanning electron microscopy (sem) at a depth of 1802.90 m in well 20 high (Fig. a).

The pore structure of this kind of throat is larger, narrower, larger in diameter and higher in sandstone under scanning electron microscope. With very low permeability, such throats are common in Chang 6 reservoirs in Ansai (Fig. a). Bundle throat in Ansai There are few in this area, and the lamina is porphyritic structure with reddish-brown color. It can be seen from that there are more in this rock under the mirror.

Of cement, there are also many micro-capillary cross, throat is fine, observed in it is difficult to, but you can see many bundle throat combination characteristics (Table 6 & Table 7), in the Chang 6 reservoir in Ansai area for secondary porosity, ultra-low permeability, which can deduce the Ansai area for low – low permeability reservoirs, developing Chang 6 reservoir of sandstone is very good dense oil reservoir (Figure 6).

**Diagenesis research**

Diagenesis is the destruction of primary pores, which essentially changes the original distribution law and its evolution characteristics, and affects the characteristics of Chang 6 reservoir, thus promoting the formation of secondary pores, making the reservoir better, and forming extremely favorable reservoir space. The crystallization, cementation, and oxidation of clinoptilolite as a depositional material have specific impact on the structure of Permian reservoirs during the diagenetic transformation process. Afterward on diagenesis, oscillatory motions trigger carbonate changes of direction or

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**Figure 5.** Throat characteristics of Chang 6 reservoir in Ansai area under scanning electron microscope.

**Table 4.** Statistical Table of Porosity and Face Rate in Ansai Area.

| Pore types                  | Rate of face value | Area/sample number |
|-----------------------------|--------------------|--------------------|
| Residual intergranular pore | Absolute value %  3.7 | Ansai/810          |
|                            | Relative %         | 63.90              |
| Between the grain of solution pores | Absolute value %  1.73 | Ansai/810          |
|                            | Relative %         | 0.53               |
| Feldspar dissolved pore     | Absolute value %  0.63 | Ansai/810          |
|                            | Relative %         | 10.88              |
| Lithic dissolved pore       | Absolute value %  0.26 | Ansai/810          |
|                            | Relative %         | 4.49               |
| Mixed base solution pores   | Absolute value %  0 | Ansai/810          |
|                            | Relative %         | 0.00               |
| Zeolite solution pores      | Absolute value %  0.53 | Ansai/810          |
|                            | Relative %         | 9.15               |
| Grain microporous pore     | Absolute value %  0.32 | Ansai/810          |
|                            | Relative %         | 5.33               |
| Pore carbonate solution pore | Absolute value %  0.01 | Ansai/810          |
|                            | Relative %         | 0.17               |
| Microcracks                | Absolute value %  0.24 | Ansai/810          |
|                            | Relative %         | 4.15               |
| Total face rate            | Absolute value %  5.79 | Ansai/810          |
|                            | Relative %         | 1.00               |

**Table 5.** Distribution of Sandstone Pores in Chang 6 Reservoir in Ansai Area.

| Block (sample block) | Data | Mean specific surface area | Sorting coefficient | Homogeneous coefficient |
|----------------------|------|-----------------------------|---------------------|-------------------------|
| Ansai (270)          | max  | 0.92                        | 1.01                | 46.73                   | 0.63                    |
|                      | min  | 0.65                        | 0.65                | 17.09                   | 0.46                    |

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![Figure a](image1.png)  
**Figure a.** Electron microscopy of the transversal-like larynx with a depth of 27 Well: 1644.80m

![Figure b](image2.png)  
**Figure b.** Banded larynged electron microscope fish 39 depth: 1327.50m
The marine and nonmarine modification of volcaniclastics produces zeolites. Cementation of clay minerals

The main cementation of Chang 6 reservoir in Ansai area is clay cementation, which is mainly caused by carbonate cementation, autogenous zeolite cementation and siliceous cementation. Cementation is the main factor influencing the porosity evolution of Chang 6 reservoir. In the Ansai area, chlorite is the main clay mineral (Fig. A), which is also the main cement of Chang 6 reservoir in the Ansai area, and it affects the pore evolution of the Ansai reservoir, while both autogenous kaolinite (Fig. B) and autogenous chlorite are the main clay minerals of Ansai.

Cementation of turbid zeolite

Laumonite cementation in Ansai area is unique mineral cementation, the main development of Chang6 reservoir in Ansai area, the cementation of laumonite in Ansai area secondary solution pores of reservoir, the main factors in Ansai area found that many laumonite dissolution pore, as shown in Figure 8 are distributed in a core photos laumonite oil punctate high hole depth of 1410.37 m, 61 black parts for oil, the white part is laumonite cementation, Fig. B for laumonite dissolution oily punctate.

Table 6. Capillary Pressure Curve Constant Rate Mercury Injection.

| Mercury injection | Mercury withdrawal |
|-------------------|--------------------|
| Pressure (Mpa)    | Pressure (Mpa)     |
| Pore radius μm    | Pore radius μm     |
| J function        | J function         |
| Mercury saturation % | Mercury saturation % |
| 0.0033 224.238 0.000 | 0.000 0.0036 1.383 | 0.000 0.000 46.75 1.286 | 100.000 |
| 0.0073 101.309 0.000 | 0.000 0.0468 0.915 | 0.000 0.000 41.30 1.286 | 63.000 |
| 0.0106 69.650 0.000 | 1.15 0.050 0.685 | 0.000 0.000 41.01 2.490 | 40.000 |
| 0.0133 55.342 0.001 | 3.66 0.063 0.544 | 0.000 0.000 40.72 2.540 | 25.000 |
| 0.0249 29.598 0.001 | 6.68 0.076 0.451 | 0.000 0.000 40.44 2.441 | 16.000 |

Figure 6. Constant Rate Mercury Injection Curve of Chang 6 Reservoir in Ansai Area.

Table 7. Capillary Pressure Curve Constant Rate Mercury Injection in Well Fal 39.

| Mercury injection | Mercury withdrawal |
|-------------------|--------------------|
| Pressure (Mpa)    | Pressure (Mpa)     |
| Pore radius μm    | Pore radius μm     |
| J function        | J function         |
| Mercury saturation % | Mercury saturation % |
| 0.0054 136.456 0.000 | 0.00 0.025 2.017 | 0.000 0.000 71.96 64.16 | 0.000 100.000 |
| 0.0054 136.204 0.000 | 0.00 0.038 1.338 | 0.000 0.000 66.91 64.16 | 0.000 63.000 |
| 0.0103 71.547 0.001 | 0.00 0.051 0.989 | 0.000 0.000 64.16 64.16 | 0.000 40.000 |
| 0.0204 36.001 0.001 | 1.16 0.063 0.794 | 0.000 0.000 63.06 64.16 | 0.000 25.000 |
| 0.0310 23.718 0.002 | 1.29 0.076 0.661 | 0.000 0.000 61.64 64.16 | 0.000 16.000 |

Fig. A mercury injection capillary pressure curve 27 Wells higher
distribution of new 105 well depth is 1817.53 m which is suitable for oily, black spot distributings even light color part for laumontite cementation, Fig. C for crystal turbidity zeolite cement filling pore at 40 times the microscopic observation sheet for 61 well depth in the 1415.25 m high contains high silicon cement, distribution of small amount of residual cement dissolution, Fig. D for Ansai area of new 105 well depth of 1825.75 m visible hoar feldspar, replacement of feldspar and feldspar dissolved pore phenomenon, thus can be drawn from Ansai area Chang6 reservoir in both turbidity zeolite to the electron probe and residual turbidity zeolite on dissolution or secondary pore filling laumontite, etc., of which there is no change in the composition of laumontite, This indicates that there is no significant change in the composition of turbidity zeolites formed in the early and late diagenesis of rocks, and it can be seen that turbidity zeolites cementation is developed in Ansai area (Figure 8), which also indicates that the reservoir in Ansai area is well developed and suitable for reservoir reservoirs.

**Conclusion**

(1) The Chang 6 reservoir in Ansai area is a low-porosity and ultra-low permeability reservoir, with a permeability of $0.86 \times 10^{-3} \text{ m}^2$ and an average porosity of 11.63%. In addition, the Ansai area is subject to different source rock types. The content of feldspar sandstone in Ansai area is developed, while the content of feldspar lithic sandstone is relatively low.

(2) The primary intergranular pores and residual intergranular pores are mainly developed in Ansai region. The average pore radius in Ansai region is
around 30 m, indicating that the reservoir properties in Ansai region are uniform and stable.

(3) Because of the throat is one of the important determinants affecting reservoir permeability it affects Ansai area Chang 6 reservoir space size, oil and gas reservoir with low permeability and Ansai district belong to the low – low permeability reservoirs, Ansai area throat volume of effective reservoir space is large, throat radius is big also these factors suggest that the highest permeability Ansai area, reservoir performance for the best in the region for dense oil reservoir.

(4) as the factors that affect the Ansai area reservoir physical properties are many to the region for the low hole – ultra-low permeability reservoir, the control factors of reservoir in the study area has rock, clay mineral cement and turbidity zeolite cement as a symbol of Ansai area, and laumontite cementation in the Chang 6 reservoir in Ansai area is very important diagenesis, and turbidity zeolite cement Ansai area development, it also for Ansai area Chang 6 reservoir density discriminant very heavy oil reservoir.

**Data Availability**

Not applicable for the paper submitted.

**Disclosure Statement**

No potential conflict of interest was reported by the author(s).

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