Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 12, No. 1, 2024

Genetic Analysis of Chang 2 Low Resistivity Reservoir in Jiyuan Area of Ordos Basin

Man Tang, Wei Lu, Ming Han, Bin Hou, Qi Yang, Qiang Li

China National Petroleum Corporation Changqing Oilfield Branch Eighth Oil Production Plant, Xi'an, Shaanxi, China

Abstract: The resistivity of low resistance oil layers is similar to that of water layers, which poses difficulties for oil and gas development. This study mainly analyzes the genesis of the Chang2 low resistance oil reservoir in Wangpanshan District of Jiyuan Oilfield from factors such as formation water salinity, physical properties, pore structure, clay minerals, debris particles, and structure. It was found that the mineralization degree of water in the Chang2 formation in the Wangpanshan area is 79.04 g/L on average, and the water type is mainly $CaCl_2$; Debris particles, clay minerals, pore types, and capillary forces affect the bound water saturation, resulting in low oil saturation in long reservoirs. The intrusion of freshwater mud causes a significant increase in water layer resistance. This study analyzes the genesis of the Chang2 low resistance oil reservoir and has certain guiding significance for oil production.

Keywords: Low Resistance Oil Layer; Chang2 Reservoir; High Bound Water Saturation.

1. Introduction

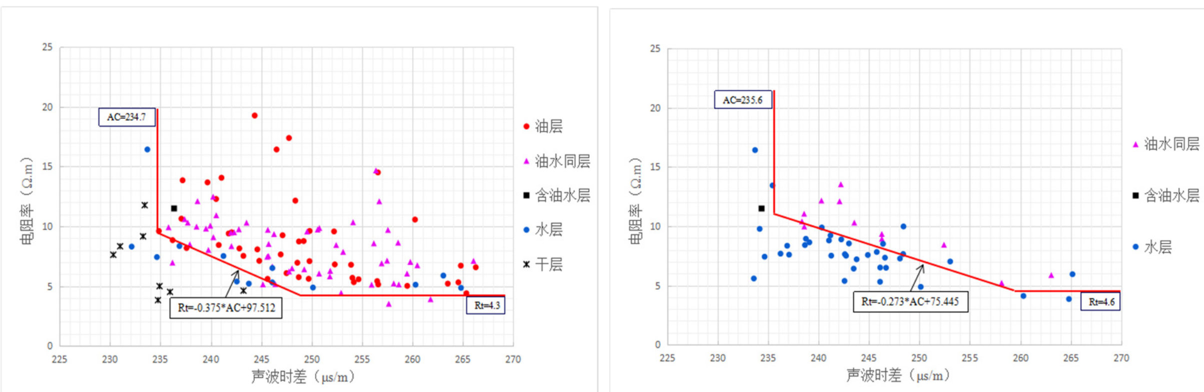
Low resistivity reservoir has always been a difficult problem in oil and gas exploration and development. At present, traditional logging technology can not accurately and intuitively discover the properties of this kind of reservoir. Low resistivity oil and gas reservoirs provide support for increasing production and tapping potential of old oil fields, so it is of great significance to carry out genetic analysis and effective identification methods of low resistivity oil and gas reservoirs [1].

Generally, reservoirs with low resistivity, such as low-contrast oil layers, or in the same oil-water system, the ratio of pure oil layer to pure water layer is less than 2 or less than 3, collectively referred to as low resistivity oil layers [2-4]. The resistivity of Chang2 reservoir in Wangpanshan block of Jiyuan Oilfield is low, which is difficult to identify and has few test Wells, and the reservoir distribution characteristics are unclear [5]. The cause of the low resistance is analyzed, so as to realize the effective identification of the low resistance oil layer in the study area and clear its distribution.

2. Regional Geological Overview

Jiyuan Oilfield is located in Dingbian County, Shaanxi Province, on the western margin of the northern Shaanxi slope of Ordos Basin, with favorable reservoir-forming conditions above Chang2 and industrial oil flows generated in Yan9, Chang2 and Chang4+5 [5]. Chang2 reservoir is the main oil reservoir for exploration and development in Jiyuan oil field. Chang2 reservoir is mainly composed of gray fine-grained rock (including feldspar and quartz sandstone), which is dominant, in addition to the reservoir also contains a small amount of feldspar lithic sandstone. The sorting of sandstone is good and the sedimentation process is orderly. Most of the clastic particles are subangular, the permeability of the reservoir is relatively good, and the cementation type is mainly porosity and pore-film. The interstitial content of Chang2 sandstone is low, averaging 13.27%.

3. Electrical Characteristics of Low Resistance Oil Layer



(a)Wangpanshan block Chang2 west acoustic time difference- resistivity intersection diagram

(b)Wangpanshan block Chang2 eastern acoustic time difference - resistivity intersection diagram

Figure 1. Wangpanshan block acoustic time difference- resistivity intersection diagram

Intersection chart method in fluid identification is the most basic and commonly used method for qualitative identification of fluid properties in actual production at present. Two different types of logging information are used as horizontal and vertical coordinates to distinguish fluid properties according to the distribution law of different types of data points in the coordinate system [6]. The lower limit of electrical property of Chang2 west is 234.7μs/m< AC< 248.8μs/m, RT>97.512-0.375*AC, AC>248.8μs/m, RT> 4.3Ω·m. The lower limit of electrical properties of long 2 is 235.6μs/m <AC<259.4μs/m, RT>75.445-0.273*AC, AC> 259.4μs/m, RT>4.6Ω·m. It can be seen from Figure 1 that under the boundary of the intersection plate, the ratio of oil to water from the test oil is high, and it is difficult to identify the Chang2 low resistance oil layer through the conventional sonic time-difference resistivity intersection plate.

Table 1. Data table of Chang2 high-yield industrial oil flow Wells in Jiyuan Area (some Wells)

Well	horizon	resistivity (Ω·m)	porosity(%)	permeability (mD)	oil saturation(%)	water saturation(%)	daily oil production (t)	daily water production (m^3)
luo179	chang2_2^2	4.4	16.6	17.3	12.5	45.6	55.08	0
geng179	chang2_1^3	7	14.5	4.3	22.7	39.2	35.7	0
yuan120	chang2_1^3	9.2	15	20	27.6	36.8	33.92	5.7
huang227	chang2_2^2	6.2	14.2	1.4	17.3	43.3	31.45	0
hu130	chang2_2^1	7.1	/	/	/	/	31.19	4.4
yuan162	chang2_1^3	7.3	17.7	34.6	26.1	33.7	30.86	0
geng130	chang2_1^3	11.8	14.6	7.7	18.3	35.4	30.7	0
geng19	chang2_1^3	7.1	/	/	/	/	25.7	6.4
geng180	chang2_1^3	6.1	/	/	/	/	23.46	4.8
geng109	chang2_1^3	6.1	/	/	/	/	22.6	0

Statistics on the data of high-yield industrial oil flow Wells in Jiyuan Oilfield show that their resistivity is basically less than 10Ω·m (Table 1). The resistivity of 78 industrial oil flow Wells in Chang2 formation in Jiyuan area is calculated, and 68 of them are less than 10Ω·m. From the comparison between different resistivity zones, there is no significant difference in the characteristic parameters (Table 2).

Table 2. Comparison table of parameters of industrial oil flow Wells

section(Ω·m)	well number()	resistivity (Ω·m)	time lag(μs/m)	density (g/cm^3)	porosity(%)	permeability(mD)	oil saturation (%)	water saturation(%)	daily oil production (t)	daily water production(m^3)
<5	13	4.1	252.3	2.3	17.7	11.5	29.2	32.6	7.77	35.5
5-10	55	7.2	246.3	2.1	15.7	12.2	26.1	37.5	9.12	12.1
>10	10	11.5	242.6	2.4	15.3	10.8	24.2	36.8	7.83	12.4

4. Cause Analysis of Chang2 Low Resistance Oil Layer

The causes of reservoir resistivity can be divided into internal causes and external causes. The internal factors leading to low reservoir resistivity are mainly bound water saturation, additional conductivity of clay minerals, conductive minerals, oil-water differentiation and high and low layer water salinity. The external cause is mainly the decrease of reservoir resistivity caused by mud invasion [7-9]. This study mainly analyzes formation water salinity, physical properties, pore structure, clay minerals, clastic particles, structure and other factors.

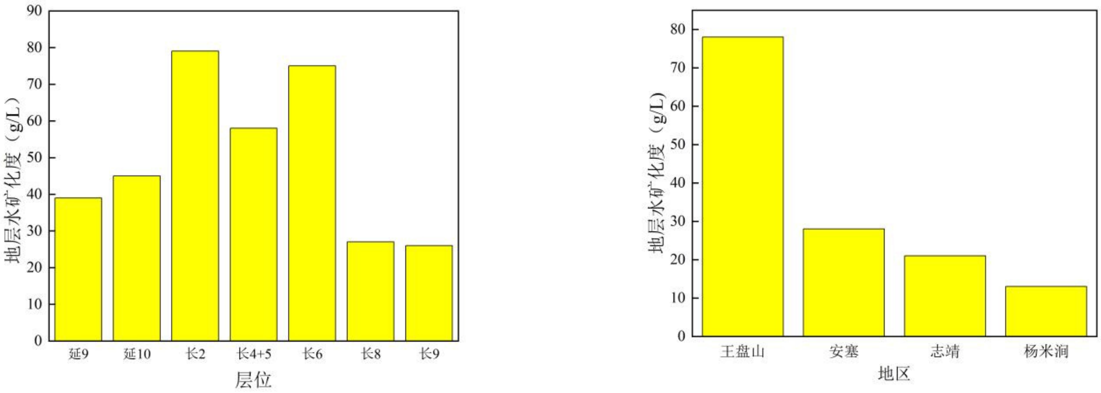
4.1. Formation Water Salinity

Formation water resistivity in pores has a direct influence on reservoir resistivity, and the salinity of formation water has a direct influence on formation water resistivity. High formation water salinity will reduce the resistivity of formation water in the pores, and reduce the resistivity of the reservoir, so that the contrast between the resistivity of the oil and gas reservoir and the water layer is not obvious, and the oil and gas layer cannot be effectively judged.

The water salinity of Chang2 formation in Wangpanshan area is higher (Figure 2-a), with an average of 79.04g/l, and the water type is mainly $CaCl_2$, which is significantly higher than that of other reservoirs. Compared with other areas, the mineralization of Chang2 in Wangpanshan is significantly higher than that in other areas (Figure 2-b). The high salinity formation water will enhance the conductivity of ions in the reservoir solution, and the resistivity in the formation will be greatly reduced, thus blurring the resistivity boundary between the oil and water layers, resulting in the decrease of the resistivity contrast of the oil and water layers.

4.2. High Bound Water Saturation

High bound water saturation has the most common and direct influence on the development of low resistivity oil reservoir, and its change is mainly controlled by the characteristics of the reservoir itself, including rock pore structure and pore throat diameter, clay composition type and content, rock wettability, etc.



Figure(a): Formation water salinity diagram of different strata in Wangpanshan area

Figure(b):Formation water salinity diagram of Chang2 formation water in different areas

Figure 2. Formation water salinity correlation diagram

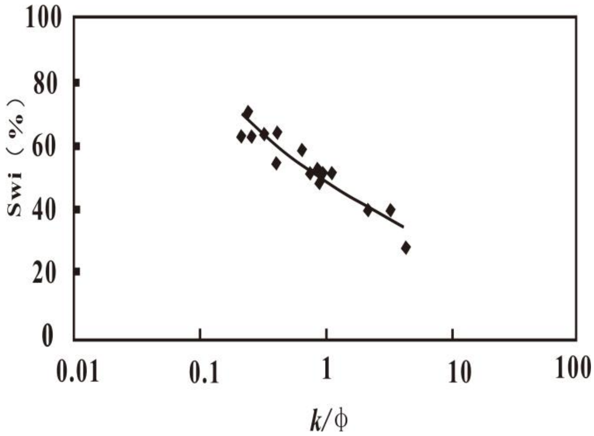


Figure 3. Relation between porosity and permeability ratio of Chang 2 reservoir and bound water saturation

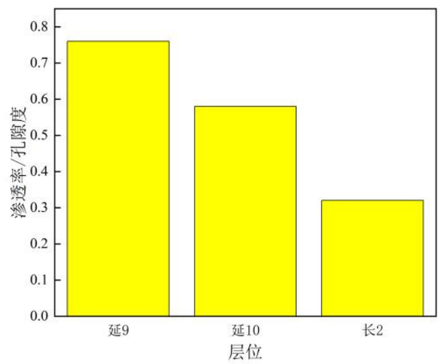


Figure 4. Physical structural parameters of different formations in Wangpanshan area

Reservoir bound water saturation is affected by porosity (φ) and permeability. In Chang2, the bound water saturation tends to decrease with the increase of φ and K, but the correlation is not good. The physical structure parameter (K/φ ratio) has a good correlation with bound water saturation (S_{wi}) (Figure 3). The average porosity of Wangpanshan Chang2 is 14.0%, the average permeability is 4.8mD, and the permeability is low, the physical structural parameters are small, and the bound water saturation is high (Figure 4).

According to the grain size analysis data of Wangpanshan area, the particles of Chang2 rock are relatively fine, mainly fine sand, accounting for 57.48% on average, and silty sand about 23.15%, and the rest are medium sand and mud, without coarse sand (FIG.5). Fine sandstone rock has a large specific surface area and is dominated by fine sand, which makes it easy to adsorb formation water and increase the bound water content.

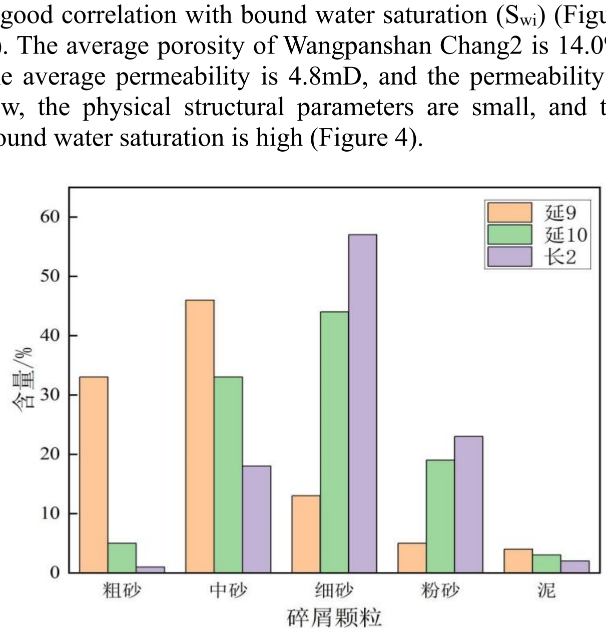


Figure 5. Size and composition of clastic particles in different beds in Wangpanshan area

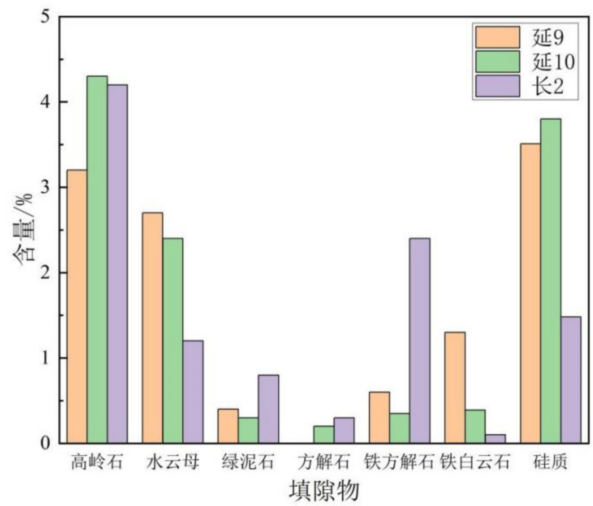


Figure 6. Contents of clay minerals in different beds in Wangpanshan area

In Wangpanshan area, the content of clay minerals is high, and the filling of clay minerals such as kaolinite makes the geometry of pores complicated and multi-end. Therefore, the channel becomes smaller, the ability to adsorb ions in aqueous solution is strengthened, and the saturation of bound water is increased (Figure 6).

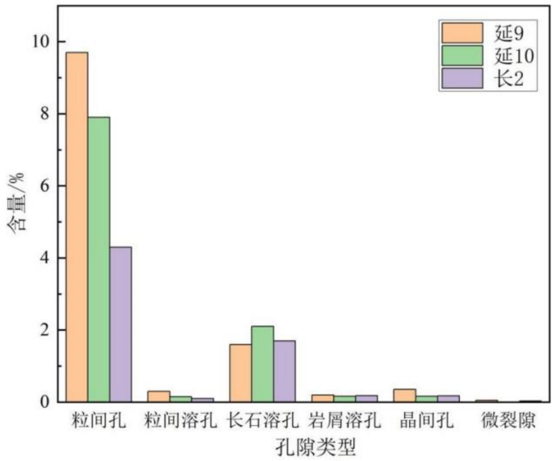


Figure 7. Pore type histogram

The main type of Chang-2 pores in Wangpanshan area is intergranular pores, the content of which is about 4.2%, followed by feldspar dissolved pores, debris dissolved pores and intergranular pores. The content of solution pores in feldspar and debris exceeds 40%, and the secondary pores are relatively developed. Smaller secondary pores lead to an increase in bound water and thus a decrease in resistivity (Figure 7).

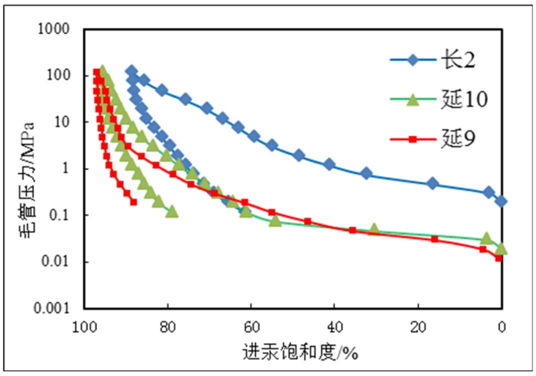


Figure (a) Capillary force curves of different layers in Wangpanshan area

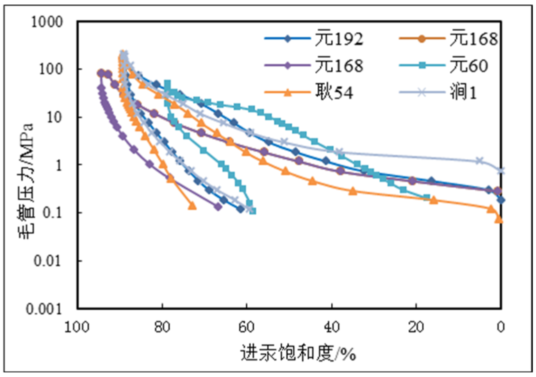


Figure (b) Capillary force curves of different samples in Wangpanshan area Chang2

Figure 8. Capillary force diagram

Chang2 reservoir in Wangpanshan area has high drainage pressure, low mercury intake saturation, capillary force curve inclined to the upper right and no good platform segment, indicating strong heterogeneity and complex pore throat structure. The complex pore throat structure results in more residual bound water in the reservoir pores, forming a low-resistivity oil layer (Figure 8).

4.3. Low Oil Saturation

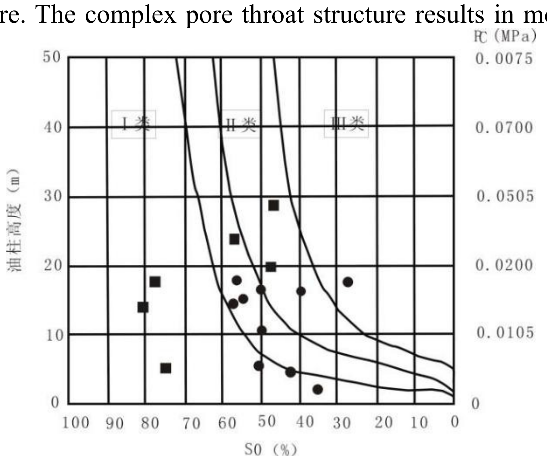


Figure 9. Diagram of the relationship between the height of long 2 oil column and oil saturation

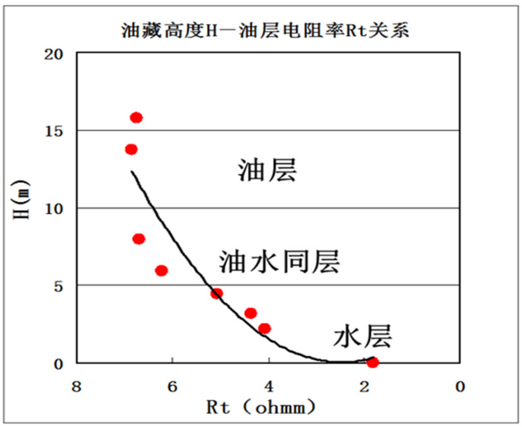


Figure 10. Relationship between reservoir height of Chang2 and reservoir resistivity

The oil source of Chang2 reservoir in Jiyuan Oilfield is mainly from the high-quality source rock of Chang7, which is far away from the oil source in the longitudinal direction and the degree of oil and gas charging is low [10]. Chang2 reservoir is a structure-lithology trap, and the oil layer is mainly distributed in the high-amplitude part of the nose structure. The structural uplift amplitude of the reservoir is low, the pore throat sorting of the reservoir is poor, the permeability is low, and the longitudinal heterogeneity is strong. These factors lead to the poor oil-water differentiation of Chang2 reservoir and the generally high-water saturation of the reservoir.

Figure 9 shows that in Chang2 reservoir, oil saturation is negatively correlated with the height of the oil column: as the oil column decreases, the oil saturation decreases. Figure 10 shows that the resistivity decreases as the reservoir depth decreases. When the height of the oil column is less than 10 meters, the oil-water separation is weakened, resulting in the coexistence of oil and water, and the oil saturation decreases significantly.

4.4. Intrusion Effect of Fresh Water Mud

In the drilling process, drilling mud slurry is easy to invade reservoirs with micro-fractures or good physical properties, and the increase of water content in reservoirs will increase the concentration of formation mineral ions and improve the conductivity of reservoirs, thus forming low-resistivity oil reservoirs [11-13]. Li Changxi et al. studied the Chang2 oil layer and the water layer through simulation experiments and concluded that when fresh water mud invaded the oil layer, the resistivity of the oil layer would be slightly reduced, while the resistivity of the water layer would be slightly increased, but the overall impact was limited. The high formation with high salinity reduces the resistivity difference between oil and water. The intrusion of fresh water mud will further reduce the difference in resistivity between oil and water layers, making it difficult to distinguish oil and water layers in absolute terms. Although it has little effect on the resistivity of the oil layer, the resistivity of the water layer increases significantly [14-15]. Li Na et al. found through statistics that except for a few Wells, the logging intrusion characteristics were not obvious, and most of the dual-induction-8-lateral resistivity logging of Chang2 layer oil reservoir, oil-water co-reservoir and water reservoir were characterized by high intrusion characteristics, which made it difficult to identify oil and water [16].

5. Conclusion

(1) The resistivity of Chang2 oil layer in Wangpanshan area is low, which is close to the resistivity of water layer, or even lower than that of water layer. The low resistivity of Chang2 is mainly affected by high formation water salinity, high bound water saturation and low oil saturation.

(2) High formation water salinity is the core factor leading to low resistivity oil reservoir. Under the same salinity and oil content conditions, the better the physical property of the reservoir, the higher the connectivity of its conductive network and the lower the resistivity. However, the intrusion of fresh water mud leads to the increase of the resistivity of Chang2 water layer, which further leads to the difficulty in identifying Chang2 low resistivity oil layer.

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