IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 05, Issue 02 (February. 2015), ||V3|| PP 11-17

Analysis method of GaoTaizi tight oil reservoirs classification in QiJia area

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***Abstract*:** In this paper, the purpose is to find a relatively good reservoir by classification, which can be explored and developed by some methods. According to the characteristics of Gaotaizi tight oil reservoir pore structure in Qijia area, comprehensively considerate the information of mercury data and testing data. On the basis of researching the pore structure characteristics, with the correlation analysis of pore structure parameters and physical parameters to determine the mercury index. According to the mercury index and porosity, reservoir classification methods and plates are established in research area, and formulated the tight reservoir classification standards by pore structure characteristics. At last, verifying the plate, the consistent rate is over 88 percent, indicating the plate has a good application effect in the region, which providing a feasible method for reservoir evaluation.

***Keywords*:** *tight oil reservoirs reservoir classification mercury index conventional curve*

I. INTRODUCTION

With the oil exploration process in Songliao Basin, the objects of exploration and development is increasingly complex, and increasingly difficult. Tight oil reservoirs has become research focus in China. How to find the relative quality of the reservoir through the reservoir classification is the key to tight oil reservoirs exploration and development. In the current studies, primarily through pore structure and pore type to divide the formation, the application of this method is widely used, and the effect is better. In recent years, many scholars have done a lot of work on reservoir classification. Jianhua Zhu[1] is using capillary pressure curve, porosity and irreducible water saturation to establish a low porosity and low permeability reservoir classification criteria. Chuang Yun Jiao[2] on the basis of flakes, scanning electron microscope, mercury and other studies, selecting reservoir properties and pore structure parameters, applying clustering methods to reservoir classification, the research is for the evaluation effect of low porosity and low permeability reservoirs. Jianlong Zhang[3] using intersection techniques and microscopic pore structure to identify the reservoir classification criteria in Nanyang Black Dragon Temple area, and classifying the reservoirs according to the standard, then supporting test oil production proposal and getting the oil industry oil flow. Hongjian Wang[4] is applying pore structure characteristic parameters to classify the reservoirs of Cretaceous volcanic clastic reservoirs in Wunan area, and establishing the logging identification plates, has strong applicability. Hao Wu[5] are applying mercury and slice identification data, factor analysis and k-means clustering analysis method to classify the pore structure, the research is for the exploration and evaluation of tight reservoir "sweet spot" areas.

Based on the pore structure analysis, through correlation analysis of pore structure parameters and physical parameters to explicit the mercury index, applying mercury index and porosity intersection to establish tight reservoir classification plates. By testing data verified, it is achieved a good application effect, providing a feasible method for the reservoir evaluation.

II. REGIONAL GEOLOGICAL FEATURES

Gaotaizi tight oil reservoirs in QiJia area belongs Cretaceous Lower Cretaceous Qingshankou green two or three paragraphs formations, mainly high three, high four reservoirs, affected by northern source system, mainly developed distributary channel, River mouth bar, and other sand. During the high three and high four times, it is deposited a thin interbedded formations by a dark gray, gray shale and gray, dark gray siltstone, mud and calcium containing siltstones, ostracods calcareous lays and ostracods fossil layers. Reservoir porosity mainly in 1.4-15.9%, average porosity of 9.5%, permeability mainly in 0.01-0.5mD, average permeability of 0.34mD, belongs to low porosity and low permeability reservoir characteristics, reservoir is strong heterogeneity. Gaotaizi oil reservoirs, with heavy mud and calcium, which changes the range of clay content is generally 5-65%, with an average of 21.8%; calcium content is generally 5.3-67%, with an average of 16.9%; Because of deeply buried and strongly diagenesis, mainly clay minerals is illite and the average is greater than 70%, followed by chlorite, Eamonn mixed layer containing a small amount of about 2-10%.

III. PORE STRUCTURE CHARACTERISTICS OF TIGHT OIL RESERVOIR

Pore structure refers to the rock pores and throats with a geometric shape, size, distribution, interconnected, as well as configure the relationship between pore, throat and so on[6-7]. It reflects a combination between the various types of reservoir voids and pore throats, is the total appearance of pore throats. There are two aspects will be studied in this paper which is micro and macro of the pore structure characteristics.

The main reflection parameters of pore structure is the maximum pore radius, the average pore radius, median pore radius, the average radius, sorting coefficient, relative sorting coefficient, structure factor, uniformity coefficient, displacement pressure and maximum mercury saturation and so on. They are important parameters to study oil recovery and productivity prediction. According to 25 wells 158 mercury sample analysis data, statistics obtained the major distribution of pore structure parameters and average in Qijia area. As shown in Table 1. As can be seen from the table, tight oil reservoirs in the region has a higher displacement pressure, pore radius is small, poor sorting, connectivity is not good, the whole performance of the pore structure is bad, and characterized by a strong heterogeneity .

Table 1: Distribution and Average Pore Structure Parameters

Pore structure parameters	main distribution	average
Maximum pore radius/μm	0.1~10	**2.501**
Average pore radius/μm	0.05~5	**0.911**
Median pore radius/μm	0.05~0.5	**0.564**
Average radius/μm	0.03~3	**0.736**
Sorting coefficient	1~4	**2.331**
Relative sorting coefficient	0.5~50	**24.026**
Structure factor	0.05~5	**2.837**
Uniformity coefficient	0.2~0.5	**0.338**
Displacement pressure/ Mpa	0.1~10	**3.725**
Maximum mercury saturation/%	**60~95**	**80.636**

The main parameters to measure reservoir properties are porosity and permeability. Through 158 mercury sample physical parameters and pore structure parameters to establish a cross-plot to find a better correlation between physical parameters and pore structure parameters. From the intersection figure, the physical parameters and the maximum pore radius, the average radius, displacement pressure, and sorting coefficient have better correlation. As shown in Figure 1. As can be seen from the figure, the physical parameters with the maximum pore radius, the average radius, sorting coefficient adding increases, with the displacement pressure adding decreases.

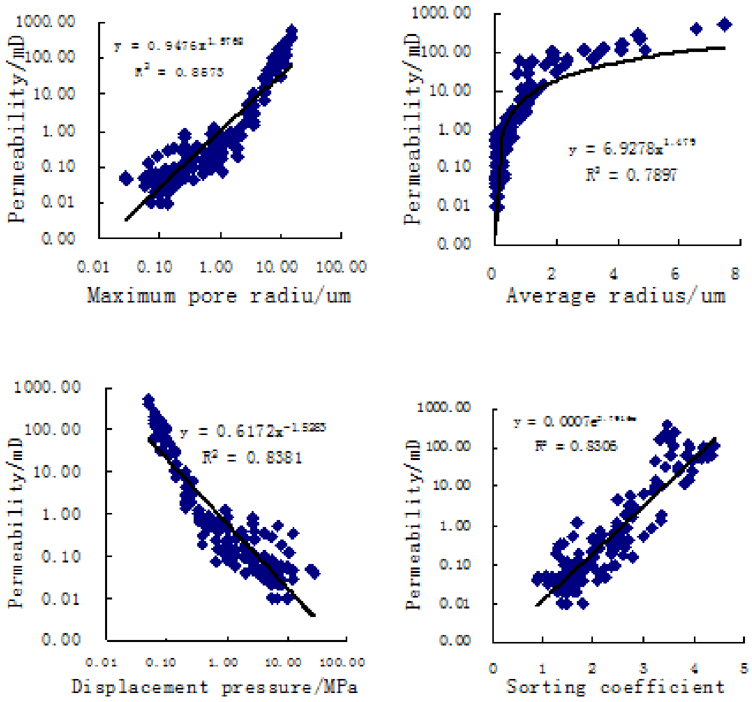

Fig. 1: Physical parameters and pore structure parameters cross plot

IV. CLASSIFICATION METHOD OF TIGHT OIL RESERVOIRS

Physical parameters of reservoir classification

Reservoir classification is generally use physical parameters (porosity and permeability) to divide the reservoir. Porosity and permeability describe pore size and fluid flow capabilities in the reservoir space. According to the study area porosity and permeability data analysis of 218 samples, do the porosity and permeability of the intersection diagram, build reservoir classification plates. As shown in Figure 2. Figure 3 is verification testing data of the plate. As can be seen from the figure, the porosity and permeability of the reservoir is divided into four categories:

(1)Type I reservoir: porosity > 10%, permeability > 0.2mD;

(2)Type II reservoir: 8 < porosity < 10%, 0.06 < permeability < 0.2mD;

(3)Type III reservoir: 6 < porosity < 8%, 0.03< permeability<0.06mD;

(4)Type IV reservoir: 4 < porosity < 6%, 0.02 < permeability < 0.03mD

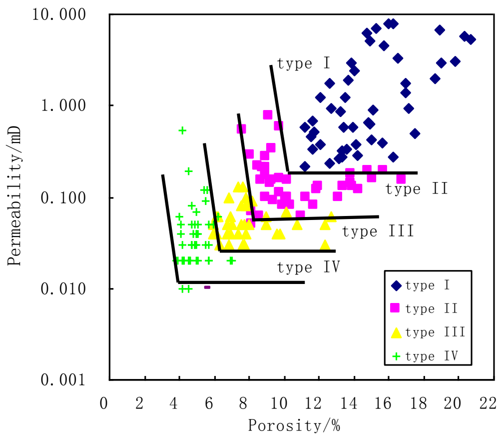

Fig. 2: Reservoir classification

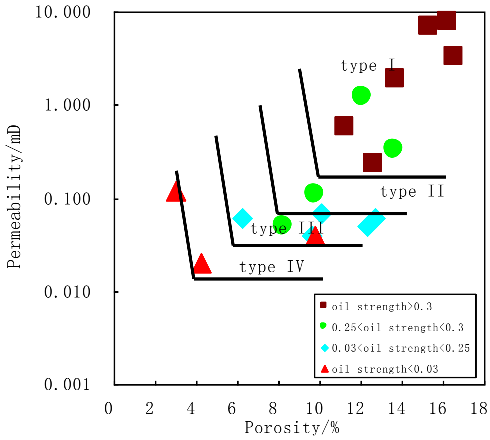

Fig. 3:Verification testing data plate

B Mercury data of reservoir classification

Articles in the macro-pore structure characteristics have analyzed the physical parameters and maximum pore radius, average radius, sorting coefficient and displacement pressure, there is a good correlation. With the maximum pore radius, the average radius, sorting coefficient adding, porosity and permeability increases, indicating pore structure changed for the better; With displacement pressure increases, porosity and permeability decreases, indicating that the pore structure deteriorated. The description of another parameters of the pore structure characteristics is maximum mercury saturation with irreducible water saturation is one, the pore structure and irreducible water saturation are closely related, the better the pore structure, the smaller the irreducible water saturation, in contrast maximum mercury saturation greater. Therefore, the choice of the five parameters using mercury data to build a new parameter - mercury index MI. The formula is:

$$MI = R_d \times S_p \times S_{Hg} \times R_z \div P_d \quad (1)$$

where, R_d= maximum pore radius, μm; S_p= sorting coefficient; S_{Hg}= maximum mercury saturation,%; R_z= average radius, μm; P_d= displacement pressure, Mpa.

Its physical meaning can be interpreted as a comprehensive characterization of pore structure complexity. maximum pore radius reflect the quality of the flow conditions; Sorting coefficient is a measure of reservoir rock samples pore throat size standard deviation, which is a direct reflection of the degree of concentration distribution of pore throats; Average radius is the measure of overall average pore throat radius size; Maximum mercury saturation reflect changes in pore volume; Displacement pressure reflects both the concentration of rock pore throats, while reflects this focus pore throat size. Based on the above analysis, the greater the mercury index, the better the pore structure; The smaller the mercury index, the more complex of the pore structure.

The lithology of reservoir is complexity, strongly heterogeneity in Qijia area, microscopic pore structure on the quality of the reservoir has a controlled action, the same porosity reservoir permeability differences greatly different pore structure. With 26 wells 163 mercury sample analysis, correlation between mercury index and porosity better than permeability correlation. As shown in Figure 4. As can be seen from the figure, the correlation coefficient of mercury index and porosity is over 0.78.

Mercury index reflects not only intuitive pore structure characteristics, but also provides a reasonable argument for reservoir classification. The reservoir is divided according to the intersection of mercury index and porosity to established reservoir classification plates and standards. As is shown in Figure 5, the tight oil reservoirs will be divided into four categories by mercury index and porosity.

(**1**) Type I reservoir: well reservoirs, MI > 10, porosity is more than 10%.The main stone is siltstone, pore types are intergranular porosity, intragranular dissolved pores. Pore throat is well sorting, the average sorting coefficient is 2.56, throat radius is large, displacement pressure is low, an average of 0.47Mpa. Such reservoirs are well reservoirs with low porosity and low permeability, the oil strength is above 0.3, you can get industrial oil.

(**2**) Type II reservoir: well-moderat reservoirs, 1 < MI < 10, the porosity of 8% to 10%, porosity is relatively low, with fine sandstone, pore types are intragranular holes, mainly residual intergranular pore. Pore throat is better sorting, the average sorting coefficient is 2.0, throat radius is large, displacement pressure is low, an average of 1.64Mpa. Medium reservoir properties such as low porosity and low permeability reservoirs better. The oil strength is between 0.25 and 0.3, you can get low-yield oil flow.

(**3**) Type III reservoir: moderate-poor reservoirs, 0.1 < MI < 1, the porosity of 6% to 8%, low porosity, mainly siltstone containing mud, pore types intergranular dissolved pore. Pore throat is poorly sorted, the average sorting coefficient is 1.69, small throat radius, displacement pressure is high, with an average of 3.55Mpa. Poor reservoir properties such as the low porosity and low permeability reservoir characteristics. The oil strength is between 0.03 and 0.25, you can get a lower capacity.

(**4**) Type IV reservoir: poor reservoirs, 0.01 < MI < 0.1, the porosity of 4% to 6%, low porosity, mainly argillaceous siltstone, pore types residual intergranular pore, intragranular dissolved pore. Pore throat is poor sorting, the average sorting coefficient is 1.63, throat radius is small, high displacement pressure, an average of 5.77Mpa. Such poor reservoir permeability, the oil strength is below 0.03, has no capacity.

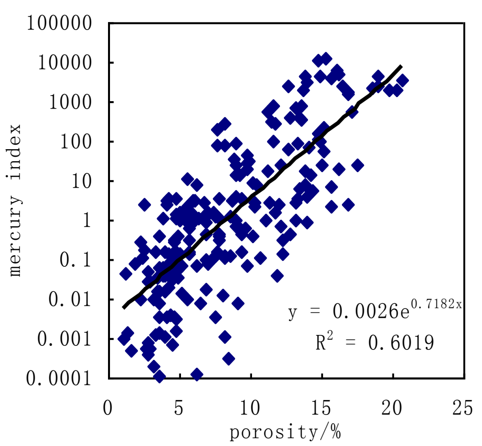

Fig. 4: Mercury index and porosity cross plot

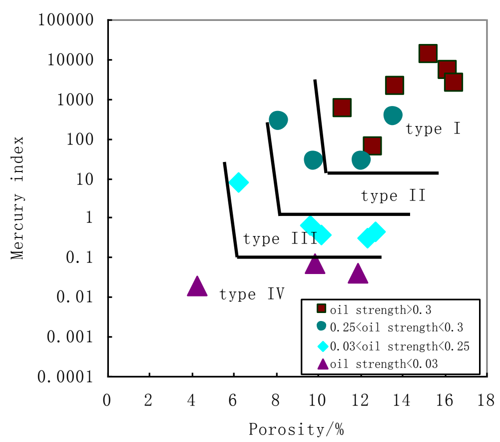

Fig. 5:Verification testing data plate

In the absence of mercury information on core data, conventional logging data can be applied to establish method for determining mercury index, in order to achieve using conventional logging data for reservoir classification. In this paper, using 17 wells 103 core data in the study area, preferably gamma, neutron, density curve to establish mercury index model to achieve reservoir classification. The formula is:

$$MI = \exp(107.98 + 0.18 * gr - 75.5 * den - 24.9 * \ln(gr) - 220 * \ln(den) + 1.27 * \ln(\quad (2)$$

Figure 6 shows that the comparison with mercury index using core data and conventional curve data. The correlation coefficient is 0.83. Figure 7 is a combination of oil strength with mercury index and porosity of the reservoir classification plate.

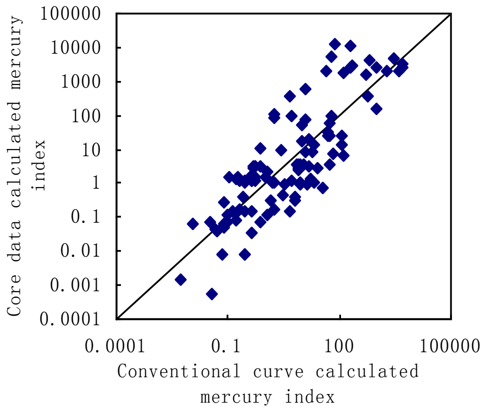

Fig. 6: Core data calculated mercury index and Conventional curve calculated mercury index

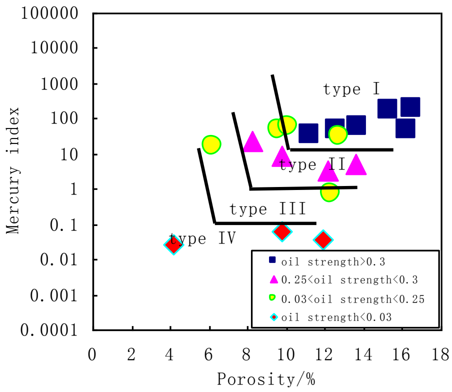

Fig. 7:Verification testing data plate

V. ANALYSIS OF APPLICATION EFFECT

By testing data to verify the classification plates. As shown in Figure 3. Testing data results show that 18 layers have 12 layers in line, and the rate of is 66.7%. The reason of low compliance rate is that tight oil reservoir heterogeneity is strong, and microscopic pore complex structure. The same porosity reservoirs have different pore structure and movable fluid differences, resulting in a great difference between the reservoir permeability. Therefore, this method with only physical parameters to divide the tight reservoir is clearly not applicable, it is difficult to achive satisfactory results. As shown in Figure 5, Testing data results show that 18 layers have 16 layers in line, and the rate of is 88.9%; As shown in Figure 7, Testing data results show that 18 layers have 15 layers in line, and the rate of is 83.3%. Take Jin393 well in QiJia area for example, as in Figure 8.

The output oil in 36th layer is 1.190t/d, mercury index is 21.69, porosity is 7.4%, conclusion is industrial oil, reservoir type is II; The output oil in 40th layer is 2.23t/d, mercury index is 7532.7, porosity is 11.5%, conclusion is industrial oil, reservoir type is I. All in line with the accuracy chart, indicating that the use of mercury reservoir data classification has a good application results can be applied to actual production.

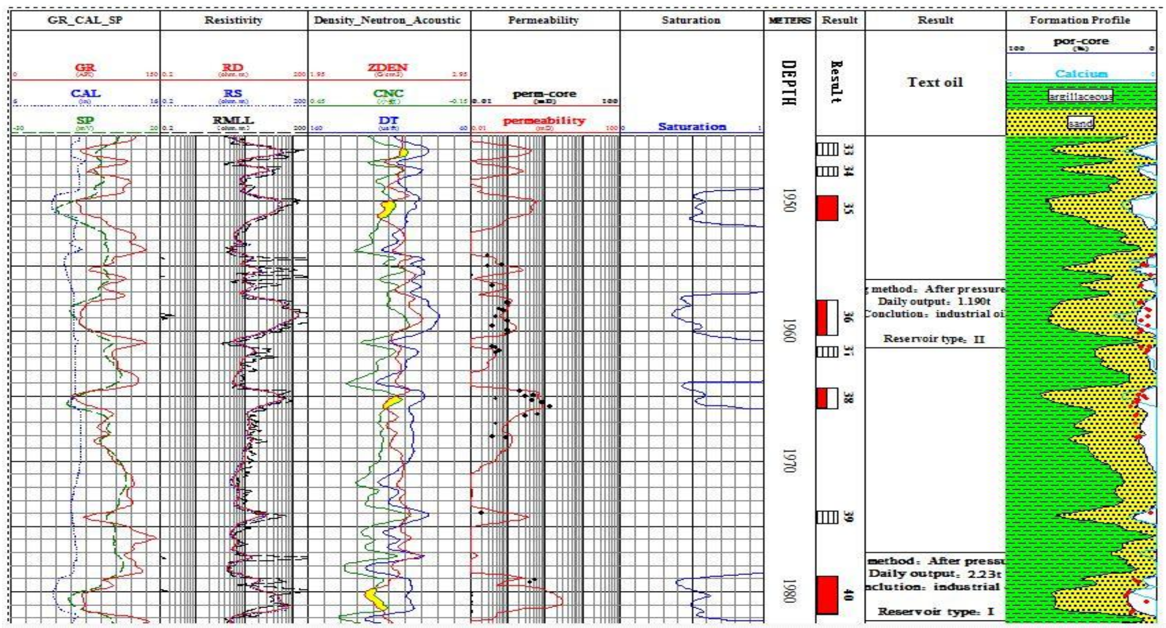

Fig. 8: Jin393 Logging interpretation

VI. CONCLUTION

The method of porosity and permeability for tight oil reservoir classification is not applicable. Through test oil data verifying, the rate of the reservoir classification plates which is established by mercury index and porosity is over 88.9 percent, by conventional curve calculated mercury index and porosity is 83.3 percent. Tight oil reservoirs can be accurately classified, that made a good application effect in research area.

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