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Quantitative Analysis Method of Microscope Remaining Oil with Fluorescence Thin Section

Hengyuan Qiu, Yan Zhang
College of Earth Sciences，Northeast Petroleum University, Daqing, Heilongjiang, China, 163318
Z13579_2005@126.com

Abstract: The distribution of microscope remaining oil is of great significance to select Reasonable improve oil recovery technology. ased on chromatically theory，the color information of each pixel in the image of rock fluorescence sheet were extracted and put into CIE chromatically diagram, The parameters such as wavelength, brightness, color saturation and difference of red and blue were calculated with the diagram. Then the discriminate functions of the rock, oil and water were constructed and the criteria for the classification of three components was determined, then initial quantitative division of three components from fluorescence sheet was achieved. It’s concluded that there is good Relevance between micro oil saturation and color saturation, so according to the oil colors in different positions of fluorescence sheet image, micro oil saturation can be calculated, then ultimately determine the exact proportion of the rock, oil and water in fluorescent sheet. By using the methods mentioned above oil displacement efficiency is calculated with the fluorescent sheet image from cores of displacement experiment in laboratory, comparison results show the accuracy of the method. Compared with the conventional estimation methods, the method can be easily and quickly to quantitatively analyze the image of fluorescence sheets, and it can eliminate artificial disturbance.it is more accurate. The methods can be used to identify distribution of microscopic remaining oil and provide technical support for formulating enhanced oil recovery measures.

Key words: *Microcosmic remaining oil; Fluorescence thin section; CIE chromatic system; Discriminate analysis*

I. INTRODUCTION

Fluorescence thin section analysis method is an important method of studying the characteristics of microscopic remaining oil distribution, the research results have important guiding significance in understanding the cause of remaining oil and making scheme of tapping of remaining oil[1-3]. In recent years, people studied the law of occurrence and genesis of microscopic remaining oil with fluorescence thin section and achieved some good effect [4-6].

In fluorescence thin section, there has different colors in rock, oil and water phase. according to the colour characteristics of samples , such as brightness, colour saturation and distribution area, the properties of oil and water, oil level can be obtained, the method is more accurate and intuitive[7-9]than other methods. Due to the different distribution relationship of three components, different concentration of oil in the pores of rock, the colours in rock thin section are very complicated, and the boundaries among oil, water and rock phase are not clear. Although at present, the studies about the types and amount of microcosmic remaining oil are more, but they are mainly of qualitative or semi quantitative, the results are not accurate and objective because of influencing by experience of observers. In this paper, with the help of CIE chromaticity diagram, author put forward a method of quantitative analysis of the distribution proportion of oil, water and rock phase in fluorescence thin section. Then the quantitative analysis result and laboratory test result are contrasted, The two values are very close, so the method is reliable. It will be more great guidance to tapping the remain oil.

II. CIE COLOR SYSTEM AND THE CHROMATICITY DIAGRAM

Colour is very complex. It involves physics, psychology, biology and materials science and other disciplines. Colour is a kind of subjective feeling of the human brain to the object, the common colour is saved in the RGB model, which is a mixture of red(R), green (G), blue (B) in different proportions, different colours are formed from different colours ratio. But the RGB model has relationship with device. from the human sensation, the same RGB models exist colour difference in different devices(including human eyes, scanners, monitors and printers).

W.David Wright (1928) and John Guild (1931) established a observer's colour perception digital system --the 1931CIE-XYZ system. According to the human vision, the system uses X,Y,Z three ideal synthetic colour instead of R, G,B colour. The idea synthetic colours are close to R,G, and B, they are known as the three stimulus values. Conversion of RGB system to CIE-XYZ system is expressed as:

$$X=2.7689R+1.7517G+1.1302B$$
$$Y=1.0000R+4.5907G+0.0601B \quad (1)$$
$$Z=0.0000R+0.0565G+5.5943B$$

The layout of different colors shown in the color space is called the chromaticity diagram, the diagram was enacted in 1931 by the Color International Commission (CIE), also known as the CIE chromaticity diagram, the horizontal and vertical coordinates are x and y in the diagram, x coordinates is indicated proportion of red, and y coordinates is indicated proportion of green, the proportion of blue is showed by coordinate z, the value of z can be obtained by x + y + z = 1 :

$$x=X/(X+Y+Z)$$
$$y=Y/(X+Y+Z) \quad (2)$$

The color changes that human eyes can distinguish can be described by tone, brightness and saturation, these parameters can be achieved from chromaticity diagram. The RGB value of any point in fluorescence thin section photographs can be Extracted by soft Matlab, then x and y values can be calculated by the formula (1) and (2), CIE chromaticity diagram (Figure 1) can be set up. In graph, spectral curve is referred to spectrum track, the points in the curve represent pure spectral color; the point on the center C represent white colour, the coordinates are: x = 0.333, y = 0.333.

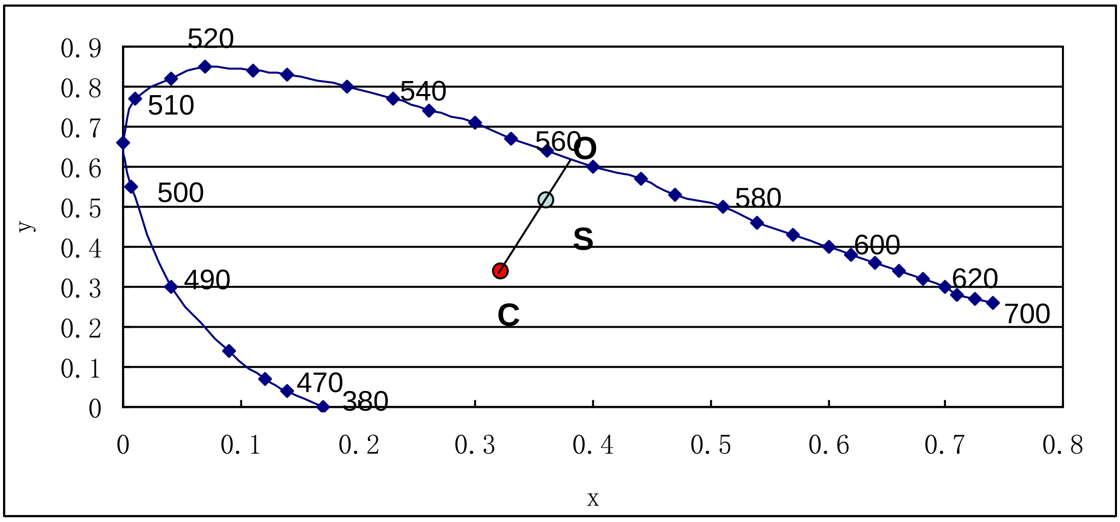


Fig.1 The CIE chromaticity diagram

Any point S in the diagram is selected, connect to point C and point S, the extension of line CS and spectral curve intersect at point O, the wavelength of point O is dominant wavelength of S, The ratio of distance from C to S and the distance from C to O indicate color saturation. The Y value calculated using formula 1 indicates brightness. Any colors can be expressed in the chromatically diagram and then calculated the three parameters, so the description of colour is more abundant and accurate.

III. DISTINGUISH METHOD USING FLUORESCENCE THIN SECTION

Fluorescence properties of petroleum depend on its chemical composition. Oil asphalt, colloid asphalt and asphalt in petroleum can emit fluorescence and the color properties can be influenced by the factors of asphalt component, content and the relationship of rock, oil and water. Under the fluorescent light, the quantity and quality of hydrocarbon are different. Oily asphalt is a light group of crude oil, fluorescence often shows white, blue-white, Blue, blue- green, green, green yellow and yellow; colloid asphalt is relatively stable group of oil, it often shows orange, brown, red brown ; the color of asphaltic is more darker, it often shows dark brown color and weak brightness. Water doesn't emit fluorescence, but there is weak hydrophilic in some hydrocarbons and their derivatives. So water mixed some hydrocarbon compounds show special fluorescent color. Most of the reservoir rocks emit no fluorescence or weak fluorescence. Therefore, remaining oil distribution and quantity can be distinguished according to the color feature of the fluorescence thin section..

From the real fluorescence thin section photograph, the color of oil phase is varied between light yellow and dark brown; while rock particles appear black and gray. Black color indicated no fluorescence, gray color indicated weak fluorescence, and blue indicated water color.

First of all, typical rock, oil and water phase are selected artificial from the fluorescence thin section photograph, then corresponding R、G、B value are extracted, then the x, y coordinates are calculated using formula (1) and formula (2), and they are mapped to the chromaticity diagram (figure 2). Wavelength, brightness and saturation can be calculated at the same time.

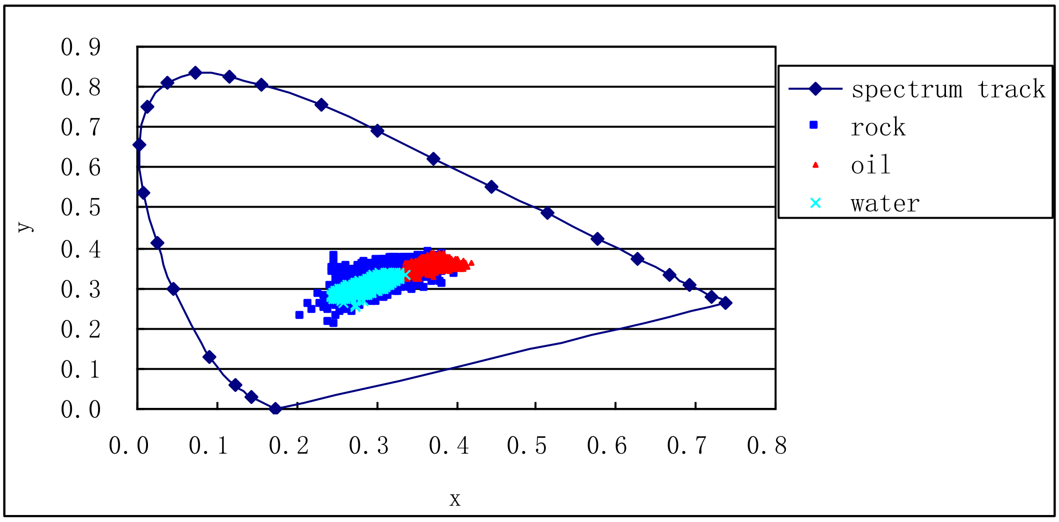


Fig.2 the scatter of micro Oil, water and rock

Drawing three parameters frequency distribution diagrams of the rock, oil and water (Fig.3), It can be seen that the difference of wavelength between oil and water phase is bigger, the oil phase wavelength is in the range of 560-620nm, the aqueous phase wavelength is between 470-520nm, the rock wavelength range is between 480-630nm. Parameters of colour saturation showed the saturation of rock is low, less than 0.2, while the distribution range of oil and water is close. Brightness of rock is minimum, less than 600nm; there has high brightness in water, between 700-1100nm. There has maximum brightness and the most widely distribution in oil phase, 500-1500nm. Because in CIE color system, x, y, z represent the red, green, blue three basic colors respectively, the color of water is blue in general, so there is more blue proportion than red proportion in water phase and there is more red proportion than blue proportion in oil phase. The difference can be measured by z-x, Seen from (z-x) frequency distribution diagrams, the range of oil phase is less than 0, the range of rock is between -0.05-0.15, the range of water is between 0.05-0.25, the value of oil phase distribution between -0.2-0.

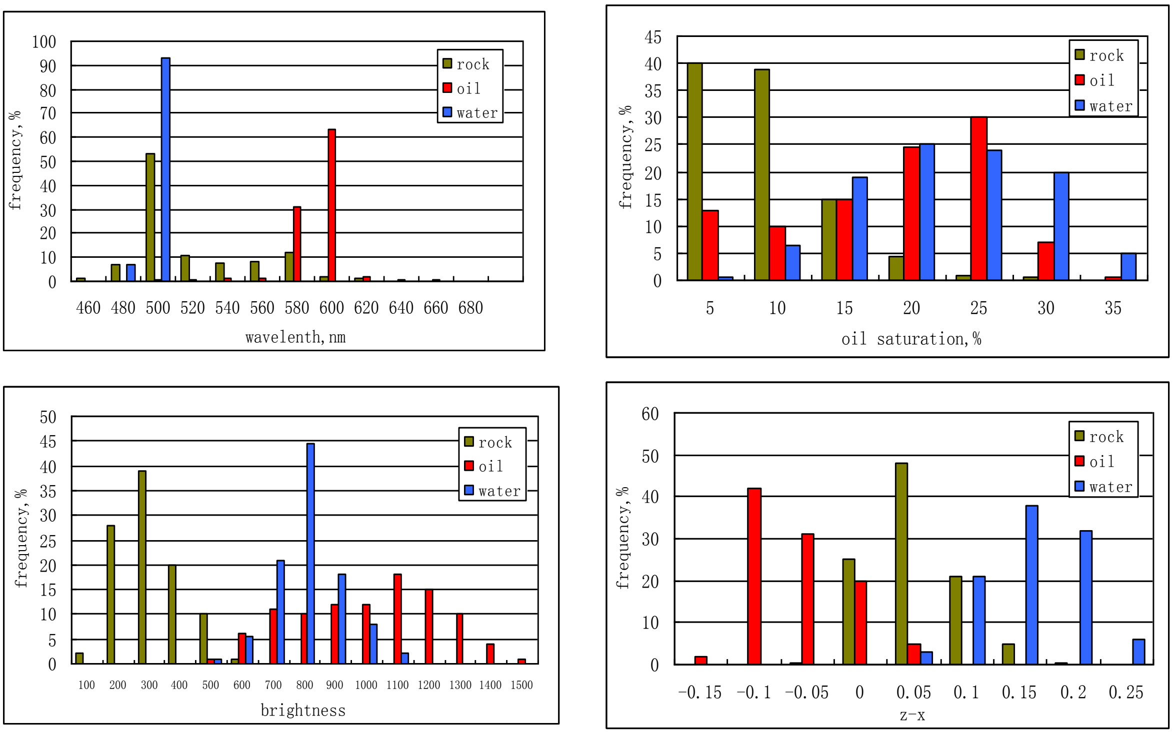


Fig.3 Different component parameters distribution in fluorescent thin section photographs

It can be concluded from the above analysis, there is overlap of different parameters among different components, regardless of any parameters as the index of classification can introduce errors, but the four parameter overlap is not consistent, so a new discriminate index contains four parameters can be established using discriminate analysis method in order to distinguish rock, oil and water phase.

Regarding any point in fluorescence thin section photograph as a sample, it can be consisted of four parameters. A total of 9000 typical samples are selected, and the samples of rock, oil and water phase are of 3000, 1000 of any phases are take out as the test samples. Then discriminate analysis execute on the samples selected by using the method of typical discriminate, the discriminate parameters include wavelength, brightness, color saturation and z-x. With the criterions of the minimum differences in the same parameters and the maximum differences in different parameters, discriminate functions are constructed:

$$Function1=-0.002*SE+14.988*BHD+0.009*LD-7.004*ZX-3.999 \quad (3)$$

$$Function2= 0*SE-4.599*BHD +0.001*LD+25.28*ZX-1.085 \quad (4)$$

In the functions: Function1 and Function2 are discriminate functions; Ld is brightness; SE is wavelength; BHD is color saturation, ZX is the difference of z and x.

Drawing the samples discriminate function graph (Figure 4), the rock, oil and water phase were concentrated in a relatively independent region, thereby the criteria is established as follows:

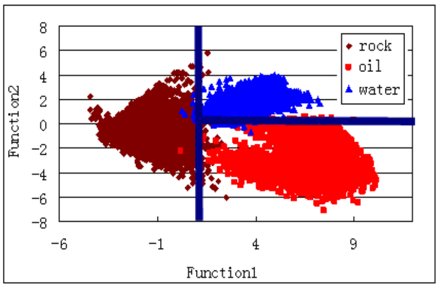


Fig.4 Different components of the discriminant function crossplot

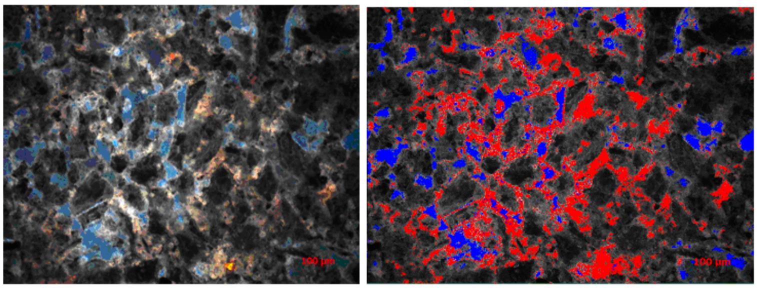


Fig. 5 The discriminant results in fluorescence thin section photographs

When the Function1≤1, the corresponding sample points belongs to rock;

When Function1>1 and Function2≤0.4, the sample points belongs to oil;

When the Function1>1 and Function2>0.4, the sample points belongs to water.

After calculating wavelength, brightness, color saturation and z-x parameters of any point in fluorescence thin section photographs and putting into Function1 and Function2. the three groups can be distinguished according to the criteria above. Using 3000 samples setting aside above to verify the accuracy, the error rate is 5.2%. Seen from the fluorescence thin section photographs distinguish results (Figure 5), It can conclude that the method of distinguishing oil, water and rock is reliable.

IV. THE DISTRIBUTION OF RESIDUAL OIL QUANTITATIVE ANALYSIS

After discriminate analysis, all pixels in fluorescence thin section photographs can be divided into rock, oil and water phase, the numbers and proportions of all three phases can be statistics. It assumed that the original pores are occupied by oil, the original oil saturation is 100%, with water injection, the oil in part of pore throat are instead of water, according to the proportion of water and oil in fluorescence thin section image, oil displacement efficiency of samples can be calculated:

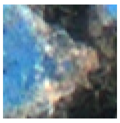
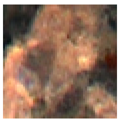
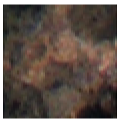
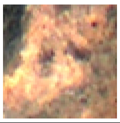
$$\eta = P_w / (P_w + P_o) \quad (5)$$

In the formula(5): η-oil displacement efficiency,%; Pw- Water surface porosity,%; Po- oil surface porosity,%.

The image in fluorescence thin section of a real samples are statistics, Pw was 11.22% and Po was 4.6%, so oil displacement efficiency is calculated as 29.1%. There has great difference between calculation result and displacement experiment measurement results of 58.8%. Further analysis shows that there exists the oil colors difference at different positions in the fluorescence thin section photographs. The oil color at position adjacent water phase is a bright white, and it's dark brown away from the water phase. During the core displacement experiment, the cores are washed by water first, and then saturated oil, there has the same oil quality in the cores, so the oil color differences in fluorescence thin section photographs are caused by different oil concentration . Therefore, the diversity of oil concentration should be taking into consideration in discriminate process, then the actual proportion of oil should be smaller, and the proportion of water should be higher.

The oil-bearing area was divided into water flood swept area and not swept area. The color of latter is more deep and small brightness, while the phenomenon of former is opposite. Different brightness in five oil region are analysis (Table 1), It can conclude that the brightness is varied with the increase of water saturation, and there exists good relationship between brightness and oil saturation. The brightness of oil at different position in fluorescent sheets are analyses and the data of brightness is achieved. The results are shown in table 1.

Table 1 List of main parameters of different average oil saturation color

Oil saturation %	fluorescence	Brightness nm	Wavelength nm	Color saturation %	Oil saturation %	fluorescence	Brightness nm	Wavelength nm	Color saturation %
10		968	581	0.13	70		766	590	0.31
30		1419	581	0.18	90		535	586	0.34
50		1132	582	0.28					

From the statistical results, the wavelengths are basically the same in different oil saturation samples, and with the increase of oil saturation, brightness has a change trend of first increase and then decrease; color saturation shows increases gradually. Further analysis shows that the oil color is the most deep when the saturation of oil is 100%; and when the oil is soluble in water, with the decrease of oil saturation, the value of brightness increased gradually to about 30%, the most bright color appeared, when the value of oil saturation is lower than 30%, the brightness decreases (Figure 6). The change trend between the color saturation and oil saturation can be fitted a linear relationship:

$$So= (BHD-0.079) /0.055 \qquad (6)$$

According to the fluorescence thin section photographs, the color saturation value of each point of the oil can be determined, then oil saturation value in different position can be obtained through formula(6). The last oil saturation value of the whole sheet can be obtained after accumulating.

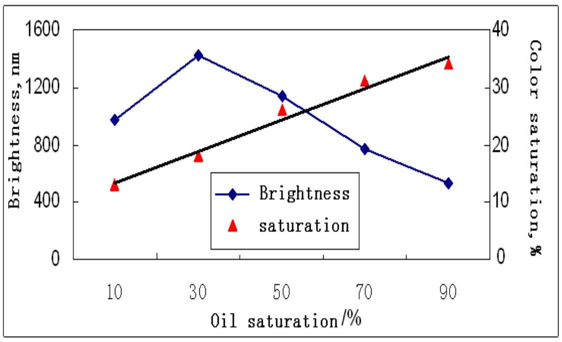


Fig.6 Color saturation and oil saturation relationship scatter diagram

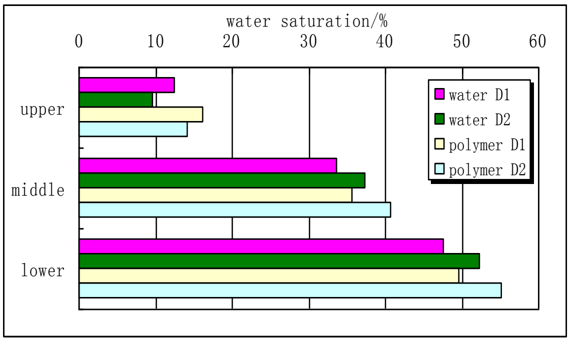


Fig.7 Water saturation histogram after water and polymer flooding

The distribution ratio of oil and water, oil displacement efficiency were calculated using formula(6) , oil displacement efficiency is 55% after conversion , and the value is close to the measure result. It's showed the method of quantitative analysis remaining oil saturation with fluorescence thin section is more reasonable.

V. V APPLICATION OF MICROCOSMIC REMAINING OIL QUANTITATIVE ANALYZING METHOD

Microcosmic remaining oil quantitative analyzing method using fluorescence thin section can achieve the information of microscopic remaining oil distribution of different cores and different displacing agent flooding , in order to evaluate the displacement effect and verify the accuracy the method. The following example will use the method to analyze microscopic remaining oil distribution of two pieces of positive rhythm heterogeneous cores after water flooding and polymer flooding.

Taking two pieces of 3 layers and positive rhythm heterogeneous cores, the size is 45×45×300mm, after water flooding and polymer flooding respectively, the samples were obtained from both the end of 5 cm in two cores, They were recorded as D1 and D2(Figure 8). Due to the cores are composed of three layers, the fluorescent images were collected as 1, 2, 3 From top to bottom, then water saturation of fluorescence images were analysis and statistical using microcosmic remaining oil quantitative analyzing method, the results are shown in figure 7.

After water flooding water saturation has the following changes: water saturation decreases gradually from bottom to top, and at the position of D1,the difference of water saturation from bottom to top is less than that at the position D2, Research shows that in the heterogeneous reservoir, due to the low viscous resistance in high permeability layer and high viscous resistance in low permeability layer, injected water break through of permeability layers first, and water injection velocity is low in low permeability layer, Coupled with the gravity, water injection time is longer, water flooding effect in the high permeability layer below is better, the water flooding effect in the low permeability layer above is worse.

After polymer flooding, , water saturation in three layers are all increased, and water saturation increased value downward gradually reduced. From fluorescence thin section images, the oil distribution is more dispersed, and the remain oil scattered in the semi closed pores in the form of cluster, the walls of pores and throats are more clear, it shows the effect of polymer flooding is better than that of water flooding. Viscoelastic of polymer can pulled the oil away from hole wall and narrow gap, this is the main reason leading to water saturation increased after polymer flooding.

VI. CONCLUSION

In fluorescence thin section image, there are different colors in rock, oil and water phase, so the color can be used to distinguish the three components. Because the color distribution in rock, oil and water phase is extremely complex, the color can be characterized by wavelength, brightness, color saturation and the z-x four parameters. All parameters of each pixel in the image of fluorescence can be obtained and calculated using the method mentioned above based on 1931CIE-XYZ color system from the International Commission.

Research find any parameter of four can not distinguish rock, oil and water phase Independently because of overlapping area existing among three components, discriminate function is established using the canonical discriminate analysis, and the identification model of discriminate function can be used to accurately distinguish the three components.

The oil colors is different at different position in fluorescence image, this difference is caused by different concentration of oil, there exists a good linear between oil saturation and color saturation. So the value of oil saturation at different position in fluorescence image can be calculated ,and then the proportion of oil and water were obtained, at last the oil displacement efficiency can be calculated by using the method mentioned above, the results are in good agreement with the experimental results. The method is a reliable method of quantitative analysis the microcosmic remaining oil distribution.

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