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Evaluation method for waterflooded zone with geochemistry

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Abstract：- Through the analysis of water flooded layer geochemical data, summarizes the geochemical characteristics of the different degree of water flooded layer, putting forward by using geochemical data from qualitative identification to the quantitative evaluation of waterflooded zone evaluation idea, established the water flooded layer watered-out degree qualitative identification method, remaining oil saturation and the moisture content of the quantitative evaluation model.

Keywords: *Waterflooded zone; Geochemistry;Evaluation methods; Geochemical pyrolysis; Waterflooded level*

I. INTRODUCTION

At present, in most of the world in the process of oilfield exploitation, by waterflood recovery of oil and gas production for the most part of all oil and gas production. Due to inject large amounts of water for a long time, the domestic and foreign each big oilfield has entered the water injection development later, is widespread in flooded reservoir, the majority of oil field exploitation of oil and gas moisture content is very high. The eastern part of our country's many old oilfield has entered high water cut even the middle and later development stage, the underground crude oil by the long-term displacement of injected water, causing water relationship is very complicated, uneven distribution of underground oil, residual oil exploitation harder, recovery factor is reduced, distribution and groundwater salinity change. So the water drive oilfield logging quantitative interpretation of water-out reservoirs is particularly important, identifying watered-out layers accurately, reasonable reservoir water level, maximize the oilfield recovery is an important way of promoting the old oil field exploration efficiency [1-2].

II. THE RELATED THEORY

2.1 The waterflooded zone evaluation theory basis

Oil field after entering for determining, various types of reservoir water flooding is serious, water flooded layer interpretation harder, to meet the demand of oilfield development, must develop water flooded layer evaluation method research.China in water flooded layer water flooding mechanism and interpretation of research has made great progress[3-5], commonly used evaluation methods have sealed coring well core analysis and production logging evaluation method, but restricted by economy, technology, and can completely meet the needs of production.

Reservoir after water injection development, the characteristics of the reservoir and fluid will change.First of all, as a result of the injected water flushing, large pore in the clay will be swept away and washed away, pore radius increase generally, connectivity, porosity and permeability have been increased to a certain extent;Second, the nature of the crude oil in the reservoir has changed too, with the increase of recovery degree, the movable oil saturation in reservoir to reduce gradually, mobile water saturation increases gradually, in addition, because of the crude oil composition containing hydrocarbons, colloid and asphaltene, etc., there is a big difference in terms of the flow of the component, in which small molecules, low viscosity, simple structure, light component priority was produced, and large molecules, high viscosity and heavy component of complex structure was left, therefore, with the increase of oil recovery degree, the relative contents of low carbon number hydrocarbons decreases gradually, high carbon number hydrocarbons, colloid and asphaltene relative content increased, hydrocarbon component of crude oil has also changed.

The change of reservoir and fluid properties are through geochemical pyrolysis and gas chromatography and other geochemical logging parameters to characterize, embodied in with the increase of oil recovery degree, the oil saturation in reservoir rock, reduce the amount of pyrolysis oil and gas, crude oil weight ratio drops, are mainly carbon number alkanes spectra response value decrease, the carbon number range Narrows, main carbon backwards, hydrocarbon normal distribution variation and baseline drift, crude oil in the pore occurrence state changing, etc.Therefore, the application of geochemical logging methods, namely, rock pyrolysis, gas chromatograph logging technology, analysis of related parameters and the relationship of the reservoir water level, establish discriminant standard water flooded layer, the quantitative evaluation of reservoir water level[6-7].

2.2 Geochemical logging technology

Water flooded layer identification and evaluation of geochemical logging technology, is based on logging data in drilling site fast, economical evaluation of water flooded layer technology.Reservoir geochemistry in the late 1980s began to rise, as a branch discipline of geochemistry, in oil and gas accumulation research and exploration stage of reservoir evaluation plays an important role, is gradually applied to the development of reservoir description.Li Yuheng professor of henan oilfield in our country since 1992 to reservoir geochemical technology is applied to the evaluation of water flooded layer, the old oil region to promote the development and popularization of the technology has done a lot of work, and published an article in the journal of logging technology, introduces the geochemical method is used to study reservoir remaining oil distribution, reservoir water level and water conditions, the theoretical basis of the interpretation and application effect.

Geochemical logging method can quickly and effectively at the scene, the quantitative evaluation of reservoir physical property and oiliness parameters function, can make up for the shortcomings of other methods.Since the 1990 s, many geological researchers application of rock pyrolysis technology, gas chromatography technology[8-9] and other geochemical logging method to evaluate the water flooded layer, but was still in the stage of qualitative and semi-quantitative.

2.3 pyrolysis analysis evaluation method

Rock pyrolysis is the function of quantitative detection of thermal evaporation and pyrolysis of hydrocarbons, the determination of hydrocarbon amount. Rock pyrolysis analysis principle is opposite in the programmed temperature pyrolysis furnace heating reservoir rock samples, the hydrocarbon thermal evaporation into gas in the rock, and make high polymerization of organic matter (kerogen, asphaltenes, glial) thermal cracking into volatile hydrocarbon products, these after thermal evaporation or thermal cracking of gaseous hydrocarbon in the carrier gas to carry, with hydrogen flame detector (FID) directly for testing.

2.4 gas chromatography analysis evaluation method

Gas chromatography is a common geochemical analysis of the technology, because the technology has the ability of the hydrocarbon mixture separation into a single component, is widely used in the oil industry.Pyrolysis gas chromatography based on pyrolysis chromatographic analysis, using chromatography separate further components of sample, for thermal evaporating hydrocarbon (S1) and thermal cracking hydrocarbon (S2) by gas chromatogram, and for evaluation of reservoir, oil source correlation information is more reliable.After dealing with the cold cut rock sample chromatographic analysis or direct thermal evaporation chromatographic analysis. Samples of hydrocarbons under the carrier gas to carry into the chromatographic column, components in the mobile phase and stationary phase distribution of the two phases to repeatedly.Due to the adsorption of components or fixed dissolving ability is different, so the speed of chromatographic column of components is different, after a certain long column, separated from each other, order leave chromatographic column into the detector, the ion current signal after amplification by a computer automatically record the chromatographic peak of components and their relative content.According to the chromatographic outflow curve characteristics and its relative content of each composition, the qualitative identification of oil and gas layer. Although modern logging methods of oil exploration means of known oil and gas layer has been greatly improved, but still has its limits, especially in some light oil, gas, and other special formation, low permeability reservoir by some kind of record alone, logging technology is difficult to correctly judge oil and gas layers, and combination with pyrolysis gas chromatography data can more accurately determine oil and gas layer.

III. PYROLYSIS ANALYSIS TECHNOLOGY OF WATER FLOODED LAYER

3.1 pyrolysis analysis technique of water flooded layer theory

Rock pyrolysis analysis and evaluation of water flooded layer theory basis for oilfield water injection, as the rise of the moisture content, oil saturation, oil property, etc, all want to change, rock pyrolysis analysis by calculating samples pyrolysis oil and gas volume index (Pg), crude oil and heavy components (PS), the remaining oil saturation can be obtained (Som), the parameters such as density, viscosity of crude oil.By estimating the original oil saturation (S0) to calculate the oil displacement efficiency, through the calculation of reservoir water production rate, and then evaluate the degree of oil layer being water flooding.

3.2 method of calculating parameters of the pyrolysis analysis technology

1) S_0:90℃when detecting unit mass of hydrocarbon content in rock (gaseous hydrocarbon), mg/g;

2) S_1:300℃when the detection unit mass of hydrocarbon content in rock (liquid hydrocarbon), mg/g;

3) S_2:300℃to 600℃detection unit mass of rock, hydrocarbon content in mg/g;

4) S_4: the reservoir rock pyrolysis unit mass residual organic carbon content, unit mg/g;
5) Tmax: S_2 peak temperature, ℃.
6) residual carbon RC, RC =12CO_2/44+12CO/28 or RC = S_4/10, said unit mass of rock pyrolysis after the percentage of residual organic carbon of rock mass.

3.3 watered-out degree evaluation method

3.3.1 chart evaluation method

Residual oil saturation, permeability and the function relation between the effective porosity, oil saturation and the watered-out degree has obvious linear relationship, therefore, can test results as the basis, establish effective porosity and residual oil saturation intersection chart, judge watered-out degree of reservoir.

3.3.2 moisture content evaluation method

According to the fluid mechanics principle of seepage formula for moisture content

$$F_w = \frac{Q_w}{Q_o + Q_w} \times 100\ \% = \frac{1}{1 + B \times \frac{K_{ro}\mu_w}{K_{rw}\mu_o}} \times 100\ \%$$

Type: Q_w -The content of water extraction liquid, m^3;

Q_O -A production of liquid medium oil content, m^3;

F_w -The moisture content, dimensionless;

K_{ro} -The oil relative permeability, dimensionless;

K_{rw} -The relative permeability of monohydrate, dimensionless;

μ_o -The oil viscosity, m Pa·s;

μ_w -Viscosity of monohydrate,m Pa·s.;

B -A parameter related to the lithology, physical property, dimensionless, lithology and physical property, the better, the smaller B values.

Practical application of the reservoir water cut for water flooded layer don't standard is: 15% or less for not watered-out layer;more than 15% or 50% or less for weak water flooded layer;80% or less for water flooded layer;more than 80% for water flooded layer.

IV. EVALUATING WATER FLOODED LAYER GAS CHROMATOGRAPHY TECHNOLOGY

4.1 gas chromatographic analysis and evaluation of water flooded layer theory basis

Gas chromatography is a common geochemical analysis and evaluation of technologies, because of its single components of hydrocarbon in rock specimens can be subdivided by C8 ~ C37 spectra and the corresponding normal alkanes was widely used in the oil industry.After oilfield water injection, as the rise of the moisture content, oil saturation, oil property, etc, all want to change, gas chromatographic spectra of each peak reflects the corresponding normal alkanes was its content in the crude oil composition, all the sum of the peak corresponding normal alkanes was high and low can reflect the change of oil saturation;Spectra of peak shape reflect the relative content of the corresponding normal alkanes was closely related to the content of crude oil composition, the peak shape features reflect the changing rule of the crude oil composition.By study the change of the peak shape form and loss magnitude, evaluation of degree of oil layer being water flooding.

4.2 different degree of water-flooded gas chromatographic spectra characteristics

For different watered-out degree of water flooded layer by gas chromatogram analysis found that reflect the status of water flooding gas chromatograph chart features mainly includes five aspects: one is the spectrum of normal distribution form;Second, the carbon number range width;Three is the chromatogram peak shape variation;Four is the baseline conditions;Five main carbon value.Reservoir water level is different, the gas chromatographic parameters will change different.As the watered-out degree by weak strength, abundance lower overall chromatographic curve, main carbon gradually back, before the main carbon nC21 components combined with main carbon after nC22 component ratio of the sum of the (∑nC21- /∑nC22+) to reduce gradually, the carbon number range gradually narrowed, peak corresponding normal alkanes was gradually reduced, main carbon peak changes obviously, baseline form from flat gradually become low amplitude uplift, uneven or curling[10].

4.2.1 Reservoir - weak water-flooded features

Figure 1-figure 2 as a set of reservoir to weak water by gas chromatogram.Figure 1 from the top 6.80 m to check 725 Wells 13 cartridge (hereinafter referred to as for 13-6.80 m) spectra.Core not washed for routine analysis, gas chromatography reflect for high peak, response value of 2.4 mV, main carbon for C23, normal peak type, reservoir characteristics. Figure 2 to 725 Wells 8-1.77 m spectra, core not washed for routine analysis, the gas phase analysis of main carbon to C20, response value of 2.5 mV, normal peak type, number near the main carbon loss, a little weak oil - water features.

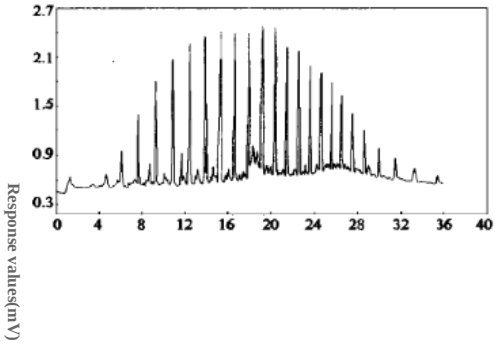

Fig.1 JIAN 725 Well 13-6.80m Gas Chromatogram

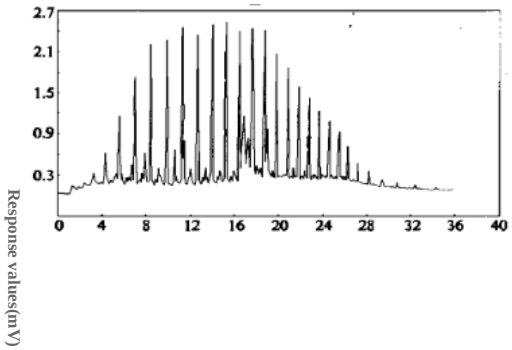

Fig.2 JIAN 725 Well 8-1.77m Gas Chromatogram

4.2.2 Weak water-flooded feature

Kurtosis of normal distribution, generally for the reservoir characteristic;Peak type change, such as "V" word, "mountain" word, etc., for the weak water features.

Figure 3-figure 4 as a set of core routine analysis weak water by gas chromatogram.Figure 3 to check 725 well 8-2.93m by gas chromatogram, main carbon for C23, response value of 2.0 mV, "V" word is not obvious.Figure 4 for the inspection of 725 Wells 10-2.55m by gas chromatogram, main carbon as the C22, response value of 2.6 mV unimodal, while oil content is higher, but the main content of carbon number before lower amplitude is larger, there have been washed.

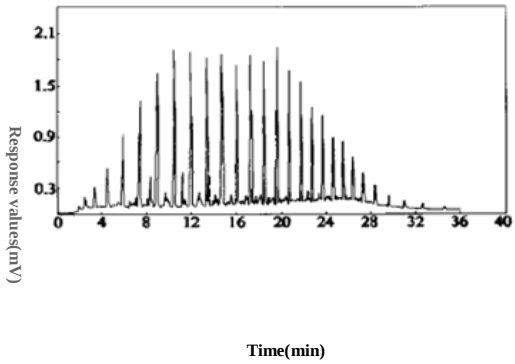

Fig.3 JIAN 725 Well 8-2.93m Gas Chromatogram

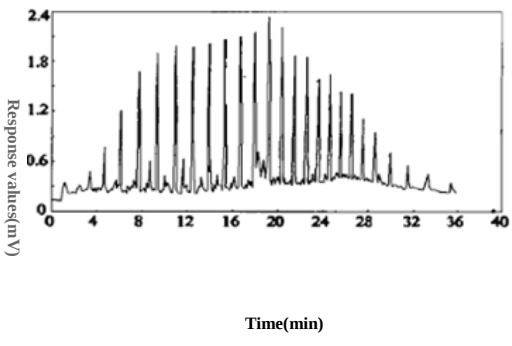

Fig.4 JIAN 725 Well 10-2.55m Gas Chromatogram

4.2.3 medium water-flooded feature

Obvious changes in peak type, the main loss to the heavier carbon number, signal amplitude decrease accordingly, such as bimodal type, "mountain" word.

Figure 5-figure 6 as a set of core routine analysis in water by gas chromatogram. Figure 5 to check 725 well 24-2.20m by gas chromatogram, main carbon for C23, response value of 1.5 mV, peak overall losses heavier, abnormal peak type, twin peaks, before and after the main loss. Both theoretical research and production practice have confirmed that this kind of spectra are typical characteristics of high water.Figure 6 to check 725 Wells 14 to 8.20m by gas chromatogram, response value of 1.2 mV, obvious changes in peak type, show clear trapezoid characteristics, peak loss rate, water level is heavier.

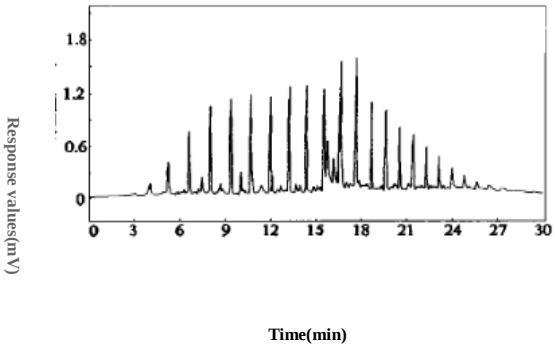

Fig.5 JIAN 725 Well 24-2.20m Gas Chromatogram

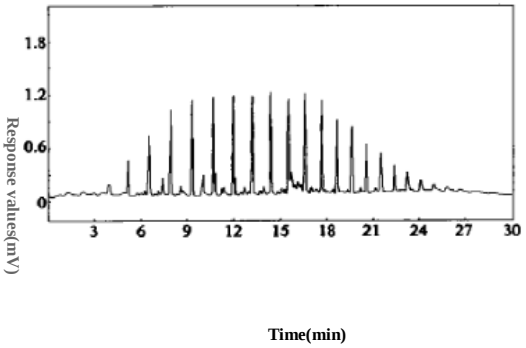

Fig.6 JIAN 725 Well 14-8.20m Gas Chromatogram

4.2.4 Strong water-flooded features

Peak type overall losses heavier, such as trapezoid peak, flat peak, such as main carbon number is not obvious, shows strong washing, heavy components has been flooding out pore [11].

Figure 7 -Figure 8 into a set of core routine analysis of strong water by gas chromatogram.Figure 7 for inspection Wells, 725 well 30-8.72m by gas chromatogram, main carbon as the C22, response value of 1.2 mV, flat peak, carbon number range and more narrow, peak loss serious. The spectra also reflects the initial formation oil content is very poor, hopeless gain capacity after washing, will be given priority to with produced water.

Figure 8 to check 725 well 22-9.40m by gas chromatogram, main carbon as the C22, response value of 0.9 mV, flat peak, carbon number range narrow, peak loss serious, core material has the characteristics of clear water to wash. The spectra are typical characteristics late high water cut.

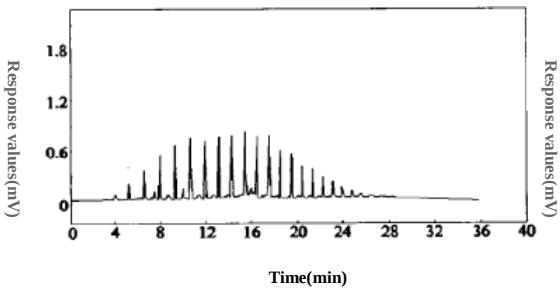

Fig.7 JIAN 725 Well 30-8.72m Gas Chromatogram

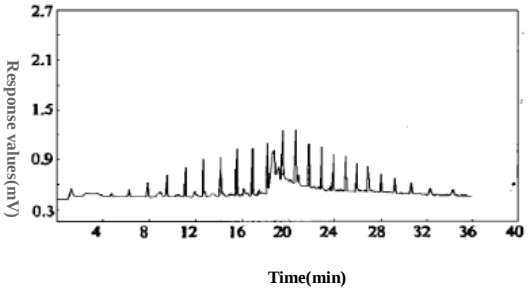

Fig.8 JIAN 725 Well 22-9.40m Gas Chromatogram

V. CONCLUSION

(1)Geochemical data is not affected by formation water salinity change, make up the conventional method of water flooded layer mixed formation water resistivity is difficult to accurate, the defects of the water flooded layer evaluation precision is improved.

(2)Using the data of geochemical qualitative identification and quantitative evaluation of the combination of water flooded layer evaluation idea, established the water flooded layer water level qualitative identification method and quantitative evaluation model.The moisture content of

(3)To establish a model to the evaluation of high water cut period, high precision and compensates for the conventional method in high water cut period to evaluate the defects of low precision.

(4)By using the proposed method and model improved the precision of water flooded layer evaluation, the evaluation results and testing, core analysis results are consistent.

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