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Application of RPM Logging for Reservoir Dynamic Monitoring at M Oilfield of Offshore

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Abstract

With the gradual depth exploit of residual oil in offshore oilfield, RPM logging are using widely in reservoirs dynamic monitoring , the process of logging RPM affected by lithology, porosity, borehole fluid and other factors, so we must do some correction for it. But M oilfield has a special well structure of gravel pack, therefore, some correction made in domestic are not suitable for application in the offshore reservoirs of gravel pack, Thus author design parallelogram method to obtain water holdup and water saturation , by comparing the calculated results with the PLT data, it is found that the error in a controllable range, and also design volumetric model to corrected formation capture cross section, by using the corrected capture cross section establish model with lithology; electrical property, then compares it with the model which corrected before, it improves the model accuracy a lot. By comparing the water saturation which calculated by corrected capture cross section with and the water saturation which obtained by the PLT data interpretation , It is found that the accuracy increased more than 6%,it provides a new method to instruct the RPM data interpretation.

Keywords: reservoirs dynamic monitoring, parallelogram method, water saturation, volumetric model, gravel pack

1. Introduction

RPM is a logging tool which through the tubing/casing for reservoir performance monitor, the current domestic and foreign dynamic reservoir monitoring instruments have RPM, RST,RMT, PNN, PND,

etc[1] .Enhancements tool design; characterization and interpretation algorithms have contributed to increases in precision and accuracy of fluid saturation measurements. Different instruments have differences in the design and interpretation [2]. There is no single solution for the complex formation and borehole environment in C/O logging including cement, casing, fluid patterns etc. Some people had only did some simulation to research the influencing factors of carbon/oxygen (C/O) spectral logging, such as porosity; lithology; and so on[3][4].M oilfield has a characteristics with gravel pack, so the above personnel, for water saturation and the water holdup correction is not suitable for M oilfields. This paper consider the situation of gravel pack in offshore, by using PLT data measured distance C/O ratio and use of interpolation theory, it establishes parallelogram plate which obtaining water saturation and water holdup, by comparing the results with the PLT data, it is found that the error in a controllable range, author also make some corrected for capture cross sections, by using the corrected capture cross section to calculate water saturation, by comparing with the saturation which after corrected and before, Accuracy is improved by more than 6%, It provides a new guiding for RPM data interpretation.

2. Method and principle of parallelogram

First ,By using the flow parameters ,it converts the wellhead fluid flow into underground fluid flow and use the slippage model calculate water holdup, second, we establish the relationship between water holdup and moisture to calculate moisture, by using the relative permeability data establish the relationship between water holdup and moisture to calculate water saturation, finally we can determine water holdup and water saturation of each layer.

First, By classifying the data according to porosity, deviation angle, saturation, then callout the measured NCOR, FCOR which corresponding to layers in each class(carbon/oxygen ratio of the near detector and carbon/oxygen ratio of the far detector)in the coordinate plane which in the X-axis NCOR and In the Y-axis FCOR, and find some regular point value(Table 2). A, B, C, D, etc. point are regular data points which picked out according to inclination and porosity and the distribution of data points (Figure.1.(a)), And list the data in Table 2. Owing to water saturation of these two points A and B approximately 0.4, so make use of these two points can determine a linear water saturation of 0.4, by using linear interpolation methods Combined with D point, we can get the lines of water saturation of 0,0.2,0.4,0.6,0.8,1.0 ; analogously, water holdup of B and C are approximately 0.5, in the same way, we can obtain the lines of water holdup of 0,0.2,0.4,0.6,0.8,1.0;four intersections of the two lines of Water saturation of 0 and 1 with two lines water holdup of 0 and 1 are WW, WO, OO, OW[5] .After we certain four specific points, we make use of interpolation theory, we can combined with the actual measurements NCOR, FCOR and porosity data, then calculate the water holdup and water saturation quickly, accurately and directly(Figure.1.(b)).

3. The theoretical basis for C/O interpolation method

The study finds that the measured values of NCOR and FCOR have a relationship with the lithology and porosity of the formation; we can obtain four measured values of NCOR and FCOR which borehole and formation are pure oil and pure water respectively, By ploting the FCOR and NCOR for these conditions to define the quadrilateral in each case. Thus, the width of the quadrilateral is affected by lithology and porosity of the formation. In the general case: all measurement points basically fall on the quadrilateral area. Water holdup in the borehole and formation oil saturation affect the values of NCOR and FCOR ,so the quadrilateral is an indicator to resolve the formation oil saturation and water holdup in the borehole[6] .

In figure.1.(a). A, B, C, D four points represents the Carbon-oxygen ratio of actual measured near and far detectors. In figure.1.(b), Straight line on the left and right is water holdup envelope which the value is 1 and

0 respectively , the straight line above and down is water saturation envelope which the value is 0 and 1 respectively.
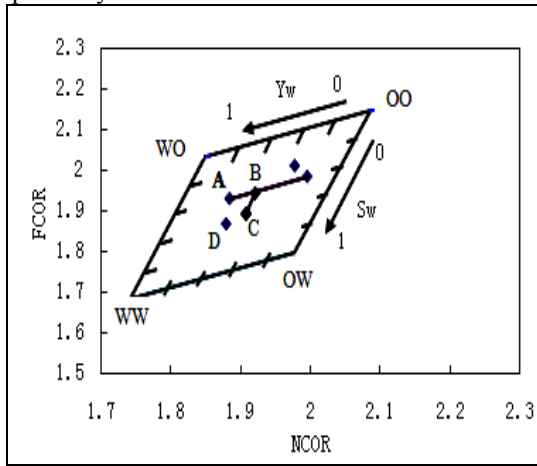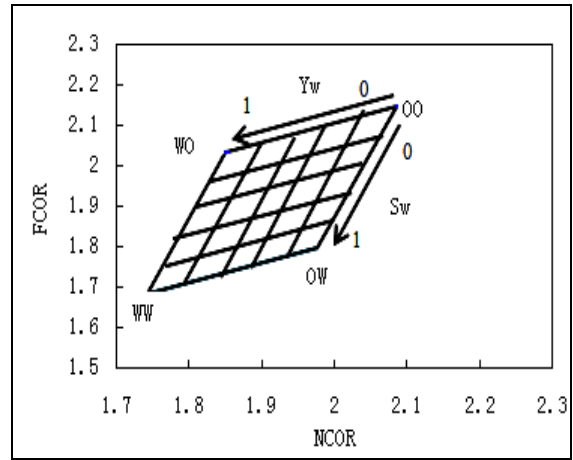

Figure1.(a)

Figure1.(b)

Figure 1.(a) Saturation parallelogram used to calculate water saturation in the formation and borehole with casing in borehole

Figure 1.(b) Saturation parallelogram Envelope diagram used to calculate water saturation in the formation and borehole with casing in borehole

4. Correction method research of the capture cross section

Gravel packing is the special well structure in offshore M oilfield, the part of gravel packing mainly in the part of the screen and casing annulus and perforation tunnel. Such as the production string structure in M oilfield, the inner diameter and outer diameter of borehole annulus section are 15.24cm and 21.1cm. But the instrument detection depth is 21cm and the C/O mode logging speed is 0.6m/min, vertical resolution is 61cm [7], so the measured capture cross section of RPM is also affected by the gravel pack. Accordingly, in order to obtain the formation parameters accurately and improve interpretation accuracy, it is necessary to do some quantitative correction for related factors. So the author designed volumetric model corrected formation capture cross sections.
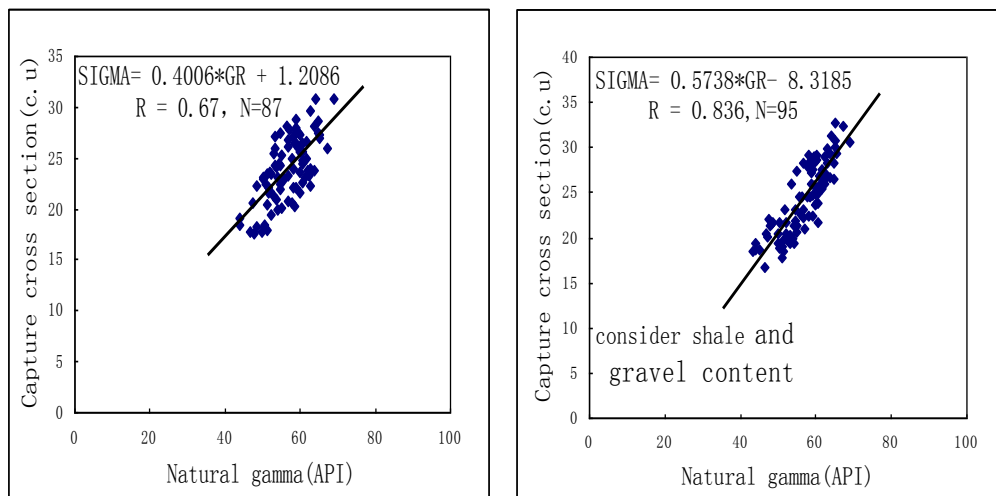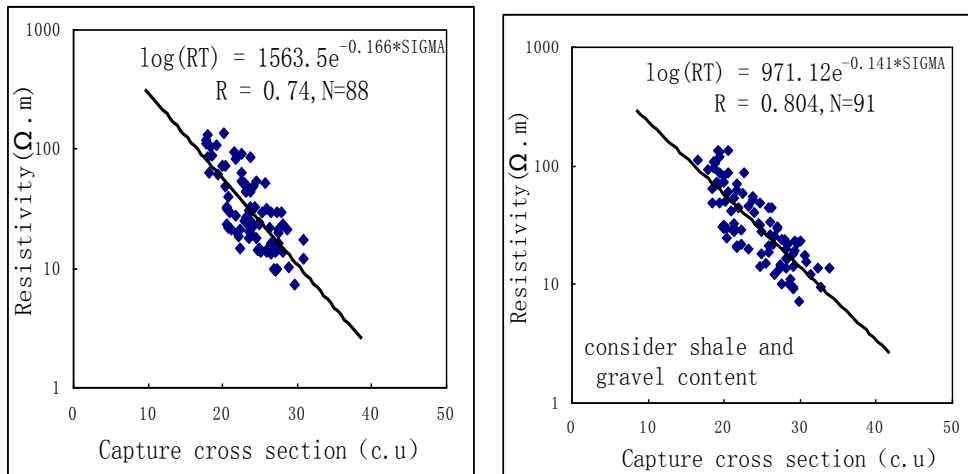
$$\Sigma_{\log}=\Sigma_{ma}(1-\phi-V_{sh}-V_g)+\Sigma_w S_w\phi+\Sigma_h(1-S_w)\phi+\Sigma_{sh}V_{sh}+\Sigma_g V_g \qquad (1)$$

Obtained from the equation(1):

$$S_w=\frac{\Sigma_{\log}-\Sigma_{ma}(1-\phi-V_{sh}-V_g)-\Sigma_{sh}V_{sh}-\Sigma_g V_g-\Sigma_h\phi}{\phi(\Sigma_w-\Sigma_h)} \qquad (2)$$

In equation(1), S_w is water saturation and $\Sigma_{\log}$ is the intrinsic formation sigma estimated by the logging tool and associated environmental corrections, Σ_{ma}, Σ_{sh}, Σ_W, Σ_h, Σ_g are sigma for rock matrix, shale, water and hydrocarbons and gravel[8]; ϕ is the effective porosity, V_{sh} is the shale or clay volumetric ratio, V_g is the gravel content.

The study found that there is some relevance between capture cross-section and natural gamma、resistivity. Compare with the Figure.2.(a) and Figure.2.(b), model accuracy of Figure.2.(b) increased 6%, Compare with the Figure.3.(a) and Figure.3.(b), model accuracy of Figure.3.(b) increased 13%.

Figure.2.(a) before correction the relationship between formation capture cross-section and the resistivity
Figure.2.(b) After correction the relationship between formation capture cross-section and the resistivity

Figure.3.(a) before correction the relationship between formation capture cross-section and the Natural gamma;
Figure.3.(b) After correction the relationship between formation capture cross section and the Natural gamma;

5. Applications and analysis of the methods

Author selecting the data of seven layers in two wells of offshore oilfield M[Table 1], the water saturation before and after corrected are shown in the following table, and compare the water saturation with actual water saturation data which measured by PLT production profile ,found that the accuracy of the after corrected increase 6% compare with the corrected before.

Table 1. error analysis of water saturation calculated by capture cross sections before and after correction

Perforating horizons	before correction	after correction	production explain	before correction	after correction	improve accuracy(%)
1418.4-1423.6	0.467	0.72	0.58	0.261	0.182	7.93%
1441.5-1449.8	0.439	0.625	0.53	0.207	0.152	5.53%
1467.8-1480.6	0.513	0.482	0.471	0.082	0.022	6.0%
1485.8-1496.0	0.547	0.449	0.467	0.146	0.04	10.62%
1560.6-1566.1	0.483	0.352	0.385	0.203	0.09	10.91%
1578.0-1578.5	0.674	0.489	0.51	0.206	0.09	11.22%
1602.8-1609.5	0.385	0.493	0.452	0.174	0.083	9.09%

Statistics the NCOR,FCOR, S_W , Y_W of ten layers of two wells on Offshore oilfield, which NCOR nearly carbon-oxygen ratio measured at the detector, FCOR far detector measured the carbon-oxygen ratio, Y_W is water holdup calculated by slippage model, S_W is water saturation calculated by built model. In accordance with degree is better when compared with water holdup calculated by Parallelogram and PLT data.(Table 3)

Table 2. Actual calibration data sheet

Horizons Number	inclination(°)	NCOR	FCOR	Y_W	S_W
A	28.3	1.976	2.011	0.413	0.407
B	30.4	1.92	1.942	0.481	0.389
C	31.7	1.907	1.892	0.492	0.517
D	33.5	1.878	1.866	0.715	0.602

Table 3. the table of water saturation error analysis

NO.	Perforating horizons	NCOR	FCOR	production explain YW	Calculate SW	Calculate YW	Error analysis	Conclusion
1	1586.4-1592.2	1.976	1.981	0.420	0.563	0.380	0.095	Yes
2	1599.6-1614.2	1.959	1.9667	0.4418	0.483	0.460	0.041	Yes
3	1634.8-1654.1	1.891	1.898	0.539	0.413	0.570	0.057	Yes
4	1657.2-1659.1	1.885	1.858	0.605	0.669	0.583	0.036	Yes
5	1660.2-1662.0	1.882	1.897	0.653	0.680	0.600	0.082	Yes
6	1672.2-1674. 7	1.862	1.869	0.726	0.411	0.690	0.049	Yes
7	1680.7-1694.3	1.862	1.867	0.824	0.574	0.610	0.259	NO
8	1467.8-1480.6	2.033	2.043	0.142	0.280	0.135	0.029	Yes
9	1485.8-1496.0	2.035	2.021	0.205	0.310	0.100	0.510	NO
10	1500.8-1510.8	2.054	2.018	0.220	0.218	0.235	0.068	Yes

6. Conclusion

·Writer considering the gravel packing characteristics of offshore oilfield M, make some correction to the capture cross section is necessary. After corrected ,the accuracy of model greatly improved.
·The accuracy of water saturation increased 6% after capture cross section has been corrected, improve the interpretation accuracy of water saturation.
·It is found that using the plates established by the parallelogram method to calculate Water holdup in borehole and formation water saturation can be very fast, accurately and directly. It is a feasible method which has some application prospect.

Acknowledgements

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