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Study on Logging Interpretation Model and Its Application for Gaotaizi Reservoir of L Oilfield

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Abstract: - L oilfield located in the south-central of the basin central depression area, belongs to the medium to low permeable oil fields, with complex rock structure, strong heterogeneity and clear difference between layers, the logging data interpretation is difficult. On the basis of the well coring analysis testing, testing, pre-production and production performance data, establishing reservoir porosity, permeability, oil saturation and gas saturation logging interpretation model. Application and interpretation model and the secondary interpretation of all the Wells in the studied area, the result of which shows the interpretation models have higher accuracy, further providing foundation for geologic modeling and remaining oil redevelopment.

Key words: - *log interpretation; interpretation model; porosity; permeability; oil saturation;gas saturation*

I. INTRODUCTION

L oilfield geological survey work began in 1956,the simulated earthquake shall census completed in 1960-1962 and discovered the L structure. After ten years of development, L oilfield has entered high water cut stage, serious conflict among layers, longitudinal reservoir mined is nonuniform and the same layer east-west well water flooded serious, such as a variety of reasons cause logging data interpretation more difficult. This article completed the logging second explanation and demonstration, redefined the log interpretation result, provided the precision based data of comparative analysis to the late reserves recalculation. In order to meet the needs of the current reservoir geological study, using the method of "core scale logging", on the basis of standardization and reinterpreted of existing log data, setting up the reservoir parameters log interpretation model[1-2].

II. STUDY ON THE LGGING ITERPRETATION MDEL OF RSERVOIR PRAMETERS

2.1 Porosity interpretation model

Porosity parameter evaluation is one of the important contents of reservoir evaluation, is also the basic factor of calculating permeability and oil saturation[3]. Rock effective porosity is the percentage of pore space of the rock volume,and the pore space is interconnected pores space and fluid can flow under natural conditions,and in the actual formation, it is closely related to the reservoir seepage effect. Due to Gaotaizi reservoir correlation of porosity and AC is best, therefore, this study uses the measured core physical property data and AC curve regression method to calculate effective porosity, that is on the basis of true depth determination of core and standardization of AC curve. Read from the AC value of core analysis porosity samples, and analyzing the single-correlation analysis of AC and porosity.

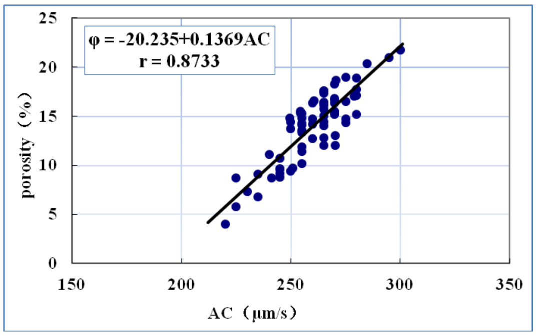

Fig.1 The chart of Gaotaizi reservoir porosity

Using 4 coring Wells 53 layer core data to establish the relationship between porosity and acoustic time figure(Fig.1)through multiple regression, we get the following formula:

$$\Phi=-20.235+0.1369AC \quad (1)$$

The mean absolute error of the model is 0.92%, the average relative error is 5.69%. The correlation coefficient is 0.87.

Second, application the empirical equation of Songliao basin, correcting the surface porosity to the subsurface porosity. Using the porosity correction equation to correct the surface porosity，and using the porosity of after correction as the reserves calculation value(Table1).

block	area type	well block	stratigraphic position	porosity %	subsurface porosity %
L7	oil	L7	$k1q_n^1$/ I	15.3	14.41
		L7	$k1q_n^1$/ II	15.8	14.88
		L7	$k1q_n^1$/III	15.9	14.97
		L7	$k1q_n^1$/IV	16	15.07
	gas	L7-11	k1 q_n^1/ I	16.1	15.16
		L7-11	k1 q_n^1/III	15.7	14.79
		L7-11	k1 q_n^1/IV	16.4	15.45
L12	oil	L12	k1 q_n^1/ I	15.3	14.41
		L12	k1 q_n^1 II	14.5	13.66
		L12	k1 q_n^1/III	14.7	13.84
		L12	k1 q_n^1/IV	16.7	15.73
	gas	L12	k1 q_n^1 I	16	15.07

Table1 Porosity values data table

The empirical equation：

$$\Phi=\Phi_0\cdot(0.39+0.6527\cdot P_e-0.05) \quad (2)$$

$$P_e=0.01\cdot H\cdot\rho_0 \quad (\rho_0=2.3g/cm^3) \quad (3)$$

Φ: the surface porosity;Φ_0: the subsurface porosity;P_e: the effectively coating pressure;ρ_0: the underlying density.

Using the above relational expression to calculate the porosity of oil-bearing area,and adopting the effective thickness weighing method to acquire single well ground porosity,then using the well point average method to acquire the ground mean effective porosity of each stratigraphic position and draw the purpose layer porosity chart.

2.2 Permeability interpretation model

Well logging information can be used to estimate or accurately calculate the lithology, porosity, saturation, but there is not a mathematical method to describe the relationship between permeability and conventional logging information. Under a certain pressure difference, the reservoir permeability is the ability of fluid through the rock, its value is mainly influenced by rock particle size, particle separation and pore tortuosity, pore throat radius, fluid properties and clay distribution form,etc., and the influence of such factors makes the relationship between the logging response and the permeability is very complicated, there is no accurate theoretical relationship between various influencing factors and there is no established theoretical equation of direct using logging data to calculate permeability[4]. Therefore, this study combined with the logging data and the core physical analysis, comprehensive study the statistical relationship between porosity and permeability,and returning permeability parameter interpretation model.

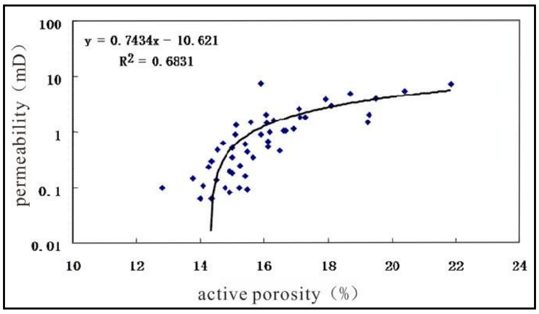

Fig.2 Gaotaizi reservoir cores relational graph of porosity and permeability

Using 4 coring Wells 49 layer core data to establish the relational graph between porosity and permeability(Fig.2),through multiple regression,we get the following formula:

$$K=-10.621+0.7434\Phi \qquad (4)$$

The mean absolute error of the model is 0.31%, the average relative error is 67.5%. The correlation coefficient is 0.83.

2.3 sturation interpretation model

L oilfield reservoir construction smoothly,and reservoir permeability is low,the reservoir completely in oil-water transition section, the production layers are all oil-water layers,the original oil saturation of determines the oil-water layer is difficult,the oil saturation of low permeability reservoir has larger changes.

2.3.1 saturation interpretation model

On the basis of archie formula, through litho-electric experiment to determine reservoir original oil saturation calculation model formula can be written as:

$$S_w = \left[\frac{abR_w}{R_t \times \Phi^m} \right]^{1/n} \qquad (5)$$

R_w—formation water resistivity,Ω·m; R_t —formation resistivity,Ω·m; Φ —active porosity, v/v; Sw—water saturation, v/v; m —porosity index; n —saturation index; a、b—the empirical coefficient related to lithology and pore structure[5-6] .

According to the result of the experiment to determine Gaotaizi reservoir: a = 0.9972, b = 0.9758, m =

1.6727, n = 1.7840.

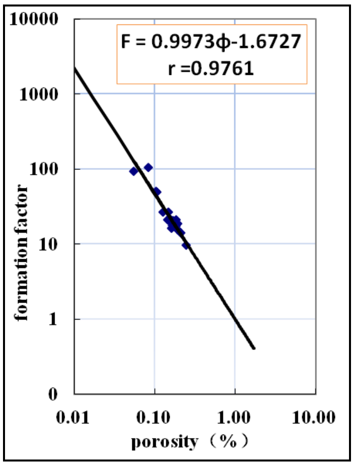

Fig.3 The relational graph of formation factor and porosity

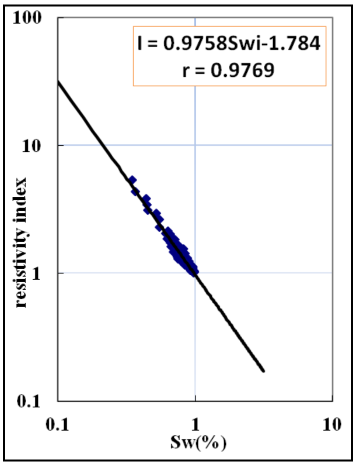

Fig4. The relational graph of resistivity index and water saturation

Using litho-electric experiment data and analysis data of formation water in this area, obtained rock electricity coefficient and formation water resistivity, qn1 formation water salinity is 13000 PPM, it is concluded that formation water resistivity is 0.42Ω·m, using the above parameters to determine the qn1 saturation equation. Its expression is:

$$S_w^{1.784}=0.1955/(\Phi^{1.6727}\times Rlld) \qquad (6)$$

Using the above oil saturation equation, putting the logging data of division effective thickness into the equation to calculation oil saturation, after each calculation unit volume weighted to calculate oil saturation [6].

2.3.2 gas saturation interpretation model

Due to the oil and gas layers in this area has the typical low resistance characteristic, resistivity, AC curve can not reflect the characteristics of atmosphere well, therefore, we cannot apply well logging method to calculate the original oil and gas saturation.Dealing with the mercury injection data with J function and get the average reservoir capillary pressure curve,then use formula method to determine the reservoir minimum flow pore throat radius. The mercury saturation which corresponds the minimum flow pore throat radius is the original oil saturation.

III. THE ALICATION OF LOGGING INTERPRETATION RESULTS

3.1 the calculation of reserves

Based on volumetric formula, used the above fine logging interpretation model and logging interpretation software, has carried on the processing and fine interpretation to 49 Wells, unified the reservoir interpretation parameters, improved the precision of reservoir interpretation, further draw the oil-water boundary, accurately calculate the reserves. After the recalculation, proven geological reserves of crude oil in the area is 2599.61×10^4 t, superimposed oil-bearing area is 39.47 km^2, dissolved gas geological reserves of $14.18\times10^8 m^3$(Table2).

block	well block	stratigraphic position	oil-bearing area km2	effective thickness m	active porosity %	So %	ground density of crude oil t/m3	crude oil volume factor	dissolved gas/oil ratio m³/m	geologic reserve: crude oil 104m³	geologic reserve: crude oil 104t	geologic reserve: dissolved gas m³	oil recovery factor %	Dissolved gas recove factor %	technical recoverable reserves: crude oil 104m³	technical recoverable reserves: crude oil 104t	technical recoverable reserves: dissolved gas m³
L7	L7	k1qn1/I	25.54	2.6	14.4	42.1	0.878	1.112	50	362.02	317.85	1.81	12.3	40.0	44.53	39.10	0.72
	L 7	k1qn1/II	24.46	3.0	14.9	42.8	0.872	1.112	50	420.83	366.96	2.10	12.3	40.0	51.76	45.14	0.84
	L 7	k1qn1/III	33.71	2.5	14.8	40.6	0.872	1.112	50	455.39	397.10	2.28	12.3	40.0	56.01	48.84	0.91
	L 7	k1qn1/IV	36.55	2.7	15.1	42.4	0.871	1.112	50	568.18	494.89	2.84	12.3	40.0	69.89	60.87	1.14
	subtotal		36.55							2876.90	2504.90	13.64			353.86	308.10	5.45
L12	L 12	k1qn1/I	2.92	2.4	14.4	47.6	0.887	1.112	50	43.20	38.32	0.22	12.3	40.0	5.31	4.71	0.09
	L 12	k1qn1/II	1.80	3.1	13.7	45.5	0.880	1.112	50	31.28	27.51	0.16	12.3	40.0	3.85	3.38	0.06
	L 12	k1qn1/III	1.56	2.7	13.8	43.0	0.874	1.112	50	22.48	19.64	0.11	12.3	40.0	2.77	2.42	0.04
	L 12	k1qn1/IV	1.15	1.4	15.4	47.4	0.874	1.112	50	10.57	9.24	0.05	12.3	40.0	1.30	1.14	0.02
	subtotal		2.92							107.53	94.71	0.54			13.23	11.65	0.21
summation			39.47							2984.43	2599.61	14.18			367.09	319.75	5.66

Table2 Reserve recalculation data sheet (sands group)

3.2 rservoir evaluation

The calculation of reserves to small layer, based on logging secondary interpretation results, combined with other related parameters (such as sedimentary facies), according to the volumetric formula., used The above parameters to calculate the proven geological reserves of crude oil in the area is 2599.61×10^{4} t, superimposed oil-bearing area is 39.47 km^{2}, dissolved gas geological reserves of 14.18×10^{8} m^{3}(Table3).

L7	k1qn1/I	G1	0.46	1.30	14.50	41.40	0.878	1.112	50	3.21	2.82	0.02	12.3	0.39	0.35	0.00
		G2	17.17	1.80	15.00	45.30	0.878	1.112	50	188.83	165.79	0.94	12.3	23.23	20.39	0.12
		G3	15.59	1.60	14.50	43.40	0.878	1.112	50	141.12	123.90	0.71	12.3	17.36	15.24	0.09
	k1qn1/II	G4	22.85	2.10	14.70	46.10	0.872	1.112	50	292.38	254.95	1.46	12.3	35.96	31.36	0.18
		G5	19.97	1.70	14.40	42.20	0.872	1.112	50	185.49	161.74	0.93	12.3	22.82	19.89	0.11
		G6	1.66	1.10	13.70	41.00	0.872	1.112	50	9.21	8.03	0.05	12.3	1.13	0.99	0.01
	k1qn1/III	G7	28.06	2.10	15.20	46.30	0.872	1.112	50	372.98	325.24	1.86	12.3	45.88	40.00	0.23
		G8	2.38	1.20	13.20	37.50	0.872	1.112	50	12.70	11.07	0.06	12.3	1.56	1.36	0.01
		G9	0.22	1.00	15.20	46.70	0.872	1.112	50	1.38	1.20	0.01	12.3	0.17	0.15	0.00
	k1qn1/IV	G10	31.93	2.70	14.20	45.20	0.871	1.112	50	497.65	433.45	2.49	12.3	61.21	53.31	0.31
		G11	7.75	1.20	14.10	42.60	0.871	1.112	50	50.24	43.76	0.25	12.3	6.18	5.38	0.03
subtotal			36.55							2741.60	2387.18	13.03		337.24	293.62	1.61

L12	k1qn1/I	G1														
		G2	1.25	1.30	14.70	47.50	0.887	1.112	50	10.17	9.02	0.05	12.3	1.25	1.11	0.01
		G3	0.76	1.90	13.90	45.00	0.887	1.112	50	8.13	7.21	0.04	12.3	1.00	0.89	0.00
	k1qn1/II	G4	1.76	2.20	13.70	47.50	0.880	1.112	50	22.65	19.92	0.11	12.3	2.79	2.45	0.01
		G5	0.68	2.70	13.10	41.60	0.880	1.112	50	8.94	7.87	0.04	12.3	1.10	0.97	0.00
		G6	0.05	2.40	15.20	54.00	0.880	1.112	50	0.80	0.70	0.00	12.3	0.10	0.09	0.00
	k1qn1/III	G7	1.25	2.10	13.80	42.50	0.874	1.112	50	13.79	12.05	0.07	12.3	1.70	1.48	0.01
		G8	0.25	1.40	13.90	40.40	0.874	1.112	50	1.80	1.57	0.01	12.3	0.22	0.19	0.00
		G9											12.3			
	k1qn1/IV	G10	0.49	1.10	13.90	42.60	0.874	1.112	50	2.87	2.51	0.01	12.3	0.35	0.31	0.00
		G11	0.04	0.70	14.10	42.90	0.874	1.112	50	0.15	0.13	0.00	12.3	0.02	0.02	0.00
subtotal			2.92							69.30	60.98	0.33		8.53	7.51	0.03
summation										2810.90	2448.16	13.36		345.77	301.13	1.64

Table3 Reserve recalculation data sheet (single layer)

IV. CONCLUSION

This paper adopts the method of "core scale logging" to establish the reservoir parameters log interpretation model, and provides the accurate basic data of comparative analysis for late reserves recalculation, and obtains the good application effect.

(1) Set up Gaotaizi reservoir logging interpretation model of porosity, permeability, oil and gas saturation. Studies show that the interpretation model of "core scale logging" method has higher precision.

(2)Apply the interpretation model to each well logging data in the research area for processing and fine interpretation, provides accurate geological parameters for reservoir numerical simulation and reservoir evaluation, and provides reference for residual oil exploration.

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