Evaluation method of vuggy carbonate reservoir constrained by multi-parameters and its application in Mesopotamia Basin

Wu Yiping[1]，Xue Zong'an[2]，Wang Zhaoming[1]

1.Research Institute of Petroleum Exploration & Development of CNPC

2.Geoscience Center of CNPC Great Wall Drilling Company, Beijing

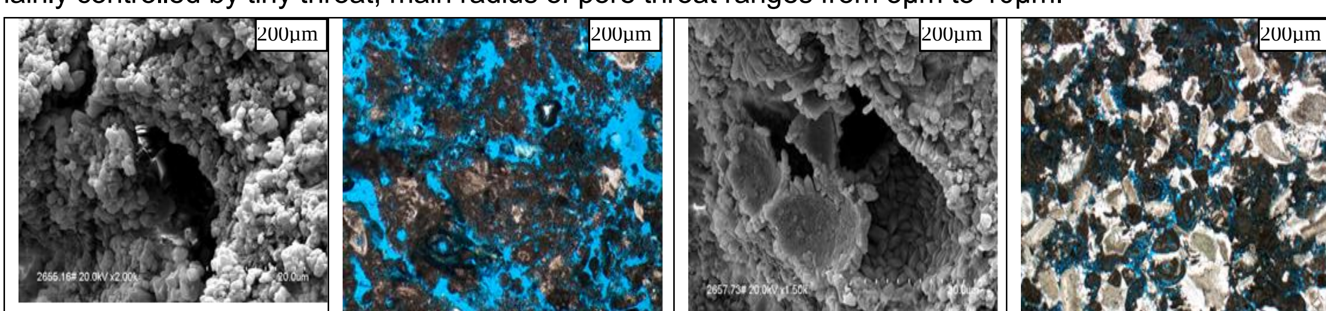
Summary

According to thin section and mercury intrusions and scanning electron microscopy and seismic facies and log facies, the paper summarizes the reservoir petrology and sedimentology, put forward new evaluation method of vuggy carbonate reservoir constrained by multi-parameters, and establishes quantitative evaluation chart, composed of the pore structure parameter Z, Imaging Surface Area and NMR T2 Logarithmic mean and Dipole acoustic wave Anisotropy, diveded vuggy carbonate reservoir of the upper Cretaceous in Mesopotamia basin into I, II, III and IV.

Introduction

In recent years, the vuggy carbonate reservoir of the oil fields in Middle East becomes the overseas exploration hot spot for oil company. The vuggy carbonate reservoir property of middle-upper Crataceous presents heterogeneity characteristics in both horizontal and vertical direction in Mesopotamia basin.

It is mainly developed three kinds of lithology in limestone reservoir of study area.It is granular limestone composed of micritic calcsparite biodetritus limestone, micritic biodetritus limestone and micritic biodetritus chaloroalgal limestone.The average porosity is about 23.4% and average permeability of micritic biodetritus limestone is 12.8md,it is the most favorable reservoir in the study area.The vuggy carbonate reservoirs in the study area were formed by the limestone under the environment of psammitic beach,biodetritus beach microfacies in carbonate open platform and internal part in carbonate plateform gentle slope, biodetritus beach microfacies is the most valuable facies for carbonate reservoir development. Dissolved pores were caused by fresh water leaching in exposed shoal reservoir of syngenetic and epigenetic diagenesis stage.There mainly are intergranular dissolved pore, moldic pore, dorsal foramen and organic framework dissolved pores(figure 1).Reservoir physical property in study area presents heterogeneity characteristics in both horizontal and vertical direction, porosity distribution ranges from 15% to 30%, most of the permeability is less than 100md, it is high pore medium-low permeability reservoirs.The channels in reservoir pore are mainly controlled by tiny throat, main radius of pore throat ranges from 3μm to 10μm.



intergranular dissolved pore	moldic pore	dorsal foramen	organic framework dissolved pores

Fig.2 Core slice analysis of vuggy carbonate reservoir of middle-upper Crataceous in Mesopotamia basin

In the study area conventional logging can divide the reservoir section and calculate the permeability by porosity and permeability correlation, but the results have deviation from the actual.Meanwhile we can only use the pore structure parameters to judge the pore structure of reservoir qualitatively，however can't calculate the pore throat structure.So the paper explores new methods to solve this problem.

Method

Based on laboratory geological analysis and rock physics experiments, we disscuss multi parameter correlations between physical properties data of conventional logging and identification parameters of pore structure of image logging and NMR Anisotropy. During data processing and analysising evaluation method of vuggy carbonate reservoir constrained by multi-parameters composed of the pore structure parameter Z, Imaging Surface Area and NMR T2 Logarithmic mean and Dipole acoustic wave Anisotropy is proposed.

Pore structure parameter (Z) is obtained by acoustic transit time and compensation density of imaging logging, is used to qualitatively evaluate the development degree of matrix porosity and secondary porosity, and more sensitive to pore structure of reservoir.

$$Z = \frac{DEN}{DT} \times 30.48 \times 10$$ （Formula 1）

where

Z：Apparent impedance，$g/cm^3 \cdot cm/us \cdot 10$

DEN：Density log value，g/cm^3

DT：Acoustic logging value， us/ft

The imaging Area (AREA) is the ratio of all meaningful targets in a unit interval. In the micro resistivity imaging logging static graph, the cavities and pores are extracted from the rock skeleton background, and non karst geological bodies are excluded,then image segmentation is used in the gray value histogram,thus segmentation shreshlod T by shreshold partition algorithm in imaging processing software Logview and AREA will be returned(Formula 2).

$$Area = \int_{T1}^{T2} H(D) \Big/ \int_{0}^{T1} H(D)$$ （Formula 2）

where：

H(D)：Gray histogram

T：Segmentation shreshlod

T**2** logarithmic mean (T2LM) is obtained through averaging logarithmic mean after extracting the T2 spectrum, and it can very reflect the pore throat radius, compared to the simple geometric mean, the larger the T2LM, the higher the porosity, the better the permeability. Based on the data recording format of MRIL-P type nuclear magnetic instrument of Halliburton company, 30 data points are recorded in the range of 0-3000ms, and each point represents the peak of the T2 spectrum(Formula3).

$$T_2LM = 10^{(lgT21 + lgT22 + lgT23 + \cdots + lgT230)/30}$$ （Formula 3）

where：

T2LM：Logarithmic mean of relaxation time，ms

T**2**：，Relaxation time，ms

Dipole acoustic anisotropy (ANI): the difference between slow and fast acoustic dipole modes (Formula 4).Anisotropy of formation is mainly caused by the pore development zones, and the anisotropy values in the high porosity zones are relatively high.

$$ANI = \frac{DTS - DTF}{DTF + DTS} \times 100\%$$ （Formula 4）

Where ：

dts：Slow-wave moveout， us/ft

dtf：Fast-wave moveout， us/ft

Through the statistics of 101 reservior parameter of pore structure parameter (Z) and AREA and T2LM) and ANI, we find that the pore structure parameter (Z), T2LM and AREA have good correlation, while the reservior with higher porosity have larger ANI accordingly. Then interactive chart of four parameters is established (Figure 1), and set the classification standard of four types of reservoir (Table 1), of which reservoir class I is good, as well as class II is moderate and class III is poor,but classⅣbelongs to non reservoir.

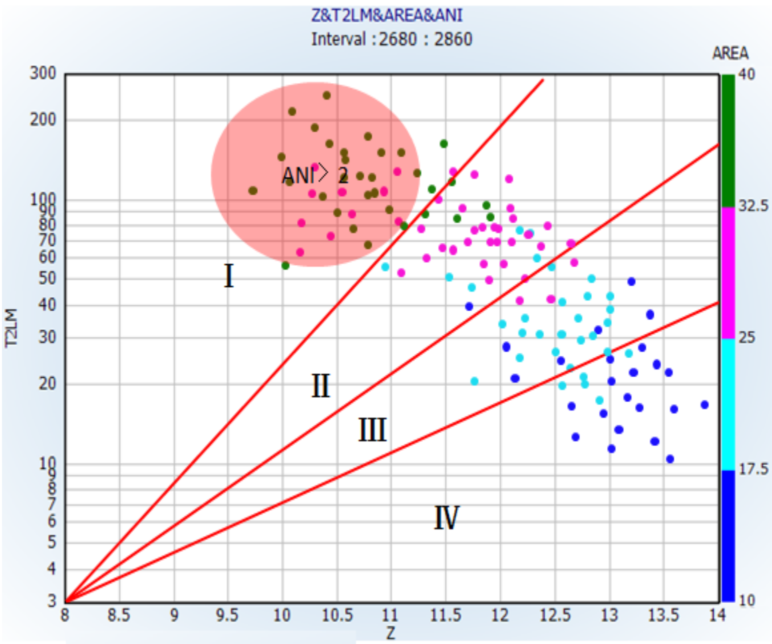


Fig.1 Intersection evaluation chart of Multi well logging parameter

Table.1 The vuggy carbonate reservoir classification standard

Parameters	Reservior Classes			
	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Pore structure parameter（Z）	9.5～11	11.5～12.0	12.0～13.0	>13.0
Imaging Area（AREA）	10～17.5	17.5～25.0	25.0～32.5	32.5～40.0
T2 logarithmic mean（T2LM）	>100	50～100	30～50	<30
Dipole acoustic anisotropy（ANI）	> 2	< 2	< 2	< 2

Examples

The reservoirs in the study area are divided into four classeds by using intersection chart and classification standard. The results show that the horizontal distribution is wide and relatively stable, and the reservoir thickness of sand beach and debris beach are controlled by open platform. Reservoir quality varies greatly and is greatly influenced by diagenesis.Class I and II reservoirs develop effective oil and gas pools, and the poor pools can be seen in the class Ⅲ reservoir, and the class IV reservoirs belong to ineffective, mainly dry layers(fig.3).

Conclusions

In the study area, typical middle high porosity and low permeability reservoirs are developed. The main rock types are sand debris and debris particle limestone; dissolution is an important factor for reservoir modification; pore types are mainly intergranular (internal) dissolution pores and pore forming pores.

Pore structure parameters Z of conventional logging have negative correlations to permeability; Imaging parameters AREA and core hole are characterized by reservoir porosity development degree; T2LM can reflect the pore size; ANI in large pores appears at relatively high value.

According to the chart and the classification standard by Z and Area and T2LM and ANI, the vuggy reservoir could be divided into classI, II, III and IV.

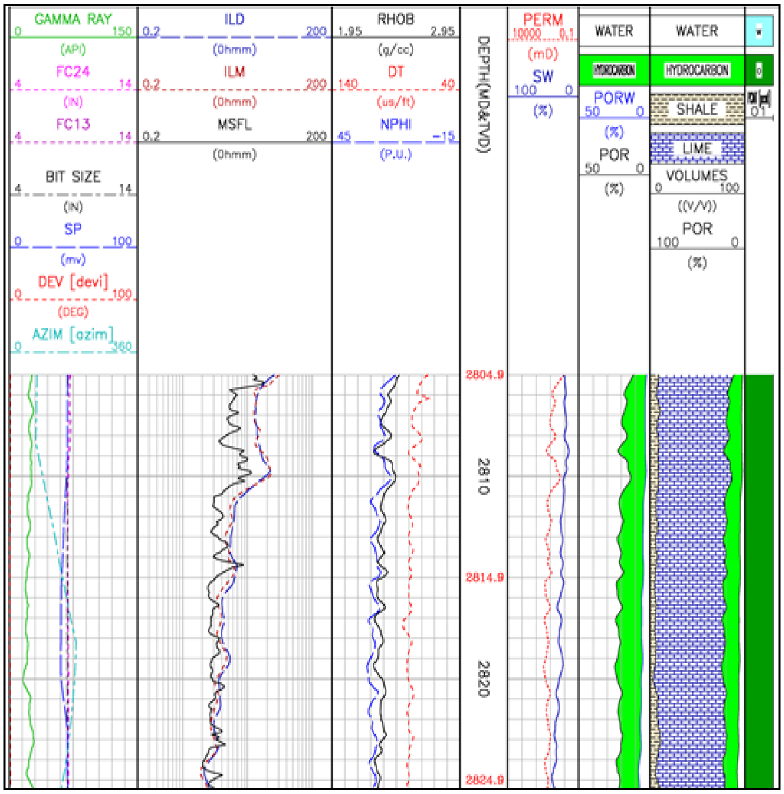


Fig.3 Reservoir class I section of Kh layer well AD5-4 in Mesopotamia basin

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