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Petrophysical models for estimating filtration-capacity parameters of complex reservoir rocks at Kachalivske oil and gas condensate field

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SUMMARY

According to the results of laboratory and wells studies reservoir rocks of coal deposits at Kachalivske oil and gas condensate field it is established that these rocks have a complex geological structure, which is due to the structure of pore space, presence sandstones with monomineral and polymineral types, as well as different clay content. As a result of statistical processing of experimental laboratory and geophysical researches data the petrophysical models are constructed and its allowing to define reliably filtration-capacitive parameters for this type reservoir rocks. The established models can be used both to determine the reservoir parameters of reservoir rocks for these sediments, and in the rapid interpretation of well logging results.

Introduction

Existing methods for establishing the filtration-capacitive properties of reservoir rocks based on the results of geophysical studies in wells work well in homogeneous strata. But in complex structural productive horizons, the definition of these parameters is complicated by individual characteristics of the mineral composition and structure of the pore space of the rock skeleton. To this type belong reservoir rocks of coal deposits at Kachalivske oil and gas field. The complexity of structure in this deposit is due to the presence in geological section sandstones with monomineral and polymineral types, as well as reservoirs with different content of clay material.

A number of scientists have dealt with the issue of petrophysical modeling filtration-capacity parameters for reservoir rocks with complex geological sections (Fedoryshyn et al., 2019; Femyak et al., 2020; Vyzhva et al., 2017). Construction of filtration-capacity models for specific oil and gas deposits is a priority in the reliable interpretation of well logging results. However, due to insufficient study of core material and incomplete geophysical studies of wells, there is a need for improved petrophysical models of reservoir rocks with complex geological structure, which will take into account the above features and, thus, increase the informativeness of well logging.

The purpose of the study

Investigate and establish the relationship between filtration and capacity parameters, the structure of the pore space and geophysical parameters of the reservoir rocks for coal deposits at Kachalivske oil and gas condensate field. Build petrophysical models of the relationship between physical and reservoir properties such as "core-core" and "core-geophysics" for the reservoir rocks of the above sediments.

Research method

The main research methods are experimental laboratory measurements of petrophysical parameters of reservoir rocks at the representative collections of the core selected from the productive horizons coal deposits at Kachalivske oil and gas condensate field.

The obtained results were processed by the method of mathematical statistics.

Analyzing a number of scientific works, it should be noted that in the study of complex reservoir rocks there are a number of difficulties in determining the actual values of filtration-capacitive parameters, which are associated with the influence of pore space structure and mineralogical composition of the rock skeleton (Fedoryshyn et al., 2019; Fedoryshyn et al., 2018; Yakovyna et al., 2019).

To establish petrophysical models of filtration-capacity parameters, the analysis of geological-geophysical studies reservoir rocks of coal deposits at Kachalivsre oil and gas condensate field was carried out.

In some cases, in coal deposits, the multicomponent composition of rock matrix affects the actual value of geophysical parameter, which causes erroneous conclusions about the reservoir rock and the nature of its saturation.

The basis for the construction of filtration-capacity models of coal deposits at Kachalivske field was that the petrophysical model for different types of reservoir rocks is based on the structure of rock matrix, mineralogical composition of cement and the structure of pore space.

Physical-lithological properties of productive horizons at Kachalivske field are studied, generally, by results of laboratory researches of core. Binding the core to the section was performed according to control measurements of drilling tool length, and also associated with logging diagrams.

Statistical characteristics of estimates the main petrophysical parameters

In order to analyze the reliability of use the results of geophysical well logging for determining the reservoir properties of productive rocks at Kachalivske oil and gas condensate field, a statistical approach was used. We determined the main descriptive statistical values of petrophysical parameters for coal deposits at Kachalivske field (Table 1).

Using the critical value of Kolmogorov-Smirnov for our samples, their affiliation to the normal or lognormal distribution laws was established. Table 1 show that almost all petrophysical parameters are subject to the normal distribution law, except $\rho_п$, and P_s.

We analyzed the pairwise correlation coefficient of petrophysical models (Table 2).

Table 1 – Statistical analysis of petrophysical parameters for reservoirs rocks

Parameter	N	$\overline{X}$	*med*	*min*	*max*	$\widetilde{\sigma}$	Stat.dev.	Var.coeff.	Distribution law	K-S–stat.	K-S–crit.
ρ_r, Om·m	47	11,68	6,00	0,80	55,30	148,959	12,204	104,486	*Normal*	0,1932	0,1785
									Log-normal	0,0618	
ΔT, mcs/m	47	213,40	211,00	198,00	260,00	139,811	11,824	5,540	*Normal*	0,1314	0,1785
									Log-normal	0,1331	
Iγ, mcR/hour	47	4,03	3,50	2,00	7,50	2,236	1,495	37,110	*Normal*	0,1728	0,1785
									Log-normal	0,1048	
ΔIγ	47	0,16	0,13	0,00	0,49	0,015	0,124	75,699	*Normal*	0,1181	0,1785
									Log-normal	0,2841	
Inγ, conv.un.	47	3,03	2,96	1,38	4,48	0,501	0,70780	23,3531	*Normal*	0,0862	0,1785
									Log-normal	0,1168	
ΔInγ	47	0,52	0,54	0,12	0,84	0,030	0,17213	32,7406	*Normal*	0,0975	0,1785
									Log-normal	0,1875	
$C_p^{AL\text{-}GL}$, %	47	9,43	9,10	7,00	19,80	4,897	2,21298	23,4732	*Normal*	0,1498	0,1785
									Log-normal	0,1025	
$C_p^{NGL\text{-}GL}$, %	47	12,85	12,60	3,50	23,80	21,903	4,68006	36,4177	*Normal*	0,1111	0,1785
									Log-normal	0,0867	
$C_p^{accep.}$, %	47	9,43	9,10	7,00	19,80	4,880	2,20912	23,4376	*Normal*	0,1493	0,1785
									Log-normal	0,1020	
P_p	47	95,24	89,70	17,40	159,20	1184,57	34,4176	36,1392	*Normal*	0,0745	0,1785
									Log-normal	0,1060	
P_s	47	10,62	5,10	0,91	54,30	176,412	13,2820	125,0736	*Normal*	0,2649	0,1785
									Log-normal	0,1377	
C_{og}, %	47	58,40	67,00	0,00	97,00	802,724	28,3323	48,5108	*Normal*	0,1452	0,1785
									Log-normal	0,2734	
C_{boun}, %	47	16,96	18,00	3,00	25,00	20,694	4,54904	26,8262	*Normal*	0,1438	0,1785
									Log-normal	0,1728	

Table 2 – Matrix of paired correlation coefficients between individual petrophysical parameters

Parameter	ρ_r, Om·m	ΔT, mcs/m	Iγ, mcR/hour	ΔIγ	Inγ, conv.un.	ΔInγ	$C_p^{AL\text{-}GL}$, %	$C_p^{NGL\text{-}GL}$, %	$C_p^{accep.}$, %	P_p	P_s	C_{og}, %	C_{boun}, %
ρ_r, Om·m	**1,00**	0,02	-0,07	-0,15	0,14	0,19	0,13	-0,13	0,12	-0,24	**0,89**	**0,68**	-0,06
ΔT, mcs/m	0,02	**1,00**	0,36	0,52	-0,42	-0,43	**0,78**	0,19	**0,78**	**-0,61**	0,27	0,24	-0,55
Iγ, mcR/hour	-0,07	0,36	**1,00**	**0,83**	-0,11	-0,32	-0,16	-0,09	-0,16	0,21	-0,03	0,05	-0,22
ΔIγ	-0,15	0,52	**0,83**	**1,00**	-0,34	-0,41	-0,11	-0,08	-0,11	0,23	-0,06	-0,09	-0,16
Inγ, conv.un.	0,14	-0,42	-0,11	-0,34	**1,00**	**0,87**	-0,24	**-0,77**	-0,24	0,18	0,08	0,17	0,05
ΔInγ	0,19	-0,43	-0,32	-0,41	**0,87**	**1,00**	-0,21	**-0,87**	-0,21	0,13	0,13	0,12	0,14
$C_p^{AL\text{-}GL}$, %	0,13	**0,78**	-0,16	-0,11	-0,24	-0,21	**1,00**	0,29	**0,99**	**-0,87**	0,36	0,35	-0,52
$C_p^{NGL\text{-}GL}$, %	-0,13	0,19	-0,09	-0,08	**-0,77**	**-0,87**	0,29	**1,00**	**0,79**	-0,27	-0,10	-0,08	-0,06
$C_p^{accep.}$, %	0,12	**0,78**	-0,16	-0,11	-0,24	-0,21	**0,99**	**0,79**	**1,00**	**-0,87**	0,36	0,35	-0,52
P_p	-0,24	**-0,61**	0,21	0,23	0,18	0,13	**-0,87**	-0,27	**-0,87**	**1,00**	-0,46	-0,37	0,34
P_s	**0,89**	0,27	-0,03	-0,06	0,08	0,13	0,36	-0,10	0,36	-0,46	**1,00**	**0,87**	-0,28
C_{og}, %	**0,68**	0,24	0,05	-0,09	0,17	0,12	0,35	-0,08	0,35	-0,37	**0,87**	**1,00**	-0,45
C_{boun}, %	-0,06	-0,55	-0,22	-0,16	0,05	0,14	-0,52	-0,06	-0,52	0,34	-0,28	-0,45	**1,00**

* Note: Significant values of parameters that exceed the absolute value of 0.60 are underlined

It has been established that in some cases there are close links between individual petrophysical parameters (Figure 1).

The results of petrophysical modeling

Taking into account the statistical characteristics of two-dimensional petrophysical connections filtration-capacitive and geophysical parameters "core-core" or "core-geophysics" type, it is established that the dependences $C_p=f(\Delta T)$, $C_p=f(\Delta I_{n\gamma})$ and $C_{st}=f(K_p)$ are insufficient for their use in establishing the results of calculated parameters by geophysical well logging in reservoir rocks of coal deposits at Kachalivske oil and gas condensate field.

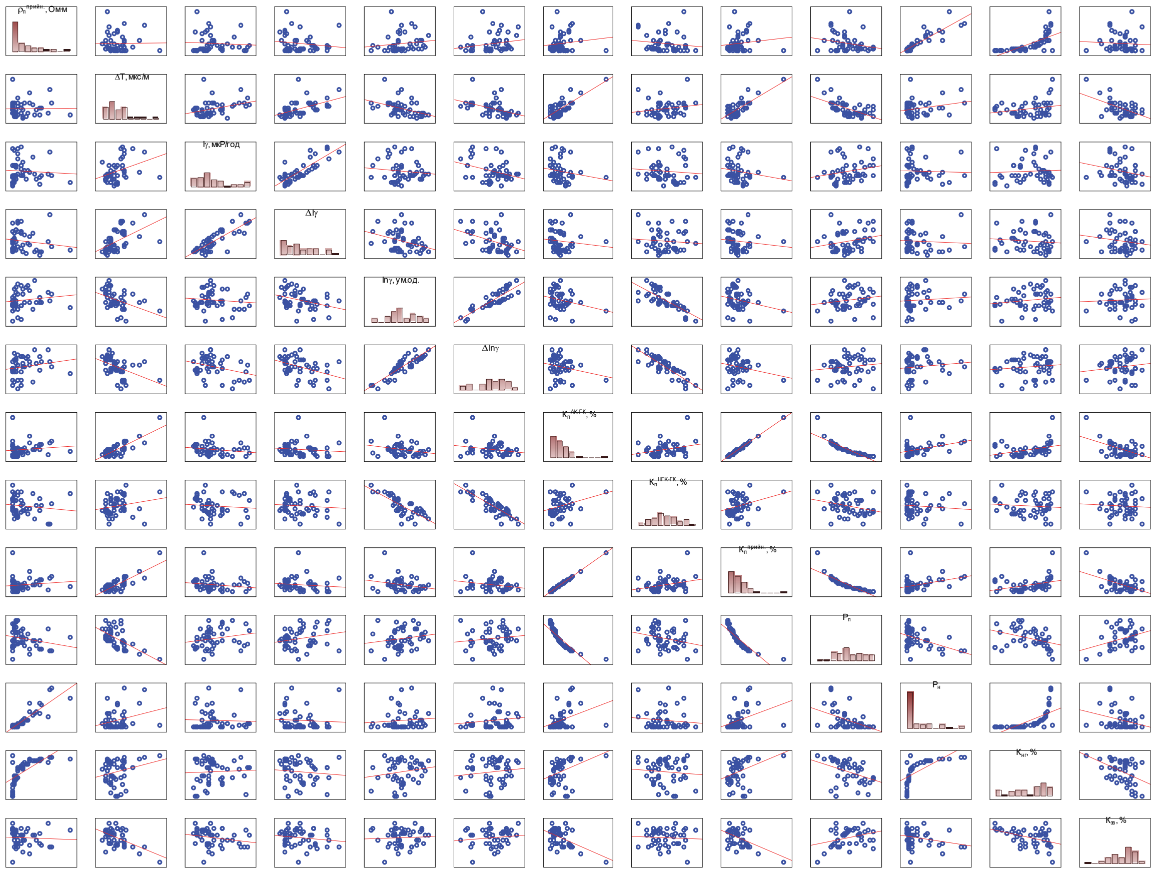

***Figure 1** – Matrices of two-dimensional relationships between individual petrophysical parameters.*

To increase the informativeness of geophysical well logging results, we built three-dimensional petrophysical models $C_p=f(\Delta T, \Delta I_\gamma)$, $C_p=f(\Delta I_{n\gamma}, \Delta I_\gamma)$ and $C_{st}=f(C_p, C_{boun})$, which allow more reliable assessment of filtration -capacitance parameters for these reservoir rocks (Figure 2, 3, 4).

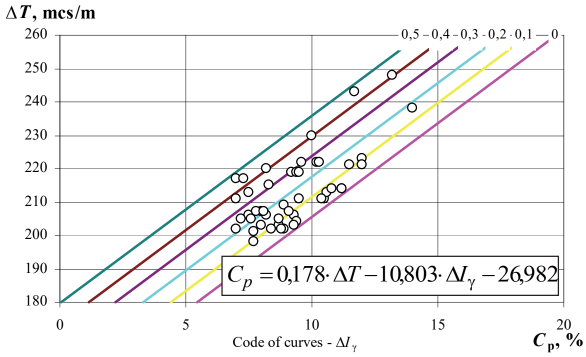

***Figure 2** – Petrophysical model for estimating the porosity coefficient according to AK and GL*

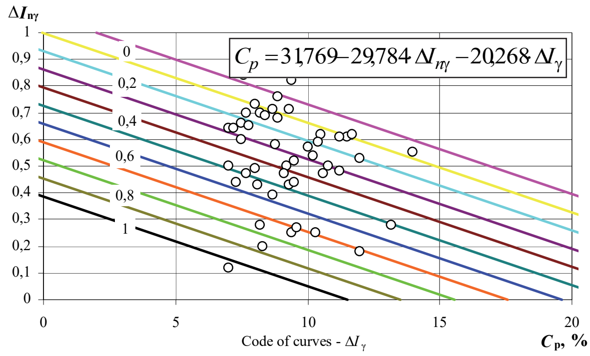

***Figure 3** – Petrophysical model for estimating the porosity coefficient according to NGL and GL*

It should be noted that the correlation between these parameters has increased and is sufficient for the use of these petrophysical models in interpreting the results of geophysical well logging at Kachalivske oil and gas condensate field.

Conclusions

According to the results of laboratory and wells studies reservoir rocks of coal deposits at Kachalivske oil and gas condensate field it is established that these rocks have a complex geological structure, which is due to the structure of pore space, presence sandstones with monomineral and polymineral types, as well as different clay content. As a result of statistical processing of experimental laboratory and geophysical researches data the petrophysical models are constructed and its allowing to define reliably filtration-capacitive parameters for this type reservoir rocks. The established models can be used both to determine the reservoir parameters of reservoir rocks for these sediments, and in the rapid interpretation of well logging results.

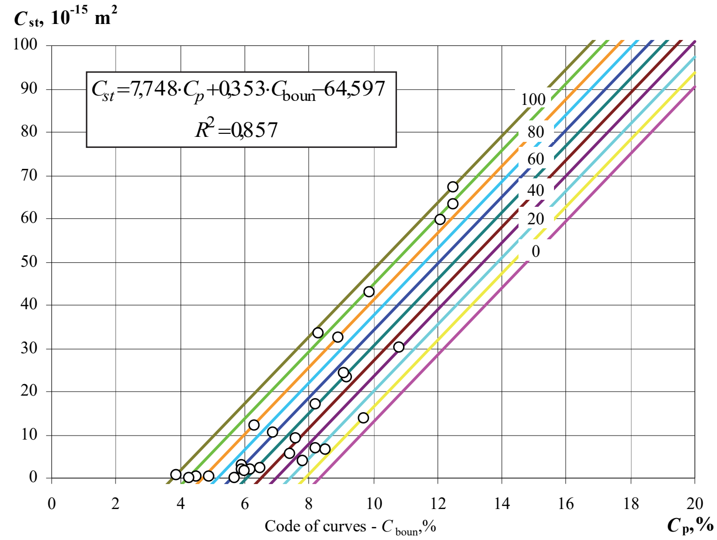

***Figure 4** Petrophysical model of permeability assessment based on the results of determining the porosity coefficient and residual water saturation coefficient*

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