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USE OF PROBABILISTIC AND STATISTICAL METHODS FOR SEPARATION OF ROCKS INTO PERMEABLE AND IMPERMEABLE PARTS (ON EXAMPLE OF CLASTIC DEPOSITS OF VISEAN STAGE OF SOFYINSKOE FIELD)

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ИСПОЛЬЗОВАНИЕ ВЕРОЯТНОСТНО-СТАТИСТИЧЕСКИХ МЕТОДОВ ДЛЯ ДЕЛЕНИЯ ПОРОД НА ПРОНИЦАЕМУЮ И НЕПРОНИЦАЕМУЮ ЧАСТИ (НА ПРИМЕРЕ ТЕРРИГЕННЫХ ОТЛОЖЕНИЙ ВИЗЕЙСКОГО ЯРУСА СОФЬИНСКОГО МЕСТОРОЖДЕНИЯ)

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Separation of well section into permeable and impermeable parts is one of the main problems for further construction of a geological model, reserves estimation and field development planning. Quality of separation depends on amount of knowledge about geological section, level of theoretical development of well logging methods and general geophysical characteristics of the area. The fullest differentiation is obtained by using a complex of geological and geophysical methods.

The paper is focused on Visean deposits of well of Sofyinskoe field drilled in 2014. A complex of activities was performed along with well logging. Porosity was calculated by acoustic and neutron logging. Core analysis was performed.

Using well logging and results of core analysis selection was made, used for construction of statistical models. Based on statistical models all parameters were made-up to a single measurement system. The analysis of degree of influence of geological and geophysical parameters was made. The geological analysis shows that the greatest influence belongs to porosity and residual water. The geophysical analysis shows that the greatest influence belongs to hydrogen content and own radioactivity of rocks.

A complex probabilistic parameter that includes all measurements according to core and geophysical parameters is calculated. Results of core analysis are considered fully in order to obtain a highest degree of difference. Almost all the parameters of geophysical data increase the degree of difference, except for lateral logging, microgradient and micropotential tools and transit time of P-wave for short tool, which reduces the degree of difference.

Based on values of a complex parameter that have maximum differences in geological and geophysical parameters, relationships of geological and geophysical parameters were built. Scatter charts show that fields of measured points are not intersected, which confirms a correct separation of a section.

Using a statistical method allows to consider fully available geological and geophysical data to separate a section into permeable and impermeable parts.

Ключевые слова:
скважина, разделение разреза скважины, коллектор, покрышка, открытая пористость, остаточная водонасыщенность, водородосодержание, естественная радиоактивность, геофизические методы исследования, исследования керна, визейский нефтегазоносный комплекс, линейные модели, статистическая вероятность, математическая статистика, точечная диаграмма, коэффициент Стьюдента, комплексная вероятность.

Разделение разреза на проницаемую и непроницаемую части – одна из основных задач для дальнейшего построения геологической модели, подсчета запасов и планирования разработки месторождения. Качество разделения зависит от степени изученности геологического разреза, уровня теоретической разработки геофизических методов исследования скважин и общей геофизической характеристики района. Наиболее полная дифференциация получается при использовании комплекса геологических и геофизических методов.

В работе рассматриваются визейские отложения скважины Софьинского месторождения, пробуренной в 2014 г. В скважине с использованием геофизических исследований проведен комплекс мероприятий, рассчитаны параметры пористости по акустическому и нейтронному методам, проведены исследования керна.

По геофизическому каротажу и результатам исследования керна составлена выборка, использованная для построения статистических моделей. На основании статистических моделей все параметры приведены к единой системе измерения. Проведен анализ степени влияния геологических и геофизических параметров. Установлено, что по результатам исследования керна наибольшую степень влияния имеют коэффициент пористости и остаточной водонасыщенности, а из геофизических параметров – водородосодержание и собственная радиоактивность пород.

Рассчитан комплексный вероятностный параметр, включающий в себя все определения по данным керна и по геофизическим параметрам характеристик разреза. Результаты исследования керна полностью учитывались для достижения наиболее высокой степени различия. Из геофизических данных практически все параметры увеличивают степень различия, кроме бокового каротажа, микроградиента, микропотенциала зондов и времени пробега *P*-волны по короткому зонду, которые уменьшают степень различия.

Исходя из значений комплексного параметра, имеющих максимальные различия по геологическим и геофизическим данным, построены зависимости геологических параметров от геофизических. Полученные точечные диаграммы показывают, что поля точек не пересекаются. Это подтверждает правильность проведенного разделения разреза.

Использование статистического метода позволяет наиболее полно учитывать всю имеющуюся геологическую и геофизическую информацию для разделения разреза на проницаемую и непроницаемую части.

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Introduction

One of the main tasks of oil and gas field geology is picking permeable and impermeable interlayers in rock strata. Separation of rock strata is basis for building a geological model, reserves evaluation and further planning of field development.

To separate oil-bearing well section it is necessary to pick layers of different lithologic composition, determine sequence of their occurrence and finally identify reservoirs and impermeable sections between them. These challenges are solved with help of a complex method of studying sections. Well logging methods, used in mandatory order in wells of all categories (prospecting, exploration, operation etc.), are the main in this complex. Geophysical data are correlated with available geological data of rock description (core, sludge), with well test results for inflow and results of hydrodynamic studies.

The quality of separation depends on degree of geologic certainty, level of theoretical development of geophysical methods of well survey and general geophysical characteristics of an area. Interpretation of geophysical curves is most reliable in conjunction with geological studies. Wherein, it should be clear that in some cases core does not provide complete understanding of location of layers boundaries. It is associated with low percentage of its removal and challenges of correlation of core material with depth [1].

Research subject

A well for prospection and evaluation is research subject. It was drilled in 2014 at North Efremov Dome of Sofyinskoe field.

In administrative terms Sofyinskoe field is located in territory of Uinsk, Chernushka and Oktiabrskii country of Perm region. In terms of tectonic zone it is confined to Tanyp Late Devonian Atoll located in northeastern part of Bashkir Arch [2].

A complex of geophysical studies was carried out in a well 119, including standard logging (A2M0.5N), lateral logging, micro logging, lateral, microlateral, induction, acoustic, radioactive logging and cavernometry.

Also in a well with core gathering 172.4 m of rocks were passed, core removal was 170.1 m (98.7 %). Coefficients of porosity, permeability, oil saturation and bulk density of core are determined.

Oil-bearing formations are picked in Verei, Upper Visean and Upper Devonian-Tournaisian oil and gas bearing complexes. Results of well logging interpretation and study of core from Upper Visean oil and gas complex are used in the study [3, 4].

It is important that definition of rock characteristics was carried out not only in reservoirs identified by geophysical data, but also in non-reservoirs.

The volume of data obtained and its diversity made it possible to compile a database with representative samples.

Analysis of reservoir picking

Separation into permeable and impermeable parts was carried out according to a complex of field geophysical studies using conventional methods [5]. Following qualitative features of well logging curves were also taken into account [6-11]:

– low and medium readings of carrier rocks on radioactive logs.

– increased resistance values with respect to carrier dense and clay rocks.

For analysis of average values of classes of permeable and impermeable rocks obtained from results of core and geophysical methods (Tables 1, 2) the Student's coefficient *t* was used [12-14].

All the parameters from geophysical data are statistically significant. Except for lateral logging and values obtained by micropotential tool. Values of parameters vary considerably from 0.7-0.8 according to a microgradient tool to 781.9-849.2 according to acoustic data.

According to core data, all parameters, except mineralogical density, are statistically significant. Values of parameters differ (2.1-2.3 g/cm^3) according to density of a sample to 68.7-904.1 mD for rock permeability.

Such a spread of mean values of various parameters does not allow their quantitative comparison.

To check values that most strongly affect differentiation of rocks, scattering diagrams for data obtained as a result of core material and geophysical parameters are plotted (Fig. 1, *a*, *b*).

The largest comlete separation into permeable and impermeable rocks according to core data is observed during comparison of parameters of porosity coefficient and irreducible water saturation (see Fig. 1, *a*). Hence, it can be seen that rocks related to reservoirs have high porosity and low irreducible water saturation and vice versa. Seal rocks have low porosity and high irreducible water saturation. The regression equation for permeable rocks looks like

$$K_w = 214.9 - 19.8K_p + 0.5K_p^2,$$

for impermeable rocks

$$K_w = 63.2 + 3K_p - 0.3K_p^2.$$

Analysis of values of coefficients *Z* and free terms shows that they differ significantly.

Table 1

Values of Student's *t*-criteria from well logging data

Method	Mean		Value of Student's criteria	Number of degrees of freedom	Significance point	Number of observation		Standard deviation		Relative variance	Variance
	imper-meable	perme-able				imper-meable	perme-able	imper-meable	perme-able		
BK	7.52	7.57	–0.04	334	0.97	147	189	15.68	5.35	8.59	0.00
BMK	4.59	11.19	–5.41	334	0.00	147	189	6.85	13.49	3.88	0.00
DTP	239.99	272.59	–10.66	334	0.00	147	189	9.43	36.12	14.67	0.00
GK	4.04	13.94	–32.82	334	0.00	147	189	1.63	3.36	4.25	0.00
IK	606.69	194.00	13.40	334	0.00	147	189	385.82	153.80	6.29	0.00
MGZ	0.84	0.71	2.61	334	0.01	147	189	0.16	0.58	12.71	0.00
MPZ	0.81	0.79	0.58	334	0.56	147	189	0.24	0.51	4.64	0.00
NKTB	4.75	2.58	17.22	334	0.00	147	189	0.83	1.33	2.55	0.00
NKTS	1.77	1.16	18.26	334	0.00	147	189	0.16	0.38	5.41	0.00
TP_1	662.26	712.83	–9.86	334	0.00	147	189	33.61	54.66	2.65	0.00
TP_2	781.98	849.22	–12.26	334	0.00	147	189	32.30	60.04	3.46	0.00
dGK	0.14	0.74	–32.82	334	0.00	147	189	0.10	0.20	4.26	0.00
W	21.04	32.64	–11.02	334	0.00	147	189	3.02	12.47	17.10	0.00
DS	0.22	0.24	–7.85	334	0.00	147	189	0.00	0.04	1961.62	0.00
K_{clay}	8.88	46.44	–32.82	334	0.00	147	189	6.18	12.76	4.26	0.00
K_pAL	20.48	28.34	–10.66	334	0.00	147	189	2.27	8.70	14.67	0.00

R e m a r k s : BK – lateral logging, Om·m; BMK – micro lateral logging tool, Om·m; DTP – interval time of *P*-wave run on basis of broadband acoustic logging, µs/m; GK – gamma-ray intensity from gamma-ray logging µR/h; IK – induction logging, conductivity, mS/m; MGZ – gradient micro logging tool, Om·m; MPZ – micro potential logging tool, Om·m; NKTB – neutron-neutron logging by thermal neutrons (NNLt), big tool, c.u.; NKTS – neutron-neutron logging by thermal neutrons (NNLt), small tool, c.u.; TP_1 – time of P-wave travel over a short wave sonic logging tool, µs; TP_2 – time of P-wave travel over a long wave sonic logging tool, µs; dGK – gamma-ray index from GR log; W – hydrogen saturation, %; DS – measured well diameter, m; K_{clay} – clay index, % (from logging); K_pAL – porosity coefficient from AL, %. Here and in the Tables 2, 5, 6 red color correspond to values that have level of error probability less than 5%.

Table 2

Values of Student's *t*-criteria from core study data

Method	Mean		Value of Student's criteria	Number of degrees of freedom	Significance point	Number of observation		Standard deviation		Relative variance	Variance
	imper-meable	perme-able				imper-meable	perme-able	imper-meable	perme-able		
K_p, %	10.75	18.68	–13.08	161	0	71	92	4.6	3.2	2.1	0.0
K_{perm}, mD	68.71	904.06	–6.75	140	0	50	92	206.0	860.9	17.5	0.0
$K_{i.w}$, %	45.25	9.68	6.68	54	0	20	36	29.2	10.0	8.5	0.0
$Dens^V$	2.36	2.14	10.84	161	0	71	92	0.2	0.1	3.3	0.0
$Dens^S$	2.47	2.36	7.74	161	0	71	92	0.1	0.1	6.3	0.0
$Dens^M$	2.64	2.63	0.79	161	0,43	71	92	0.1	0.0	76.6	0.0

R e m a r k s : K_p – porosity coefficient, %; K_{perm} – permeability coefficient, mD; $K_{i.w}$ – irreducible water saturation coefficient, %; $Dens^V$ – volume density of core, g/cm^3; $Dens^S$ – density of saturated core, g/cm^3; $Dens^M$ – mineral density of core, g/cm^3.

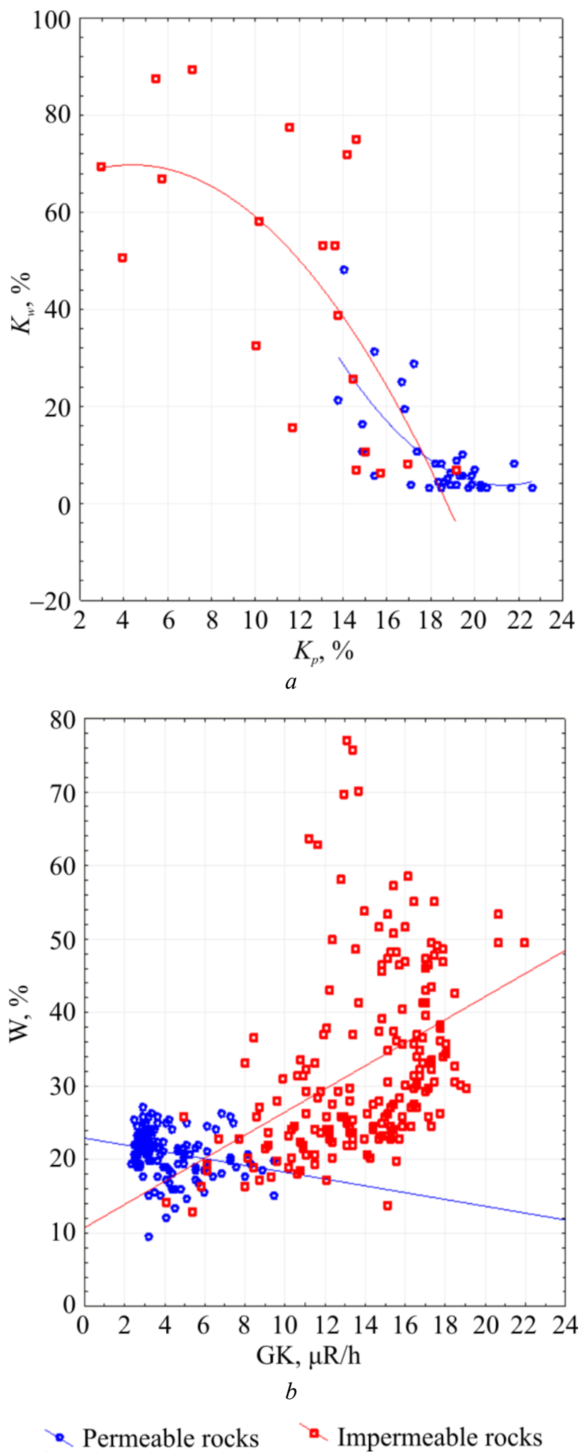

Fig. 1. Scatter chart:
a – built on core data for K_w и K_p;
b – for parameters GK and W

During analysis of geophysical data it has to be noted that the largest degree of differentiation is observed in values of own radioactivity (GK) and hydrogen saturation (W) (see Fig. 1, *b*). The figure shows that permeable rocks have low hydrogen content and low values of natural radioactivity. Impenetrable rocks have high hydrogen content and high radioactivity [15]. The regression equation for permeable rocks is W = 22,9 – 0,5GK, for impermeable W = 10,7 + 1,6GK. Values of *Z* coefficients and free terms show that they differ significantly.

Probabilistic and statistical check of separation of a section into permeable and impermeable parts

To determine quality of rock separation based on results of interpretation of geophysical studies and core data a base is built.

Coefficients of porosity, permeability, irreducible water saturation, bulk density of a sample, density of saturated core and mineral density of core were used from core data.

Data obtained using electrical, electromagnetic, radioactive and acoustic methods of survey and measured well diameter were considered form geophysical methods. Parameters obtained as a result of calculations such as double gamma-ray difference parameter, clay coefficient and porosity calculated from acoustic and neutron logs were also taken into account [16-18].

Comparison of influence of indicators on section separation into permeable and impermeable parts is difficult because of different dimensionality of parameters taken into account in rock differentiation. To bring indicators to a single dimension, it is necessary to construct linear probabilistic models for separation of a section by individual indicators. Constructed models must have following properties:

- average values in groups should be as follows in range from 0.5 to 1 for seals, in a range from 0 to 0.5 for reservoirs. Boundary value for separation was 0.5;
- average values should be located symmetrically with respect to value 0.5 [19-21].

According to core data for all parameters, in addition to mineral density, it was possible to construct models separating permeable and impermeable parts of a section.

A model describing separation of a section into permeable and impermeable rocks based on data obtained from core study has an inverse relationship that represent assignment of samples with high porosity to the class of reservoirs. Samples with low porosity belong to the class of seals.

Table 3

Models for normalization of data obtained during core study

Parameter	Linear models of probability of belonging to seals	Parameter	Linear models of probability of belonging to seals
K_p	$P(K_p) = 0.955794 - 0.0311K_p$	$Dens^V$	$P(Dens^V) = -1.178 + 0.75\ Dens^V$
K_{perm}	$P(K_{perm}) = 0.544 - 0.00009K_{perm}$	$Dens^S$	$P(Dens^S) = -0.22 + 0.3109\ Dens^S$
K_w	$P(K_w) = 0.3412 + 0.0062K_w$	$Dens^M$	Impossible to build a model

The same for permeability. Reservoirs have high values of permeability; seals have low values of permeability.

A model describing water saturation coefficient has a direct relationship, which implies that seals have a higher degree of saturation with water than a reservoir. That is caused by the fact that seals in clastic part of a section are mainly dark gray mudstones with a high volume of closed porosity, with a high degree of liquid absorption, due to which high irreducible water saturation is observed.

A direct model for distribution of bulk density of a sample and density of saturated core indicates that seals are represented by denser rocks, while the more expanded ones are reservoirs. Based on coefficients obtained during construction of statistical models of sample density it is clear that when the sample is filled with liquid, difference in density between a reservoir and seals decreases with respect to a dry sample.

Still, tests of core samples are carried out point-by-point and mainly in oil-bearing intervals. So, geophysical data were used to obtain more complete information.

Similarly to core data, probabilistic and statistical models are built for geophysical parameters as well.

Table 4

Models for normalization of data obtained during well logging

Parameter	Linear models of probability of belonging to seals	Parameter	Linear models of probability of belonging to seals
BK	P(BK) = 0.457 + 0.005BK	NKTS	P(NKTS) = 0.701 – 0.1369NKTS
BMK	P(BMK) = 0.465 + 0.004BMK	TP_1	$P(TP_1) = -0.194 + 0.00102TP1$
DTP	P(DTP) = –0.153 + 0.00259DTP	TP_2	$P(TP_2) = -0.215 + 0.00089TP2$
GK	P(GK) = 0.194 + 0.0353GK	dGK	P(dGK) = 0.425 + 0.17774dGK
IK	P(IK) = 0.769 – 0.0007IK	W	P(W) = 0.332 + 0.0069W
MGZ	P(MGZ) = 0.65 – 0.1914MGZ	Ds	P(Ds) = –0.23 + 3.1646Ds
MPZ	P(MPZ) = 0.379 + 0.1467MPZ	K_{clay}	$P(K_{clay}) = 0.254 + 0.0096\ K_{clay}$
NKTB	P(NKTB) = 0.589 – 0.0221NKTB	K_p^{AL}	$P(K_p^{AL}) = 0.331 + 0.0072\ K_p^{AL}$

Electrical methods. The methods of lateral and micro lateral logging work identically to detect permeable and impermeable interlayers. The higher resistance, the higher probability of an impermeable interlayer.

Micro gradient and micro potential logging tools operate in antiphase, i.e. when studying a smaller radius (radius of investigation of a micro gradient logging tool is approximately 3.75 cm), high resistance shows presence of a clay crust and presence of a reservoir in this interval. When studying a more distant zone (radius of investigation using micro potential logging tool is 2.0-2.5 times higher), the presence of a clay crust does not affect readings. At the same time the higher resistance the higher a probability of predicting of impermeable interlayers in this interval.

Induction logging has an inverse relationship: as values increase, probability to find impermeable rocks in this interval is reduced.

Radioactive methods. The gamma-ray readings are directly dependent on probability of determining impermeable rocks. This is due to the fact that the most impermeable interlayers are associated with presence of clays in them, which have a high natural radioactivity. This is also proved by feedback during determination of probability of predicting impermeable interlayers by neutron logging.

Acoustic methods. Presence of direct link in determination of probability of finding impermeable interlayers shows that more dense rocks are more likely to be impermeable than loose ones.

Well diameter decrease in reservoirs due to presence of a clay crust. At the same time it increases due to washing of clay intervals, which is demonstrated by direct relationship of probabilistic estimation of location of impermeable interlayers from well diameter.

Hydrogen saturation shows that in impermeable interlayers hydrogen content is higher than in reservoirs. The difference parameter GR, as well as a gamma-ray logging method itself, prove that finding impermeable interlayers depends directly on parameter values.

The coefficient of clayiness confirms relationship between presence of impermeable interlayers and clayiness of rock.

During determination of porosity from acoustic log, an inverse relationship is observed. That is caused by the fact that the impermeable part of clastic section consists mainly of mudstones having high volume of voids that have poor communication.

Use of probabilistic and statistical models allowed bringing all the parameters to a single measurement system. Correctness of chosen mathematical models and analysis of degree of influence of each parameter on selection of permeable and impermeable parts were chosen by Student's criteria (Table 5).

Table 5 shows that average values of classes that are in acceptable intervals of reservoir are 0.0-0.5; seals are in a range of 0.5-1.0. Parameter P (Dens^S) on core data is an exception, which is explained by ability of clay rocks to absorb saturation liquid. Analysis of degree of its influence on separation of rocks showed that out of geophysical methods values of natural radioactivity of rocks influence most strong and values of micro potential logging tool influence the less. The most strong influence among parameters determined from core belong to porosity coefficient and the less belong to density of saturated rock.

Table 5

Check of correctness of chosen mathematical models and analysis of degree of influence of each parameter on selection of permeable and impermeable parts

Parameter	Mean		Value of Student's criteria	Number of degrees of freedom	p	Number of observation		Standard deviation		Relative variance	p
	class 2	class 1				class 2	class 1	class 2	class 1		
Parameters determined from core											
$P(K_p)$	0.63	0.37	13.17	162	0	72	92	0.14	0.10	2.12	0
$P(\text{Dens}^V)$	0.58	0.43	8.66	162	0	72	92	0.15	0.07	5.04	0
$P(K_{perm})$	0.53	0.46	6.75	140	0	50	92	0.02	0.08	17.46	0
$P(K_w)$	0.62	0.40	6.68	54	0	20	36	0.18	0.06	8.53	0
$P(\text{Dens}^S)$	0.54	0.51	5.06	162	0	72	92	0.06	0.02	12.22	0
Geophysical parameters											
P(GK)	0.66	0.34	26.83	353	0	208	147	0.14	0.06	5.82	0
P(dGK)	0.55	0.45	26.83	353	0	208	147	0.04	0.02	5.82	0
$P(K_{clay})$	0.67	0.34	26.83	353	0	208	147	0.14	0.06	5.82	0
P(IK)	0.64	0.34	13.90	345	0	200	147	0.10	0.27	6.68	0
P(NKTS)	0.53	0.46	11.38	353	0	208	147	0.07	0.02	10.05	0
P(W)	0.55	0.48	8.93	353	0	208	147	0.09	0.02	19.07	0
P(DS)	0.53	0.46	7.38	353	0	208	147	0.12	0.00	1845.21	0
P(DTP)	0.53	0.47	7.18	353	0	208	147	0.11	0.02	19.86	0
$P(K_pAL)$	0.52	0.48	7.18	353	0	208	147	0.07	0.02	19.86	0
P(NKTB)	0.52	0.48	7.17	353	0	208	147	0.06	0.02	9.22	0
$P(TP_2)$	0.52	0.48	6.43	353	0	208	147	0.08	0.03	6.96	0
P(BMK)	0.52	0.48	6.20	353	0	208	147	0.07	0.03	6.51	0
$P(TP_1)$	0.52	0.48	5.32	353	0	208	147	0.07	0.03	4.74	0
P(MGZ)	0.51	0.49	2.05	353	0.04	208	147	0.11	0.03	11.96	0
P(BK)	0.50	0.49	1.50	353	0.13	208	147	0.05	0.08	2.31	0
P(MPZ)	0.50	0.50	0.55	353	0.58	208	147	0.08	0.03	4.72	0

R e m a r k s . Class 1 – permeable rocks; class 2 – impermeable rocks.

Using results obtained with help of statistical models, given in Table 3 and 4, calculation of relative complex probability is performed by the following formula:

$$P^m_{\text{comp}} = \frac{P_1 \cdot P_2 \ldots P_i}{P_1 \cdot P_2 \cdot \ldots \cdot P_i + (1 - P_1)(1 - P_2)\ldots(1 - P_i)},$$

where $P_1 \ldots P_i$ – individual probabilities.

For complex analysis multidimensional models are built with different combination of m. First probability is built with $m = 2$.

In calculations with different values of m, a special combination is used. Such combination considers as big as possible difference between mean values of classes of reservoirs and seals. Degree of difference was determined by Student's t test (Table 3). Results of calculations are given in Table 6.

Table 6

Student's criteria *t* for calculation of complex probability of different parameters

Parameter	$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$	$m = 7$	$m = 8$	$m = 9$	$m = 10$	$m = 11$	$m = 12$	$m = 13$	$m = 14$	$m = 15$	$m = 16$
Parameters determined from core															
$P(K_p)$	+	+	+	+											
$P(Dens^V)$	+	+	+	+											
$P(K_{perm})$		+	+	+											
$P(K_w)$			+	+											
$P(Dens^S)$				+											
Mean, class 1	0.67	0.72	0.74	0.67											
Mean, class 2	0.29	0.25	0.26	0.29											
t	12.07	8.60	8.65	12.07											
p	0.33	0.01	0.03	0.33											
Geophysical parameters															
P(GK)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
P(dGK)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
$P(K_{clay})$		+	+	+	+	+	+	+	+	+	+	+	+	+	+
P(IK)			+	+	+	+	+	+	+	+	+	+	+	+	+
P(NKTS)				+	+	+	+	+	+	+	+	+	+	+	+
P(W)					+	+	+	+	+	+	+	+	+	+	+
P(DS)						+	+	+	+	+	+	+	+	+	+
P(DTP)							+	+	+	+	+	+	+	+	+
$P(K_p AL)$								+	+	+	+	+	+	+	+
P(NKTB)									+	+	+	+	+	+	+
$P(TP_2)$										+	+	+	+	+	+
P(BMK)											+	+	+	+	+
$P(TP_1)$												+	+	+	+
P(MGZ)													+	+	+
P(BK)														+	+
P(MPZ)															+
Mean, class 1	0.69	0.77	0.82	0.82	0.82	0.81	0.80	0.79	0.79	0.79	0.80	0.79	0.78	0.78	0.79
Mean, class 2	0.30	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.10	0.10	0.10	0.09	0.10	0.11
t	27.75	29.66	29.58	28.38	27.68	27.57	25.63	24.77	24.43	24.11	24.63	24.12	24.01	23.07	23.25
p	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

According to core data, the greatest difference is observed at $m = 5$. Parameters of porosity, permeability, irreducible water saturation, sample density and density of saturated sample are involved in calculation. Thus, all the indicators considered in the paper increase degree of differentiation of rocks.

According to geophysical data, the greatest difference is observed at $m = 12$. Almost all studied parameters participate in calculation except TP_1, MGZ, BK and MPZ. In case these parameters are included in calculations, degree of differentiation decreases (see Table 5).

A graph with geological parameters versus geophysical data is built based on obtained values that provide minimum distribution by geophysical and geological parameters (Fig. 2).

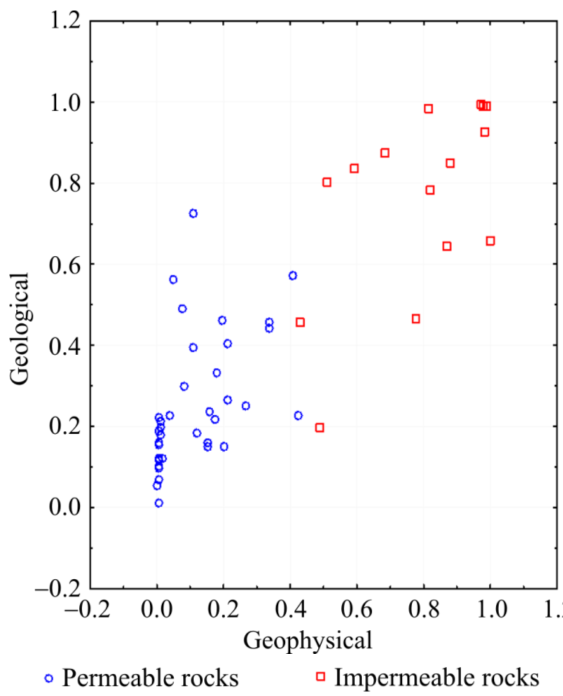

Fig. 2. Scatter diagram for geological and geophysical parameters

Analysis of the diagram shows that values belonging to the class of permeable rocks are mainly in a range from 0 to 0.4 by geophysical parameters and in a range from 0 to 0.6 by geological parameters, with exception of single samples. The class of impermeable rocks is within a range from 0.4 to 1.0 for geological parameters and from 0.5 to 1.0 for geophysical parameters, with exception of single samples. Fields of points associated with different classes are not overlapped. That allows concluding that the method is effective for separation of thickness into permeable and impermeable parts.

Conclusion

All the materials used during the research belong to a well of Sofyinskoe field. Analysis of the method for reservoir separation is carried out. The most significant parameters influencing differentiation of a well section are determined. Linear models were built to bring geophysical methods with various dimensions and cores study data to a single denominator.

Grading of geophysical methods and geological data by their influence on separation of a well section was carried out. A complex probabilistic parameter with involvement of different amount of variables is calculated. Use of core data increases rock differentiation. Most of geophysical parameters increase differentiation of rocks as well. Nevertheless, some indicators, on contrary, cannot help with separation of rocks into permeable and impermeable ones.

Thanks to this method, it is possible to perform much comprehensive separation of rock strata into permeable and impermeable parts.

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