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Peculiarities of geological structure of neogenic deposits of Haiv gas deposit and their influence on filtration capacity parameters

D. D. Fedoryshyn *(Ivano-Frankivsk National Technical University of Oil and Gas)*, **O. N. Trubenko** *(Ivano-Frankivsk National Technical University of Oil and Gas)*, ***V. V. Dmytruk** *(Ivano-Frankivsk National Technical University of Oil and Gas)*, **S. D. Fedoryshyn** *(Ivano-Frankivsk National Technical University of Oil and Gas)*, **V. V. Humeniuk** *(Ivano-Frankivsk National Technical University of Oil and Gas)*

SUMMARY

The results of studying the collector properties of rocks-collectors of the geological section of the Sarmatian and Helvetic layers of the Gayivske gas field are considered. The data of physical characteristics of productive rock-collectors are given which were obtained by the results of geological-geophysical and petrophysical researches. According to the results of experimental studies of samples of the bore core which was taken from the rocks-collectors of the Sarmatian and Helvetic layers, their geological and petrophysical parameters were established.

Introduction. The problems that arise in the process of geological and geophysical determination of filtration parameters of rocks are associated in most cases with the geological structure, methods of processing and interpretation of the results of geophysical surveys of wells (GSW). Determination and evaluation of filtration and capacity parameters of thin-bedded rocks-collectors in the process of searching for gas and oil deposits is relevant taking into account the conditions of opening geological sections in the process of drilling wells (Fedoryshyn et al., 2019; Femyak et al., 2020; Yaremak et al., 2020; Femiak et al., 2019). For solving the above tasks, we conducted petrophysical studies of rocks-collectors of the Sarmatian and Helvetic deposits of the Gaiv gas field in conditions close to the sheet deposit. Scientific developments in this area make it possible to assess the potential of the Gaivske field in the system of value based management of oil and gas companies.

Method and/or Theory. Cenozoic deposits take part in the geological structure of the Gaiv gas field, as well as in the neighboring Letnyansk gas field. Productive at these deposits are rocks of the Neogene complex, which correspond to the stratigraphic scheme (Vyalov et al., 1988) of formation of Carpathian (Helvet), Baden (Torton) and Lower Sarmatian introduced by O.S. Vyalov. The above deposits lie on the degraded pre-Neogene surface from the reef to the chalk (in some cases, Neogene inclusive). The main productive gas deposits at the Gaivske field are timed to the Lower Sarmatian and partly to the Helvetian deposits. The main gas-bearing object is the ND-16 productive horizon, timed to the lower part of the Sarmatian. In addition, industrial gas inflows obtained from the Carpathium sediments, the Barani strata and the Tiracian suite of Baden, as well as from the ND-15, ND-13, ND-12 horizons, of the Sarmatian layer. Productive rocks in the horizons of the Nizhny Dashav backlight are composed of layers of gray sandstones, siltstones, calcareous argillites with liquid layers of tuffs and tuffites. The collectors are terrigenous sand-siltstone rocks. Sandstones are fine- and multi-grained, rarely coarse-grained, well sorted. Fragmentary material is represented by semi-rolled and angular grains of quartz (up to 70 per cent). About 10-15 per cent comprise broken piece of rock fragments: feldspars, calcite, siliceous shales, muscovite scales up to 2 per cent by volume. Types of cement are contactpor and basal. There are areas of almost cementless contact of quartz grains. The pore space is represented by both cavities and the content of hydraulic mica and other materials. There is a filling of the interporous space with brown, almost black bituminous substance. Bitumen not only fills the entire intergranular space, but also spreads the grains, forming cracks completely filled with bitumen. Siltstones are oligomictic-quartz, sometimes with admixtures of gravelite material, layered texture. The fragmentary part consists of quartz grains (up to 70% of the volume), up to 20 per cent are fragments of quartzite, clay rocks. Feldspars, muscovite and glauconite account for up to 10 per cent of the volume. Cement in siltstones is complex and contact, regenerative, contact-porous and basal of mixed composition. Siltstones often in thin-layered sections inter change into calcareous, mica argillites. Argillites in the Nizhny Dashav backlight are fluid-resistant. It should be noted that the ND-17 and ND-16 horizons are gradually wedged in the north-eastern direction. At the same time there is a gradual replacement of reservoir rocks by clay varieties. A similar substitution in the same direction occurs on the above horizons. Therefore, in the ND-16 horizon, the values of open porosity increase as we approach the Krakovets fault zone. The results of determining the physical parameters of the rocks-collectors of the productive horizons of the Lower Sarmatian are summarized in Table 1. A characteristic feature of the deposits of the Lower Sarmatian and Helvet is that they are characterized by high values of gamma activity and relatively low readings of electrical resistance, gas-saturated collectors in particular. According to the results of the study of the core material selected from the sandstones of productive rocks in the horizon of the Lower Dasha suite, the presence of the following minerals was established: zircon, chlorite, garnet, single grains of glauconite and muscovite. The presence of these minerals in the rock matrix causes increased radioactivity of rocks. According to gamma spectrometry, the content of uranium, thorium and potassium in Helvet sandstones was established, which averages $2{,}3 \cdot 10^{-4}$, $3{,}7 \cdot 10^{-4}$, 0.36 per cent, respectively. The greenish color of sandstones is due to the presence of minerals of chlorite and glauconite.

Results of investigations. Analysis of the available data in comparison with the results of the study of similar rocks of the Letnyansk gas field (Hrytsyshyn, 2012) allows to assert that their lithological and petrographic characteristics are identical. The similarity of rocks-collectors of Sarmatian and Helvetic deposits of Gayivske and Letnyansk deposits is confirmed by the results of comparative analysis of porometric and lithological characteristics (Figure 1).

Table 1 *The physical parameters of the rocks-collectors of the productive horizons of the Lower Sarmatian of the Gaiv gas field.*

Horizon	Well	Coefficient porosity according to the data research of bore core, per cent	Coefficient porosity according to the GSW data, per cent	Permeability according to research of bore core, permeability coefficient 10^{-3} μm^2	Gas saturation coefficient according to GSW, per cent
ND-16	2-G	22,5	20,3	328	66
	30-G	-	20	-	66
	6-G	21,1	22,1	193,2	75
	33-G	-	16	-	56
	36-G	-	22	-	65
	8-G	-	13,5	-	58
	38-Lt	21,2	17	885,5	63
	4-G	21,9	17,9	155,2	64
	5-G	20,2	22,2	150	70
ND -15	38-Lt	-	18,8	-	62
ND -13	2-G	-	22,5	-	60
	30-G	-	25	-	-
ND -12	30-G	-	21	-	-
	32-G	-	16	-	-

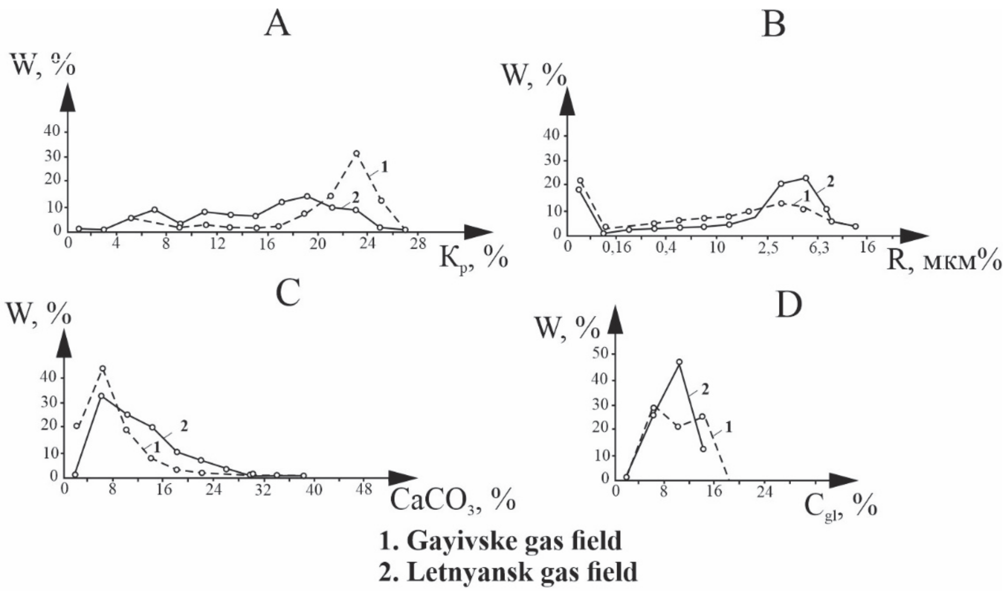

Figure 1 *Distribution of characteristics of the Lower Sarmatian rocks-collectors of Gayivske and Letnyansk gas fields.*

Comparison of the porosity distribution of samples of Lower Sarmatian rocks of Gayivske and Letnyansk fields shows that the experimental collection of rock samples of Gayivske gas field is not representative due to the lack of core selection from rocks-collectors with porosity of 8-17 per cent. Thus, taking into account the similarity of the studied rocks in the subsequent construction of statistical correlations between the petrophysical characteristics of the Gayivske gas field, porometric and geophysical data of similar rocks of the Letnyansk gas field were used (Figure 1 a, b, c, d). Petrophysical parameters of rocks-collector samples of the above deposits were established both in atmospheric conditions and in conditions close to formation. For approximate calculations of the effective pressure at the average rock density $\rho_п=2,5\cdot10^3$ kg/m^3 and the density of layer water $\rho_в=1,1\cdot10^3$, respectively (Kordiyak et al., 1975), we use the following formula:

$P_{ef} = 0{,}01565 \cdot H,$
where P_{ef} - is effective pressure, MPa;
H is the depth of laying of rocks, m

The P_{ef} pressure is calculated by formula (1) for productive sediments of the Gayivske gas field which averages 27 MPa. Under atmospheric conditions, the coefficient of open porosity and residual water saturation was established on the bore core samples. On pieces of bore core which were formed during cylinders drilling. The particle size distribution, the structure of the pore medium in the sections and the results of mercury porometry were studied on the pieces of core formed in the process of drilling cylinders. The value of the coefficient of open porosity and residual water saturation for each sample in formation conditions was calculated taking into account the measured pore space of rock samples at effective pressure by the formula:

$$K_{o.p.} = \frac{V_p - \Delta V}{V_{p.atm} - \Delta V}, \quad (2) \qquad K_{r.w.} = \frac{V_{r.w}}{V_p - \Delta V}, \quad (3)$$

where $K_{o.p.}$ is a coefficient of open porosity, fraction of units;
$K_{r.w.}$ is a coefficient of residual water saturation at effective pressure, fraction of a unit;
V_p is volume of open pores, m^3 ;
$V_{p.atm.}$ is a volume of open pores of the sample under atmospheric conditions, m^3;
ΔV - change of sample volume at effective pressure, m^3;
$V_{r.w}$ is a volume of residual water in the sample, which is determined in atmospheric conditions, m^3.

At effective pressure, the rock sample was maintained until its electrical resistance stabilized. The volume of water displaced from the rock sample was then determined by capillary, the electrical resistance, the propagation time of longitudinal ultrasonic waves were measured, and hexane filtration was conducted through the rock with measurement of hexane loss and pressure drop. According to the obtained data, the relative electrical resistance, the interval of propagation of longitudinal acoustic waves and the coefficient of effective permeability were calculated. According to the above method, about 100 samples of rocks-collectors from productive sediments of this deposit will be studied. It should also be noted that when studying the physical properties of rocks-collectors of the Gayivske deposit, there are significant difficulties associated with their significant weak cementation. The reference dependence of the $P_н = f(K_в)$ form for the study of rocks-collectors was constructed by two methods:

- by measuring the coefficient of increase of resistance $P_н$ at the residual water saturation of the rock sample;
- measurement of $P_н$ at current values of water saturation (with gradual wetting of the rock).

According to the results of research in the analysis of the obtained data, the relations for the transition of the porosity coefficients of the samples to the layer conditions were established, which can be represented by the following correlation dependencies:

for deposits of the Sarmatian layer:
$\eta = 0{,}641 \cdot K_{o.p.a.}^{0,124}; r = 0.87$ (4)

for Helvetic layer deposits:
$\eta = 0{,}686 \cdot K_{o.p.a.}^{0,105}; r = 0.79$ (5)

where $K_{o.p.a.}$ is a coefficient of open porosity under atmospheric conditions, fraction of a unit;
$\eta = \frac{K_{o.p.}\ at\ P_{ef}}{K_{o.p.a.}}$;
r is a paired correlation coefficient.

The graphs of these equations 4-6 are presented in Figure 2. Joint processing of data from experimental studies of the bore core at the Gayivske and Letnyansk deposits (Hrytsyshyn, 2012) allowed to establish the following petrophysical dependences for the rocks-collectors of the Gayivske deposit:

for sandstones of the Sarmatian layer:
$lgP = 3.9566 - 2.042 lgK_{o.p.}; \; r = 0.86$ (6)
$lgP_{i.r.} = 3.8687 - 1.952 lgK_{w.}; r = 0.8$ (7)
$\Delta T = 186{,}3 + 4{,}67 K_{o.p.}; \quad r = 0.83$ (8)

for sandstones of the Helvetic layer:
$lgP = 3.616 - 1.826 lgK_{o.p.}; \; r = -0.8$ (9)
$lgP_{i.r.} = 2.5877 - 1.256 lgK_{w.}; r = -0.83$ (10)
$\Delta T = 173{,}4 + 5{,}621 K_{o.p.}; \quad r = 0.9$ (11)

where P is the relative resistance;

$K_{o.p.}$ is a coefficient of open porosity, fraction of units;

$P_{i.r.}$ is a coefficient of increase of resistance, fraction of units;

$K_{w.}$ is a water saturation coefficient, fraction of units;

ΔT is an integrated propagation time of the longitudinal acoustic wave distribution, µs/m;

r is a paired correlation coefficient.

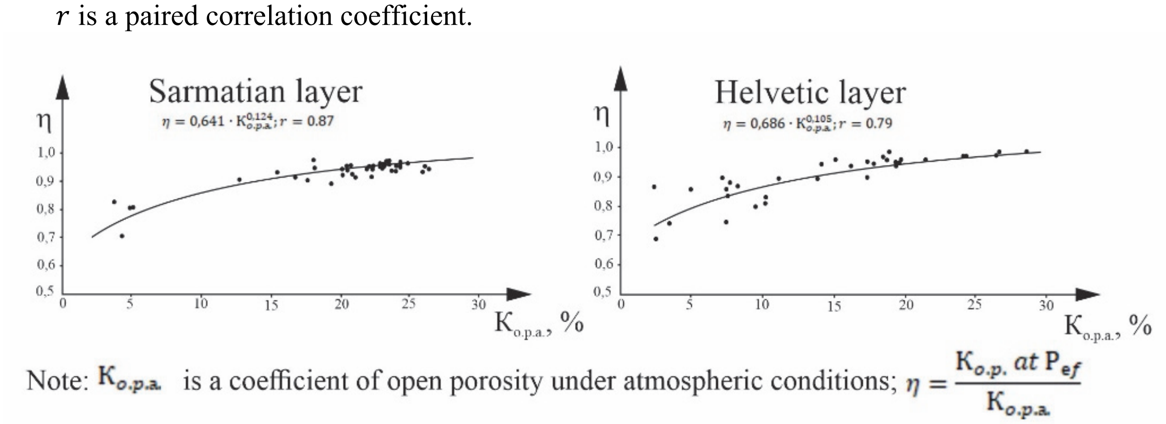

Figure 2 *The influence of effective pressure on $K_{в.п.}$ of sandstones of the Gayivske field ($P_{ef.}$ =27 MPa)*

Conclusions. Thus, based on the results of experimental laboratory and borehole studies, the peculiarities of the geological structure of the Sarmatian and Helvetic layers of the Neogene system of the Gayivske gas field were established and the values of the parameters characterizing the collector properties of rocks were substantiated. The obtained statistical dependences can be recommended for prompt interpretation of GSW data in the study of similar deposits of neighboring exploration areas and are of practical importance for value based management in oil and gas companies.

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