The research of gas tides intensification on the example of the sarmatian deposits in the northwestern part of Bilche–Volytska zone

M.Yu. Nesterenko [1], R.S. Balatskyi[1], T.V. Zderka[2]*, I.O. Piatkovska[2]

[1]*Lviv comprehensive research center UkrNDIgaz;*
144, Stryiska str., Lviv, 79026, Ukraine

[2]*Ivano-Frankivsk National Technical University of Oil and Gas;*
15, Karpatska str., Ivano-Frankivsk, 76019, Ukraine

Received: 20.11.2015 Accepted: 22.12.2015

Abstract

The article aims at the development and testing of the methods of gas flow intensification on the Sarmatian sediments samples of Bilche–Volytske zone. The existing standard methods for petrophysical study of reservoir rocks have served as the methodological basis for the implementation of research. Studies have been performed on three samples of reservoir rocks by modeling their contamination with drilling mud, resulting in the reduction of effective phase permeability of gas. The permeability of reservoir rocks has been restored with the help of modern foaming reagent, hydrochloric and acetic acid.

Lithological and petrographic features of the samples have been considered to determine their role in the restoration of effective permeability of gas bearing Sarmatian sediments.

Key words: *acetic acid, drilling mud, effective phase permeability of gas, hydrochloric acid, modern foaming component, rock microstructure, rock texture.*

Introduction

The object of the research is Sarmatian rocks reservoir layer (horizon ND-10) in the north-western part of Bilche–Volytska area of the Carpathian foredeep. Core samples have been taken from the range of 1105–1107.5 m.

The task of the article is to carry out lithologic and petrophysical study of reservoir rocks and test methodological issues to intensify gas flow in these geological conditions of deposits occurrence.

As for the methodology, the research has been performed under the existing regulatory documents [1–3] and the recommendations, described in [4–6]. The research has been conducted under conditions, simulating reservoir conditions on cylindrical specimens with the length of 3 cm and with the diameter of 3 cm, drilled out perpendicularly to the reservoir rocks layering. The value of the effective pressure depends on the depth of the rocks and in our case it was 12 MPa. Lithologic and petrographic studies have been carried out on the basis of the production and analysis of thin sections.

* Corresponding author:
zderka@ukr.net

Filtration-capacitance properties of rocks

The results of filtration-capacitance parameters, defined in the course of reservoir rocks study are listed below in a table 1.

Parameters of researched models

For accurate evaluation of the action of a reagent that can be used in the process of hydrocarbons tides intensification three models have been selected. They are characterized by similar filtration-capacitance properties and similar pore space structure, identified by capillary pressure curves.

Model No 1 (sample GR-5) has the following filtration-capacitance parameters: absolute permeability of 2.45 mD; effective phase gas permeability at 38% water saturation – 0.48 mD; residual water saturation – 47% (53% gas saturation); open porosity – 17.3%. Pore space structure parameters (Figs. 1, 2) are as follows: at a fraction of subcapillary pores that are filled with residual water and the radius of less than 0.5 microns falls 48%; proportion of capillary pore radius from 0.5 to 2.2 microns is 24%; the rest of the total volume is constituted by the overcapillary pores with radius of from 2.2 to 100 microns (26%).

The dependence of the phase permeability for gas and water (Fig. 3) indicates that for the rocks with water saturation of about 50% it is close to zero for gas as well as for water, but at a water saturation of about 40%. Therefore studied rocks are characterized by extremely low phase permeability for both phases in the range of water saturation of 30–70%.

Table 1 – The results of filtration-capacitance parameters

Laboratory No of sample	Interval coring	Porosity K_p, %		Gas permeability, mD		The residual water saturation K_r, %
		in surface conditions	in reservoir conditions	absolute	phase	
GR-1	1105–1107.5	22.8	21.9	6.90	0.20	47.6
GR-4		21.6	20.7	0.95	–	–
GR-5		18.0	17.3	2.45	0.48	47/0
GR-6		22.1	21.2	1.19	–	–
GR-7		18.9	18.1	0.29	–	–
GR-8D		17.6	16.9	10.6	5.30	45.3

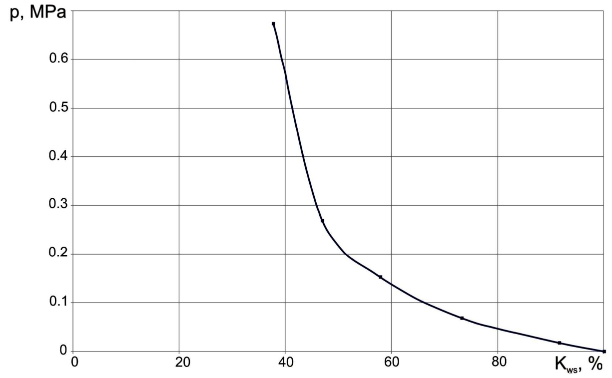

Figure 1 – Dependence of water saturation upon displacement pressure (sample GR-5 K_p=17.3 %, K_{pm}=2.45 mD, K_{pme}=0.48 mD, K_r=47 %)

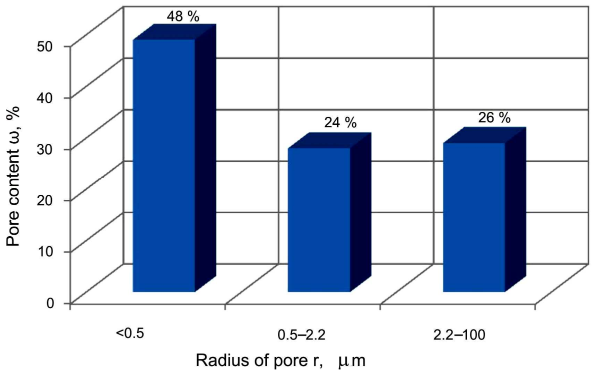

Figure 2 – Pore-metric characteristics of the sample GR-5

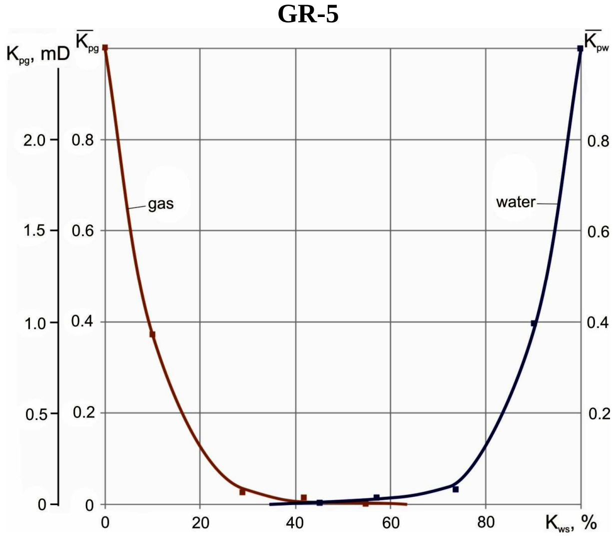

Figure 3 – Dependence relative phase permeability for gas and water upon water saturation of reservoir rocks of Sarmatian tier

The parameters of model number 2 (sample GR-1) are very similar to the previous one (Figs. 4–5), and identical with the model number 3 (sample GR-8D).

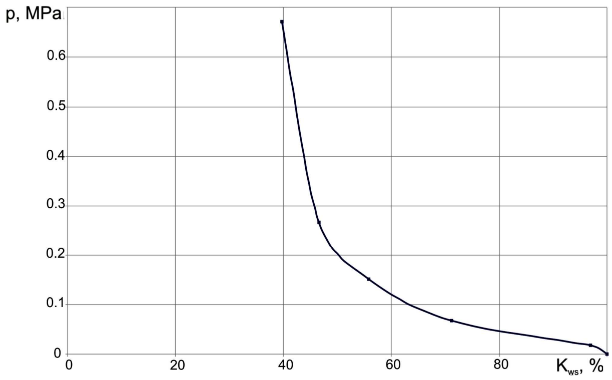

Figure 4 – Dependence of water saturation upon displacement pressure (sample GR-1 K_p=21.9 %, K_{pm}=6.9 mD, K_{pme}=0.2 mD, K_r=46.6 %)

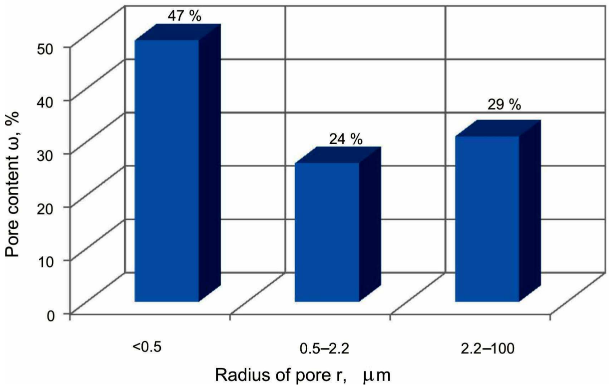

Figure 5 – Pore-metric characteristics of the sample GR-1

Drilling mud impact upon reservoir rocks filtration properties

After modeling of the residual water saturation (gas saturation) and measuring of effective (phase) permeability the lower ends of core samples were immersed in drilling mud at a depth of 4–5 mm and saturated under vacuum for 17 hours. Then the samples were in turn inserted into the core holder and after gas purging from the opposite end at the pressure of 0.4 MPa, effective phase permeability was measured once again. Driiling fluid turned out to be decreasing effective phase permeability by a factor of 1.77–2.40 (at an average of 2.1), so intensification procedure must be a compulsory one in field conditions.

ISSN 2311—1399. Journal of Hydrocarbon Power Engineering. 2015, Vol. 2, Issue 2

Simulation of recovery phase permeability after exposure of drilling fluids

Model number 1 (sample GR-5) – was subject to the influence of MFFC (modern foam forming component, I.B. Hubych, 2013) during 24 hours. In this case the effective permeability increased in the following order: first day – 0.76 mD, the second day – 1.52 mD, the third day – 2.3 mD, multiplicity of the increase permeability was respectively 1.58; 3.2; 4.8 times (Fig. 6).

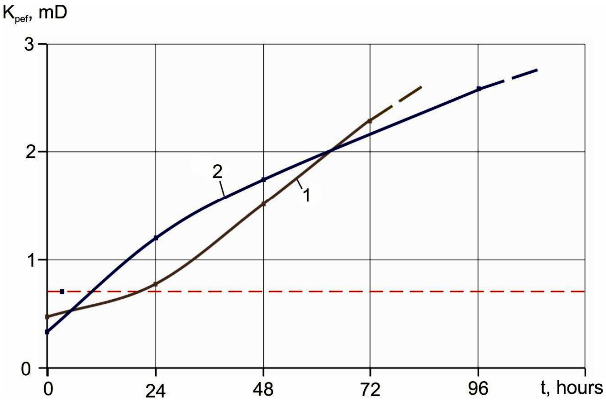

Figure 6 – Dynamics of the recovery of effective (phase) permeability over time in the model, containing 40% of residual water after treatment with MFFC reagent (1) and 10% hydrochloric acid and MFFC reagent (2); point at the beginning of the second displays effective permeability value after hydrochloric acid treatment (HAT)

Model number 2 (sample GR-1) was subject to the influence of 10% hydrochloric acid solution by means of its capillary saturation under vacuum for 1 h. After purging the reaction products from the porous medium gas through its relief under the pressure from 0.4 to 0.1 MPa, the phase permeability was 0.7 mD (in Fig. 6 it is shown with the point and dotted line) that is increased by 3.5 times (as compared to the initial 0.2 mD).

Then, after treatment with 10% hydrochloric acid sample was saturated with a MFFC reagent under vacuum during 24 hours, inserted in core holder and blowed by gas through relief of pressure from 0.4 to 0.1 MPa.

Effective phase permeability measurements confirmed its growth over time in the following order: first day – 1.2 mD, second day – 1.75 mD, the fourth day – 2.6 mD, ie multiplicity of the increase permeability was – 6; 8.7; 13 times (compared with the initial 0.2 mD) (Fig. 6). For comparison the results of treatment with MFFC reagent are shown on this graph.

Model number 3 (sample GR-8D) – was subject to the influence of 10% solution of acetic acid for 21 hours. through its capillary saturation under vacuum. Effective gas permeability measurements showed that it was increased to 8 mD over the initial 5.3 mD (1.5 times).

Lithologic and petrographic features of Sarmatian tier rocks (horizon su-10) before and after the intensification

Structural and textural features of rocks that were detected, its internal structure and results of hydrochloric acid treatment and interaction with the reagent are as follows.

Rocks are characterized by irregularly layered texture, which was formed under the delay conditions of sediment in coastal-marine (beach) environment. Formation of layers took place by successive laying of individual layers and layers of small thickness (from the first mm to few cm). These layers and thin-layers are characterized by different grade and variable-multi-directional nature, as in the adjacent series of layers and thin-layers are seeing a fall in different directions. One series of layers is represented by mixed (poorly sorted) silt-finely psammite terrigenous accumulations, cemented by apoclay pellicle-porous cement with partial filling of pores with basal. Siltstone terrigenous component with clay cement characterized by uneven distribution can prevail in the following series.

This layering is usually formed by ocean currents in the coastal zone, which are characterized by periodic changes of direction.

Often layers and thin-layers consist mainly of siltstone and medium-small psammite terrigenous material. In siltstone cement is apoclay with addition of small amounts of calcite. In sandy parts calcite component is prevailing in the cementing mass. Sometimes calcite is dominant as compared to terrigenous part, that stipulates the transition to terrigenous-carbonate rocks.

It is significant that the next layer or thin-layer overlaps the previous one, usually contrary, as if cutting off the previous layering. This feature is closely related to the processes mentioned above (Yu.I. Fedoryshyn, 2013). Convolution of layers within the certain series points to slide of unconsolidated but already precipitated material under the influence of various dynamic factors (tsunamis, severe storms, earthquakes, gravitational processes, etc.) (Fig. 7).

Typical structural heterogeneity of rocks can be observed and therefore the figure 7 displays the following: light spot on the right side of the figure (below) is a layer enriched with carbonate cement; curved dark gray area in the middle of both halves of the cut is the siltstone layer with predominant apoclay cement; black lenticular layers are enriched with organic matter; blue areas are differently directed hidden fractures areas, some of which are enriched with organic matter and are closely associated with lenticular anomalously enriched in organic matter thin-layers. Essentially zones of fracturing and thin-layers, abnormally enriched with organic matter represent a single cavity-fracture system of secondary void space.

Fragment of line-scattered zones, enriched with organic matter, filling cracks and cavities, is shown on Fig. 8. Within these areas growth of calcite in the cement composition is inherent.

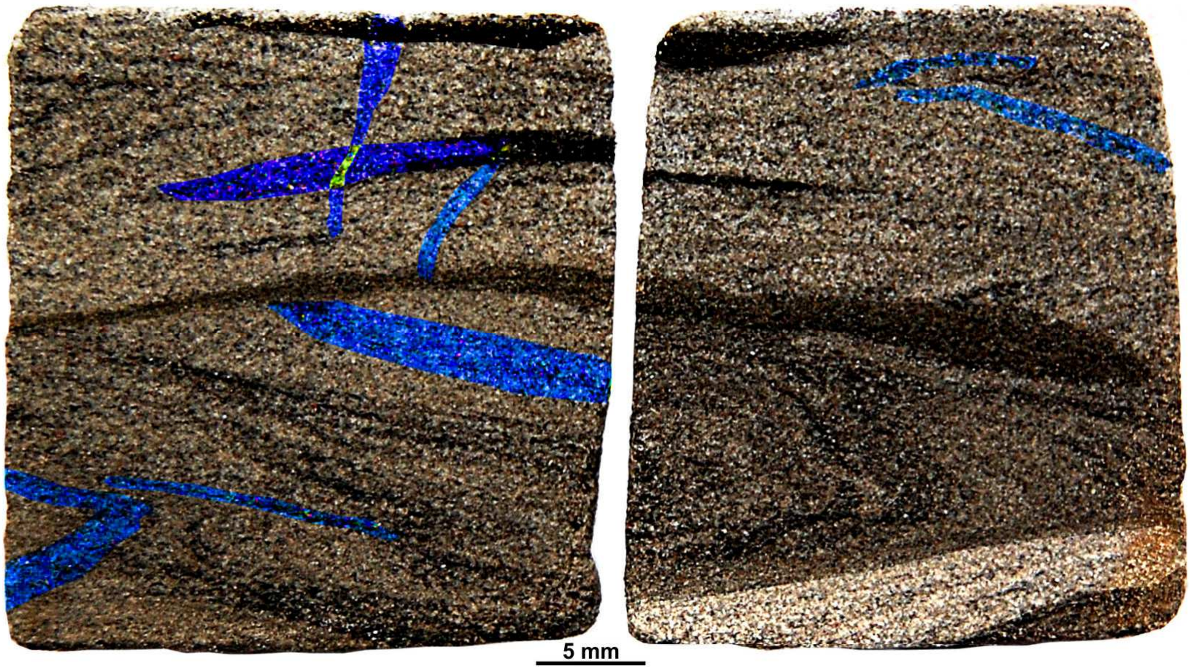

Figure 7 – GR-1 example (sampling interval – 1105.0–1107.5 m): the cross-section of core cylinder after treatment with hydrochloric acid and MFFC

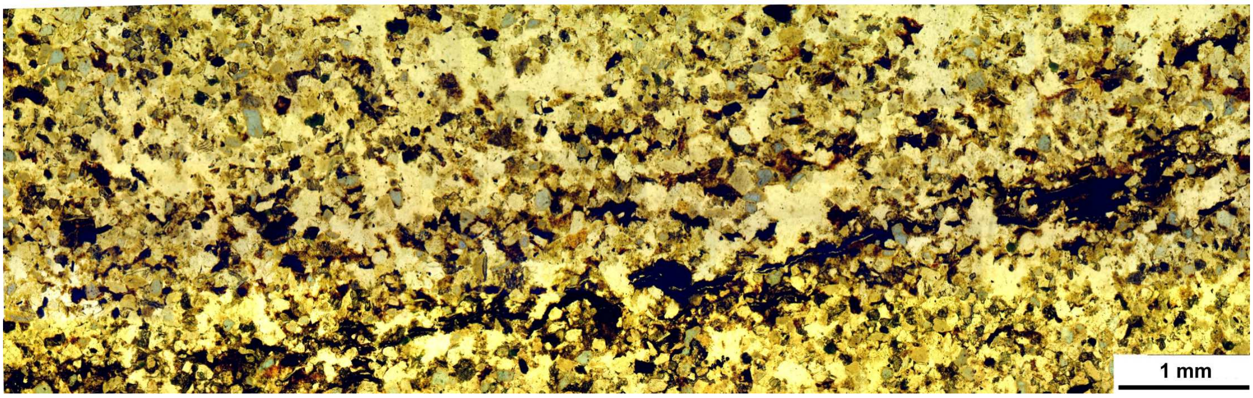

Figure 8 – Example GR-1 (sampling interval – 1105.0–1107.5 m): there is panoramic image of thin sections before treatment with hydrochloric acid and MFFC

Lens-layered formations of concentrated accumulation of organic matter and mica minerals are located according to the stratification, and sometimes are partially penetrating into individual layers. Their thickness is usually from a part of mm to 3–4 mm (Fig. 9). General view of the section along the core axis. In this cross-sectional allocated: dark gray fragment right at the top – a layer of sandy siltstone with clay-hydromica-chlorite cement composition, calcite is virtually nonexistent; light gray fragment in the center of the cross-section – silt medium-grained sandstone with significantly calcite cement; lenticular black stripe at the bottom right and upper left – layers with high concentration of mica mineral and organic matter that fills the intermittent cracks and cavity located according layering.

These lens-layered clusters at microscopic studies turned out to be extended cavernous-fractured zones of permeability, closely related with differently directed fracture zones. In this case fracture porosity became apparent only after treatment with hydrochloric acid and MFFC (Figs. 7–10). Blue color on Fig. 10 shows the extent of increase in volume of the void space after hydrochloric acid and the MFFC reagent treatment.

The volume of initial void space was significantly reduced by imposed carbonization. Carbonization developed unevenly in the rock. In some cases there is a slight presence of calcite, in the others there is a continuous zone of carbonization.

Zones of cavernous-fissure type are formed on the boundary of layers and thin-layers at the stage of transformation of plastic sediment into rock by layers displacement. The bulk of organic matter is focused there.

The other type of fractured zones usually crosses the layers. Most cracks are short, rarely go beyond one or two layers, randomly oriented, organic matter is usually absent, the void space for them is not typical (Yu.I. Fedoryshyn, 2013).

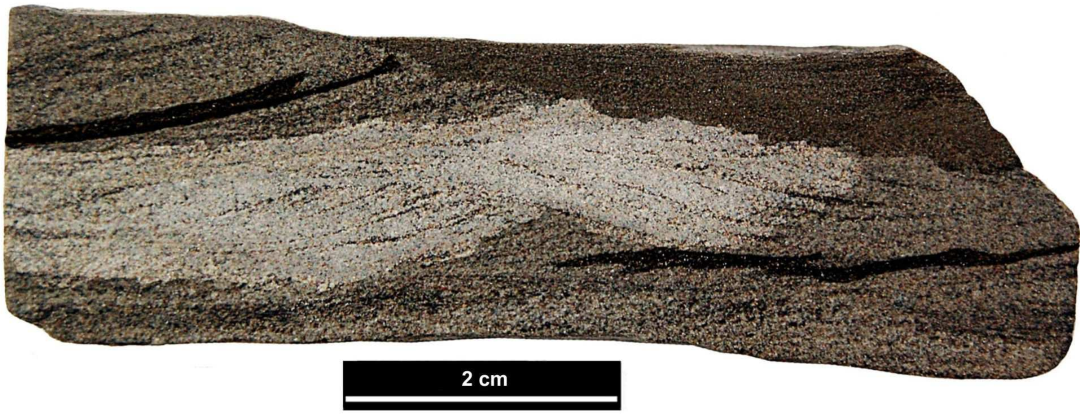

Figure 9 – Example GR-1 (interval of selection 1105.0–1107.5 m): it's to hydrochloric acid treatment and interaction with the reagent

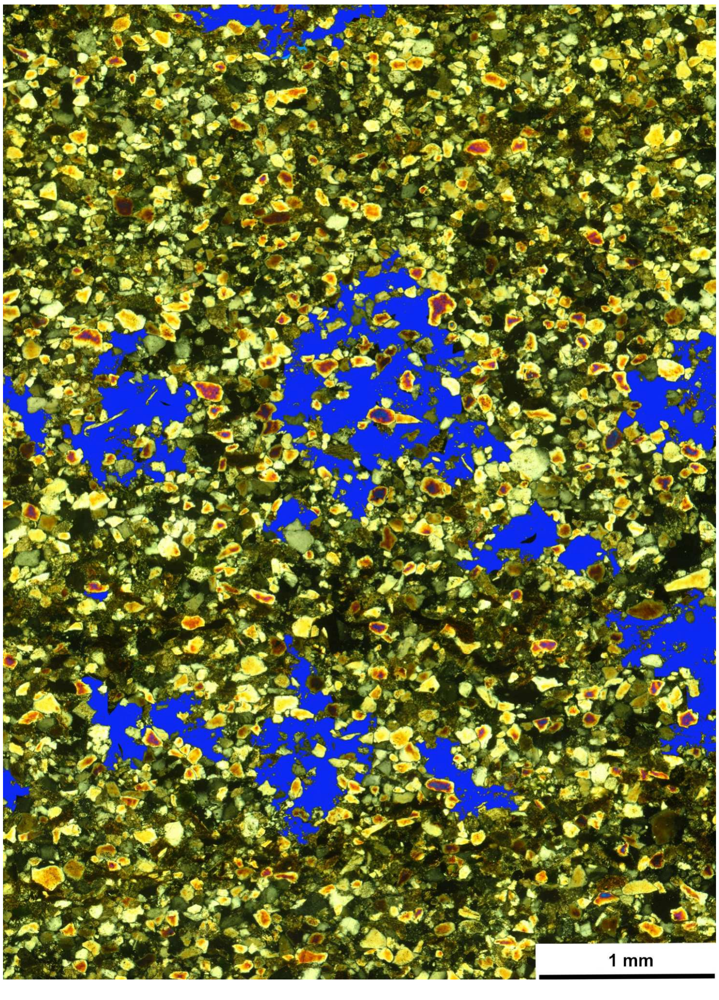

Figure 10 – The sample GR-1 (sampling interval is 1105.0–1107.5 m)

Conclusions

1. Despite the high porosity of 17.6–22.1% of the studied rocks they have very low filtration properties – their permeability is in the range of 0.29–10.6 mD, the gas saturation ratio is about 53%.

2. The influence of the drilling fluid upon the reservoir leads to the 2.1 times deterioration of effective gas permeability on average. Therefore, the intensification for the purpose of its recovery should be a compulsory technological procedure.

3. The influence of the MFFC reagent on the reservoir rocks helps to increase the effective gas permeability to 4.8 times.

4. The comprehensive action of the 10% hydrochloric acid for one hour and then the action of the MFFC reagent for four days results in an increase of the effective gas permeability (gas flow rate) by 13 times.

5. The action of the 10% solution of acetic acid has led to the destruction of reservoir rocks along the micron of sandstone and siltstone foliation layers.

Therefore the effective permeability increases by 1.5 times.

6. Due to the wide range of quantitative variations of different granulometric classes of the clastic material (silt and finely psammite) and the apoclay composition of cement with carbonization the studied rocks should be classified as silt-sandstone with apoclay mica-hydromica-carbonate cement (Yu.I. Fedoryshyn, 2013).

7. The structural features and a the rock`s textural features (wavy stratification with pouring and sliding characteristics, concentration of mica as separate layers, pseudostratification without clear boundaries) resulting in its internal texture and morphological textural features of the layers` surface, and authigenic glauconite among minerals allow us consider the rock as a coastal-marine-lagoon (with low salinity) facies.

8. The presence of the newly formed carbonate in the cement indicates the secondary formation of minerals that has occurred at the phase of dia- and katagenesis. The fact that the clay minerals of cement underwent structural and genetic transformation, having transformed into a new mica-hydromica association, indicates catagenetic transformations.

9. The void space is of the initial origin, its volume is slightly decreased due to the newly formed calcite and authigenic glauconite, which are structurally confined to the intergranular space.

10. The void space is classified as a complex one due to the combination of pore and cavernous types of voids, its uneven spread along the strike and cross-section (Yu.I. Fedoryshyn, 2013). The size of the cavities is 2 mm (as it is shown in Figures), the chains of approximated cavities and pores are extracted by 5–10 mm. Under the favorable conditions (grain size, non-conformal packaging of fragments) the void space is open in vertical and horizontal directions. Can acid treatment of the reservoir results in the increase of the void space volume at about 30% based on the amount of carbonaceous material in the cement.

References

[1] Standards Russia 1985, *Rocks. General requirements for the selection and preparation of samples for the determination of reservoir properties*, 26450.0–85, Moscow. (in Russian).

[2] Standards Russia 1985, *Rocks. The method of determining the coefficient of open porosity fluid saturation*, 26450.1–85, Moscow. (in Russian).

[3] Standards Russia 1985, *Rocks. Method for determination of the absolute gas permeability coefficient in stationary and non-stationary filtration*, 26450.2–85, Moscow. (in Russian).

[4] *Methodical recommendations for research reservoir rocks of oil and gas by physical and petrographic methods* 1978, VNIGNI, Moscow. (in Russian).

[5] *The study of the physical properties of granular reservoir rocks for the calculation of oil and gas by volumetric method* 2010, DKZ & LV UkrDRHI, Kyiv–Lviv. (in Ukrainian).

[6] Nesterenko, MY 2010, *Petrophysical fundamentals of substantiation the fluid saturation of reservoir rocks*, UkrDGRI, Kyiv. (in Ukrainian).

УДК 553.98

Дослідження інтенсифікації газовилучення на прикладі сарматських відкладів північно-західної частини Більче-Волицької зони

***М.Ю. Нестеренко*[1], *Р.С. Балацький*[1], *Т.В. Здерка*[2], *І.О. П’ятковська*[2]**

[1]*Львівський комплексний науково-дослідний центр УкрНДІгазу; вул. Стрийська, 144, м. Львів, 79026, Україна*

[2]*Івано-Франківський національний технічний університет нафти і газу; вул. Карпатська, 15, м. Івано-Франківськ, 76019, Україна*

Метою статті є розроблення та відпрацювання методики дослідження інтенсифікації припливів газу на зразках сарматських відкладів Більче-Волицької зони.

Методологічною основою для виконання досліджень слугували існуючі стандартні методики петрофізичних досліджень порід-колекторів. Дослідження виконано на трьох зразках порід-колекторів моделюванням їх забруднення буровим розчином, внаслідок чого ефективна фазова проникність зменшується вдвічі. Проникність порід-колекторів відновлювали дією сучасного піноутворюючого компоненту, соляної та оцтової кислоти.

Розглянуто літолого-петрографічні особливості досліджуваних зразків для встановлення їх ролі у процесі відновлення ефективної проникності газоносних сарматських відкладів.

Ключові слова: *буровий розчин, ефективна фазова проникність газу, оцтова кислота, соляна кислота, структура породи, сучасний піноутворюючий компонент, текстура породи.*