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Main types of reservoirs of pre-jurassic deposits in the Ustyurt region

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Abstract. This article compiles and presents the tangible records encompassing drilling operations, testing procedures, and geophysical loggings conducted in the Ustyurt oil and gas region of Uzbekistan. These consolidated materials provide a comprehensive overview of the exploration efforts undertaken in this region. The dataset includes information on core samples extracted from drilling, their subsequent analysis, and the outcomes of tests conducted on intervals within the Pre-Jurassic deposits. Through a meticulous examination of core samples, drilled wells, and geophysical loggings, the study delves into the reservoir properties of rock formations in this geological region. The research identifies distinct groups of rocks within the Pre-Jurassic complex, categorized by their porosity characteristics. This categorization serves as a foundational step in understanding the geological composition and potential reservoir properties of these formations. An important outcome of this analysis is the identification of five distinct types of reservoirs based on the structure of the pore space within the pre-Jurassic sediments. This categorization holds immense potential for future predictions and assessments concerning these sedimentary deposits. By amalgamating core data, geophysical readings, and testing outcomes, the research contributes to a holistic understanding of the geological attributes and reservoir potential of the Ustyurt oil and gas region. This foundational information sets the stage for informed decision-making in exploration, production, and resource management activities within this significant geological area.

1. Introduction

The study of the deep structure of the Ustyurt region in order to determine the prospects of oil and gas potential began in 1960. In the 70s, as a result of the introduction of seismic exploration by the OGT method, it became possible to explore the pre-Jurassic deposits of the region [1].

Prospects of oil and gas potential of the Pre-Jurassic formations of the Ustyurt region were considered in the works of A.M. Akramkhodzhaev, A.A. Abidov, G.S. Abdullaev, A.E. Abetov, A.A. Bakirov, T.L. Babajanov, R.A. Gabrielyan, R.G. Garetsky, S.K. Salyamov, N.A. Krylov, A.V. Kirshin, A.H. Nugmanov, A.P. Payzullayeva, H.U. Uzakova, Zh.Yu. Yuldasheva, and others [2-9].

From 2000 to 2009, JSC "Regionalgeology" (the State Committee of the Republic of Uzbekistan for Geology and Mineral Resources) performed cosmophotogeological mapping within the Ustyurt region, according to the results of which, with the involvement of materials from a comprehensive interpretation of geological, geophysical, morphometric studies and drilling, the features of the deep geological structure of the territory of the region were established, the allocation of numerous promising sites for search was justified hydrocarbons (HC) in Mesozoic and Paleozoic rock complexes [10].

Currently, all researchers recognize the fact that large-scale processes of oil and gas formation took place in the Paleozoic strata and, consequently, pre-Jurassic formations in this region should be regionally productive [11].

Despite the fact that no large deposits have been identified in the pre-Jurassic complex of Ustyurt to date, during drilling and drilling in a number of wells of the Kuanysh-Koskalinsky shaft (well № 18 Akchalak up to 308 thousand m3/day, well № 3 Karachalak, well № 1 Chibiny gas fountains) and Sudochy deflection (well № 1p Urga, well № 1 Northern Urga) gas manifestations were observed and significant gas inflows were obtained, and oil inflows were obtained in wells № 1 Karakuduk, № 3 Western Barsakelmes.

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Thus, in the Ustyurt oil and gas region (OGR), the main search object with proven oil and gas potential in the Pre-Jurassic complex of rocks is the carbonate-clay strata of the Upper Paleozoic [12, 13].

Finding out the reasons for the failure of prospecting is an urgent task today, the solution of which requires the involvement of a large volume of factual material, first of all, drilling data, geophysical loggings of wells, core study and testing, as well as large-scale work on the analysis, generalization, processing and interpretation of geological and geophysical research materials and, at the final stage, analysis the results obtained and the development of recommendations for the further direction of work [14-16].

This article examines such geostructural elements of the region as Kuanysh-Koskalinsky shaft, Sudochy deflection and Takhtakairsky shaft. The actual material. The results of the study showed that within the studied territory, Pre-Jurassic deposits were uncovered in 99 wells, including: on the Kuanysh-Koskalinsky shaft in 79 wells; in the Sudoch deflection 14 wells; on the Takhtakair shaft in 6 wells.

2. Research methodology

In total, core sampling was carried out in 89 wells (89.9% of all those who opened the pre-Jurassic complex). The penetration of the pre-Jurassic sediments with core sampling amounted to 2429.15 cubic meters (8.5% of the total uncovered capacity of the pre-Jurassic sediments), and the removal of the core 1076.16 cubic meters (44% of the penetration or 3.7% of the total uncovered capacity).

Laboratory studies of the core taken from the Pre-Jurassic deposits were carried out at 63 wells (63.6% of all those who opened the pre-Jurassic deposits or 70% of all in which the core was taken). A total of 761 samples were selected for laboratory studies from Pre-Jurassic deposits, including 731 samples for the determination of filtration-capacity properties (FCP), 36 samples for paleontological studies.

Table 1 presents data on the selection of samples for research on all Pre-Jurassic lithological and stratigraphic complexes for each territory as a whole. Tests in the cased and open bore were performed in 49 wells (50.5% of all those that opened the pre-Jurassic complex). A total of 152 objects were tested, including 152 tested objects, gas inflows, including weak and two-phase (gas with water) were obtained from 34 objects (22%), non-flowing objects turned out to be 27 (16.4%). In 91 objects (61.6%), water inflows were obtained, including 14 with oil. Distribution of test results by geostructural objects (Table 1):

Table 1. Data on core analysis performed in Pre-Jurassic deposits.

Age	T_3-J_1		P_2-$T_{1\text{-}2}$		C_3-P_1		$C_{2\text{-}3}$		$C_{1\text{-}2}$		D_3-C_1		$D_{1\text{-}2}$		PR		Total
	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCP	Paleon-tological spore-pollen research	FCPPaleonto-logical spore-pollen research
Kuanysh-Koskalinsky shaft																	
Total (quantity of analyzed core)	1	1	244	7	116	1	152	2	73	12	11	2	7	-	26	-	661

Quantity of wells	Takhtakairsky shaft: Total (quantity of analyzed core)	Quantity of wells	Sudochiy deflection: Total (quantity of analyzed core)	Quantity of wells	**Total (quantity of analyzed core)**	**Quantity of wells**
1	13	4	40	5	**54**	**10**
1	5	3	4	2	**10**	**6**
16	-	-	-	-	**244**	**16**
6	-	-	-	-	**7**	**6**
13	5	1	10	2	**131**	**16**
-	-	-	2	1	**3**	**2**
31	-	-	-	-	**152**	**31**
1	-	-	-	-	**2**	**1**
9	3	1	-	-	**76**	**10**
6	-	-	-	-	**12**	**6**
4	13	1	-	-	**24**	**5**
2	-	-	-	-	**2**	**2**
2	2	1	3	1	**12**	**4**
-	-	-	-	-	**-**	**-**
4	-	-	-	-	**26**	**4**
-	-	-	-	-	**-**	**-**
-	41	-	59		**761**	

- Kuanysh-Koskalinsky shaft, 114 objects in total; gas, gas with water – 19 objects, "dry" – 20 objects, water – 75 objects (including 14 with oil);
- Sudochye deflection, total 25 objects; gas, gas with water – 8 objects, "dry" – 6 objects, water – 11 objects;
- Takhtakairsky shaft, 13 objects in total; gas – 7 objects, "dry" – 1 object, water – 5 objects.

A characteristic feature of the gases of this region is the almost absence of hydrogen sulfide in their composition [12]. Below we will consider the illumination by geological and geophysical studies of all selected lithological and stratigraphic complexes.

1. The deposits of rat-leyas (T_3-J_1) were uncovered in 21 wells, including on the Kuanysh-Koskalinsky shaft – in 1, in the Sudochye deflection – 14, on the Takhtakair shaft – in 6 wells. The core was not taken in 3 wells (№ 1P Shagyrlyk, № 1 Kabanbai, № 9 Urga). Core was taken from 18 wells (85.7%). Of the 4162 m traversed through the

Rhet-Leiass deposits, core sampling was 285.5 m (6.4% of the uncovered capacity), core removal was 175.1 m (61.6% of the penetration or 3.9% of the uncovered capacity). For laboratory studies, the core was selected in 13 wells.

In total, the results of laboratory core studies for 11 wells were analyzed. 64 samples were selected for laboratory studies, including 54 for the determination of FCP and 10 for paleontological studies. 23 objects were tested in T_3-J_1 deposits (Table 2) in 15 wells. Of the 23 tested objects, gas inflows were received in 5 (21.7%), water – in 15 (59.3%), no inflows were received in 3 objects (11.1%) [7, 13].

2. Deposits of the Upper Permian-Lower-Middle Triassic were uncovered in 33 wells on the Kuanysh-Koskalinsky shaft. Core was taken from 25 wells (75.8%). From 7 wells (№ 1 Chink, № 2, 8, 10 Western Barsakelmes, № 6 Karachalak, № 2 Chibiny, № 1P Urtatepa), the core was not taken from these deposits.

Of the 5,544 m traversed through Permo-Triassic sediments, core sampling was 446.8 m (8.3% of the uncovered capacity), core removal was 315.46 m (70.2% of the penetration or 5.8% of the uncovered capacity). For laboratory studies, the core was selected from 17 wells. For 16 wells, the number of samples taken was 251, including 244 for the determination of FCP. 5 objects were tested in the P_2-T_{1-2} deposits (wells№ 1P Eastern Alambek, № 2 Alambek, № 1 Abadan, № 8 Western Barsakelmes, № 2P Kuanysh) in 5 wells. During tests, water inflows were obtained in 3 objects (60%), 2 objects (40%) turned out to be dry. No gas inflows have been received from the P_2-T_{1-2} deposits.

3. Core was taken from deposits of Upper Carboniferous – Lower Permian in 28 wells (90.3%). In 2 wells (№ 1P, 6 Karachalak), the core was not taken. By well№ 5 Karachalak there is no data on core sampling.

Of the 3,847 m of uncovered capacity, the penetration with core sampling was 423.5 m (8.7%). Core removal was 267.14 m (57.9% of the penetration or 5.1% of the opened capacity). A total of 134 samples were selected for laboratory tests, including for the determination of FCP – 131.

Tests of C_3-P_1 deposits were carried out in 14 wells. A total of 24 objects were tested, including gas inflows were received in 7 (29%), water in 9 (52.2%), 8 objects (34.8%) turned out to be non-flowing.

4. Core was taken from C_{2-3} deposits in 44 wells (91.7%). In 3 wells (well№ 3 Central Kushkair, № 3 Karachalak, № 2 Chibiny), the core was not taken. By well№ 5 Karachalak there is no data on core sampling.

Of the 3,284 m of uncovered capacity, the penetration with core sampling was 445.8 m (12.6%). Core removal was 205.4 m (44.6% of the penetration or 5.6% of the opened capacity). A total of 154 samples were selected for laboratory tests, including for the determination of FCP – 152. C_{2-3} deposits were tested in 23 wells. A total of 36 objects were tested, including gas inflows were received in 8 (21.1%), water in 21 (60.5%), 7 objects (18.4%) turned out to be non-flowing.

5. Core was taken from C_{1-2} deposits in 19 wells (86.4%). In 2 wells (well№ 7 Karachalak, № 2 Akchalak), the core was not taken. Of the uncovered capacity, the penetration with core sampling was 607 m (9.8%). Core removal was 57.8 m (13.9% of the penetration or 1.4% of the opened capacity). The core was selected from 13 wells for laboratory studies. A total of 88 samples were selected for laboratory tests, including for the determination of FCP – 76.

C_{1-2} deposits were tested in 15 wells. A total of 46 objects were tested, including gas inflows were received in 7 (24%), water in 33 (36%), water with oil in 14 (28%), 6 objects turned out to be non-flowing (12%) (Table 2).

Table 2. Data on testing in Pre-Jurassic deposits.

Quantity	T_3-J_1			P_2-T_{1-2}			C_3-P_1			C_{2-3}			C_{1-2}			D_3-C_1			D_{1-2}			PR			Total		
	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry	Gas	Water	Dry
Kuanysh-Koskalinsky shaft																											
- objects	-	2	-	-	3	2	-	8	4	8	21 (3 with dissol-ved gas and oil)	7	7	32 (10 with oil)	6	-	6	-	-	1	1	4	2	-	19	75 (13 with dissol-ved gas and oil)	20

- wells	-	1	-	-	3	2	-	7	3	6	14	3	3	12	2	-	3	-	-	1	1	2	2	-	8	25	9
Takhtakairsky shaft																											
- objects	1	3	1	-	-	-	3	1	-	-	-	-	-	1	-	-	-	-	3	-	-	-	-	-	7	5	1
- wells	1	2	1	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	2	3	1
Sudochiy deflection																											
- objects	4	10	2	-	-	-	4	-	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	8	11	6
- wells	2	6	2	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	1	-				3	7	2
Total																											
- objects	5	15	3	-	3	2	7	9	8	8	21	7	7	33	6	-	6	-	3	2	1	4	2	-	34	91	27
- wells	3	9	3	-	3	2	3	8	4	6	14	3	3	13	2	-	3	-	1	2	1	2	2	-	13	35	12

6. Core was taken from D_3-C_1 deposits in 7 wells (87.5%). In 1 well (well№ 1 Kublachink), the core was not taken. Of the 1,556 m of the opened section, the penetration with core sampling was 53 m (4.3%). Core removal was 29.75 m (24.5% of the penetration or 1.1% of the opened capacity). For laboratory studies, the core was selected in 7 wells. A total of 26 samples were selected for laboratory tests, including for the definitions of FCP – 24.
7. From deposits D_{1-2} and PR, which are not the subject of consideration in this work, the core was selected in 16 wells. Processing of geophysical loggings of wells materials on these deposits was not carried out. According to the D_{1-2} deposits, the core was selected in 7 wells. No core was taken for 1 well (well№ 1 Kublachink). The authors have collected core analyses for 4 wells (Table 2). A total of 6 objects were tested in the D_{1-2} deposits. According to the PR deposits, core sampling was carried out in 9 wells. The PR deposits were tested in 4 wells. In total, 6 objects were tested: gas inflows were obtained from 4 intervals, and reservoir water inflows from 2.

3. Results and discussion

As is known, reservoirs are divided into terrigenous and carbonate by their material composition. Terrigenous reservoirs include permeable capacious sandstones, gravelites, gravel sandstones, conglomerates and gravel-sand conglomerates, siltstones and siltstone sandstones, gravelites. Carbonate reservoirs include permeable and capacious limestones, dolomites, and dolomitized limestones [3, 10].

According to the distribution of clay material in the rock and its quantity, carbonate reservoirs are divided into clay and non-clay. The nature of the distribution of clay material significantly affects the FCP of carbonate reservoirs. Pure non-clay limestones and dolomites of organogenic and organogenic-clastic origin have the highest FCP.

The terrigenous and carbonate reservoirs described above belong to rocks with primary, consedimentary porosity, or to reservoirs with a granular type of porosity (pore).

As is known, rocks are exposed to secondary processes (leaching, calcification, hardening, etc.) associated with infiltration movements of groundwater, as well as with the impact of tectonic processes (cracking, discontinuity, etc.), regardless of their material composition. As a result of these processes, additional void space or secondary porosity is formed in terrigenous and carbonate reservoirs, which is divided into cavernous (a consequence of leaching) and fractured (a consequence of tectonic influences) components.

Quite often, due to the effects of these processes, terrigenous and carbonate rocks, which were previously low-capacity impermeable, acquire both porosity and permeability, and form a group of collectors with secondary porosity (cavernous, fractured collectors). Most collectors belong to the mixed type, when granular pores, cavities and cracks are present in the rock and the type of collector according to FCP is determined by their ratio (crack-pore, pore-crack, crack-cavern-pore, crack-cavern, etc.). Collectors with secondary porosity and mixed type form a group of collectors with a complex structure pore space.

It should also be noted that secondary processes, especially hydrothermal ones, can completely change the original structure of the pore space and dramatically worsen the FCP of collectors, up to their transformation into non-collectors (regardless of the material composition of the collectors). Taking into account that the pre-Jurassic deposits of Ustyurt had a long geological history of development, as well as the fact that they were affected by tectonic processes (hydrothermal metamorphism), we should expect the development of reservoirs with a complex structure of pore space in the sediments of this complex mainly [5, 8].

With porosity values of less than 25% and permeability of less than 100 mld., collectors are low-porous and weakly permeable (IV, V, VI, VII classes according to K.I. Bagrintseva, 1977). Laboratory studies of single core samples taken from Pre-Jurassic sediments have shown that the class of reservoirs of terrigenous sediments does not exceed V in porosity, and carbonate – IV. Therefore, reservoir rocks of Pre-Jurassic deposits according to FCP belong to low-porous and difficult-to-penetrate reservoirs of IV, V, VI and VII classes [3, 10].

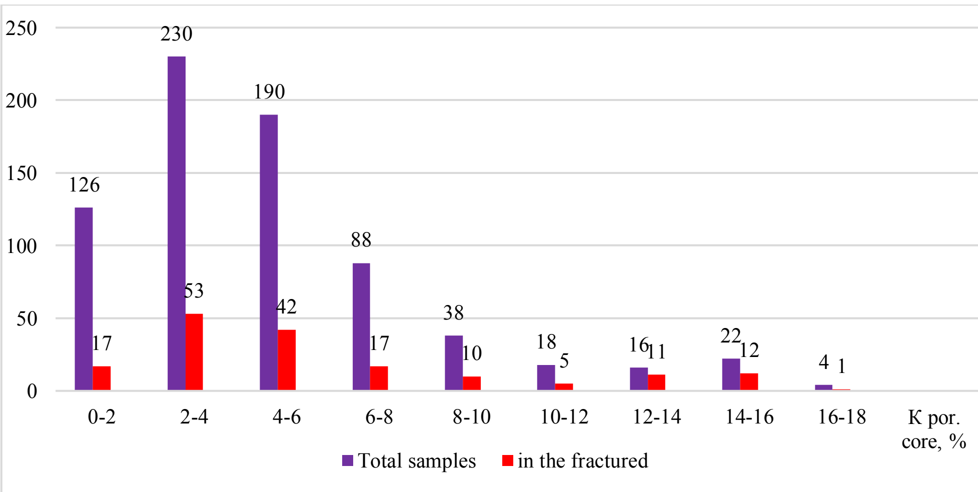

Fig. 1. Histograms of the $K_{core}^{por.}$ Pre-Jurassic deposits.

When studying the reservoirs of the Pre-Jurassic deposits, we proceeded from the model of the monomineral matrix of a granular collector, the presence of an admixture of clay matter in it and the development of secondary porosity, which makes a certain contribution to the FCP of collectors. However, monomineral rocks – terrigenous reservoirs (for example, quartz sandstones) in the pre-Jurassic deposits of Ustyurt are extremely rare. Basically, terrigenous reservoirs are represented by rocks of complex, polymineral composition (quartz-feldspar sandstones, etc.) [9]. Monomineral rocks – carbonate reservoirs (for example, limestones, dolomites) They also make up a small volume of the total capacity of carbonate deposits of the Paleozoic of Ustyurt. Basically, carbonate reservoirs are represented by dolomitized limestones, calcareous dolomites, etc. A total of 761 samples were selected for pre-Jurassic deposits in the region, of which 731 samples (95.3%) were selected for the study of FCP (K_{por}, K_{per}, $K_{org.matter}$). For lithological and stratigraphic complexes, these values were, respectively:

- According to the rat-leias for the study of FCP, 54 samples, 11 of them permeable samples;

- according to permotrias for the study of FCP 244 samples, of which 34 samples are permeable;
- on the lower Permian – upper carboniferous for the study of FCP 131, including permeable 12 samples;
- according to the terrigenous-carbonate complex of C_{2-3} sediments, 152 samples were used for the study of FCP, 49 samples of which were permeable;
- according to the carbonate complex of C_{1-2} deposits, 76 samples were used for the study of FCP, 45 samples of which were permeable;
- according to the clay-carbonate complex of deposits D_3-C_1 for the study of FCP 24 samples, of which 10 samples are permeable;
- according to the Devonian terrigenous-effusive complex of sediments, there are 12 samples for studying FCP, of which there are no permeable samples;
- according to the Proterozoic sediment complex, there are 26 samples for studying FCP, of which there are no permeable samples.

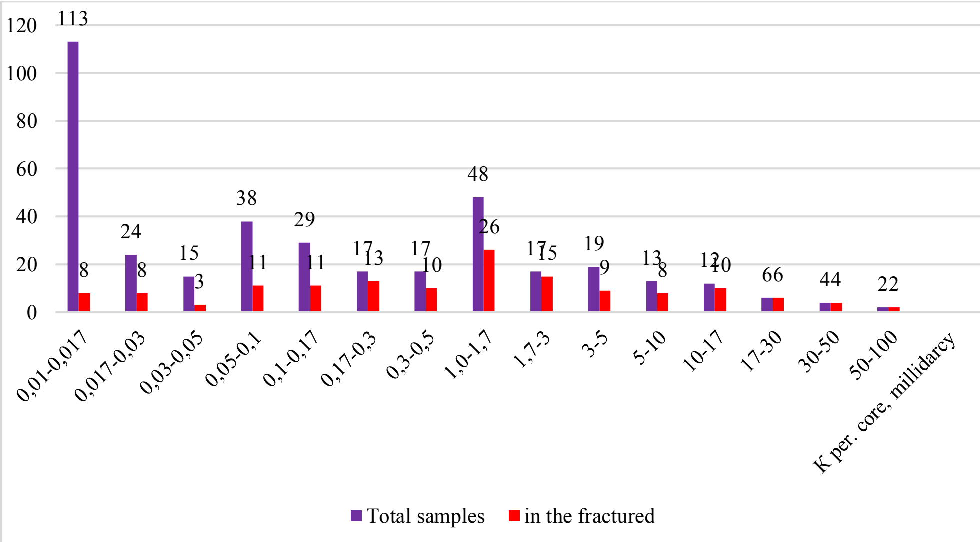

Fig. 2. Histograms of the K $_{core}$ $^{per.}$ Pre-Jurassic deposits.

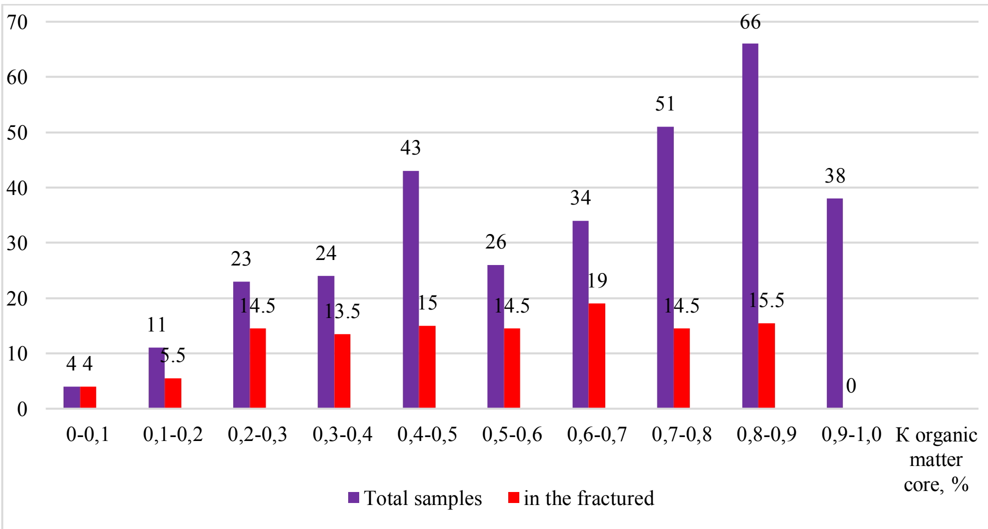

Fig. 3. Histograms of the K $_{core}$ $^{organic\ matter}$ Pre-Jurassic deposits.

From the analysis of the above material, it can be assumed that the reservoirs of the pre-Jurassic deposits of Ustyurt are represented by:
- rocks of complex mineral composition, often containing a clay substance in the skeleton and pore space (clay);
- with a complex structure of the pore space (primary porosity, secondary porosity);

- the widespread development of fracturing has led to the fact that in reservoirs that remained low-porous, permeability improved due to fracturing.

Thus, the reservoirs of the pre-Jurassic deposits of Ustyurt belong to reservoirs of a complex type (in terms of material composition, pore space structure, permeability), the diagnosis of which and the determination of their FCP are difficult. It can be seen from the above data that the selected core is clearly insufficient to create geological and petrophysical reservoir models for all selected lithological and stratigraphic complexes based on core data.

As shown by the distribution of fractured samples (Figures 1, 2 and 3), their share of the total number of studied is 185 (24.9%), including for impermeable samples, the share of fractured samples is 114 (19.3%), for permeable 71 (46.1%)

4. Conclusions

The porosity distribution of all samples selected for the determination of reservoir properties shows that four groups of rocks are distinguished by porosity in the sections of the Pre-Jurassic complex:

- the first group of rocks with porosity 0-2%;
- the second group of rocks with a porosity of 2-6%;
- the third group of rocks with a porosity of 6-10%;
- the fourth group of rocks with porosity over 10%.

Within the first group, the largest number of fractured samples falls on rocks with a porosity of ~ 1%, which indicates the presence of purely fractured differences in the section, i.e. fractured reservoirs with a small capacity, but increased fracturing, which can ensure the receipt of tributaries of reservoir fluids from them.

For rocks in the porosity range of 2-6%, the proportion of fractured differences was 51.4% of the total number of fractured samples. The presence of some capacity in combination with fracturing suggests the presence of pore-crack collectors, for which the pore and crack components provide capacity, and the crack – permeability.

For a group of rocks with a porosity of 6-10%, in which the proportion of fractured differences reaches 21.6, it is most likely that the distribution of pore-cavern-fractured (cavern-pore-fractured) reservoirs, the capacity of which is provided by pore and cavern, and permeability – by the fractured component.

For rocks with porosity over 10%, the proportion of crack differences is 56.1%, i.e. fracturing is significantly developed in these rocks, but their FCP are determined by the pore component. Therefore, in this group of rocks, the most likely distribution of crack-pore (crack-cavern-pore) differences. For the analysis of porosity, permeability and residual water saturation in the region, histograms of the distribution of K_{por}, K_{per} and $K_{org.matter}$were compiled for all samples taken from Pre-Jurassic sediments.

The dependences of K_{per} = f (K_{por}) and K_{per} = f ($K_{org.matter}$) showed that a small group of rocks about 17.5% stands out among the pore reservoirs, which are characterized by high porosity (>10%), high residual water saturation ($K_{org.matter}$ = 0.4-0.6) and low permeability (0.17-1 mld.), which indicates the presence of collectors with a thin-pore structure of the pore space.

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