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Review Article

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# Geological Aspect and Oil and Gas Potential of the Mesozoic and Cenozoic Units of the Tajik Depression (Southwestern Tajikistan)

**Tuichi Khalikulovich Shoymuratov[1], Saken Koptleuovich Kurbaniyazov[2]*, Adil Ozdemir[3], Shynar Magzhanovna Belasarova[4], Arman Zakarievich Zhumagaziev[5], Kairbek Kaldarbekovich Makulov[6], Emin Atasoy[7]**

[1]*Institute of Geology and Exploration of Oil and Gas Fields, Ministry of Mining and Geology. Tashkent, Uzbekistan*
[2]*Department of Ecology and Chemistry, Khoja Ahmed Yasawi University, Turkestan, Kazakhstan*
[3]*Department of Geological Engineering, Institute of Science and Technology, Atatürk University, Erzurum, Turkiye*
[4]*Department of Ecology and Chemistry, Khoja Ahmed Yasawi University, Turkestan, Kazakhstan*
[5]*Atyrau University, Atyrau, Kazakhstan*
[6]*Yessenov University, Aktau, Kazakhstan*
[7]*Department of Geography, Uludağ University, Bursa, Turkiye*

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**Contact**
*Saken Koptleuovich Kurbaniyazov
saken.kurbaniyazov@ayu.edu.kz

**ABSTRACT**

25 oil, condensate, and gas fields have been discovered in Tajikistan, most of which are under development. These fields, of which 8 are located within the Tajik Depression. The Tajik Depression is a central tectonic element of regional importance. This study reviews the geological aspect and oil and gas potential of the Mesozoic and Cenozoic deposits of the Tajik Depression. In the context of Jurassic-Paleogene deposits, productive horizons, depth of their occurrence, lithology, and reservoir properties are distinguished. The article also gives characteristics of the prospects of oil and gas potential of individual territories.

## 1. Introduction

25 oil, condensate, and gas fields have been discovered in Tajikistan, most of which are under development (Fig. 1). The state balance of oil reserves includes 20 fields, of which 12 are located within the Fergana Basin and 8 within the Tajik Depression. The maximum volume of production fell in 1973 and 1979 when 520 million $m^3$ of gas and 418 thousand tons of oil were produced. Most of the developed fields are at a late stage of development and are accordingly developed by 80-85%. High water cut (80-90%) and lack of discovery of new deposits led to a drop in production. In 1986, oil and condensate production reached 450 thousand tons, gas – 250 million $m^3$, then in 2017, oil – 23.482 thousand tons, gas – 1492 thousand $m^3$. Annual capacity (2018) of hydrocarbon feedstock amounted to 23,780 tons of oil and 1,600 thousand $m^3$ of gas. It is worth noting that today, subsalt deposits and deep wells drilled in the areas of Southwestern Tajikistan are considered to be more promising objects. Most have not reached the design depth, and the subsalt deposits studied have not yet produced a positive result. With a view to the sustainable, dynamic, and balanced development of the oil industry, the Government of the Republic of Tajikistan in 2015 Law on Oil and Gas. The law establishes the legal, economic, organizational framework and state policy in the oil and gas field and aims to develop this industry in the Republic of Tajikistan (UNECE, 2020).

The Tajik Depression is a central tectonic element of regional importance (The Geology of USSR, 1972). All open Tajikistan multi-layer deposits are confined mainly to the Paleogene deposits, to a lesser extent to the Cretaceous deposits, and to a small extent to the Jurassic deposits. Collectors, which are the reservoirs of hydrocarbon accumulations, are sandstones, siltstones, and limestones (UNECE, 2020) (Fig. 2). The study reviews the geological aspect and oil and gas potential of the Mesozoic and Cenozoic deposits of the Tajik Depression. In the context of Jurassic-Paleogene deposits, productive horizons, depth of their occurrence, lithology, and reservoir properties are distinguished. The article also gives characteristics of the prospects of oil and gas potential of individual territories.

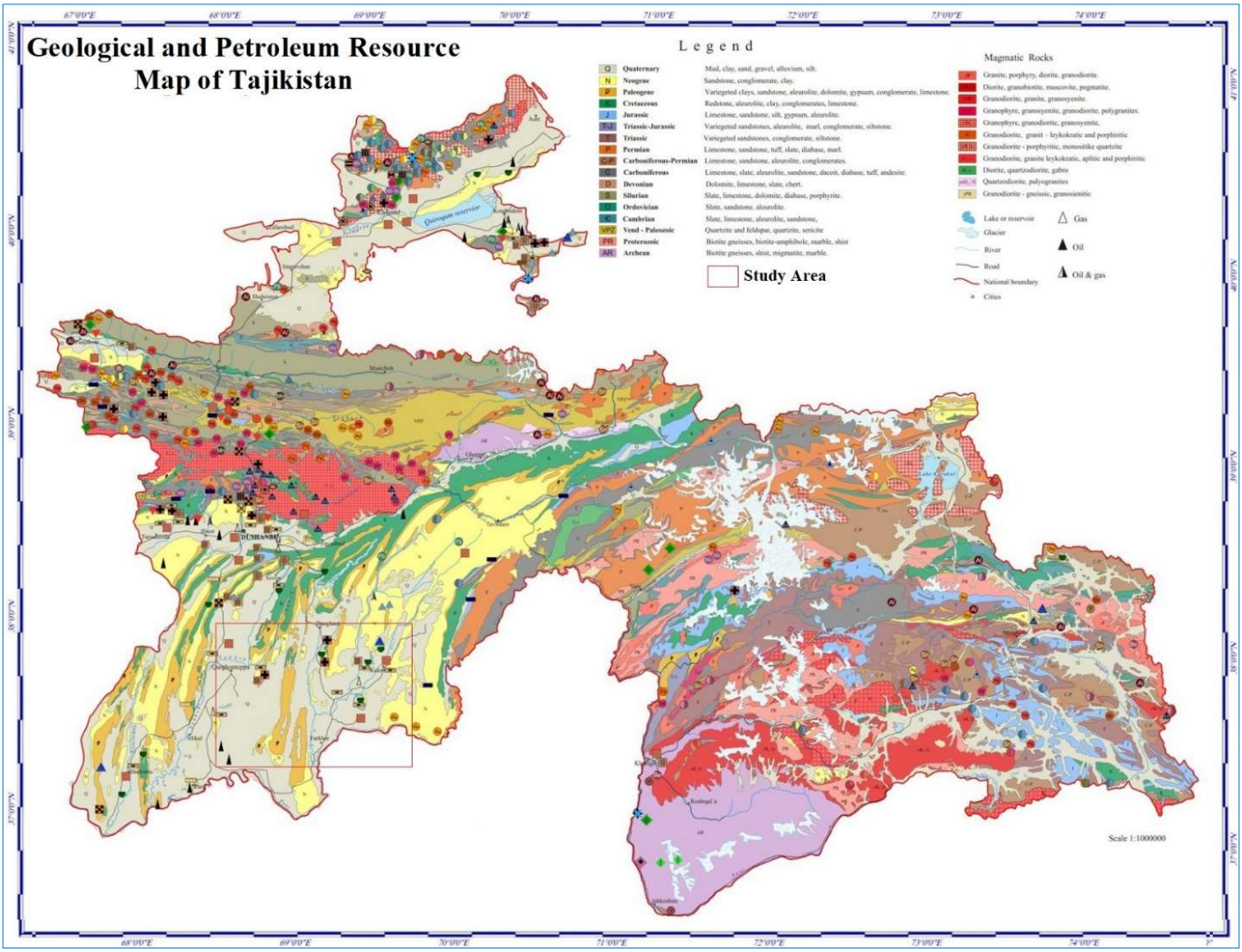


Fig. 1. Geological and petroleum resource map of Tajikistan (scale 1:1 000 000) (modified from https://geoportal-tj.org/deposits/)

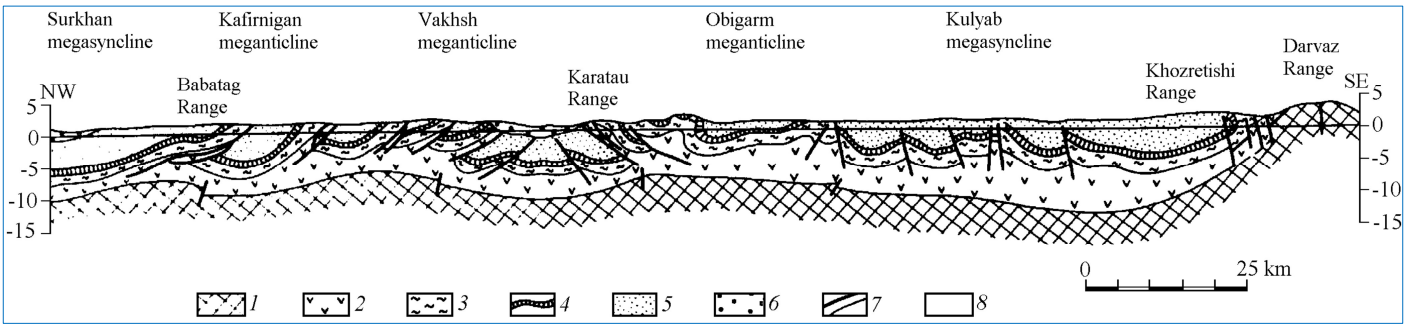


Fig. 2. Geological cross-section of the Tajik Depression (Fig. 1). 1- Paleozoic, 2- Jurassic, 3- Cretaceous, 4- Upper Cretaceous-Paleocene (Bukhara Beds), 5- Paleogene (Eocene-Oligocene) to Neogene (on the cast, Quaternary is included), 6- Pliocene-Quaternary, 7- overthrusts and nappes, 8- faults (Nikolaev, 2002)

## 2. Geological Setting

The Tajik Depression is structurally a typical superimposed intermountain depression located on an ancient crystalline massif surrounded by folded structures of different ages. Compared with the median massifs of other intermountain depressions, the crystalline massif at the basement of the Tajik Depression is characterized by solid fragmentation, which caused the depression's high mobility, prolonged deflection, and the accumulation of a robust cover of Meso-Cenozoic, mainly marine sediments.

Tectonically, most geologists consider the Tajik depression as a geostructural unit of the first order, in the volume of which they distinguish three megastructures of the second order - the Surkhandarya and Kulyab megasynclines, respectively, in the western and eastern parts of the depression, and the Vakhsh-Kafirnigan uplift separating them (Babayev and Valiyev, 1994). The Kafirnigansai and Obigarm uplift zones and the Vakhsh trough separating them are distinguished within the megaanticline, in the southern part of which the Akbash-Adyr anticline fold is located. In the northern part of the depression, a rather sizeable structural element of the second order – the Dushanbe trough is distinguished.

The Tajik Depression structure distinguishes the basement and sedimentary cover. The latter comprises Mesozoic-Cenozoic sediments with a 10–12 km thickness. The basement includes a pre-Jurassic sediment complex composed of Paleozoic geosynclinal formations and epigeosynclinal formations of the Upper Permian and Triassic. Some researchers distinguish Permo-Triassic formations into an intermediate series. This structural and formation complex of sediments reflects the region's Hercynian development cycle. The Alpine complex forms a sedimentary cover and combines sediments from the Lower Jurassic to modern ones. The platform and orogenic stages are distinguished in the Alpine cycle of the history of development. The platform stage of development corresponds to the accumulation time from the Triassic up to and including the Paleogene, and the orogenic (epiplatform) corresponds in time to the accumulation of the Molasse formation of the Neogene and formations of the Quaternary (Volosa, 1975; Nikolaev, 2002).

## 3. Oil and Gas Potential of the Mesozoic and Cenozoic Units

Oil and gas fields are confined to the Mesozoic-Cenozoic deposits of the Dushanbe, Vakhsh, Kulyab basins and the Babatag uplift zone (Fig. 2). Deposits of the Jurassic-Paleogene strata accumulated during the territory's platform stage of development when the Afghan-Tajik intermountain depression was part of the Epigercine platform, forming part of the Turan Plate. Therefore, to some extent, the Mesozoic depression section is identified with the platform section.

About 20 horizons with reservoir properties are distinguished (Table 1) from the Jurassic to the Paleogene. This allocation has certain conventions since horizons are sometimes divided into smaller layers in some regions of the Tajik Depression. Reservoirs from the Eocene to the Upper Cretaceous (Horizon V) have been studied in comparative detail, and deeper parts of the section have been left unexplored due to insufficient drilling data.

Table 1. The characteristics of permeable horizons of Mesozoic-Cenozoic deposits of the Tajik Depression (see Fig. 2)

| Commercial horizons | Age | | Reservoir | Types of fluids | Fields and promising areas |
|---|---|---|---|---|---|
| Ia | | $P_2$ rs | Sandstones | Oil | Beshtentyak |
| Ib | | $P_2$ al | Limestone, limestone-seashells | Oil, gas | Lalmikar |
| | | | | Oil | Shaambara, North.Kurgancha, Jalair |
| I-II | Paleogene | $P_1$ bh | Limestones, dolomites, marls | Oil | Kyzyltumshuk, Kichekbel, Khaudag, Uchkyzil, Lalmikar, Kokaity, Akbash, Amudrya, Koshtar, Aktau, South Mirshdi, Dasmanaga-Karsagly |
| | | | | Gas | Komsomolskoye |
| III-IV | | $P_1$ ak | Limestones, dolomites | Oil, gas<br>Oil gas | Beshtentyak<br>Kyzyltumshuk, Lyalmikar |
| V | | $K_2$ m | Limestones | Oil | Kyzyltumshuk, Lyalmikar |
| VI | | $K_2$ st | Sandstones, limestones | Gas | Gas emissions at Haudag and Uchkyzyl |
| VII | | $K_2$ c | Limestones | Gas | Lalmikar |
| VIII | | $K_2$ t | Limestones | | Carbonate horizons (VI-VIII) are located inside the regional seal |
| IX | Cretaceous | $K_2$ cm | Limestones with sandstone interlayers | | HC footprints in Bayangara square (gas indication was obtained during drilling) |
| X | | $K_2$ cm | Limestones with sandstones | Gas | Komsomolskoye, Andygen |
| XIa,b | | $K_1$ al | Sandstones, limestones | Gas | Komsomolskoye, Andygen, Shaambary |
| XII | | $K_1$ap | Sandstones, limestones | Gas | Komsomolskoye, Andygen |
| XIII | | $K_1$ ap | Sandstones, limestones | Gas | Komsomolskoye, Andygen |
| XIV | | $K_1$ h-v | Sandstones, limestones | Gas | Komsomolskoye, Andygen, Gadzhak, Kagnisai |
| XV, XVa | | $J_3$ ox | Carbonates | Gas | Komsomolskoye, Andygen, Gadzhak |
| XVI | Jurassic | $J_3$ kel | Carbonates | Gas | - |
| XVII-XX | | $J_{1+2}$ | Sandstone, siltstones | - | - |

Reservoirs of the Sumsar and Rishtan layers do not represent regional seals. The carbonate horizons from Alai to Senon (Ia-V horizons) are regionally sustained.

Filtration, capacity, and structure (FCS) of these reservoirs are low, and porosity values below 15% prevail. According to the above-mentioned authors, only in the II horizon of the

Bukhara layers is a significant area in the Vakhsh and Kafirnigan zones occupied by highly porous reservoirs (over 15%) distinguished.

Irregular and low-power limestones represent horizons from VII to VIII. The IX and X horizons of the Cenomanian are relatively pronounced, although their FCS has been little studied. Horizons of the Lower Cretaceous have been studied only in the Dushanbe trough, where their FCS deteriorates along the line of the area of Andygen-Komsomolskaya-Shaambary. In the direction to the east, the section of Cretaceous sediments changes. In the Kulyab trough, all Lower Cretaceous reservoirs from Alba to Valangin represent a single horizon without significant seals. Jurassic reservoirs (XV horizon) are known only in the Dushanbe trough, where their FCS (porosity below 5%) is very low. A study of the permeability of Paleogene-Jurassic horizons showed a tendency of deterioration of the FCS with a depth range from 0 to 3 km, which does not exclude an improvement in these properties at great depths.

Aquifers and water-bearing formations are overlain by water-resistant rocks (seals); the insulating properties depend on their material composition, degree of epigenetic transformation, solidity, and capacity. In terms of specifics of their distribution, local, zonal, and regional seals are distinguished among them (Babayev and Valiyev, 1994). Local seals are isolated within Paleocene sediments and are characterized by insignificant capacities and limited distribution. They overlap with II, III, IV, and V productive horizons on some local structures. Zonal seals are heterogeneous clay, less often sulfate strata, isolating horizons V, VI, VII, VIII, IX, XI, XIII, and XIV in some depression areas. Regional seals are spread over the entire area of the studied region and are almost entirely composed of impermeable rocks. They include seals of horizons: I-a, I, IX, XII, XV.

Within the Tajik Depression, a seal of sulfate-halogen formations of the Gaurdak formation and red-colored clay rocks of Karabil horizon is ubiquitous. Total seal capacity varies widely: from 80-100 m in the northern regions to 800 m or more in the southern regions of the depression. In the Dushanbe trough, the Gaurdak formation wedges out, and the Oxford-Kimmeridge section (Varzob formation is represented by a complex alternation of fractured carbonate rocks and anhydrites. Judging by the bituminological indicators, anhydrite and dolomite-anhydrite interlayers are also relatively permeable, indicating a hydraulic connection between separate intervals of fractured rocks combined into the XV productive horizon. The primary seal for this horizon in the Dushanbe trough can be considered the red-colored clay rocks of the Karabil formation of the Lower Cretaceous (Ziyayev, 2021).

The Upper Aptian-Lower Albian (upper part of the Karakuz and Derbent formations) seal also has a regional distribution and isolates the XII horizon, the industrial gas content established in the Dushanbe trough. The sealing capacity ranges from 80-100 m in the peripheral parts to 220-240 m in the most submerged areas of the depression. In the south and southwest direction, there is a decrease in the capacity of porous, permeable horizons inside the seal under consideration. In the southwestern part of the region, shallow-sea and coastal-marine clay rocks play a significant role in the structure of the seal, which is gradually replaced by red-colored formations to the east. Variability of lithological and facies composition and the degree of epigenetic transformation of rocks is reflected in the mixed mineralogical composition of clays. Despite the diversity of mineralogical composition, the predominance of hydromica is characteristic of all parts of the territory.

Among the regional ones is the seal composed of impermeable clay (to a lesser extent sulfate) rocks of the lower Alba, upper Cenomanian, Turonian, and lower Campanian. They share permeable Paleogene-Maastrichtian, Middle Albian, Neocomian-Aptian, and Jurassic horizons complexes. Total seal capacity is significant (400-800 m). Along with impermeable ones, porous-permeable (carbonate and terrigenous) rocks, the thickness of which reaches 100 m or more, take part in the structure of the seal. These rocks form the VI-VIII horizons of the anomalous Upper Cretaceous complex. In the western part of the depression, the mineralogical composition of clays is represented by hydromica, mixed layered formations, and kaolinite (Babayev and Valiyev, 1994; Ziyayev, 2021). The central part, along with hydromica and mixed layered formations, is noted by montmorillonite (less than 10%), and chlorite already plays a significant role to the east. The considered seal isolates the IX horizon, which is gas-bearing in the Dushanbe trough.

The mudstone-like clays of the Suzak formation of the Lower Eocene are a regional water barrier for the underlying aquifers of the Paleocene. Babayev and Valiyev (1994) believe that the volume of the seal becomes complete only when the impermeable or weakly permeable rocks of the upper part of the Bukhara and lower part of the Alai layers are included in its composition. Seal thickness varies from 10-38 to 130-210 m, increasing in the western and southwestern regions of the Tajik Depression.

The role of non-clay (sandy) rocks increases in the northern and eastern directions. Within the limits of the Suzak seal extension, several areas are isolated, characterized by specific features of the mineralogical composition of clay rocks. At the same time, the disappearance of montmorillonite is observed in the clays of the eastern parts of the depression. In contrast, in other parts of the region, it is present in 10 to 50% of the composition of the clay fraction (Babayev and Valiyev, 1994).

A powerful (up to 300-400 m) regional water barrier is mainly the clay deposits of the Turkestan-Rishtan layers of the Paleogene, which overlap the fractured carbonate rocks of the Alai layers (horizon I-a). Along with clay rocks, sulfate rocks and terrigenous and carbonate formations take part in the structure of the seal. The latter's power increases in the northeastern regions of the Tajik Depression (up to 80-100 m or more). Usual values of capacities of porous, permeable horizons are of the order of 10-40 m. In most considered territories, clay rocks mainly comprise hydromica and montmorillonite. In the northeastern regions, mixed layered

components and chlorite are present along with hydromica, and kaolinite and chlorite are available in the extreme eastern regions.

More than 20 oil and gas fields were discovered in the Tajik Depression, and the industrial oil and gas content of Paleogene deposits and the gas content of Cretaceous and Jurassic strata were proven. The main productive horizons are as follows: XV, XVa, XIV, XIII, XII, XI, X, IX, VI, V, IV, III, II, I and I-a.

Horizons related to Jurassic and Lower Cretaceous sediments in most of the Tajik Depression have not been exposed by drilling. The gas content of the Mesozoic was established on the structures of Hajak, Cognisai (XIV, XV, XVa) in the Kelif-Sarykamysh ridge of the Surkhandarya megasyncline, Shaambary (XV), Komsomolskoye (X-a, b, XI, XII, XIV, XV) and Andygen (IX, X-a,b. XI, XII, XIII, XIV, XV) in the Dushanbe trough and Kyzyltumshuk (V) in the Vakhsh synclinal zone.

The largest oil and gas fields have been identified in the productive horizons of the Akjar (IV, III), Bukhara (II, I), and Alai (I-a) deposits. 14 of them (Khaudag, Uchkizyl, Kokaity, Lalmikar, Amudarya, Jeyrankhana, Koshtar, Mirshadi, South Mirshadi, Jalair, Aktau, Dosmanaga-Korsagly, Akjarsai and Northern Kurgancha are located within the Surkhandarya megasyncline, three each in the Vakhsh uplift (Kyzyltumshuk, Kichikbel, Akbash–Adyr) and the Dushanbe trough (Shaambary, Komsomolskoye, Andygen) and 1 Kulyab synclinal zone (Beshtentyak).

According to the genetic principle of systematization proposed by Bakirov et al. (1976), the identified accumulations of oil and gas belong to the class of deposits of a structural type. The traps for their formation are anticline folds with different shapes of the structure of the crest of the reservoir, from dome-shaped to wedge-shaped. This group includes three subgroups of deposits: arch-like, hanging (hydrodynamic), and tectonically shielded. Most deposits in the territory under consideration are associated with hydrodynamic traps, dome-shaped impermeable barriers bounded from below by an inclined oil-water contact. The condition for preserving deposits from mechanical destruction by water in well-permeable layers of these traps is the excess of the angles of incidence of rocks on the wings above the angle of inclination of the oil-water (gas-water) contact (Volosa, 1975).

Most of the oils known in the Tajik Depression are heavy, viscous, highly resinous, sulfurous, and paraffins, with a low yield of gasoline-kerosene fractions. The HC classes in the distillate part belong to the methane-naphthenic-aromatic type. Lighter and higher-quality oils are confined to the Middle Eocene deposits (Alai layers) of the Dushanbe trough (Shaambara) and the West Babatag district (Northern Kurgancha), as well as to the Paleocene deposits (Bukhara layers) of the Kulyab zone (Beshtentyak). These oils are characterized by significantly lower asphaltene-resinous components and organosulfur compounds, a high yield of gasoline-kerosene fractions, and a predominantly aromatic-methane-naphthenic composition of the distillate part.

Gases of free accumulations are associated with productive horizons and Mesozoic-Paleogene deposits. The essential permanent components of gases are methane, its heavy homologs ($C_2H_6$ and higher), carbon dioxide, nitrogen, and inert gases: argon (combined with krypton and xenon) and helium (the sum of helium and neon). The composition of gases from the Jurassic and Cretaceous deposits of the Dushanbe trough is dominated by methane (up to 93,5% by volume). Heavier methane homologs are contained within I, 7-7,0%. Nitrogen content varies from 1,0 to 16,0%, but in some cases (Andygen - IX horizon, Komsomolskaya - II horizon), there is a significant enrichment of gas mixtures with them (33,5-58,5% by volume). Helium content varies from 0,043 to 0,885%, and argon from 0,014 to 0,121%, while the maximum concentrations of inert gases are noted in Cenomanian sediments (X-IX horizons) of the Andygen field. Hydrogen sulfide is usually absent in the composition of free gases, except for gases from the Upper Jurassic (XV horizon) deposits of the Andygen field, where its concentrations reach 0,0% or more. Gases associated with the Paleocene-Maastrichtian deposits of the Vakhsh synclinal zone at the Kyzyltumshuk field are characterized by the following composition: $CH_4$ - 88,7-92,3%, $C_2H_6$ + higher - 0,3-2,7%, nitrogen - 5,6-8,0%, argon - 0,029-0,37%, helium - 0,046-0,079%. Hydrogen sulfide is practically absent.

Condensates are associated with gas-bearing horizons in the Cretaceous and Jurassic sediments of the Dushanbe trough and are also noted in the Paleocene reservoirs of the Beshtentyak field. Their specific weights are not more than 0,80 g/cm$^3$, and they boil off in the temperature range from 61°C to 353°C. Sulfurous and high-sulfur differences are often noted among condensates. Nitrogen was found in most of them (up to 0,05%) and in condensates from Upper Jurassic deposits (XV horizon). Silica gel resins have been noted in the Shaambara and Komsomolsk fields. The group hydrocarbon composition is dominated by the methane-naphthenic fraction, which mainly determines the aromatic-naphthenic-methane condensate type. In the Lower Cretaceous and Cenomanian deposits of the Andygen field, the composition of condensates is primarily naphthenic, and the type, respectively, is aromatic methane.

## 4. Conclusion

The Tajik Depression is one of the most promising oil and gas basins, within which deep drilling wells have proven the industrial oil and gas potential of Paleogene (Dushanbe, Vakhsh, Kulyab and Surkhandarya Basins) and Upper Cretaceous (Vakhsh, Surkhandarya basins) deposits, as well as Lower Cretaceous (Dushanbe and Surkhandarya Basins) and Upper Jurassic (Surkhandarya Basin) sediments. Consequently, the prospects of Paleogene and Cretaceous deposits of the anticline zones of the Tajik Depression remained relatively high, and Jurassic deposits retained their prospects throughout the territory.

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