Analysis of structural-tectonic and petrophysical features of productive horizons of Mishovdag fold

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Abstract. The article analyzes the geological structure, lithofascial, tectonic, and morphological features of the Mishovdag oil field, which is a productive area in terms of oil content. Morphologically, it represents a brachianticinal fold located in the north-west and south-east directions. The Mishovdag fold is located on the Kalamaddin-Bandovan anticline zone between the Kichik Harami (in the northeast) and Galmaz (in the northwest) structures. The Mishovdag-Galmaz part of the anticlinal zone extends in the sub-southern direction. The structures included in the zone are represented on the surface mainly by Aghjagil, Absheron, and ancient Khazar sediments. Productive layer sediments come to the surface in few areas. The tectonic movements and activity of mud volcanoes (active or buried) have left characteristic traces in the geological structure of the research area. Brachianticinal and other types of structures were formed here. Under the strong influence of tectonic movements, the layers forming them were deformed and broken into blocks by regional tectonic faults. The anticlinal structures of the zone are complicated by longitudinal and latitudinal faults. The Mishovdag fold is represented by a brachianticline, 20-25 km long and 4-6 km wide. Brachianticline has a sharply asymmetrical structure. The southwestern limb is steep, and inclined at an angle of 25-45°, while the northeastern limb is flat and characterized by an inclination angle of 7-25°. As a result of the analysis of the cross-sections of deep wells drilled in the field, it was determined that Mesozoic, Paleogene-Miocene, and Pliocene-Anthropogenic sediments are developed in the section of the fold. Sediments representing the cross-section are characterized by high reservoir properties. Geological-geophysical works are carried out in the field. Core materials were taken from wells. The lithological-petrophysical characteristics – carbonate, porosity, and permeability of reservoir rocks have been determined according to core samples taken from exploration wells drilled in the field. The lithological-petrophysical characteristic regularities of change were investigated depending on depth.

Keywords: Absheron and Akchagil stages, depression, sandy horizons, anticline zone, alteration of sand, sandstone, clay

Анализ структурно-тектонических и петрофизических особенностей продуктивных горизонтов Мишовдагской складчатости

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Анотация. У статьї проаналізовано геологічну будову, літофасціальні, тектонічні та морфологічні особливості Мишовдагського нафтового родовища, яке є продуктивним за нафтоємністю. Морфологічно вона являє собою брахіантріклінальну складку, розташовану в північно-заходньому та південно-східному напрямках. Мишовдагська складчастість розташована на Каламаддин-Бандованській антиклінальній зоні між структурами Кичик Харами (на північному сході) і Галмаз (на північному заході). У південному напрямку простягається Мишовдагсько-Галмазька частина антиклінальної зони. Структури, що входять до зони, на поверхні представлені переважно алджагільськими, апшеронськими та давньохозарськими відкладеннями. Відклади продуктивного шару виходять на поверхню на нечисленних ділянках. Тектонічні рухи та діяльність грязьових вулканів (діючих або похованих) змінили характерні сліди в геологічно-структурній будові району досліджень. Тут сформувалася брахіантріклінальна та інші типи структур. Під сильним впливом тектонічних рухів відкладення утворилися на глибинній, вони характеризуються захисними слідами в геологічно-структурній будові району досліджень. Тут сформувалася брахіантріклінальна та інші типи структур. Під сильним впливом тектонічних рухів змінилися на північному сході і південному заході. Антиклінальні структури зони укладені здовжінні та широтними розломами. Мишовдагська складчастість представлена брахіантріклінальною ділянкою довжиною 20-25 км і шириною 4-6 км. Брахіантріклінальна має різко асиметричну будову. Південно-західне відтинання структур, нахилене під кутом 25-45°, а північно-
східне – пологе з кутом нахилу 7-25°. В результаті аналізу розрізів глибоких свердловин, пробурених на родовищі, встановлено, що в розрізі складчастості розвинені мезозойські, палеоген-міоценові, пліоцен-антропогенові відклади. Проведені геолого-геофізичні роботи на родовищі. Кернові матеріали брали зі свердловин. За керном, відібраним з розвідувальних свердловин, пробурених на родовищі, визначено літолого-петрофізичні характеристики – карбонатність, пористість і проникність порд-колекторів. Досліджено закономірності зміни літолого-петрофізичних характеристик залежно від глибини.

Ключові слова: апшеронський і акчагільський яруси, западина, піщані горизонти, антиклінальна зона, зміна піску, пісковик, глина.

Introduction

The Mishovdag structure is one of the largest structures in the Lower Kura depression. It is located in the northeastern part of the depression (Fig. 1) (Hasanov, Ganbarova, 2021; Hasanov, Sultanov, Ganbarova, 2021; Hasanov, Ganbarova, 2021). The territory of this structure is represented by hills extending in the north-west-south-east direction. The largest of them are Boyuk Mishovdag, Kichik Mishovdag and Gizdag hills, which are in fact geomorphological reflections of the Pliocene fold on the earth’s surface. The absolute height of these hills is 297.4, 281.7, and 294.4 m, respectively. The slopes of the hills are complicated by very deep ravines and are partially filled with volcanic breccias ejected by mud volcanoes.

The geological structure of the field associated with the Mishovdag structure is composed of Productive series, Aghjagil and Quaternary sediments (Fig. 2). At the same time, Pontian (Miocene) sediments were observed in the section of some wells (Gurbanov, Narimanov, Nasiboba, 2021; Kerimov, Gasanov, Gurbanov, Abbasova, 2020; Narimanov, 2003; Gurbanov, Hasanov, Nasimov, Sultanov, Ganbarova, 2017).

In most parts of the structure, the sediments of Baku, Absheron, and Aghjagil stages are cropped out to the day. However, the sediments of the Productive series crop out to the day in the crest position of the structure. The limbs of the fold are covered with modern and ancient Khazar sediments and volcanic breccias.

The sediments of the Productive series (PS) are represented by alternating different colored sands, sandstones, and clays. Clay interlayers up to 20 separate sandy horizons. The high sand content in the cross-section (50-55%) is mainly characteristic of the upper horizons. The total thickness of the Productive series (PS) is 3105 m (well 59).

Interpretation of the well sections drilled in the field revealed that the sediments of the Aghjagil stage consist mainly of clays. Carbonate sand interlayers are also found in the lower part of the stage section of the stage. The thickness of the stage varies between 60-190 m on drilled wells.

Fig. 1. Lower Kura oil and gas-bearing region. Location scheme of oil and gas fields and local folds

Local folds of Lower Kura depression: 1-Pirsaat, 2- Kalamaddin; 3-Boyuk Harami, 4- Girlikh, 5-Kichik Harami, 6-Mishovdag, 7-Galmaz, 8-Khidirli, 9- Bandovan; 10- Kursangi; 11-S.Kursangi; 12-Padar; 13-Kurtalysh; 14- 15- Garabagli; 16- Kurtashi; 17- Kurovdag; 18- Garabagli; 19- Babazanan; 20- Durovdag;21-Khilli; 22-Neftchala; 23-Garasu; 24-Govlar; 25-Sarkhanbeyli; 26-Gizilagaj.

The sediments of the Quaternary period are represented by alternation of sand and clay in the lower part of the section. However, the upper part of the section represents an alternation of strata of sandy loam and clay loam. The thickness of the section varies between 20-230 m according to well data.

Sediments of the Absheron stage are represented by all three substages. The cross-section of the stage consists of the sand, sandstone, and clay alternation. In some cases, there is an alternation of
limestone and bark limestone in the section (upper Absheron). Unlike other substages (upper and lower), the sediments of the middle Absheron stage are more sandy. The total thickness of the stage is 1700 m. (Hasanov, Ganbarova, 2021; Mukhtarova, Nasibova, 2023).

The Pontian sediments are composed of clays according to the analysis of well sections.

The Mishovdag fold is located on the Kalamadin-Bandovan anticline zone between the Kichik Hayrami (in the northeast) and Galmaz (in the north-west) structures (Ganbarova, 2022; Mukhtarova, Nasibova, 2020). The fold is represented by a brachianticline, 20-25 km long and 4-6 km wide. Brachianticline has a sharply asymmetrical structure. The southwestern limb is steep, and inclined at an angle of 25-45°, while the northeastern limb is flat and characterized by an inclination angle of 7-25° (Fig. 3).

The arch of the fold is complicated by a large regional fault along a longitudinal axis, during which the northeastern limb rises 100-200 m relative to the southwestern. The longitudinal fault does not reach the northwestern periclinal of the fold. It touched the east latitudinal fault located far from wells 19 and 436 and is dying out (Fig. 3, 4).

The fold is also complicated by latitudinal faults ranging in amplitude from 50 to 250 m, mud volcanoes, and numerous mud springs and salses. In this sense, the fold is divided into blocks. Mud springs and salses are mainly associated with normal faults, reverse faults, and lateral slip-type faults.

Oil and gas manifestations were found in the first exploration wells drilled in the Mishovdag structure, but its industrially significant oil and gas content was determined in 1956 and put into operation as an oil field. As a result of testing the wells drilled in the structure, it was found that the main oil content is related to the I, II, and III horizons of the Productive series, and relatively to the IV and XII horizons. The oil saturation of the field is mostly related to the I and III horizons. As a result of the analysis, the oil and gas content are mainly related to the horizons identified in the north-western limb of the fold.

The oil saturation of the blocks and horizons is different. Horizon I of the PS is productive in the 1, 1a, 1b, 2, 3, 4, 5, 6, 7, 8, 9, 11 and 12 blocks. Horizon II is oil-bearing in the 1, 1a, 1b + c, 2, 5, 6, 9 blocks. Horizon IV is oil-rich in blocks 1b + c and 5, and horizon XII is oil-bearing in blocks 1, 2, 3, 4, and 5 (see Fig. 2, 3, 4).

Due to the influence of bottom and contour waters, the reservoirs of the horizons of the PS are also water-bearing. There is no regularity in the oil-and water saturation of the reservoirs (Ganbarova, Askerova, Kerimzade, Sadygzade, 2022; Feyzullayev, Gadirov, 2016; Gulmammadov, Mammadova, Tagiyev, 2022).

The oil of the Mishovdag field is highly resinous and paraffinic. The density of oil in the I horizon is 0.861-0.918 g/cm³, in the II horizon 0.876-0.907 g/cm³, in the III horizon 0.866-0.913 g/cm³, in the IV horizon 0.875-0.893 g/cm³.

The petrophysical characteristics of the main oil reservoirs of the field were analyzed (Table 1). A chart was drawn to observe the change in reservoir properties depending on the depth (Fig. 5).
Table 1. Distribution of reservoir properties in Mishovdag field by depth

<table>
<thead>
<tr>
<th>Age</th>
<th>Lithology</th>
<th>Depth, m</th>
<th>Carbonate, %</th>
<th>Porosity, %</th>
<th>Permeability, $10^{-13} m^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS Aghjagil</td>
<td>Clay, sandy aleurite</td>
<td>506</td>
<td>-</td>
<td>28.2</td>
<td>-</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sandy aleurite</td>
<td>1225</td>
<td>10.4</td>
<td>26.3</td>
<td>210</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sandy aleurite</td>
<td>1397</td>
<td>17.1</td>
<td>20.5</td>
<td>430</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, aleurite sand</td>
<td>1410</td>
<td>14.5</td>
<td>25.1</td>
<td>440</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sand and aleurite</td>
<td>1441</td>
<td>16.8</td>
<td>18.9</td>
<td>12</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sand and aleurite</td>
<td>1512</td>
<td>18.3</td>
<td>25.6</td>
<td>89.4</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sandy aleurite</td>
<td>2000</td>
<td>14.5</td>
<td>19.8</td>
<td>90</td>
</tr>
<tr>
<td>PS PS</td>
<td>Clay, sand and aleurite</td>
<td>2175</td>
<td>14.0</td>
<td>13.9</td>
<td>32.1</td>
</tr>
</tbody>
</table>

Fig. 3. Mishovdag field. Structural map by top of the II horizon of the Productive series

Fig. 4. Mishovdag field. Geological profile on line I-I
As can be seen from the table, there are deep-seated porous rocks in the bed. Based on this, it can be assumed that there are oil and gas reservoirs in the lower parts, i.e. in the lower parts of the existing individual deposits (productive layers). On the other hand, the study of the rock-petrophysical property data shows that in some cases, due to physical and geological changes, as the depth increases, the regularity of changes in the physical properties of reservoir rocks is violated (Fig. 6).

**Fig. 5.** Mishovdag field. Geological profile on line II-II

**Fig. 6.** Changes in petrophysical properties depending on depth

- $K_r$ - permeability, $K_p$ - porosity, $K_{car}$ - carbon content
Thus, there is an increase or decrease in petrophysical properties.

It can be seen from the chart of the change in reservoir properties depending on the depth, that the reservoir properties of rocks at different depths are expressed in different values. Porosity is more than 20% in most cases. If it is 28.9% at 506 m depth, it may be 13.9% at the depth of 2175 m. At this depth, the reservoirs are mainly composed of siltstone and sandstone. Apparently, this was since fine siltstones filled the pores of sand and sandstone reservoirs. This also affected the permeability of the reservoirs. Thus, at this depth, the permeability of the reservoirs was 32.1·10^{-15} m^2. It is clear from the analysis of the chart that the reservoir properties of the rocks even occurred by leaps and bounds at some depths.

Conclusions

According to the research conducted in the Mishovdag area, it can be seen that the sediments in which the deposit is located consist mainly of alternating layers of sand, sandstone, aleurolite, and aleurites of the Productive series with clay layers. At some depths, changes in porosity and permeability occurred by leaps and bounds. The reason for the wide range of petrophysical quantities in the area is due to the lithological heterogeneity of the complexes, the diversity of bedrock depths, and tectonic conditions. The high reservoir properties in the deep-seated layers of structures close to this field allow us to predict the presence of oil and gas reservoirs in the deep layers of the studied area.

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