Intensification of oil production in long-term developed offshore fields

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Abstract. Reasonable allocation of operational facilities in the context of multilayered reservoirs is the foundation of all scientific and practical work on the development of petroleum fields. The parameters of deposits are subject to changes over the course of development, and therefore the previously identified system of objects should be updated periodically. This is especially true for offshore multilayered fields, mining which is time-limited due to corrosion of hydraulic structures and high costs for their renewal. In this regard, the rate of using offshore deposits should be quite high not only at the initial stages, but also remain so in subsequent mining periods. Maintaining a high rate of mining is often associated with high material costs (drilling new wells to compact the well network, applying new methods of enhanced oil recovery, etc.), which is not economically viable for the fields in long-term operation. As the practice of mining multilayered fields in Azerbaijan shows, the enlargement of objects allows compacting a mining network while maintaining the total number of wells for a field. At the same time, average daily oil production rates significantly increase as a result having included capacities of contiguous objects. The research aimed at identifying similarities or differences between adjacent horizons of the section of multilayered deposits. Based on the delineated boundaries, there are possibilities of their joint operation as one object, separate or simultaneous-separate operation of wells under appropriate technical conditions. As a result of such measures, all the wells are used rationally and the development rates are increased without additional capital investment. Section of objects of the 3rd tectonic block of the Neft Daşlari offshore field, confined to the Apsheron archipelago of the South Caspian Depression (SCW). The Rodionov’s method was used for a substantial and reliable identification of stratigraphic boundaries. Preliminarily, based on averaged data on 11 parameters, we calculated \( \chi^2 \) critical value at 95% significance, corresponding to \( m=0.05 \), which is used to assess the state of boundaries between the horizons. Then, by implementing software, the values for the boundaries of adjacent objects were calculated, comparing which with the critical value allowed for a conclusion about possible joint or separate mining of those productive strata. As a result of the implementation of the corresponding program, the clarity of the boundaries between the objects of the 3rd tectonic block of the offshore Neft Dashlari field was determined. The need for joint exploitation of horizons VII and VIIa, KS1 and KS2, as well as KaS1 and KaS2 horizons has been determined, which would optimize the mining of the field and is economically feasible.

Keywords: selection of objects, Rodionov’s method, association of objects, Neft Daşlari field, use of reserves, change in parameter values.

Інтенсифікація видобутку нафти морських родовищ, що довго розробляються

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Анотація. Обґрунтоване виділення експлуатаційних об’єктів у розрізі багатопластових родовищ є фундаментом усіх науково-практичних робіт із розробки родовищ нафти та газу. У зв’язку з тим, що в процесі розробки параметри покладів схильні до змін, раніше виділена система об’єктів повинна періодично уточняватися. Особливо це актуально для морських багатопластових родовищ, термін вироблення запасів яких обмежений у часі, що пов’язано з корозією гідротехнічних споруд та великими витратами на їх оновлення. При цьому темпи використання запасів морських покладів може бути досить високим як на початкових стадіях так і у наступні періоди розробки. Підтримування темпу розробки на високому рівні часто пов’язане з великими матеріальними витратами (буріння нових свердловин з метою ущільнення мереж свердловин, застосування нових методів підвищення нафтовидідчих пластів тощо), що економічно нерентабельно для родовищ, при у
trivial stage of exploitation. Indeed, in the case of highly productive deposits, the extraction of raw materials is most promising in the water area of the South-Caspian Depression (SCD), to which a number of large and medium deposits of oil, gas and condensate are confined, especially at various levels of the development. A large number of deposits, situated both inland and in the water area of the sea, are at the late development stages. This stage is characterized by oil degassing, low yield of wells and mining rates.

Exploitation of multilayered fields in general and of each object in particular is carried out based on the designed mining projects. During a technological period, the initial parameters of deposits are elucidated and complemented by new elements. Therefore, those corrections should be introduced to the oil extraction.

As known, during the technological process, the geological-industrial parameters of deposits are also subject to changes, and therefore differences in the parameters of adjacent objects of a section sometimes disappear over time, and sometimes, on the contrary, become starkly contrast. In the first case, those parameters can be classified to one plurality, and unified development of those objects would be the most efficient and practical from the geological standpoint (Abdullayeva, 2001; Bagirov, et al., 2000-2002).

In general, in the section of deposits, an exploitation object is considered a geological body that consists of one or several contiguous layers, designated according to geological, technological and economic indicators, and is mined through an individual (single) network of wells.

It has to be noted that albeit mining of each stratum separately is the most efficient from the geological perspective, it is not profitable from the economic standpoint, and therefore costs for and extraction period of deposits increase tremendously. This is especially relevant for offshore deposits, since an optimal exploitation period of the hydrotechnical construction – based on the global practice of oil extraction – is considered to be around 25-30 years (Baryshnikov, 2012; Baziev, 2005; Belous, et. Al., 2006; Davis, 1990; Diyashev, 2005; Gabdulov, et. Al., 2010). After this period of time, when the extracted deposits become significantly depleted, expenses for repair, reconstruction or building of hydrotechnical constructions significantly affect cost price of the extracted products, and sometimes this production becomes completely unprofitable. Therefore, for marine conditions – from a geological-technological perspective – there should be designed particular projects that would ensure high rates of oil extraction. Enhancing the mining rates of long-exploited offshore deposits as a result of increase in mean daily yields should be correlated with measures that would be feasible from both geological and technical-economic perspectives. In other words, maximal possible extraction of marine deposits should be achieved not only by all known progressive development methods but also to such that are currently really economically feasible. At the same time, along with new methods of enhancing oil recovery, it is now practical to use methods of intensifying oil extraction, namely simultaneous separate exploitation of wells and unification of the horizons (Golovachev, 2010; Graifer, 2000; Ivanov, et. Al., 2010; Kildyshev, et. Al., 2011; Motsohain, 2002).

For this purpose, first of all, there arises a prac-
tical need of intensifying neighboring objects of multilayered reservoirs. Therefore, so as to identify distinctness between boundaries of the objects, it is important to use statistical methods that can reliably solve this issue. Thus, we studied deposits of the 3rd tectonic block of the Neft Daşları field (ND). This field, confined to the Apsheron Archipelago of the SCD, is situated 110 km southeast of Baku (Fig. 1). Depth of the sea in the area ranges 15-25 m (Fig. 1).

Fig. 1. Overview map of the Apsheron oil and gas-bearing region

The ND field is divided into 6 tectonic blocks, each mined separately (Fig. 2). Within the 3rd block, which was the object of our studies, the productive horizons start from the 4th KaS of the Productive Layer (the Lower Pliocene). From this field, the overall extracted oil has amounted for 15 M T since the start of mining, and the remaining reserves account for 2 M T, which reflects the potential properties of this block. Those deposits, discovered in 1949, have been mined for a long time. Therefore, enhancing

Fig. 2. Neft Daşları Field. Structural map of the dome of the Podkirmakinskaya Suite of the Productive Layer.
oil mining in order to speed up production rates, and mine and use the deposits more completely is a relevant task of industrial geologists. To achieve these goals, first of all, there are needed studies identifying objects of the entire section of the 3rd block, in which the KaS3 and KaS4 are practically not mined and have not been characterized by factual data. Similarities or differences between the productive strata should be identified according to parameters characterizing them, using methods of mathematical statistics by which a researcher can accurately solve tasks without subjectivity. Identifying distinct boundaries between the objects consists in detecting sharp changes in behaviour of not only just one, but an entire complex of the objects of the entire section of the 3rd block, in which a researcher can accurately solve tasks without subjectivity. Identifying distinct boundaries between objects can be considered comparatively identical and vice-versa: if they are of greater critical value, then those objects significantly vary between each other. The scheme demonstrates the proposed designation of the exploited objects.

Thus, in category I, we included the following parameters: porosity, permeability, current parameters of deposit mining (current coefficient of oil recovery, average daily oil extraction, average water extraction, water content and reservoir pressure) and current physical-chemical properties of fluids (gas factor, oil density, oil viscosity and general mineralization of water). Category II was comprised of such parameters as total stratum thickness, effective thickness, area of oil bearing and number of producing wells.

For accuracy, we employed the Rodionov’s criterion, calculated according to the following formula:

\[ \nu(r^2) = \frac{\sum_{j=1}^{n} \left( x_{j1} - x_{j2} \right)^2}{(n_1 + n_2) s_j^2}, \]  

(1)

where \( x_{j1}, x_{j2} \) – mean arithmetic features by j number, calculated for each of the two pluralities, by which a set of n observations is divided; \( n_1, n_2 \) – number of observations in those pluralities; \( s_j^2 \) – assessment of the dispersion of feature by j number, calculated assuming equilibrium of dispersion of each of the two groups of divided plurality. This assessment is convenient to make according to the following formula:

\[ s_j^2 = \frac{1}{n_1 + n_2 + 2} \left[ \sum_{i \in A_1} x_{ij} + \sum_{i \in A_2} x_{ij} - \frac{1}{n_1 + n_2} \left( \sum_{i \in A_1} x_{ij} \sum_{i \in A_2} x_{ij} \right) \right] \]  

(2)

where \( A_1 \) and \( A_2 \) – pluralities by which T space is divided, having \( A_1 \cup A_2 = T \). Function \( \nu(r^2) \) is easier to calculate using the formula below:

\[ \nu(r^2) = \frac{n_1 n_2 - 1}{(n_1 + n_2) n_1 n_2} \left[ \sum_{i \in A_1} x_{ij} - n_1 \sum_{i \in A_2} x_{ij} \right] ^2 \]  

\[ \sum_{i \in A_1} x_{ij} - \sum_{i \in A_2} x_{ij} \left( \sum_{i \in A_1} x_{ij} + \sum_{i \in A_2} x_{ij} \right) \]  

(3)

If the tested hypothesis is correct, \( \nu(r^2) \) would be a random variable, distributed as \( \chi^2 \) with \( m \) degrees of freedom. Thus, hypothesis on uniformity is accepted if

\[ \max_{r \in R} \nu(r^2) \leq \chi^2_{g,m}, \]  

(4)

and rejected if

\[ \max_{r \in R} \nu(r^2) > \chi^2_{g,m}. \]  

(5)

Such a dichotomic division of the studied complex continues until all the smaller designated more fragmented complexes are uniform (Rodionov, 1981).

As a result of software-performed designation of the objects of the 3rd tectonic block of ND deposits using the Rodionov’s statistical criterion, we calculated values for the boundaries of all adjacent objects, comparing which to the critical values allowed for an unambiguous conclusion on possibility of their combined or separate exploitation.

Critical value of degree of similarity between the objects was with 95% likelihood determined using the Pearson’s criterion, resulting in \( V(r^2) \) \( x^2_{0.05;11} = 19.7 \). Also, using the Rodionov’s method and necessary software, we determined values for all the adjacent objects of the 3rd tectonic bock of the multilayered ND deposits. If the obtained values are lower than the critical, then the compared objects can be considered comparatively identical and vice-versa: if they are of greater critical value, then those objects significantly vary between each other. The scheme demonstrates the proposed designation of the exploited objects.

Therefore, according to the results, in all the cases except the boundaries between the 7th and 7a; KS1 and KS2; KaS1 and KaS2, the statistical boundaries are reliable \( V(r^2) > \chi^2_{g,w} \). Horizons VII and VIIa, KS1, KS2, and also KaS1 and KaS2, would be practical to unify into a single exploitation object. The conducted geological-industrial comparative analysis of those deposits revealed that the results correspond to the current stage of development. The remaining reserves of horizons VII and VIIa account for 132.0 and 167.2 M T respectively, those of horizons KC1 and KC2 for 46.5 and 72.5 M T, and of KaC1 and KaC2 for 32.0 and 0 M T. Such low values and similarities of deposits of those horizons also confirm the need of their unification and joint exploitation.
Table 1. Geologic-industrial parameters of exploited objects of the 3rd tectonic block of the Neft Daşları field.

<table>
<thead>
<tr>
<th>Number</th>
<th>Exploited object</th>
<th>Porosity, %</th>
<th>Permeability, µm²</th>
<th>Current parameters of oil mining</th>
<th>Current physical-chemical properties of fluids</th>
<th>General water mineralization, mg/eq</th>
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<tr>
<td></td>
<td></td>
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<td>Total layer thickness, m</td>
<td>Effective thickness, m</td>
<td>Oil-bearing area, 10³ m²</td>
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<td></td>
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<td>10³</td>
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Conclusions:

1. Using the software algorithm, we calculated critical values and respective values for boundaries of all the adjacent objects of the 3rd block of the ND deposits, based on which we determined the extent of how distinct they are.

2. The data and the geological-industrial analysis suggest a necessity of involving horizons VII and VII, KS, and KS, and also KaS, and KaS. Their further separate exploitation is not economically beneficial.

3. As known, unifying the objects can optimize mining of multilayered long-mined oil reservoirs by effectively using all the wells of the field. Enlargement of the objects can consolidate the mining network, maintaining the general number of wells of the field with no additional expenses required.

4. Enhancement of mining rates of long-mined marine deposits, achieved by increase in mean daily production of oil, should be consistent with measures that would be feasible from both geological and technological-economical standpoints. In oth-
er words, maximal possible mining of reserves of offshore deposits should be carried out not only by

References


Reglament sostavleniya proektnych tehnologicheskih dokumentov na razrabotku netfanych i gazoneftanych mestorozhdeni. [Regulations for the design of technological documents for the development of oil and gas and oil fields]. OJSC All-Russian Oil and Gas Research Institute named after V.I. Academician A.P. Krylov', Moscow, (1996), 201 p. (In Russian).


