Modeling of Karachaganak field development

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Abstract. Management of a geological deposit includes the study and analysis of oil recovery, identification of factors influencing production performance and oil-bearing rock flooding, reserve recovery and other indicators characterizing field development in general. Regulation of oil deposits exploitation is a mere control over the fluid flow within a reservoir, which is ensured through the designed system of development via continuous improvement of production and injection wells placement, optimum performance modes, service conditions of downhole and surface oil-field equipment taking into account various changes and physical-geological properties of a field when using modern equipment to obtain the best performance indicators.

1. Introduction
Flooding method is used in the development of the majority of oil fields. Large-scale implementation of this method made it possible to obtain a high-efficiency result, i.e. oil recovery was enhanced considerably; recovery rates were increased alongside with production and economic performance. Despite extensive use of this advanced field development method, at least less than a half of initial oil reserves still remain unrecovered. Thus, there is an urgent task to increase substantially the oil recovery rates. To solve the above-mentioned task, besides the application of more efficient recovery methods, it is necessary to improve the existing ones.

One of the perspective methods to improve flooding is clear, reasonable and correct solution of issues related to production management under various geological and physical conditions of oil occurrence modes.

Even being similar in some indicators, the development objects of different fields within various oil provinces significantly differ in some parameters, i.e. they have considerable difference in geological, physical and performance parameters, where every such parameter contributes differently to the entire variability of a system.

The success of oil recovery geological models will strongly depend on objects classification according to geological and physical parameters with particular focus on uniform parameters of a chosen basic development object and on informational content of geological and physical parameters being part of the model, provided there is no correlation between them [1].
2. Materials and methods
Geological modeling of field development as such is based on a set of measures according to search and assessment of the need for industrial measures related to mineral production within specific layers with appropriate location (reservoir models). Thus, the geological reservoir model includes some high-quality and numerical characteristics, which lead to the assessment of geological, financial and performance indicators [2].

In general, the management of field development begins from the implementation of the designed development system, i.e. after drilling operations or after drilling production and injection wells in separate sections (areas), field construction and installation of oil gathering and water injection facility and consequently, oil production according to a reservoir management plan (project).

3. Results and discussion
Modeling is understood as the decision on upcoming development, i.e. forecasting of the technological development flow in the future. Therefore, forecasting includes all development methods, including hydrodynamic methods to define the performance data.

At the same time, it should be taken into account that geological modeling of field development shall be separated from computational schemes, which only consider the formation in general (its profile). For example, nonuniform stratified formation was designed as a model, which in the computational scheme is shown as a flat geometrical component of a surface.

Thus, it should be considered that geological models of minerals recovery from a field are definitely presented as a set of conditioned correlative formulas [3]. Another important factor is that the most critical engineering tasks are based on calculations of field discovery and modeling of geological and physical, as well as hydraulic study of wells.

Let us consider types of field models. For instance, mineral deposits can have diverse characteristics [1].

1. Lithological differences, which means that there are nonuniform pore sizes in different locations of a formation.
2. Level and existence of cracks, which indicates that cracks in a field can be spatially variable.
3. Determination level, which is caused by the fact that with the increase in the determined level the accuracy of transmission of layer characteristics and their structure by the designed model proportionally increases [4].

Following the accuracy of geological modeling, let us consider in detail the determination level, which specifies properties of the determined sample with regard to developed layer design. Such geological model, provided precise measurements of reservoir properties are made, is equivalent to the image of this formation. Since this level is correct, the drawings of the studied formation can be used as a reference development model.

Fast breakthrough in practical application of targeted systems caused the large-scale development of innovative nanotechnologies and corresponding measuring equipment.

When using a particular geological modeling, the formation surface is divided into a certain number of cells due to required accuracy of data for further calculation and opportunities of computer systems. Each cell is attributed data typical for the field in a particular development area, which corresponds to its localization [5].

Let us consider geological modeling in more detail in the context of Karachaganak field. Karachaganak gas-condensate field is located in the west of Kazakhstan, near the city of Aksai (Kazakhstan). The field was discovered in 1979, and commercial development began in the 1980s.

The field has the following characteristics:
- massive reservoir (height over 1 510 m / top depth – 3 667.5 m);
- located in the Pre-Caspian oil-and-gas basin;
- reservoir porosity: 9-13%;
- formation pressure: 57.5 MPa;
- methane content: 84.01%;
- condensate density is about 796 kg/m$^3$;
- oil density reaches 849 kg/m$^3$.

Thus, experimental modeling under certain conditions showed that when feeding a compressed gas in the volume of 0.46 in relation to oil volume in the formation, the original oil is dissolved within the range of up to 40.25% in terms of the equivalent amount of degassed oil. Besides, the addition of the small amount of gas to light oil almost completely transfers oil into gas condensate, the content of condensate in which ranges from 845 to 8 550 g/m$^3$, thus resulting in the drop of critical temperature below the formation temperature [6].

The calculation data within geological modeling of a certain formation make it possible to assume that after the formation of Lower Permian impermeable layer, the Karachaganak trap was filled with light oil with further smooth shift of a contact zone along the formation. The relicts of paleocontact zones, identified in core samples, prove this assumption.

With regard to this process, the net residual oil contained in rocks of the Karachaganak field shall be minimum [7].

The mosaic nature is a consequence of volatile oil transition within phases at inconsistent injection of gas. This explains clearly the oscillatory yield of liquid hydrocarbons in a separator observed during the study of some production wells. In order to transfer relatively heavy oil fractions located in bottom formation into their gas-condensate state, a thermal recovery method is used in some fields, but in this case, the use of such technologies is insufficient [8]. This therefore resulted in the formation of a gas-saturated oil pad with relatively heavy oil fractions being in contact with light oils, which, in turn, forms the top of the oil leg.

This proves the fact that oil is unevenly dissolved in gas and serves an essential differentiation in relation to heavy oils (ranging from 0.845 to 0.885 g/cm$^3$) at an insignificant distance (up to 210 m), which is greater in a lowermost section of formation [9].

In turn, the critical gas content was estimated via the pseudo-flash test and degassing with a gradual change of gas content in this fluid [10]. If gas is present in rather critical quantity – 710 m$^3$/m$^3$, the selected formation fluid is in its gas-condensate state with conservative gas content of 470 m$^3$/m$^3$ or condensate content within the range of 735-745 g/m$^3$ [11].

4. Conclusions
Thus, one may say that with the increase in condensate content to 1 425 g/m$^3$ and above, or with the decrease in gas content to 689 m$^3$/m$^3$ and below, the studied system may turn into liquid [12]. Besides, it should be noted that the increase of formation temperature approximately to 155 °C may lead to the decrease in gas content to 655 m$^3$/m$^3$.

In general, the real development of certain fields and deposits differs from the project design. This is caused by complex and insufficient study of the development object, mapping and simplification of a reservoir (deposit) geological structure and its development at the stage of design. However, targeted and clarifying information obtained through the control over development allows changing or influencing the entire development process.

The achievement of the maximum oil production from all formations of the development object is the purpose of modern control and analysis of oil field development. This major task can only be solved through joint analysis of all partial information on every individual well [13]. An essential condition of such analysis includes the design of an accurate geological model of productive formation structures on the basis of detailed correlation of well logs and the use of available information on formation performance, pressure, temperature, fluid content, etc.

References
[1] Almukhametova E M, Gizetdinov I A, Kilmamatova E T, Akimov A V, Kalinina S V, Fatkullin I F 2017 *IOP Conference Series: Earth and Environmental Science* 87
[2] Almukhametova E M, Akimov A V, Kalinina S V, Fatkullin I F, Gizetdinov I A 2017 *IOP Conference Series: Earth and Environmental Science*. 87 062001
[3] MORE 6.7 2011 *Technical Reference.* (ROXAR)

[4] Mustoni J L, Norman C A, Denyer P 2010 *Deep Conformance Control by a Novel Thermally Activated Particle System to Improve Sweep Efficiency in Mature Waterfloods of the San Jorge Basin. SPE 129732.* SPE Improved Oil Recovery Symposium (Tulsa, OK, USA)

[5] Vladimirov I V, Al'mukhametova E M 2014 *Control and regulation of oil fields development. Study guide.* (Ufa)

[6] Kuznetsov G S, Leont'yev E I, Rezvanov R A 1991 *Geophysical control methods of oil and gas fields development. Study guide.* (M.: Nedra)

[7] Tokarev M A, Akhmerova E R 2001 *Efficiency analysis of enhanced oil recovery at large development objects. Study guide.* (Ufa: Izd-vo UGNTU)

[8] Khusnullin M Kh 1989 *Geophysical control methods of oil formation development.* (M.: Nedra)

[9] Sultanov S A 1974 *Control over oil formation flooding.* (M.: Nedra)

[10] Orlinskiy B M 1977 *Control over oil development via geophysical methods.* (M.: Nedra)

[11] Mustoni J L, Norman C A, Denyer P 2010 *Deep Conformance Control by a Novel Thermally Activated Particle System to Improve Sweep Efficiency in Mature Waterfloods of the San Jorge Basin. SPE 129732.* SPE Improved Oil Recovery Symposium, 24–28 April 2010 (Tulsa, OK, USA)

[12] Ohms D et al. 2009 *Incremental Oil Success from Waterflood Sweep Improvement in Alaska. SPE 121761.* In Proceedings of SPE International Symposium on Oilfield Chemistry, 20–22 April 2009 (The Woodlands, TX, USA)

[13] Qiu F 2010 *The Potential Applications in Heavy Oil EOR with the Nanoparticle and Surfactant Stabilized Solvent-Based Emulsion,* CSUG/SPE 134613.