EDITORIAL

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Problems of exploration and development modeling of oil fields

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Abstract. The article shows the construction features of geological and geological-hydrodynamic models for solving various problems: prospecting, exploration, development and design of enhanced oil recovery (EOR) methods application. Depending on the tasks assigned, the simplest models should gradually and continuously become more complex. When constructing geological models, it is necessary to take into account all the geological reserves in the subsoil of the object under consideration, regardless of whether they can be extracted today or not. In this case, much attention should be paid to the so-called tight (in the modern sense) sections between the layers and the study of their role in filtration processes. In the construction of geological and filtration models for deposits with hard-to-recover oil reserves, it is necessary to study the details of the geological structure and especially the fracturing, since these details have a determining effect on the efficiency of the development and application of the EOR. Essentially new approaches to modeling are presented.

Keywords: hard-to-recover reserves, geological and recoverable reserves, methods for increasing oil recovery, processing of bottomhole well zones, geological and geological-hydrodynamic models

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The specific feature of designing each field (as opposed to the design of any other facilities and structures) is the specificity of each field. In the world there are no fields identical in geological structure. Therefore, any new technologies applied on any fields, which turned out to be successful in certain geological conditions, tend to become ineffective in other geological conditions in other fields. To design new technologies in new fields, large studies are needed to research the features of the geological structure (at macro, micro and nano levels) and the compatibility of these technologies with the geological structure of the deposits. This requires efforts of specialists from universities, research centers, industry, sufficient time and resources.

The process and organization of creating oilfield models depend on the goals set for the designers. These goals can be combined in the following areas:

• Exploration and preparation for the development of fields;

• Design and development of oil fields by conventional methods;

• Modeling the exploitation of oil fields using (as main) tertiary methods of development (thermal, gas) from the very beginning of the development of the facility;

• Modeling of various methods and technologies for increasing the efficiency of oil field development (oil recovery enhancement, bottomhole zone treatment, hydraulic fracturing, drilling of horizontal wells, lateral wells, multihole wells, drilling of additional wells, forced liquid withdrawal, etc.);

• Modeling of the previously unaccounted for reserves of deposits in tight (ultralow-permeable) layers in exploited fields;

• Modeling of oil reservoir reformation (regeneration) processes in the fourth stage of field development and hydrocarbon feeding from the depths of the Earth's interior.

The expansion of the modeling objectives is a result of new ideas about the staging of the development of oil fields. Earlier we also adhered to the allocation of four stages of development of oil deposits. But at the same time, the IV stage of development (on the significance in the formation of high oil recovery values and the duration of development terms) was understood quite differently (Muslimov, 2003; 2016). But at the present time it is obvious that it is necessary, first of all, for large fields to allocate also the V stage of development, in which the oil reserves will be exploited that were not previously accounted either in the official oil balances or in the accepted development projects (reserves in tight strata, previously stationary reserves in the exploited objects).

The main question is what to invest in the concept of a geological model?

S.N. Zakirov (Zakirov et al., 2009) quite rightly considers the very ideology of building models wrong. In his opinion, the methodological documents prescribe “non-reservoirs” not to include into 3D geological models. That is, all (almost all) created 3D geological models in the country are defective, as in them the real geology of fields is artificially distorted (Muslimov, 2014; Muslimov et al., 1994).

In connection with the foregoing, there is a need to reassess the geological resources of oil, since balance and recoverable reserves, in the old, established understanding, leave behind substandard reserves, and they, according to preliminary estimates, may amount to 15-20% of approved ones.

It seems advisable to develop a methodology for calculating geological reserves, taking into account the tremendous progress in the West in the field of geological research and the available experience in extracting hydrocarbons from tight rocks (or shales). In that case, the current “substandard” reserves in the overall balance sheet will be the object of the oil company activity in carrying out research and development projects and searching for ways to extract them.

At the same time, it is more understandable for all specialists to suggest that all geological reserves (including “substandard reservoirs” in carbonate deposits (Muslimov et al., 1998; Volkov et al., 2007) should be considered. Deposits with terrigenous strata are more difficult to conceive, but such a model construction can be more acceptable if we study the structure of the so-called tight reservoirs between the strata and their role in the filtration processes. It can be significant.

The estimates made by the authors (Volkov et al., 2000) suggest that vertical flows in the development of a layered heterogeneous reservoir consisting of layers, represented by different types of reservoirs, can play a significant role. Interlayers can be produced from them, which, when tested directly through wells, give no oil at all or only non-industrial inflows.

The fundamental problems include the need to build a model based on the concept of effective pore space (Zakirov et al., 2009). At the same time, data on reservoir properties should be obtained from real cores with real content of associated water. According to the concept of effective pore space, petrophysical dependencies need to be built based on realistic coefficients of effective permeability and effective porosity, because the degree of reliability of petrophysical dependencies within the framework of the effective pore space is significantly higher than in the concept of absolute pore space. Then it is obvious that the reliability of the logging data for the construction of 3D models will become essential.

Also, special attention should be paid to the determination of the real displacement efficiency K_d – the most important parameter for evaluating the effectiveness of applied and projected development systems and the efficiency of geological and technical measures. The experience of long-term development of fields shows that in developed areas, K_d is higher than that determined by laboratory studies with the so-called endless flushing. Consequently, in these areas, the coverage ratio of K_c will be lower and should be increased by compacting wells pattern and improving the impact on the reservoir. This is a cardinal promising conclusion for the design of measures to increase oil recovery factor (Zakirov et al., 2009; Muslimov, 2012).

Thus, when constructing geological models of oil deposits, it is necessary to:

- study the volume distribution for all models not only balance, but all geological reserves of oil, differentiating the latter into moving, slow-moving and immobile;

- fix the location and determine the reservoir properties of not only the oil-saturated, but also all “tight” and water-saturated interlayers, between the impermeable roof and bottom of the single hydrodynamic system. The system includes the considered deposit or considered set of oil layers (Dyachuk, Knyazeva, 2016).

This fundamentally new approach to geological modeling requires a lot of work to create completely new geological models that most fully take into account the geological basis of the formation of oil deposits.

Models for exploration and preparation for development should be based on the use of primary data from field geophysical measurements, logging data and laboratory studies. All these data should be used in the drafting pilot projects for testing recommended future development technologies.

Design should be based on the classification of fields with active oil reserves (usually large and supergiant), inefficient fields with reserves difficult to recover (mainly medium and small) (Muslimov, 2003), also taking into account the modern classification of oil deposits (Dyachuk, 2015).

For fields that are in the later stages of development, a revision of the entire geological model is necessary, taking into account successful development of deposits in the West with low-permeability reservoirs and technogenic changes in reservoir parameters during long-term operation (Muslimov, 2012), and a synthesis of development experience (as supergiant Romashkino field development shows) is needed. Here it is necessary to radically change the ideology of building a geological model, in which all the oil reserves of an operating facility should be considered, including conditioned and substandard rocks. This is due to new technologies for developing reserves in the final development period (Zakirov et al., 2009; Muslimov, 2012; Dyachuk, Knyazeva, 2016).

At the same time, at the beginning of operation, usually each object of independent development tend to be distinguished into a large number of layers with different geological characteristics, each of which usually serves as an object of independent impact. Then at the late (IV) stage of development previously separated layers of an operational object must be combined to operate the facility in forced modes and high water cut of wells to increase the recovery efficiency.

During this period, it is envisaged to use the already developed methods of enhanced oil recovery (mainly physicochemical and physical, then forced fluid withdrawal), and further to study the processes of re-formation of deposits in the long-term operation and to use them in modeling the current production and oil recovery factor (Dyachuk, 2015; Plotnikova et al., 2013), further modeling of the processes of recharge of exploited hydrocarbon deposits from the depths (Belyaev et al., 2002; Kudinov, Suchkov, 1998).

However, this does not limit the potential for the further increase in resources of the supergiant Romashkino field. To increase it, it is necessary to conduct a large amount of research (including fundamental research). These works should be carried out in the following directions:

- study of tight sections between productive strata of traditionally allocated operational facilities (porosity, permeability, oil saturation, particle size distribution, and other parameters characterizing the geological structure features of tight rocks in sediments of terrigenous and carbonate complexes, lower and middle Carboniferous);
- study of tight rocks of carbonate Devonian, Lower, Middle and Upper Carboniferous deposits for the identification of promising objects for possible future use as objects of exploitation using the latest research and mining technologies;
- determining, by the indicated groups of deposits, methods of research that can be used to attribute their possible resources to the balance reserves, outline possible ways of their development, evaluate the recovery factor and recoverable reserves (in ultra-low-permeability formations);
- study of the hydrocarbon potential of the ultra-viscous oil and natural bitumen of the Permian deposits of the field, the search for new ways to develop reserves in unconventional hydrocarbon deposits.

It is necessary to start modeling the processes of re-formation (regeneration) of oil deposits and supplying them with hydrocarbons from the depths of the Earth's interior, while modeling of exploration and development of tight (ultra-low-permeable) formations is already needed.

The features of modeling geological structure and oil displacement processes in small and medium-sized fields are determined by the specifics of their development strategy.

The experience of developing small and medium-sized fields allows determining a different (than large and giant fields) development strategy. Highly productive development of these fields should be phased. But at the same time, it is necessary to take into account the peculiarities of the geological structure of these fields. While in high-yield fields there is a large proportion of active oil reserves, reaching up to 65-80% of all reserves, then in low-productive fields, as a rule, it is no more than 10%. In the first case, their high proportion provides a quick exit to the maximum level of oil production and a relatively long retention period (before extraction about 50% of initially recoverable reserves), in the second case such dynamics of oil production is not possible. Here it is immediately necessary to apply new enhanced oil recovery methods and bottomhole zone treatment to ensure an acceptable level of production and its subsequent retention. The stage of development of the field here is not due to the consistent development of different levels of oil, but mainly the phased introduction of various components (elements) of the development system.

It should be noted that the role of cracks in the displacement of oil in the development process is crucial not only for cavernous fractures, but also for granular

reservoirs. Indeed, macro- and microcracks are present in almost the vast majority of reservoir rocks. They play a major role in filtering processes. Moreover, in practice the case prevails when there is an inflow of oil into the cracks from the reservoir matrix as a result of the creation of different-variable pressure drops between the cracks and the main part of the rock in the process of development. This occurs during unsteady waterflooding and pulsed operation of production wells. Fracturing in carbonate reservoirs plays an especially important role.

The peculiarity of hard-to-recover reserves is that the seemingly insignificant features of the geological structure details which, in most cases, we either do not know or do not focus on them, have a decisive effect on the efficiency of their development. Let us explain this with some examples.

Macro- and microheterogeneous carbonate formations contain inclusions of other minerals: gypsum, calcite, anhydrite, clays, pyrite, as well as bitumen and various metal oxides. The combined filtration of oil and water, or oil, water and gas, is greatly influenced by the composition of the rocks and the physicochemical properties of these phases, as well as the fractured rock itself and the degree of crack opening.

Thus, the presence of fracturing in the roof of the Kizelovsky deposit of the Tavelsky field according to the R.Kh. Zakirov 1.5-1.8 times increases the flow rate of oil, and therefore oil recovery factor, and the flow rate of oil directly depends on the opened thickness of the formation.

According to the Bashkirian layer of the Akansky field, represented by extremely heterogeneous carbonate reservoirs, the use of waterflooding methods (including in the treatment with nanofluid) turned out to be ineffective. This is due to the presence of cracks of different origin. Here, against the background of small cracks of various generation, larger vertical and sub-vertical cracks of tectonic origin are also present. These structural features of the deposit were recently identified by I.N. Plotnikova and V.P. Morozov. Naturally, under these conditions, any liquid to displace oil from carbonates will not work until it is possible to heal large tectonic cracks. For this we need completely new innovative technologies. L.K. Altunina tried to implement this task. After a long period of original research, the reasons for the inefficiency of conventional flooding methods became clear. The task is extremely complicated - it is necessary to heal powerful vertical tectonic fractures and make small fractures of deposits to take water.

In the Serpukhovian-Bashkirian deposits of the Romashkino field (deposits 301-302), as established by D.V. Guskov, within the limits of positive local structures, compression occurs in the basement part of the formation, which hinders the rate of watercut of the wells with bottom water. Anhydrous periods in such areas are maximal, which allows recommending these areas of the deposit as the most promising for laying producing wells, killing the second wellbore and carrying out various geological and technical measures in order to obtain oil flows with low watercut. Negative local complications are zones of loosening reservoirs in the area of oil-water contact, leading to intensive watering, therefore, it is necessary to produce reserves of these sections in a part load mode.

Today, the issues of studying the directions and development of fractured zones are a priority task for detailed geological studies. Modern geological models should designate these details in order for designers to most effectively determine the location of injection wells and the position of tracks in horizontal wells. Depending on the thickness and reservoir properties of the formations, injection wells can be located either across, along or diagonally to the development of fractured zones. With such geological models, designers can purposefully force cracks to increase oil displacement from the main matrix of the rock (for example, using cyclic flooding).

Knowledge of such details of the projected objects, embedded in the geological models, obviously, will suit the designers in the preparation of technological schemes and field development projects. But they are not enough for the purposeful design of the use of enhanced oil recovery methods in fields. It can be designed as in new fields, the development of which from the very beginning is projected using new development technologies in non-flooding regimes (the introduction of thermal development methods in fields with high-pressure oil and steam, gas and water-gas methods at fields with low-permeability and ultra-low-permeability formations), and at fields developed with the use of flooding. In the latter, the enhanced oil recovery factors should improve the efficiency of developing reserves and increase oil recovery. For such a design, subtle, more detailed, advanced geological models should be applied.

According to the operating experience of unproductive fields of Tatarstan, the following strategy for their development is recommended:

1. Drilling of initially large well pattern (12-16 ha);

2. Clarification of the geological structure of the deposit with the construction of a geological model with fundamentally new approaches that take into account the fundamental laws of geology, i.e. with the inclusion in the object of the entire strata of the oil-bearing floor (from the roof to the bottom of the selected object of operation);

3. Gradual, incremental infill of well pattern (up to 8, then 4 and 2.5-3 ha/well).

At all these stages, a new refined model of the geological structure of the object is being built, taking into account the new grid of wells.

4. At each stage, geological models must be turned into geological and hydrodynamic, taking into account the organization of the waterflood system with its gradual improvement, ensuring the development of deposits at optimum reservoir and downhole pressures. At the same time, it is necessary to take into account the use of impact methods with their gradual complication:

- complex development technologies worked out in Tatarstan of low-permeability and clay terrigenous reservoirs and high-viscosity oils, complex technologies for the development of deposits in carbonate reservoirs, in less permeable formations – hydraulic fracturing;

- the use of light thermal enhanced oil recovery methods and bottomhole treatment (TGHV, PPH, VPTHO, PTOS, electrical heating, PZP, etc.) (Muslimov, 2012);

- injection of hot (or heated) water into the formation, including refined with various chemicals. Here it is necessary for each object to build the oil viscosity-temperature curve, which will help determine the optimal temperature of the pumped agent.

5. After infilling the wells pattern to the optimum value for classical thermal enhanced oil recovery methods (PTV, steam gas, in-situ combustion), update the geological-hydrodynamic model obtained after the above actions. Further design should be based on it.

The problem of linking new development technologies to the geological conditions of the designed field (their compatibility and adequacy) is solved by innovative design of development systems.

Innovative design is the lever that can control the development of a field (from additional exploration to enhanced oil recovery). Firstly, this includes all the necessary research on the development problems of each field in accordance with its specificity. Under normal conditions, this requires performing dozens of different topics. Secondly, such a project after official approval acquires the force of law and obliges the oil company to execute it.

In this connection, Yu.A. Volkov recommends starting the drafting of the project with the analysis of the simplest models and complicating their structure gradually, as necessary, i.e. introducing into practice a multi-model approach to the creation and improvement of oil recovery technologies, representing the "new design philosophy" of oil field development.

The ways to solve these problems are the essence of the cluster approach to the development of the new generation standard "the regulation of innovative design development and optimization of the development of hydrocarbon reserves with their continuous replenishment". In contrast to the standard recommended by the Central Committee of Reserves for mass design, it may also include conducting pilot works to test new technologies at a particular field in specific geological conditions.

References

Belyaev S.S., Borzenkov I.A., Glumov I.F., Ibatullin R., Muslimov R.Kh., Ivanov M.V. (2002). Development and application of biogeotechnology for increasing oil recovery in the Tatarstan deposits. *Georesursy = Georesources*, 1(9), pp. 36-37 (In Russ.)

Dyachuk I.A. (2015). Reformation of oil fields and reservoirs. *Georesursy = Georesources*, 1(60), pp. 39-45. (In Russ.)

Dyachuk I.A., Knyazeva E.V. (2016). Features of the late stage of development of oil fields and measures to increase the oil recovery of depleted reservoirs. *Proc. Int. Sci. and Pract. Conf.*, Kazan: Ikhlas, vol.1, 300 p. (In Russ.)

Kudinov V.I., Suchkov B.M. (1998). New technologies to increase oil production. Samara: Samara Publ. House. (In Russ.)

Muslimov R.Kh. (2003). Modern methods for managing the development of oil fields with flooding. Kazan: Kazan. univer. Publ., 596 p. (In Russ.)

Muslimov R.Kh. (2012). Oil recovery: past, present, future. 2 Ed. Kazan: Fen Publ., 664 p. (In Russ.)

Muslimov R.Kh. (2012). Oil recovery: past, present, future (production optimization, maximization of oil recovery). 2 Ed. Kazan: Fen, 750 p. (In Russ.)

Muslimov R.Kh. (2016). Ways of transition from resource-raw to resource-innovative development of the oil industry. *Proc. Int. Sci. and Pract. Conf.*, Kazan: Ikhlas, vol.1, 300 p. (In Russ.)

Muslimov R.Kh., Volkov Yu.A., Kasimov R.S., Rozenberg I.B., Suleimanov E.I. (1994). Problems of constructing geological models of oil deposits in carbonate reservoirs] *Problemy kompleksnogo osvoeniya trudnoizvlekaemykh zapasov nefti i prirodnykh bitumov: Tr. mezhd. konf.* [Problems of integrated development of hard-to-recover oil and natural bitumen reserves: Coll. papers], Kazan, vol.2, pp. 496-510. (In Russ.)

Muslimov R.Kh., Volkov Yu.A., Shakirov A.N. et al. (1998). New approaches to constructing a geological model of a carbonate reservoir based on improved interpretation of GIS. *Opyt razvedki i razrabotki Romashkinskogo i drugikh krupnykh neftyanykh mestorozhdenii Volko-Kamskogo regiona: Tr. nauch.-prakt. konf.* [The experience of exploration and development of Romashkino and other large oil deposits of the Volko-Kama region: Coll. papers], Kazan: Novoe Znanie, pp. 355-360. (In Russ.)

Plotnikova I.N., Pronin N.V., Nosova F.F. (2013). On the source of oil generation in the Pashi horizon of the Romashkino field. *Georesursy = Georesources*, 1, pp. 33-35. (In Russ.)

Volkov Yu.A., Danilova T.E., Kasimov R.S. (2007). Necessity for a layered core study with reference to the GIS without disturbing the natural sequence of stratification. *Mat. region. naucho-prakt. konf. «Problemy povysheniya geologicheskoi informativnosti geofizicheskikh issledovanii skvazhin»* [Proc. Conf. "Problems of increasing the geological information content of geophysical well studies"], Kazan: Pluton, pp. 64-80. (In Russ.)

Volkov Yu.A., Faizullin I.N., Kormil'tsev Yu.V., Fedorov V.N., Chekelin A.N. (2000). About cyclic impact through horizontal wells on deposits, represented by different types of reservoirs. *Mat. seminara-diskussii «Gorizontal'nye skvazhiny: burenie, ekspluatatsiya, issledovanie»* [Proc. Sem. "Horizontal wells: drilling, operation, research"], Kazan: MasterLain, pp. 123-130. (In Russ.)

Zakirov S.N., Indrupskii I.M., Zakirov E.S. et al. (2009). New principles and technologies of oil and gas fields development. Part 2. Moscow-Izhevsk: Institut komp'yuternykh issledovanii, 484 p. (In Russ.)

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