Consideration of Multiscale Permeability Studies of the Formation for Creation of the Targeted Permanent Geological and Technological Model of a Cavern and Pore Collector

N D Kozyrev¹, A A Kochnev¹, A G Mengaliev²
¹Perm National Research Polytechnic University, 29, Komsomolsky avenue, Perm, 614990, Russia
²TPP "Yamalneftegaz" LLC "LUKOIL — Western Siberia", Integrated Modeling Department, 24, Matrosova Street, Salekhard, 629008, Russia

E-mail: nikitonkozyrev@gmail.com

Abstract. The geological-hydrodynamic model of the reservoir is very important in predicting oil field performance. Reliability and accuracy of the forecast depend on the quality and quantity of the initial information. The assessment and accounting of the results of various methods of reservoir analysis is often carried out separately from each other and at different times of model creation. As a result, it becomes impossible to describe clearly physical processes occurring in the formation. In addition, the degree of uncertainty of the reservoir properties remains high, even with a sufficient information. So a comprehensive analysis of all initial information is needed. The paper presents a methodological approach for integrating multi-scale data. Based on the clarification made Cuba permeability of the reservoir complex manifold in “Vostochno Lamsheyskoe” field. Taking into account all borehole studies allowed reducing the degree of permeability uncertainty and more accurately assessing the filtration processes occurring during the development of the field. The proposed method of aggregation is universal and can be replicated for all oil fields with different degrees of study.

1. Introduction

Today geological-hydrodynamic modeling is an important part of the design process for the development of oil and gas fields. The hydrodynamic model allows you to predict many technological indicators for the short and long term, such as oil and gas production, watering rates, reservoir and bottom-hole pressures and many others. One of the main advantages of using geological-hydrodynamic models in predicting of field development is the consideration of geological heterogeneity, which allows to accurately predict the filtration and physicochemical processes occurring in reservoirs[1-3].

The reliability and accuracy of the forecast done with the hydrodynamic model directly depends on the quality and quantity of the initial information taken into account in creating the model. The assessment and accounting of the results of various methods of reservoir analysis is often carried out separately from each other and at different times of model creation. Using this approach, in particular for deposits with a complex geological structure, the degree of uncertainty of the reservoir properties
remains high, even with a sufficient information, which negatively affects the technological and economic projections of field development. Therefore, to ensure the high quality of the predictive ability of the hydrodynamic model, a comprehensive analysis of all initial information is necessary [4-8].

In modeling one of the most important properties of the reservoir is absolute permeability, because this property determines the dynamics of reservoir pressure, the rate of watering of wells, and also has a high degree of uncertainty, which does not allow to predict technological and economic projections of field development with an acceptable accuracy [9–15].

This article presents the methodological approach that allows to combine the results of multi-scale studies in creating and refining the absolute permeability of the formation in the geological-hydrodynamic model on the example of the priority multilayer field characterized by a complex geological structure.

2. Materials and methods
To improve the accuracy of the geological and hydrodynamic model, it is proposed to refine the permeability cube by taking into account all studies. The methodological approach includes four basic steps (fig.1): 1. Accounting of the standard complex of geophysical studies. In this stage for each well studied using the petrophysical dependence of permeability-porosity synthetic absolute permeability logging curves in the LAS format were created. 2. Accounting of direct core research. In this stage the synthetic logging curve of permeability is refined according to the core data. 3. Accounting of the results of hydrodynamic and flowmetric studies. Under the stage the working thickness is clarified according to flowmetric studies, the average phase permeability for each working interval is determined. Then the phase permeability is converted to absolute and the permeability logging curve is calibrated according to hydrodynamic studies. 4. Interpolation of synthetic permeability logging curves through all geological-hydrodynamic model. Interpolation is based on seismic attributes [16-18].

**Figure 1.** The flowchart of the process of refining absolute permeability when modeling productive oil reservoirs: \( k_a \) – absolute permeability values; \( k_{ph} \) – values of phase permeability; \( m \) – open porosity.
The analysis of studies at each stage was carried out and the logging curve was refined (fig.2).

![Figure 2](image1.png)

**Figure 2.** The full process of refining the synthetic absolute permeability logging curve: a – according to the results of well logging and petrophysical dependence; b – according to the results of well logging, petrophysical dependence and direct core studies; c – according to the results of well logging, petrophysical dependence, direct core studies, well test and flowmetric studies.

Then, based on the new logging curves, the values were interpolated. Interpolation was performed using the krigging method using the trend cube of seismic studies (fig.3) [16-18].

![Figure 3](image2.png)

**Figure 3.** Visual characteristic of absolute permeability cubes: a – standard technique; b – proposed methodology.
3. Results
To evaluate the effectiveness of the proposed methodology, it was carried out the comparative analysis of the results of reproduction of the history of field development obtained from models created by using the standard method and by integrating multiscale information [19-20]. The application of the aggregation of research results made it possible to reproduce the actual accumulated liquid and oil withdrawals in general for the studied field with greater accuracy (table 1). The hydrodynamic model with author's method was taken as the basis for further tuning of the performance of each well.

Table 1. Comparative characteristics of the results of reproducing the development history on models.

| Method for creating the hydrodynamic model | Parameter            | Fact   | Calculation | Error, % |
|-------------------------------------------|----------------------|--------|-------------|----------|
| standard method                           | Oil production total, kt | 9123,1 | 5874,2      | 35,6     |
| author's method                           |                      |        | 7854,7      |          |
| standard method                           | Liquid production total, kt | 9996,2 | 6216,2      | 37,8     |
| author's method                           |                      |        | 8375,7      | 16,2     |

Since the main task of geological-hydrodynamic modeling is forecasting field development indicators, at the final stage of work, in order to assess the predictive ability of the model, the retrospective forecast was made that showed acceptable convergence of calculated and actual field development indicators. 6-month retrospective forecast was also made. On the model with a modified permeability cube, the discrepancies do not exceed 5 percent, on the model created using the standard methodology, the deviations are increasing and by the end of the analyzed period they amount to 35 percent.

4. Conclusion
Given the growing share of hard-to-recover reserves, the development of complex reservoirs is an urgent issue. The proposed approach of integrating multiscale permeability studies allowed to create a geological-hydrodynamic model that complies with the regulations and is able to predict the development of a priority oil field with acceptable accuracy.

Taking into account all borehole studies allows to reduce the degree of the uncertainty of permeability and assess the filtration processes occurring during field development more accurately.

The proposed integration technique is universal and can be replicated for all oil fields with various level of knowledge.

5. References
[1] Gavris A S and Kosyakov V P et al 2015 The concept of effective design of hydrocarbon fields development Software solutions. Oilfield engineering 11 75-85
[2] Bashirova A M and Yarkeeva N R 2015 Digital filtration model as a method for predicting the indicators of project wells on example of a BV81 formation, Severo-Pokursky field Petroleum Engineering 4 97-102
[3] Zakirov R Kh 2009 Role of geological-hydrodynamic modelling at designing of oil field development Georesources 4 34-36
[4] Ipatov A I and Kremenetskiy M I et al 2015 Reservoir surveillance when hard-to-recover reserves developing Oil Industry 9 68-72
[5] Repina V A 2017 How to consider rock density in fluid flow model of oil fields during permeability modelling Bulletin of the Perm National Research Polytechnic University. Geology. Oil and gas and mining 2 104-112
[6] Repina V A and Galkin V I et al 2018 Complex petrophysical correction in the adaptation of geological hydrodynamic models Journal of Mining Institute 231 268-274
[7] Gimazov A A and Fokeeva E E et al 2018 Integrated approach to adapting and forecasting the parameters of secondary porosity for the R Trebs oilfield Oil Industry 10 20-23
[8] Ardislamova D R and Salimgareeva E M et al 2015 Integrated approach to modelling naturally fractured carbonate reservoirs SPE Russian Petroleum Technology Conference 1-17
[9] Dikalov D V 2018 Comprehensive approach to the construction of a permanently working geological-technological model on the example of the Western-Tugrovsky deposit Geology, geophysics and development of oil and gas fields 9 34-40
[10] Bozhenyuk N N and Belkina V A et al 2018 Geological model of the vikulovskaya suit deposits, including analysis of a manifold connectivity and the data on horizontal wells Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering 329 (4) 30-44
[11] Belov K V and Lisenkov A B et al 2017 Study of fluid filtration in a porous medium using physical and numerical modeling Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering 328 (8) 64-74
[12] Viktorin V D 1988 Influence of carbonate reservoir parameters on oil reserves development efficiency (Moscow: Nedra Press) p 150
[13] Putilov I and Krivoshchekov S et al 2020 Methods of predicting the effectiveness of hydrochloric acid treatment using hydrodynamic simulation Applied Sciences 10 (14)
[14] Voevodkin V L and Galkin V I et al 2012 Investigation of the effect of oil-content and research criteria in the Perm region on the hydrocarbon deposits distribution Oil Industry 6 30-34
[15] Krivoshchekov S N and Kozlova I A et al 2014 Estimate of the petroleum potential of the western solikamsk depression based on geochemical and geodynamic data Oil Industry 6 12-15
[16] Yin Z and Feng T et al 2019 Fast assimilation of frequently acquired 4D seismic data for reservoir history matching Computers & Geosciences Vol 128 30-40
[17] Raeesi M and Moradzadeh A et al 2012 Classification and identification of hydrocarbon reservoir lithofacies and their heterogeneity using seismic attributes, logs data and artificial neural networks Journal of Petroleum Science and Engineering 82 151-165
[18] Boadu F K 2000 Predicting the transport properties of fractured rocks from seismic information: numerical experiments Journal of Applied Geophysics 44 (2-3) 103-113
[19] Olenchikov D M 2007 Interactive step-by-step calculation as the basis of automation methods for adapting hydrodynamic models with a large number of wells Scientific and Technical Bulletin of OJSC OI «ROSNEFT» 2 38-40
[20] Ilamah O 2019 A multiobjective dominance and decomposition algorithm for reservoir model history matching Petroleum 5 (4) 352-366

Acknowledgments
This research was funded by the state assignment of the Ministry of Science and Higher Education of the Russian Federation as part of a government assignment, grant number FSNM-2020-0027.