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WATERFLOODING AS THE BASIS OF OIL FIELDS DEVELOPMENT IN RUSSIA

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Abstract. The paper reviews the 65 years' experience of progress of the contour waterflooding technology to increase production from the Russian super-giant Romashkinskoye field. The technology has come a long way having witnessed the emergence of different scientific schools competing with each other and offering their solutions, having overcome a lot of doubts and fears as to feasibility of water injection and, finally, having matured to its current status of an efficient world-class technology, maximizing oil production, yet at reasonable costs.

Waterflooding systems, in and of themselves, and, importantly, a wide-scale and universal application of the technology at early production stages resulted in unprecedented flow rates and high production performances of oil fields in the former Soviet Union. Owing to the grand-scale implementation of water-injection projects, the USSR was able to attain one of the highest annual oil production levels in the world, about 625 million tonnes, which was 1.56 times higher than in the USA with the total well count 6 times less, at that. However despite the evident advantages of the waterflooding technology, in many cases being the single option whatever, some authors have persisted in criticizing the waterflooding process basing their arguments on the alleged destruction of subsurface formations because of water injection. The author dispels these myths, and shows the groundlessness and even noxiousness of such assertions. Quite the contrary, the waterflooding technology has a high potential for further improvement and application. Technology development and improvement opportunities in the light of the newly-discovered phenomena characteristic of the advanced stage of reserves production (re-forming of deposits and hydrocarbon charge from deeper sediments) are discussed.

Key words: *contour waterflooding, waterflooded development, modern waterflooding methods, waterflood as secondary EOR, man-induced damage to oil fields, destruction of formations, forced production, cyclic waterflooding, irregular displacement, poor conformance, water fingering, hard-to-recover reserves, re-forming of deposits, hydrocarbon charge, crystalline basement.*

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**GENERAL PRINCIPLES OF INTEGRATED HYDROCARBON RESERVES
ASSESSMENT IN PETROLEUM INVESTMENT PROJECTS**

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Abstract. The paper considers general principles of integrated assessment of natural hydrocarbons in petroleum investment projects. It is demonstrated that analysis of cost-effectiveness of petroleum investment projects entails estimation of the main economic performance indicators for various scenarios; selection of the best scenario to ensure maximization of the project's net present value from probably complete extraction of oil reserves with identification of funding sources. Evaluation of available scenarios in multi-staged design of field development projects should be risk-oriented to account for risk effects on efficiency and reliability of engineering and economic decisions under particular conditions of oil and gas production operations. Of great current interest is that reviewed approaches have been included into industry-related automated system allowing for multi-scenario estimates of cost/performance indices in petroleum investment projects inclusive of risk factors.

Key words: *economic assessment, petroleum investment project, economic and mathematical method, design solutions.*

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УДК 553.982

**ASSESSMENT OF POTENTIAL OF ALBIAN OIL AND GAS SOURCE ROCKS OF
THE GULF OF GUINEA ON THE EXAMPLE OF THE COTE D'IVOIRE BASIN**

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Abstract. Using the pyrolysis method, analysis of thermal alteration index and vitrinite reflectance of multiple samples of rocks in the basin, sufficient data were obtained to assess the potential of oil and gas source rocks in the Cote-d'Ivoire basin. The results of the study show that the rocks have from satisfactory to very high organic matter content, which indicates the existence of good conditions for the production and preservation of organic material in the pool. Organic matter is of continental and marine origin and corresponds to type III and type II kerogen. Thermal indicators show that the rocks at the initial and full stage of maturity. These rocks are capable of generating liquid and gaseous hydrocarbons.

Key words: *organic matter, source rock, hydrogen index, kerogen, common organic carbons, reflection power of a vitrinite, hydrocarbonic potential and thermal alteration index.*

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**ANALYSIS OF FEATURES OF DEVELOPMENT OF STOCKS OF DEPOSITS OF
THE ACHIMOVSKY OIL-AND-GAS COMPLEX**

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Abstract. The article is devoted to the state of development of Achimov oil and gas complex in the territory of the Khanty–Mansiysk District, the difficulties with the involvement of Achimov deposits in the development and the reasons for the low level of oil recovery. In all, 58 Achimov facilities, containing more than 50% of the total petroleum reserves of the oil and gas complex, covered by regular development. The oil recovery coefficients of in the Achimov formations are taken in the design at a low level, which is associated with low permeability and oil saturation, hydrophilicity, therefore — the mobility of water in productive interlayers.

In addition, the analysis of the results of the development of Achimov facilities showed that even the design level of oil recovery while maintaining the current state might be unattainable for most facilities. The key reason of acts is incomplete realization of the design of the Fund, since most of the Achimov objects are not drilled completely. Among other reasons are: low permeability, discontinuous geological structure, understated count of project wells (when the design takes a rare operational grid for economic reasons) and premature watering of the extracted products, as established by the results of the analysis, are subject mainly to low-permeable strata. As another result of the study, it should be noted that the nature of the relationship between the coverage of the reservoir by the development processes, sand content and the operational grid.

Accessible to on average in the developed objects it is estimated at 0,131 shares of unit when maintaining current state and at 0,233 shares of unit at the complete realization of design fund. Low level of oil recovery demonstrate that the traditional way of development based on naphtha replacement by water in general is represented ineffective.

Key words: *Achimov thick layer, oil recovery coefficient, sand content, oil saturation, permeability.*

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STUDYING UNSTEADY-STATE FLOW IN HORIZONTAL WELLS

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Abstract. The paper presents analysis of pressure transient tests in a horizontal well over a long development period, effect of injection on a horizontal well production rate, and pressure transient test interpretation problems.

Geological environment is a combination of interbedded layers with different physical and chemical properties. Each geological block is characterized by inherent dynamic stress system. In case of rapid-rate reservoir development, pressure events result in difference between rock stresses in the adjacent zones. Pressure decline tests in producing wells give higher net-pay thickness values than pressure buildup tests.

Yusupov and Medvedsky's studies show that long-term production can be accompanied by fracturing. Pressure transient test curve for a horizontal producing well demonstrates continuous linear flow, which can probably be due to a fracture presence. The injection well testing curve reveals parameters typical of fractures, though hydrofrac jobs were not performed in that well.

Reservoir cooling due to injection of cold water with temperature significantly lower than reservoir temperature results in elastic stress decrease and reservoir fracturing in injection wells under pressures applied during water-flooding.

By now, we know that significant difference between reservoir temperature and the injected water temperature results in reservoir fracturing, which is proved by pressure decline curve for the injection well, where long-term injection entailed self-induced hydraulic fracturing. Fracture closure stress increases with reservoir pressure depletion, resulting in lower fracture conductivity. Long-term observations revealed fracture dimensions variability.

Key words: *horizontal well, pressure transient tests, pressure buildup curve, pressure decline curve, injection well, hydraulic fracturing, self-induced hydraulic fracturing, reservoir cooling.*

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**APPLICATION OF OPTIMIZATION AND NEURAL NETWORK ALGORITHMS
FOR EFFECTIVE PORTFOLIO OF GEOLOGICAL AND TECHNOLOGICAL
ACTIVITIES FORMATION OF AN OIL COMPANY**

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Abstract. The article presents the result of the research of reasonable selection of geological and technological activities for an activities portfolio formation of an oil company in the context of restrictions on production volume and investment area. The number of statistical, neural network, optimization algorithms has been applied while solving this issue. The possibility of using Kohonen self-organizing maps for clustering activities under the terms of use and technologies is considered. It was proposed to build a probabilistic model for evaluating the effectiveness of the planned activities based on Bayesian networks, which can be visualized as an acyclic directed graph reflecting the consistent interrelation of the parameters included in the model. This model is based on the accumulated statistics of the activities effectiveness and other characteristics. The constructed model allows us to obtain a nomogram of the probability distribution of a given activity for any combination of parameters, for example, the probability of achieving exact or approximate value of the activity effectiveness specific measure. After evaluating the effectiveness of the planned activity, the task of forming an optimal portfolio of geological and technological activities under the restrictions on the production volume and capital expenditures can be set. The issue of forming a portfolio of geological and technological activities for a large oil company has been studied and solved using the implemented package of optimization algorithms (branch and bound method, genetic algorithms, cross-entropy method). The software tool for the effective investment portfolio formation in the "Development and production of oil" block of PJSC TATNEFT has been implemented. The tool has significantly increased the planned net present value and the number of activities taken in the portfolio under restrictions on production volume and capital expenditures.

Key words: *geological and technological activities planning, Kohonen self-organizing maps, Bayesian networks, optimization algorithms, activities portfolio formation*

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THE MODELS APPLICATION AT THE OIL FIELDS DEVELOPMENT

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Abstract. The paper deals with the features of the models choice at the oil fields development, depending on the goal and objectives delivered to the developer. The role and place of various types and methods of modeling, the relationship and purpose of models in the study of the structure of oil deposits and processes during their development, depending on the degree of knowledge, are shown. It is revealed, that the complication of the model leads to an increase in uncertainty in the adaptation of the model due to the redundancy of the identified parameters. It is shown, that the requirements for approximation of the adapted indicators with higher accuracy than the error of the parameters, put into the model, are inexpedient. Increase in the complexity and the growth in the dimension of the model is advisable while providing the data with the necessary completeness and reliability, while the model is adequate to the real object and processes, as well as to the economic efficiency when applying the results in practice.

Key words: *geological and hydrodynamic modeling, physical and mathematical models, adaptation of the model, empirical and semi-empirical models, the adequacy of the model*

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**THE USE OF GEOLOGICAL AND HYDRODYNAMIC MODELING TO STUDY
THE SPATIAL ORIENTATION OF CRACKS IN CARBONATE COLLECTORS
BASED ON TRASSERAL RESEARCH METHODS**

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Abstract. The article proposes to use the results of indicator research methods to clarify the geological structure of deposits. Comparing the dynamic filtration rates of fluids with the actual results of indicator studies, it is possible to determine the preferred directions and orientation of cracks in carbonate reservoirs.

In order to study the spatial orientation of cracks in carbonate reservoirs based on the results of tracer studies, a geological-hydrodynamic model of the Tournaisian deposits of 101 deposits of the Novo-Elkhovskiy deposit was used. At the same time, geological and technological modeling with an iterative method of creating models is used as an implementation of this approach. The filtration model was selected on the basis of the physicochemical properties of the carbonate sediments fluids saturating the formation, taking into account the double porosity and double permeability of the object under study. In the filtration model, the size and number of cells of the geological model were saved.

The adaptation of the parameters of the filtration model according to the development history was carried out in two versions. In the first variant, the parameters of the filtration model were adapted without taking into account the results of indicator studies. The values of permeabilities in the directions of the X, Y and Z cracks were assumed to be equal. In the second variant, the parameters of the filtration model were adapted to reflect the results of indicator studies. As a result of adaptation, the values of permeabilities in the directions of the X and Z cracks were obtained more than in the Y direction.

The use of directional orientation in modeling allowed us to establish the main direction of the cracks along which the fluid is filtered. Application of the results of indicator studies in the construction and adaptation of parameters of the reservoir filtration model increases the degree of compliance with the geological and technological model and the real object of development.

Key words: *indicator, filtration, spatial orientation of cracks, carbonate reservoir, adaptation of the filtration reservoir model.*

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GEOLOGICAL AND RESERVOIR FLOW MODELS ARE USED TO OPTIMIZE DEVELOPMENT OF KURMANAEVSKOYE FIELD'S CARBONATE RESERVOIRS

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Abstract. Geological and reservoir flow models have been built for the carbonate Bashkirian and Vereiskian reservoirs of the Kurmanayevskoye oil field. The geological model was built using the ROXAR's modeling system IRAP RMS. The grid size was 0.4 m, the same for both simulated targets. The dynamic model was built using the ROXAR's Tempest 7.2. software.

To model the geology of carbonate reservoirs, J-curve was used. Upscaling was not performed. The model was history matched using the available production data. Carter-Tracy aquifer model was used to consider for aquifer performance (effect of marginal and bottomhole water).

Using the production history matching results, the forecast reservoirs performances considering production enhancement operations were calculated. The paper presents the maps of mobile oil reserves of the Kurmanayevskoye oil field throughout the field production life. The expected oil recovery factor in the recommended development option is 0.244.

Key words: *carbonate reservoir, the Bashkirian formation, the Vereiskian formation, geological and flow models, the Middle Carboniferous, well log interpretation, cross-plot, relative permeability, production history, mobile oil reserves, aquifer performance, reserves' development.*

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FORECAST OF CHANGES OF ROCK STRENGTH WITH DEPTH

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Abstract. The process of drilling and fastening wells is very complex in engineering terms, as it is accompanied by the destruction of rocks of different properties.

The stability of rocks is sharply reduced in the presence of different types of water. In clay rocks and salts, the processes of moistening, swelling and dispersion play a significant role, causing a weakening of the structural bonds between the rock particles.

In order to prevent complications during the well wiring, it is necessary to study the causes of changes in the properties of rocks in various geological conditions, as well as to determine the nature of the violation of the stability of the wellbore drilled in terrigenous rocks containing clay inclusions, as well as in salt and inter-salt deposits.

The results of studies of changes in the properties of clay rocks in the formation of the wellbore during drilling.

Experimental data on the determination of mechanical properties of different lithotypes of terrigenous clay rocks at different depths are systematized.

An important conclusion that follows from the constructed dependences: with a depth of more than 1500 m, the compressive strength of clay rocks (σ_{sj}) becomes less than the skeletal stresses in the range of anomalous reservoir pressure (abnormally low – ALRP and abnormally high – AHRP) from $0.25 \leq Ka < 1.0$ (ALRP), and from depths of 3000 m and more – in the range of $1.0 < Ka \leq 1.5$ (AHRP).

The areas of changes in the stress state of the bottomhole formation zone (BFZ), where there is a violation of the stability of the wellbore (scree, landslides, cavern formation, narrowing of the trunk)

On the basis of the calculations, and builds established that the abnormal ratio of the anomalous $Ka \geq 2,0$ with depths greater than 3000 m. Most of the obtained data concentrated in the range of skeletal stresses in the PZP when $1,22 \leq Ka \leq 2,0$. For five wells in which there was a violation of the trunk, skeletal stresses are in the $Ka > 2.0$.

On the basis of statistical data of change of properties of clay mountain with depth the technique of the prevention of complications at conducting of wells in difficult mountain-geological conditions is developed.

Key words: *Bottomhole formation zone, drilling, workover, complications when posting wells, the stability of the borehole walls and clay rocks, strength rocks, skeletal stresses, rock pressure, formation pressure, pore pressure, downhole pressure, density of rocks, density of drilling mud.*

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**ON IMPLEMENTATION OF EFFICIENT METHODS TO IMPROVE ACCURACY
OF MEASURING GAS-OIL RATIO IN MATURE FIELDS**

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Abstract. The paper reviews development of efficient methods to improve accuracy of measuring current and total gas-oil ratio (GOR) in mature fields. Development of mature fields becomes complicated due to production-induced factors, such as formation temperature, high water cut, low reservoir pressure, low GOR, which greatly influence the accuracy of GOR measurement by present-day automatic group metering stations.

Analysis of home-made commercial group metering stations performance shows that they do not comply with requirements for GOR measurement accuracy, both in terms of environmental safety and GOR level control to increase the efficiency of enhanced oil recovery techniques based on water-alternating-gas injection.

Based on the performed experimental studies, the authors could solve a technical challenge involving improvement of present-day commercial measuring equipment, as well as provide technical justification for development of a measuring unit for rapid estimation of gas-oil ratio in a multi-zone well without lifting the oil samples to the surface.

Key words: *associated gas, gas-oil ratio, automated group metering station, gas rate, water cut*

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**THE CHOICE OF COMPONENTS FOR BUFFER FLUIDS AT THE COMPLETION
WELL WITH DRILLING FLUIDS ON OIL-BASED**

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Abstract. The article deals with the contact of cement stone with the casing string, which are used in drilling hydrocarbon-based solutions, as well as the influence of some buffer fluids on the quality of wells and the choice of their components. To study this issue, experimental studies were carried out, the schemes of which are described in this paper. The aim of the research was to assess the effect of hydrocarbon solution on the quality of adhesion and washing capacity of the buffer liquids. The results of the study showed how the quality of adhesion changes, and revealed the most effective buffer fluid.

Key words: *the buffer liquid; cleaning power; hydrocarbon based muds (OBM); adhesion; surface -active substances (surfactants); hydrocarbon layer.*

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**INTEGRATED APPROACH TO PREVENTION OF BEHIND-THE-CASING LEAKS
DURING AND COMPLETION AND HYDRAULIC FRACTURING OPERATIONS**

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Abstract. The paper present the result of field experiments and analytical studies that bring forth potential solutions to the problem of behind-the-casing leaks encountered during well completion operations. Requirements to strength capacity and stress/strain behavior of cement sheath are highlighted. These properties should be taken into account while formulating oil well cement compositions intended for wells selected for further perforation and hydraulic fracturing operations.

Key words: *cement sheath, strength, stress-strain behavior, stresses*

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**ON DEVELOPMENT OF EQUIPMENT FOR TIME-EFFICIENT CRUDE OIL
SAMPLING AND RAPID GAS-OIL RATIO MEASUREMENT**

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Abstract. This paper discusses the gas-oil-ratio (GOR) measuring technique for various geologic conditions. In case of GOR measuring in wells producing from multilayered reservoirs the available technologies based on downhole sampling with a multi-chamber sampling tool and further laboratory analysis of the samples are inefficient and require long-term well shutoff. Based on recent advances in geophysical tools development, fluid samplers are suggested to be equipped with temperature-controlled heaters and ultrasonic fluid-density meters. This will provide rapid measurement of GOR directly in a borehole without sample lifting to the surface, thus significantly increasing technical-and-economic efficiency of this operation.

Key words: *gas-oil ratio, fluid sample, sampling tool, rapid measuring, heater, ultrasonic density meter*

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**TECHNOLOGY OF OBTAINING AND EVALUATING THE EFFICIENCY OF
ADDITIVES FOR INCREASING THE CAPACITY OF THE PIPELINES**

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Abstract. Proved the feasibility and effectiveness of the use of composite additives for the processes of pipeline transport on the domestic material base and raw materials. The additive was prepared by compounding: NMPE, surfactant, nanoparticles. The use of such an additive is preferable to the existing anti-turbulent additives in solving important economic, technological, and environmental aspects of oil production and transportation.

Key words: *low molecular weight polyethylene; anti-turbulent additives; high viscosity oils; additive technology; transportation of oil emulsions; aluminum oxide nanoparticles.*

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**THE DEVELOPMENT OF THE RECULTIVATION'S METHOD OF PONDS
SLUDGE COLLECTORS**

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Abstract. Waste processing of oil refineries and petrochemical industries is currently one of the pressing environmental problems in Russia. One of the most dangerous pollutants of almost all components of the natural environment are oily waste - oil sludge. At present, fundamentally new technical solutions are being developed for the remediation of sludge storage ponds and the processes of obtaining chemical products as a result of the utilization of waste accumulated in them. According to the research results, a method of remediation of sludge storage ponds, which is a two-stage process, has been developed. At the first stage, biological decomposition of oil waste is carried out using microorganisms, which allows to solve the problem of their subsequent disposal. At the second stage, the fertility of disturbed lands is restored by phytoremediation. The method consists in planting herbaceous vegetation and tree seedlings over the entire area of recultivated land. The implementation of this method of remediation of sludge ponds will reduce the cost of services to third-party companies for the disposal of oil sludge.

Key words: *oil sludge, sludge pond, bioremediation, phytoremediation, remediation of oil-contaminated lands, biological remediation.*

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**ECONOMIC SANCTIONS: COSTS AND BENEFITS FOR THE OIL AND GAS AND
BANKING INDUSTRIES IN MODERN TERMS**

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Abstract: The modern unstable economic processes between the participants of the financial and commodity markets not only in Russia, but also in the international format, which are caused by sanctions against oil and gas companies and systemically important banks of the country, have led to the need to neutralize the emerging external challenges in the form of unplanned risks of doing business and reorientation of partnership and financial and economic relations from some participants in the world markets to others. At the same time, there was a definition of ways to reduce risks among banks and oil and gas companies by identifying domestic, national sources, allowing to gradually reduce financial gaps in the course of the gradual development of sanctions

For oil and gas companies and commercial banks, the risks caused by sanctions were significant not only from the point of view of not being incorporated in their tactics and strategies of doing business, but also from the point of attracting foreign capital to continue effective management of their own projects, customer service, and so on. The ability to generate projected profits and other financial/non-financial benefits in the face of evolving risks has proved difficult. Today there is a favorable tendency of gradual stabilization of activity of these categories of institutions and, accordingly, reduction of financial risks in the form of reduction of financial result of the activity.

Key words: *risk, Bank risks, financial risks, oil and gas risks, oil and gas business, banking system, sanctions, profit.*