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PROBLEMS AND NEW APPROACHES TO GEOLOGICAL MODELING OF OIL RESERVOIRS AND SIMULATION OF OIL EXPLORATION AND PRODUCTION PROCESSES

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Abstract. The paper presents special aspects, associated with construction of geological and reservoir simulation models for addressing various challenges related to oil prospecting, exploration, field development and EOR design applications. Depending on the objectives, the simplest models require constant step-wise refinement. Geological models must take into account the total amount of in-place reserves trapped in the productive formation, regardless of whether they are economically recoverable to date or not. At the same time, great attention must be paid to so-called tight (in modern understanding) interlayers and their function in fluid flow processes. During construction of geological and fluid flow models for hard-to-recover oil fields, details of geological structure must be well studied; particularly, the fracture network, because such details are critical for efficient field development. This is the same with EOR applications. The paper presents fundamentally new approaches to the modeling process: transition from economic reserves to original oil-in-place volumes, consideration of large oil fields reformation processes at late stages of development, production of unrecorded reserves in low- and ultra-low-permeability reservoirs, long production induced changes in the field, hydrocarbon migration processes from deep petroleum subsurface.

Key words: *active and hard-to-recover reserves, in-place and recoverable reserves, enhanced oil recovery, bottomhole treatments, geological and reservoir simulation models, innovative design, geological and field classification of reserves, tight (ultra-low-permeability) reservoirs, highly viscous oil, integrated field development technologies, physical/chemical, thermal, gas-assisted, water/gas-based EOR methods, unconventional oil reserves, low- and ultra-low permeability reservoirs, natural bitumen.*

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OVERVIEW OF RESERVES ESTIMATION METHOD BASED ON STANDARD REGRESSIVE DEPENDENCIES AS APPLIED FOR TATNEFT'S FIELDS

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Abstract. Estimation of reserves, current re-estimation of oil in place, and reserves assessment require considerable detailed research efforts for substantiation of volumetric parameters. In this context, minimization of time and labor intensity of reserves estimation while ensuring the accuracy sufficient for field applications becomes critical. Rapid assessment of original oil in place is applicable at various stages of exploration activities. Seismic interpretation capabilities and standard regressive dependencies, constructed based on strong correlation of volumetric parameters, enable estimation of in-place reserves and resources without the need for spudding new wells, and ranking of drilling sites in order of priority. In this experimental research, the authors will resort to rapid assessment method for estimation of reserves and resources of Tulskian terrigenous oil reservoirs in 10 oil fields operated by TATNEFT. Developed in West Siberian oil fields, this method will be put into practice in Volga-Ural petroleum province for the first time ever.

Key words: *estimation of reserves, rapid assessment of reserves, correlation coefficient, reserves per well, net oil-saturated thicknesses, regressive dependencies.*

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DISTRIBUTION OF RESERVOIRS AND IDENTIFICATION OF PROSPECT FEATURES IN UV1 FORMATION OF SAMOTLORSKOYE FIELD

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Abstract. This paper presents and discusses changes in oil-water contact surface, as well as tectonic and seismic facies aspects of UV1 formation in the Samotlorskoye field. Direct dependence of oil-water contact position on the present-day top of UV1 formation across the field has been specified. Low-relief prospect features have been identified in this field.

Key words: *low-relief prospect, oil-water contact, geology, tectonic model*

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ANOMALIES OF WELL LOGGING CURVES AND METHODS OF CORRECTION

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Abstract. Typical well logging curve anomalies (defects) have been analyzed. This is particularly the case with full-wave acoustic logging, induction logging and density logging methods.

Various methods for correction of defective well logging curves are proposed for producing areas of south-eastern part of Tatarstan. Case studies are also provided.

The following conclusions have been made:

1. Commercial hydraulic fracturing simulators, such as MFrac or FracPRO, require revised and corrected well logging curves.
2. Lack of information on the type of tools and logging sonde as well as the conditions of data registration in LAS files, prevents leveraging the reading correction opportunities of PRIME software package. One of the possible solutions is generation of curves.
3. Some downhole elements may distort information related to geophysical parameters. It is necessary to specify the presence, date and depth of setting of columns, profile liners and other downhole elements. In a number of wells, some portions of well log may be recorded within the column with the resultant curve distortion.

Key words: *geophysical surveys, curve defects, methods for correction and generation*

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SELECTION OF GRID GEOMETRIZATION OF A 3D GEOLOGICAL MODEL AND COMPARISON OF RESERVOIR DISTRIBUTION METHODS IN CARBONATE DEPOSITS

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Abstract. The main cube of a 3D geological model is a lithology cube which determines reservoir distribution pattern, connectivity and number of reservoir layers, and layer correlation. Two approaches are used for construction of lithology cubes. These are deterministic and stochastic approaches. The authors analyzed Bashkirian and Tournaisian sediments and selected the optimal method for reservoir distribution with combination of various trends. For Bashkirian deposits, the authors selected the cube constructed using “facies indicators” method and 3D trend of continuous reservoir parameter. For Tournasian reservoirs, a cube constructed using "parameter interpolation” method was selected as most accurately reflecting the athors’ understanding of the Tournasian stage geological structure. A conclusion was made that the best results are obtained from combination of different algorithms both during model construction and in the course of history matching of 3D geological model with reserves estimation data.

Key words: *modeling; lithology cube; deterministic; stochastic; combination*

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RESERVOIRS SIMULATION STUDIES OF PRODUCTION PERFORMANCE OF TERRIGENOUS BOBRIK RESERVOIRS OF YUZHNO-NURLATSKOYE OIL FIELD

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Abstract. The authors of the present paper consider construction of geological and reservoir simulation model for terrigenous Bobrik reservoirs of Yuzhno-Nurlatskoye oil field, history matching of the resultant fluid flow model to historical production data and application of the history matched model for forecasting the performance of producing reservoirs.

Initial oil saturations have been obtained from Leverett J-function for Bobrik deposits. However, deficiency of initial data has hindered construction of relative permeability curves.

History matching and forecasting data are indicative of the degree of match between predicted and actual production data.

Reservoir simulations have been run to evaluate various improved and enhanced recovery methods as of the forecast period.

Key words: *producing reservoirs, heterogeneity, terrigenous reservoir, Bobrik horizon, stratal surface, geological and fluid flow model, well logging interpretation, relative permeability, history matching, ultimate water cut*

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SELECTING OPTIMAL PROCEDURE OF CLUSTERING DATA FROM GEOMECHANICAL MODELING FOR HYDRAULIC FRACTURING DESIGN

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Abstract. Hydraulic fracturing is one of the most common methods to enhance oil recovery all over the world.

Taking into account changes of stress-strain properties and stresses along the wellbore calculated using well log data from correlations based on core analyses significantly improves quality of estimated parameters of hydraulic fracture geometry.

This paper reviews the problem of geomechanical models incorporation into fracturing design. Several options of geomechanical modeling data adaptation have been offered to optimize fracture design. Based on engineering analyses, pilot projects have been implemented in three wells. Downhole logging, including full-wave acoustic logging, noise logging, and pulsed neutron logging with tracer injection confirmed matching between model parameters and actual hydraulic fracture geometry.

Key words: *geomechanical modeling, fracture design, clustering, full-wave acoustic logging, pulsed neutron logging, hydraulic fracturing*

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APPLICATION OF ION-MODIFIED WATER TO ENHANCE OIL RECOVERY FROM LOW-PERMEABILITY CARBONATE RESERVOIRS

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Abstract. Development of low permeability carbonate reservoirs presents challenges associated with the original structure of such reservoirs and complex molecular and mass processes, which take place in their porous & fractured structure during reservoir and injected fluids flow.

With available commercial technologies (*in PJSC TATNEFT*) based on hot water injection and surfactant flooding oil recovery factors in such reservoirs do not exceed 0.25.

One of the key factors responsible for efficiency of oil recovery from carbonate rocks is surface wettability of capillary porous rock space. It has been demonstrated previously, that application of ion-modified water enables efficient adjustment of surface wettability in carbonate rocks [1 - 4].

This can be attributed primarily to high affinity of Ca^{2+}, Mg^{2+} and SO_4^{2-} to carbonate rock surface. In addition to that, the temperature of flowing fluids has a significant impact on changes of surface wettability in fractured and porous rocks and increase in displaced oil mobility (due to oil viscosity reduction).

The paper describes fluid flow experiments with ion-amended fresh process water conducted at high temperatures (75^{o}C) on Bashkirian core samples from Akanskoye field. The results suggest high efficiency of ion-amended fresh water for enhancing oil recovery from low-permeability carbonate rocks.

Key words: *hot waterflooding, hot smart water, wettability, oil recovery, oil recovery factor*

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3D VISUALIZATION OF POST-FRACTURING WELL PRODUCTION PERFORMANCE PREDICTION

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Abstract.

Research goal:

- statement, theoretical and experimental justification of hypothesis on hydraulic fracturing process morphology in carbonate reservoirs;
- development of a mathematical model for prediction of post-fracturing performance of hydraulically fractured wells;
- designing a 3D hydraulic fracturing simulator based on the developed mathematical model.

Problem statement:

Deficiency of individual methods and computer-aided systems for prediction of hydraulic fracturing efficiency in carbonate reservoirs, lack of control over fracture pattern geometry development, related to high degree of structure uncertainty, result in critical production forecast errors; thus necessitating development of methods for proper evaluation of fracturing performance and associated risks.

Scientific novelty:

The present research effort relates to the system and method for prediction of well production rates after hydraulic fracturing treatments and involves:

- fundamental hypothesis on hydraulic fracturing process morphology;
- mathematical model relying on initial database, with final stage to be the estimation of post-fracturing well production rate;
- hydraulic fracturing simulator designed for visualization and estimation of ultimate production due to fracturing.

Practical importance:

Once completed, the intended research efforts will provide means for prediction of post-fracturing production performance of wells and will improve the accuracy of forecast production estimates at high consistency of resultant values.

Key words*: reservoir simulation modeling, fracture network, hydraulic fracturing, production rate*

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ON ONE OF THE WAYS OF GEOTHERMAL ENERGY PRODUCTION

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Abstract. This paper reviews the state of geothermal energy sector in the world. Today, geothermal heat generated at geothermal stations is used in many countries as electric or thermal energy. Huge potential of geothermal heat provides prospects for further development of this kind of energy in many industries. This entails the necessity in theoretical studies.

One of the ways of geothermal energy production discussed in this paper is heating of liquid in a two-string well. Water is injected into the tubing-casing annulus. When moving downward, water is heated by the casing string walls due to convection and conduction. Heat from the earth depths is transferred to the surrounding rock. Average heat stream is 50 mW/m^2 varying from region to region. Heated water goes to the surface via the tubing string. The tubing string should be heat-insulated to minimize heat losses.

This paper presents mathematical model of water heating in a wellbore due to conductive transfer of heat from the surrounding rock. Various well depths, rock temperature gradients and rates of flow are discussed. Based on diagrams of outlet liquid temperature vs time, injection rate, and temperature gradient, application of this technology in a certain region has been analyzed.

This paper also presents temperature patterns near the wellbore at various time points, which can be used to analyze rock cooling due to conductive transfer of heat to the wellbore.

Conclusions have been drawn concerning the possibility of using this method to capture geothermal energy in various regions.

Key words: *heat transfer, geothermal gradient, neutral layer, heat conductivity, temperature pattern*