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Results of international research-to-practice conference "On New Paradigm of Petroleum Geology Development" held on 2-3 September, 2020, in Kazan

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Abstract. The paper discusses the results of the international research-to-practice conference "On New Paradigm of Petroleum Geology Development". Assessment of the oil and gas potential of the Russian Arctic zone and offshore territories has been made, the development priorities of oil and gas discoveries are offered. The paper presents a classification of hard-to-recover reserves in the Republic of Tatarstan. Focus is made on development of reserves in shale and domanik formations. The objectives of geologic and reservoir modeling are set forth. A critical analysis of the new paradigm of Russia's oil industry development offered by the Academy Fellow A.E. Kontorovich has been carried out. It is deemed advisable to consider the crystalline basement as a contributor to replenishment of oil, gas, and gas-oil fields by hydrocarbons and to include it into the research scope.

Key words: *oil reserves, oil resources, hard-to-recover reserves, unconventional reserves, shale oil, classification of reserves, development stages, crystalline basement, forming and re-forming of fields, replenishment of oil and gas reserves, Earth degassing*

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Morphological diversity of plankton and bituminous matter in the Upper Cretaceous Berezovian and Gankinskian formations in the south of West-Siberian basin

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Abstract. With depletion of major gas reservoirs in West Siberia, survey of the Upper Cretaceous (the over-Cenomanian) sediments known for gas shows, inflows, and gas discoveries has assumed an increasing importance. In the sediments dated to the Coniacian, the Santonian, and the Campanian that overlie the Cenomanian formations, uncharacteristic for West Siberia silica clay rocks occur, including gaize sediments in the Upper Santonian and calcareous shales dated to the Maastrichtian age. Taking into account the fact that depending on the present-day conditions the same-genesis formations can act either as reservoirs or as caprocks, a non-conventional comprehensive approach should be applied to study the lithological-mineralogical structure of the Upper Cretaceous formations. The paper presents new results of studies obtained in 2019, including an integrated characteristic of dispersed organic matter in the Upper Cretaceous rocks and the objective estimate of its oil-generating potential, as well as the economic assessment.

Key words: *core, silica clay, gaize, Upper Cretaceous, bituminous matter, radiolaria, bacillariophytes, foraminifera, coccolithophora, smectite, peach-stone, kaolinite, earth silicon*

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Assessment of reliability of petrophysical data during construction of unified petrophysical model

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Abstract. Extensive drilling activities within a field often bring about new understanding of reservoir geology following evaluation of new input data. This often results in revision of previously approved petrophysical model due to changes of the dependencies and, hence, the original oil and gas in place. Case studies of three fields with different input data set are presented to demonstrate how to quickly evaluate the impact of reservoir properties on hydrocarbon reserves in place and analyze the degree of variation of properties distribution in the geological space.

***Key words**: petrophysical parameter, criteria for assessment, testing, interpretation, geological model, Unified Petrophysical Model*

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The field experience of using carbon-oxygen (c/o) logging in oil wells of Tatarstan

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Abstract: This article presents the interpretation results of the geophysical methods for well research and field development monitoring of PJSC "Tatneft". According to the presented results, the structures of fields are characterized by different mining and geological conditions, multiphase saturation of reservoirs, etc. For this reason, the paper considers the interpretation results of the investigated method for various conditions. Based on the results of the work, the authors managed to increase the reliability of the current oil saturation assessment, which consequently made a positive contribution to the increase in oil reserves at the late stage of field development. On the basis of the results of the carbon-oxygen logging interpretation, authors present examples for determination of the WOC position, the material composition of rocks, and the type of saturation for layers of various mineralization.

The relevance of this article is not in doubt, since at the late stage of development, detailing the geological structure in order to search for missed oil deposits and effective technologies for development of oil reserves is an urgent and desired task. One of the geophysical methods that allows us to assess the current of oil saturation and build a lithological model of the reservoir is carbon-oxygen logging.

Key words: *carbon-oxygen logging (C / O logging), reservoir, oil saturation, interpretation, oil, wells, geophysical parameters.*

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Application of permeability cube construction method with account of reservoir heterogeneity in oil fields of the Volga-Ural Region

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Abstract. The paper reviews different methods for construction of permeability cube. It is demonstrated that comparison of two cubes constructed using different methods reveals substantial differences. This inconsistency stems from peculiarities of averaging (export) of well data to a three-dimensional grid. Comparison of two methods promoted the development of permeability cube construction method accounting for reservoir heterogeneity. The paper presents the results of application of permeability cube construction method with account of reservoir heterogeneity during three-dimensional geological and reservoir simulation modeling. It was found that application of the proposed permeability cube construction method on the three-dimensional geological and reservoir simulation model of the Pashian D1 reservoir in one of the fields of the Volga-Ural Region enabled determination of actual permeability variations. As opposed to previously used method, this method demonstrated a general increase in permeability by 6.1% and reduction of total number of less permeable interlayers.

***Key words**: three-dimensional model, permeability, porosity, Pashian horizon*

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Selection of a petroelastic model (a rock physics model) for the pokur formation in the Uvat project

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Abstract. The article describes the process of selecting a rock physics model for the oil-saturated PK1 reservoir of the pokur formation, based on the data of the core description and thin sections. The input parameters of the model based on the representation of the texture of the studied sediments are specified: the calculation of porosity, provided the contribution of laminated clay volume on the Thomas-Stieber pallet, and the actualization of the volumetric model of sediments. The results of rock physics modeling of P-wave, S-wave velocities and density by various theoretical models are analyzed, based on the likelihood of the standard deviation between the modeled and measured curves. The result of the rock physics modeling is demonstrated, which makes it possible to obtain a confident separation by lithology and saturation in the field of elastic parameters according to well logging data, which provides a basis for carrying out a synchronous inversion according to seismic data.

***Key words**: rock physics modeling, elastic parameters, theoretical model*

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On dependence of minimum horizontal stress on extent of pressure decline in Devonian terrigenous reservoirs of Romashkinskoye field Minnibaevskaya area

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Abstract. For practical application of geomechanical tools in PJSC TATNEFT, methods to calculate the stress state of rocks taking into account regional features are required. Commercial development of terrigenous deposits of the Romashkinskoye field has resulted in reservoir pressure depletion and the associated change in effective stresses. The minimum horizontal stress can be determined through hydrofrac data or calculated using values of vertical rock stress, formation pressure, and Poisson's ratio of producing rocks. The paper discusses analysis of pressure behavior during hydraulic fracturing to determine the current minimum horizontal stress. Procedure of calculating of vertical stress and the original reservoir pressure to obtain the values of initial minimum stresses in the fracked intervals of wells under study is presented. Difference between the initial and the current stress states in the target intervals of hydraulic fracturing in the Kynovskian and the Pashiyan horizons was determined. By the example of the Minnibaevskaya area of the Romashkinskoye field, change in the minimum horizontal stress vs. decline of reservoir pressure in the Devonian terrigenous productive formations was determined.

Key words: *minimum horizontal stress, matrix stress ratio, fracture analysis, G-function, horizontal stress variation, formation depletion, stress path, Biot coefficient.*

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Impact of wettability recovery on electrical properties of the Lower Vendian carbonate rocks in East Siberia

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Abstract. Surface characteristics of rocks largely influences the estimates of oil saturation factor, displacement efficiency, and relative permeabilities. In in-situ systems, the wettability can change from hydrophilic to hydrophobic depending on the interaction between fluid (brine and oil) and pore surface. The paper shows the influence of extraction and the following stages of samples' preparation for wettability recovery on electrical properties of carbonate rocks. Following exposure of samples to pressure and temperature, the pore space surface tends to be more hydrophobic, resistivity increases, and petrophysical relations between resistivity index and water saturation factor change.

Key words: *reservoir, wettability, porosity, water saturation, oil saturation, resistivity, formation resistivity factor, resistivity index, petrophysical equations*

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Optimization of existing development system under conditions of limited wells in a multi-reservoir field

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Abstract. The world practice has shown that the development of shelf multi-reservoir fields is associated with challenges when forming a development system due to reservoir heterogeneity, lateral mismatch of productive reservoirs, as well as technological challenges related to well design and construction.

Wells on an offshore platform can be both multi-lateral vertical with dual-completions and targeted horizontal extended-reach wells (ERW). The operation of such wells imposes obligations on a subsoil user to perform regular PLT in order to organize well interventions (WI), to use innovative technologies for active inflow control, which, in turn, is a highly effective way to control water inflows from highly permeable intervals and gas inflows from gas caps.

The production well pattern is formed with the utmost precision and detail. When drilling from the shore or from a platform, there is a risk of wellbore crossing, therefore, spatial control over the well trajectories is carried out while drilling.

In order to maintain reservoir pressure (RPM), edge or peripheral water flooding is often used. In rare cases, barrier flooding is used, in particular, agent injection into the top of a structure, i.e. a gas cap.

The number of drilling slots when drilling from a platform is usually limited, therefore, in order to increase oil recovery, special attention is paid to identifying areas with low efficiency of reservoir pressure maintenance and to developing measures on conformance control and isolation of water-flooded intervals.

The paper describes the existing system for the development of a multi-reservoir field X and an analysis of the operation of development wells in order to identify problem areas. The effect of injection wells on offset production wells was analyzed and the possibility of auto-hydraulic fractures was assessed using the existing injection wells. Recommendations were given to increase oil recovery by optimizing the reservoir pressure maintenance system, to drill new wells, including multilaterals, in the conditions of the continental shelf from an offshore platform with a limited number of wellheads (slots) and infrastructure limitations related to compressor and separator capacity.

Key words: *water flooding optimization, dual completions, inflow control system, flow simulation model, water flooding system performance, auto hydraulic fracturing, multilateral wells, multi-reservoir field, gas caps, drilling slots, offshore platform*

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Influence of link injection wells on the efficiency of the Tyumen formation development system at the fields of Rosneft oil company

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Abstract. The tyumen formation is a low-permeability object with a complex geology. The reaction of production wells to the RPM system in such conditions is less pronounced than in traditional reservoirs. In connection, the question often arises about the efficiency of drilling additional injection wells in an in-line development system (link wells).

As part of the work, a sector of hydrodynamic model was created. Model calculations were made for performed to assess the effect of drilling nodal injection wells. In addition, without those stagnant zones are formed, the reserves of which are not developed.

A method for assessing the feasibility of drilling nodal directional injection wells using a hydrodynamic model is proposed.

Key words: *Jurassic sediments, Tyumen Formation, hard-to-recover oil reserves, low-permeability reservoir, horizontal wells with multi-stage hydraulic fracturing (horizontal wells with multistage hydraulic fracturing), the efficiency of the RPM system, link wells, assessing the effectiveness of drilling link wells, the effectiveness of the development system, Rosneft Oil Company*

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Simulation of the process of surfactant-polymer flooding in high-permeable pore-type reservoirs containing high-viscosity oil

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Abstract. The article presents the results of hydrodynamic modeling of various options for using a surfactant-polymer composition to increase oil recovery in highly permeable pore-type reservoirs containing high-viscosity oil. The substantiation of the use of the hydrodynamic modeling tool is given, a brief description of the research object, the research problem is given. Multivariate calculations of the injection of a surfactant-polymer system with a change in the volume and concentration of the reagent have been carried out. The dependences of the increase in oil production on the volume of reagent injection have been obtained. The change in the type of the dependence on the injection volume is shown.

Key words: *surfactant-polymer flooding, high viscosity oil, high permeability reservoir, porous reservoir, hydrodynamic modeling*

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Effect of mud filtrate invasion in cavernous reservoirs of B5 horizon in the Danilovsky field on NMR results

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Abstract. The paper presents the results of integrated cavernous core sample studies with imitation of rock saturation typical for NMR studies area using a specially designed structure that allows fluid retention in outer caverns during NMR measurements. GeoSpec DRX-HF NMR-relaxometer has been selected for the studies whose resonant frequency is the same as of a downhole logging tool. Standard cutoffs for irreducible water and caverns in carbonate reservoirs applied for NMR interpretation are 90 ms and 750 ms, respectively. Their application often results in incorrect values of residual oil saturation and vuggy porosity. The paper discusses a common technique to define a cutoff that differentiates irreducible water from free water, as well as offers an efficient method to define cavern cutoffs by combination of laboratory NMR studies and X-ray computer tomography.

Key words: *total porosity according to NMR studies, cavernous porosity, well logging, X-ray computer tomography, nuclear magnetic logging (NML), nuclear magnetic resonance (NMR), specialized structure to retain fluid in caverns, NMR T2 distribution, bulk relaxation, surface relaxation, diffusional relaxation, irreducible water cutoff value, cavern cutoff value, fixed cutoff value method, spectral method, hydrogen content, permeability and porosity, residual water saturation, formation pay zone, extraction, desalting, bitumen, process liquids*

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Technologies developed by PJSC TATNEFT for breaking of stable water-in-oil emulsion stabilized by solids and bottom sediments

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Abstract: During development of hydrocarbon reserves, stable aggregative systems – water-in-oil emulsions and bottom sediments – form and accumulate in flow tanks at oil production units impairing, thus, stock tank oil quality. The common practice of disposal of these systems using outsource services results in loss of valuable hydrocarbons.

Specialists of TatNIPIneft Institute have developed effective technologies to break bottom sediments and stable water-in-oil emulsions stabilized by solid particles in flow tanks.

The technologies of thermochemical and acid treatment aim at breaking of stable water-in-oil emulsions, the technology of treatment using diluent is effective for breaking of bottom sediments. The technologies were successfully tested at the Company's facilities.

Commercialization of these technologies will allow the Company to cut down expenses related to disposal services; also, the volume of additional on-spec oil will be increased.

Key words: *stable water-in-oil emulsion, bottom sediments, blending, treatment technologies*

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Hydrogen sulphide stripping technologies used at TATNEFT's assets

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Abstract. Need for H_2S stripping at field facilities is dictated by the requirements of GOST R 51858-2002 standard which limit H_2S content in sales oil by 100 and 20 ppm. This is a pressing challenge for TATNEFT Company since in previous years it transferred over 16 mln tonnes of oil per year to PJSC Transneft with H_2S concentration over the acceptable limits. To select the best technologies for H_2S removal from oil, a differential approach has been used to consider operating conditions at all field facilities. An optimum H_2S stripping method has been selected for each facility with due regard for its effective application environment. Adjustment and optimization of oil treatment plant operational parameters provided the required oil quality at minimal costs.

H_2S stripping method has been used at seven facilities. Hot vacuum oil separation technology has been used at Bavlyneft's oil treatment facility, and technology of direct H_2S oxidation with ambient oxygen in the presence of ammonia solution with phthalocyanine catalyst has been used at Kutema sour crude oil treatment facility of NGDU Nurlatneft. H_2S scavengers are used for treating oil from Andreevka and Kamenka sour crude oil treatment facilities and for advanced treatment of oil after vacuum separation at Bavlyneft's oil treatment unit. Implementation of these technologies at TATNEFT's assets has allowed to reduce H_2S content in oil that is transferred to the central metering station to less than 100 ppm.

Key words: *hydrogen sulphide, oxygen, vacuum, stripping column, chemicals, hydrocarbon gas, H_2S scavenger*

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Technologies of water discharge at well pads in the fields of PJSC TATNEFT

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Abstract: An efficient way to reduce costs associated with production of high water cut oil is preliminary water discharge on-site at multi-well pads followed by water injection into injection wells at the same well site. This reduces consumption of energy required to pump liquid through oil gathering system and inject water in reservoir pressure maintenance system, decreases fresh and formation water use for reservoir pressure maintenance, reduces liquid loading on field gathering and transportation facilities, and minimizes adverse effects resulting from commingled production from different production zones.

Tatneft's engineers have developed and currently implement three configurations of water discharge units. The choice between these is dictated by the amount and properties of produced water, injection water quality requirements, and availability of infrastructure facilities.

The first configuration consists of an inclined pipe with certain diameter and length, where free water is separated from crude oil and treated due to autoflotation process. Oil phase and gas return back to oil gathering system, while treated water is directed to reservoir pressure maintenance system. Currently in operation are more than 20 units.

Another configuration comprises a slug catcher for removal of associated petroleum gas, two-section settling vessel for water separation and further settling, and a coalescing filter to improve the performance of water treatment process. Currently in operation is 1 unit.

The third configuration consists of a casing string with blind bottom end, wellhead fittings used to attach a pipe piece intended to maintain the oil level in the casing string, and a tubing string intended to divert treated water from the bottom portion of the casing string to pumping unit. By now, 5 units have been installed at Tatneft's fields.

Key words: *high water cut production stream, water discharge at the well pad, unit configurations*

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System aspects of combining technologies of transportation and preparation of wells products

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Abstract. Combining the technological operations of oil, gas and water treatment is an extremely fruitful method for improving the efficiency of oilfield processes. This universal approach to improving the technology of collecting, transporting and preparing well products allows you to use the internal resources of well products. It is particularly effective to combine operations for transportation and destruction of emulsions in field pipelines, which allows you to use reservoir pressure and temperature to reduce operating costs.

Combining technological operations that implement heterogeneous physical phenomena creates a number of fundamentally new and complex problems. The transition to complex processes implies the need to justify their composition and structure, which are implemented in the development of a specific oil production facility. Unlike simple homogeneous processes, combining requires a systemic approach and is limited by the possibilities of physical phenomena that are involved in each project. Along with the choice of possible elements of complex technological processes, it is necessary to coordinate the result of their interaction.

This is the most complex and non-formalizable task that requires knowledge of the specific features of the subject area and experimental research data that cannot be obtained using General methods of theoretical analysis. Coordination of mechanisms of simple physical phenomena as part of a complex process is a resource for energy saving in the destruction of commercial emulsions.

***Key words**: collection of well products, oil emulsions, oil preparation, destruction of emulsions, combined technologies, interrelation of physical phenomena*

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Oxidation-catalytic process for on-site removal of H_2S and low molecular weight mercaptans from oil

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Abstract. The paper presents oxidation-catalytic process for on-site removal of H_2S and low molecular weight C_1-C_2 mercaptans from heavy oil. The paper also discusses dependence of H_2S and ethyl mercaptan oxidation reaction rate in case of their joint presence in oil on temperature and catalyst consumption.

Key words: *hydrogen sulphide, mercaptans, oxidation, oil treatment, cobalt phthalocyanine*