Simulating Geological Features of Torrential Deposits

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***Abstract*—Nowadays the main oil recovery is done in Western Siberia. The biggest deposits are at the final stage of the recovery. The oil recovery increase can be achieved by heavy oil recovery and correct development and supplementary development of medium and small deposits. Torrential deposit is one of the most perspective from the point of view of oil recovery increase by correct supplementary development. The purpose of the article is to study the efficiency of constructing geological models of torrential deposits on the sites which will further help create filtration models. Simulating is the process of creating a geological model of a certain deposit according to known parameters. Geological model is a necessary part of modern designing of production facility development (deposits reach in hydrocarbons) necessary for correct composition of a mining method. 2-D and 3-D filtration models, results of quiescent parameters convergence estimation witness high models accuracy, that allows to know actual data of development before time.**

Key words—torrential deposits; geological model; lithology cube; IRAP RMS; 3D geological model

I. INTRODUCTION

The ground for creating digital 3-D dimensional filtration models are digital 3-D geological models done using the software "Irap RMS" of the company ROXAR. Filtration models are created in the software application "Tempest More" of the company ROXAR with the use of software solutions "SUFR X+" and "EUCLID". [1]

Implementation of digital 3-D geological models of torrential deposits on the sites AC13+AC2, BC5+BC6+BC8+BC9+BC10+BC11, Ach1+Ach21+Ach22+Ach3, UC0 and UC11 is done basing on the G&G data of 01.01.2012. Models are created in the software system IRAP RMS of company ROXAR.

The previous 3-D digital geological models were done in 2010 year basing on the G&G data of 01.01.2010 within the framework of "Constructing digital geological model, estimating of volumes in-place oil and dissolved gas in torrential deposits". The models were created in the software program Petrel of company Schlumberger, then converted into IRAP RMS. [1]

During the period from creating previous 3D geological models of transitional zones, further data were taken into account:

- drilling results of two exploration wells: 57P in the western part and 118P in the eastern part of the Main Oil pipeline, in the junction with North-Torrential Main Oil pipeline. Well 57P tapped seams of AC group; well 118P discovered the whole section of the deposit;

- drilling results of 22 development wells, 15 wells of which are in the north-east part of the Main Oil pipeline, the rest are the infill wells in the central part of the deposit [2];

- gyroscopic inclinometer measuring results in 9 wells of the first drilling - № 279, 1547, 1642, 1703, 1858, 1897, 1951, 1991, 2054 [2].

II. CHOICE OF LIQUID STRATA PHYSICAL MODEL

Productive strata collector of objects AC1-2, BC5, BC6, BC8, BC9, BC10, BC11, Ach, UC0, UC1 is composed of sandy-aleuritic interlayers. Fracturing and cavern porousness are absent. Reservoir type is terrigenous and pore [2].

Strata do not contain gas caps. Development is done under pressure exceeding saturation pressure. During the forecast object development water-alternation and dissolvent gas drive are not planned. As hydrocarbon models it is possible to deal with the simplified model of 3-D two-phase filtration of black oil hydrocarbons.

Filtration process can be considered isothermal due to slight temperature variations.

Filtration hydrodynamic model is based on numerical solution of the system of equation describing 3-dimensional filtering of oil and water in the porous medium [3]:

- Mass balance equation of components in phases;
- Equation in motion in phases;
- Equation of state;
- Initial and boundary conditions of filtration;
- Boundary conditions.

The filtration model takes into account:

- Gravity forces;
- Strata coercibility and fluids saturating it;
- Hydrocarbon components phase transformations;
- Strata heterogeneity by collecting properties.

Research findings of surface and subsurface samples show that oil characteristics within the objects AC_{1-2}, BC_5, BC_6, BC_8, BC_9, BC_{10}, BC_{11}, Ach, UC_0, UC_1 change insignificantly, that allows specifying parameter mean values in the filtration models of objects. Water and oil are weakly compressible fluids of constant viscosity.

Within the hydrocarbon models black oil for describing PVT of the formation fluid properties it is enough to specify the fluids properties at some pressure and temperature, where original reservoir pressure and temperature are chosen in models.[3]

III. Grounding of Filtration Models Grid Dimension

Grounding of grid dimensions for filtration models includes the following requirements [4]:

- the number of nodes in models should allow multiple calculations within reasonable time;
- geological inhomogenuity of the strata in the filtration model should be kept to the maximum;
- interwell space in the filtration model should include not less than three nodes.

After choosing node optimal dimensions permeability and porosity are averaged. Parameters transfer and averaging from the detailed geologic grid onto the filtration was done with the help of the following algorithms:

Sandiness of every node was calculated by averaging with weighing to geometric scope. The effective volume is determined as the product of the node geometric volume by its sandiness [5].

Formation porosity factor is determined by averaging based on weighing to effective volume, and this averaging is done within collectors. The pore volume is determined as the product of the effective volume by porosity.

Saturation parameter is determined by weighing parameter to porosity volume.

Absolute permeability is calculated by the inclined tensor method, based on maintaining the balance of the single-phase filtration flow in three main directions in the enlarged node and nodes of the geological model, within the enlarged nodes. As a result for every node block of the enlarged structure three components of the permeability are calculated (kx, ky, kz). Tensor method of permeability averaging allows preserving geometry of flows.

IV. Grounding of Initial and Boundary Conditions

Initial distribution of fluids and strata pressure was set with mixed initiation in the software application Tempest. This method determines equilibrium rates of fluid contacts and rates of strata pressure at a certain depth and oil saturation cube received as the result of geological modelling. In this case the initial strata pressure is calculated from the conditions of capillary-gravitational equilibrium with the account of fluids distribution determined by the cube of original oil saturation.

At the border of filtration area excepting deposits shielding areas water-driven limit of Carter-Tracy was set with the pressure corresponding to the initial strata pressure in borderline nodes [5]. Filtration properties in the water-driven area are set similar to collecting properties of edge zones where an aquifer was connected to. Upper and lower contacts of zones are considered impermeable zones. As boundary conditions at recovery wells historical debits of fluids were set, and at discharge wells –rates of intake.

V. Frame Parameters of Torrential Deposits

Structural surface at upper and lower edge of a collector was determined by method of geological constructing a horizon by adding the isochores from the above surface along the stratigraphic strata roof and outcome data of the well findings (well log interpretation results), the quality of the construction was determined by back interpolation of layer intersection values and comparing them with structural marking. When constructing the surface by adding isochores from the above surface gross thickness of all the wells was taken into account [6].

Stratification dimension for the objects was set as similar and corresponds to the minimal net reservoir thickness, determined on logging during well survey data interpretation (PWL) and equals to 0.4 m. Stratification model is considered proportional; choosing this model we meant a compensated character of sedimentation deposits. Horizontal grid dimension for modeling was 50x50 m, according to the requirements “Regulations on creation continuously functioning geologic-technological models of oil and gas deposits” (RD 153-39.0-047-00), and calculating the possibility of describing inter well space between 5-6 grid nodes. During volume grids formation XY regular grid was chosen.

TABLE I. FRAME PARAMETERS OF TORRENTIAL DEPOSITS

deposit	Strata number	Strata thickness, m	Gross thickness variation limits, m	Number of nodes
AC_1^3	30	11	5-30	6228300
AC_2	60	22.5	3-39	12456600
BC_5	60	21	2-35	7817100
BC_6	120	32	3-46	15634200
BC_8	60	23	4-34	7817100
BC_9	50	17	2-30	6512800
BC_{10}	80	37	1-48	10422800
BC_{11}	50	16	1-29	3908550
Ach_1	90	45.4	18.5-66.4	7955810
Ach_2^1	60	22	1-43	5216976
Ach_2^2	60	23.5	1-51	4791328
Ach_3	50	9	0-55.5	2132605
UC_0	45	10	0-21	36918636
UC_1^1	49	10.5	0-23	4421250

Structural framework was created for every stratum separately. Node sizes for every stratum were: 50x50. Frame parameters are in Table I.

VI. INITIAL AND BOUNDARY CONDITIONS GROUNDING

As initial parameters for constructing the structural surface along the stratigraphic formation top AC13 strata surface was constructed on seismic grid by reflecting horizon "M", and stratigraphic tagging by drilled holes [7]. Structural surfaces along the top and bottom of the collector below embedded strata were created by the method of geological constructing a horizon by adding the isochores from the above surface along the stratigraphic strata roof and outcome data of the well findings (well log interpretation results) [6]. As initial data for constructing structural surface along the stratigraphic formation tops BC5, BC6, BC8, BC9, BC10 and BC11 Achimov sequence, UC0 and UC11 were used correspondingly structural surface constructed basing on seismic grids by reflecting horizons BV5, BV6, BV8, BV9, OG B, JV1 and stratigraphic marking according to the drilled wells.

During 3-D modelling strata collector distribution 2 lythotypes were taken into account – sand rock and clay (collector-noncollector) [8]. These lythotypes position within the deposits frame was modelled by Sequential Indicator Simulation (Fig. 1).

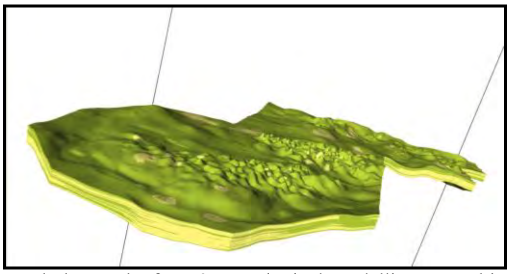

Fig. 1. Lythology cube from 3D Geological Modelling. AC Object

During lithology cube construction geological statistic section comparison was conducted (GSS) by well data and received collector distribution in the cube (Fig. 2) [9], that allowed controlling collector distribution through the section and trace the correctness of their distribution in the plane.

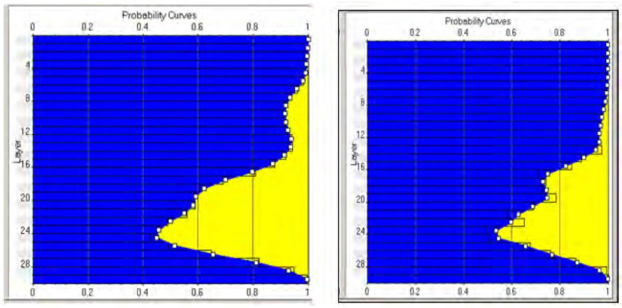

Fig. 2. GSS of the object AC along the lithology cube nodes (left) and according to well data (right)

During modeling cubes of strata parameters geophysical dependencies and boundary values were used, taken in the report on reserves calculation on 01.01.2011. Taking into account that all layers have identical dependencies according to Factor of Porousness, Permeability Coefficient, Compensated Neutrons, and parameters modelling for the strata were similar. Critical data of FP, PC and Irreducible water saturation were driven from the basic report.

TABLE II. LOWER CUT OFF ACCEPTED VALUES IN THE TORRENTIAL PRODUCTIVE STRATA DEPOSITS

Stratum	Boundary parameter value				
	C watering, unit fraction.	*Coefficient porosity efficiency, unit fraction*	*Coefficient of permeability, unit fraction*	*Cporousness,* 10^{-3} *mkm*^{2}	α_{ps}
AC_1^3	0.745	0.047	0.17	0.68	0.32
AC_2	0.7	0.05	0.162	1.13	0.345
BC_5	0.655	0.056	0.165	1.17	0.34
BC_6	0.66	0.06	0.163	1.4	0.35
BC_8	0.67	0.055	0.15	0.63	0.34
$BC_{9\text{-}10\text{-}11}$	0.73	0.039	0.147	0.25	0.38
Ach	0.766	0.032	0.141	0.15	0.4
UC_0	0.766	0.032	0.141	0.15	0.4
UC_1^1	0.73	0.033	0.122	0.23	0.4

Porosity cube construction was done on the basis of lythological models of productive strata with an interpolation device "Petrophysical modeling". This method allows specifying conditions of the cube data fit to WLIR input results, as well as near-normal interpolation parameterization.

Lower cutoff accepted values which were determined both by quantitative and qualitative parameters with application of the whole complex of geophysical methods are shown in Table II [6].

Porosity cube construction was done on lythological models of the deposit productive strata with the interpolation device "Petrophysical modeling". This method allows setting the condition of cube data correspondence to the input data WLIR, and receiving near-normal interpolation parameter distribution.

Productive strata porosity coefficient was determined according to the dependencies given in Table III [2].

TABLE III. ACCEPTED DEPENDENCIES FOR CALCULATING COLLECTOR POROUSNESS COEFFICIENT IN THE TORRENTIAL PRODUCTIVE STRATA DEPOSITS

Stratum	**Dependence for calculating porosity coefficient**
AC_1^3	C porosity = $25.3\ \alpha_{ps}^{0.35}$
AC_2	C porosity = $24.5\ \alpha_{ps}^{0.39}$
BC_5	C porosity = $21.8\ \alpha_{ps}^{0.257}$
BC_6	C porosity = $23.3\ \alpha_{ps}^{0.34}$
BC_8	C porosity = $21.4\ \alpha_{ps}^{0.34}$
$BC_{9\text{-}10\text{-}11}$	C porosity = $21.5\ \alpha_{ps}^{0.39}$
Achimov strata and UC_0	C porosity = $18.387\ \alpha_{ps}^{0.2896}$
UC_1^1	C porosity = $18.383\ \alpha_{ps}^{0.4303}$

Calculation of the permeability cube of stratum is done on the basis of constructed porosity cubes with geophysical dependence C porosity = f (C porosity efficiency) for every simulated strata, accepted at calculating deposits of the torrential deposit and given in Table IV [2].

At the final stage of permeability cube construction survey according to well information with setting weight (interpolation radius was the same as at calculating porosity cube) [10].

Estimation algorithm of stratum saturation behaviour is determined by comparing well log interpretation results with data of single-valued selective flow tests and consequent critical values determination ρ_{flowul}, typical of the studied collector type.

Boundary "oil-water" location was determined by the ultimate value ρ_{flowul}.

Local cube reconfiguration of oil saturation was done by interpolation of mean values on the well information grid, with well radius range 600, with trend Kn. Kn cubes in current geological models were received with interpolation method. As monitoring Kn maps data were compared received from this cubes with the account of WLIR in order to avoid Kn increased values on the outer contour.

TABLE IV. ACCEPTED DEPENDENCIES FOR CALCULATING COLLECTORS PERMEABILITY IN TORRENTIAL PRODUCTIVE LAYERS DEPOSITS

Stratum	**Dependence for calculating permeability**
AC_1^3	Cper = 0.0737 $e^{47.15\ \text{Productivity coeff}}$ where Productivity coeff = 1.69 Cper – 0.24
AC_2	Cper = 0.136 $e^{42.28\ \text{Productivity coeff}}$ where Productivity coeff = 1.78 Cper – 0.206
BC_5	Cper = 0.075 $e^{49.2\ \text{Productivity coeff}}$ where Productivity coeff = 1.7 Cper – 0.225
BC_6	Cper = 0.062 $e^{51.9\ \text{Productivity coeff}}$ where Productivity coeff = 1.72 Cper – 0.22
BC_8	Cper = 0.024 $e^{59.3\ \text{Productivity coeff}}$ where Productivity coeff = 1.44 Cper – 0.161
$BC_{9\text{-}10\text{-}11}$	Cper = 0.028 $e^{56.14\ \text{Productivity coeff}}$ where Productivity coeff = 1.765 Cper – 0.22
Achimov strata and UC_0	Cper = 0.0314$e^{48.961\ \text{Productivity coeff}}$ where Productivity coeff = 1.9 Cper – 0.236
UC_1^1	Cper = 0.04 $e^{52.6\ \text{Productivity coeff}}$ where Productivity coeff = 1.58 Cper – 0.159

According to the geological 3D-models updating 2D-dimension parameter maps are uploaded which are shown in corresponding applications.

After constructing the enumerated cubes volumes of hydrocarbon deposits were estimated. Calculated parameters comparison of OOIP approved by State Committee of Mineral Reserves (SCMR) according to the data of 1.01.2011 and updated model of 1.01.2012 are introduced by objects in Table V [6].

TABLE V. COMPARISON OF VOLUMETRIC DATA AND OOIP DETERMINED BY SCMR ON 1.01.2011 AND UPDATED 3D MODEL ON 01.01.2012 OF AC13 TORRENTIAL STRATA DEPOSIT

parameter		**deviation by models 2D and 3D, %**
Strata deposits. Thousands of tons		0.5
Oil saturated rock volume, thousands of tons^3		8.1
Coefficients. Unit fractions	Effective porosity	0.5
	Oil saturation	-8.9
	Recalculated	0
Oil density. g/sm^3		0

As comparative tables show OOIP approved by SCMR by the state on 1.01.2011 and received by updating digital 3D geological models on 01.01.2012 differ not more than by 5% that corresponds to the requirements of detail documentation for the construction of on-going geological engineering models of oil and gas deposits.

Geological models constructed according to the objects of development were based on construction of filtration models for torrential deposits.

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