

Method and Results of Geological Exploration on the Tuimetkinsky, Ulanovsky and Varvarian Heavy Oil Deposits of Sheshmian Horizon for the Purpose of Pre-commercial Exploitation

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Abstract. The paper considers the method of geological exploration on heavy oil deposits of Sheshmian horizon used in PJSC Tatneft, and the requirements that must be fulfilled in order to obtain conditioning material (geophysical well logging, exploration well testing, analysis of core material and reservoir fluid, etc.). As an example, the results of geological exploration on Tuimetkinsky, Ulanovsky and Varvarian deposits of heavy oil for the purpose of pre-commercial exploitation are considered. The obtained results allow to recalculate reserves of heavy oil deposits, clarify the dynamic viscosity of hydrocarbons and make adjustments to the state balance of oil reserves.

Keywords: Sheshmian horizon, method of geological exploration, exploration wells, core sampling, an optimal geophysical well logging complex, well testing, viscosity

DOI: 10.18599/grs.18.1.2

For citation: Khisamov R.S., Saakyan M.I., Gatiyatullin R.N., Sukhov K.A., Akhmetshin A.Z., Yarullin R.N. Method and Results of Geological Exploration on the Tuimetkinsky, Ulanovsky and Varvarian Heavy Oil Deposits of Sheshmian Horizon for the Purpose of Pre-commercial Exploitation. *Georesursy* [Georesources]. 2016. V. 18. No. 1. Pp. 8-12. DOI: 10.18599/grs.18.1.2

Currently in PJSC Tatneft a large-scale project is being implemented, providing commissioning to the industrial development of heavy oil resources. The project is divided into four stages, for its implementation it is necessary to carry out works for the preparation of the resource base for development.

On the 3rd stage in the framework of this Project, works are performed on the geological additional study and preparation for commissioning to the industrial development of the Lower-Karmalsky, Karmalinsky, Upper-Karmalsky, Tuymetkinsky, Mikhaylovsky 1, Polyansky, Ulanovsky, North-Karmalinsky, Olkhovsko-South-Chumachkinsky, Chumachkinsky and Melnichny deposits of heavy oil. The main objectives of the work are as follows: clarification of the geological structure and reserves of heavy oil deposits, obtaining geological and technological parameters used in the preparation of development plan of heavy oil deposits, transferring pre-explored reserves of C₂ category in reserves of industrial C₁ category, followed by their presentation to the State Commission on Reserves.

Obtained geological and geophysical data will allow us to recalculate reserves of additionally explored heavy oil deposits, clarify dynamic viscosity of hydrocarbons and make appropriate adjustments to the state balance of oil reserves of the Ministry of Natural Resources of the Russian Federation.

1. Methods of exploration works

Based on the tasks and geological exploration, heavy oil deposits included in the third stage of the Project, are conventionally divided into 3 groups:

1. Explored and prospected with reserves of categories C₁ (Lower-Karmalsky, Karmalinsky, Tuymetkinsky) and C₂ (Upper-Karmalsky), for which it is necessary to clarify

the meaning of hydrocarbon dynamic viscosity at reservoir conditions;

2. Prospected with reserves of C₂ category (Mikhaylovsky, Polyansky, Ulanovsky);

3. Explored with reserves of C₁ category (North-Karmalsku, Olkhovsko-South-Chumachkinsky, Chumachkinsky, Melnichny).

In determining the drilling points on 1 group of heavy oil deposits, a task for specifying HC viscosity at reservoir conditions is defining. For this purpose we test wells in the natural regime and using steam stimulation to the productive formation. Test wells are placed in arched parts of uplifts. In this case the projected thickness of productive formations vary from 6 to 12 m.

The main task of performing exploration works on deposits of the 2nd group is to clarify the reserves of heavy oil and their transition into industrial C₁ category. Design exploration wells on Mikhaylovsky, Polyansky, Ulanovsky deposits, where tests suppose to be conducted on the inflow of hydrocarbons to oil reservoir by means of steam stimulation, are laid in the arched parts of uplifts. The choice of placing design wells on deposits of the 3rd group is caused, first of all, by the task to clarify recoverable reserves of heavy oil.

The wells are located relatively evenly over the area of uplifts on the top of sheshmian horizon in dome, interdome and winged parts. Determination of calculation parameters for the productive clastic Ufimian reservoirs, as well as the reliability of cap rocks is based on laboratory studies of the reservoir properties and oil saturation of core samples. Core recovery from the productive formation must be at least 80%.¹⁾

¹⁾ Temporary position on the stages and phases of exploration works for oil and gas. Appendix 1 to the order of the Ministry of Natural Resources of February 7, 2001 No.126.

2. Requirements to obtain conditioned material

Based on the above requirements, core sampling in exploration wells is carried out in the interval from the top of the upper baytuganskian pack (“upper spirifer limestone”) with the penetration of sand pack of sheshmian horizon to the full thickness and deepening into the underlying sand-clay pack of at least 10 m.

Two sets of logs are provided in the wells:

- Optimal at a scale of 1: 200 - GK, NGK, GGKp, IR, BK, PS, KS, BKZ, DS, KNK, resistivity survey;
- To determine the cementing quality of conductor and casing at a scale 1: 200 – AKTs, GGG, SGDT.

Optimal set is performed in the interval from top of the upper baytuganskian pack (“upper spirifer limestone”) to the bottom of the well. The purpose of conducting geophysical survey is the allocation in the well section of conditioned oil saturated intervals and interpretation of calculation parameters. When calculating hydrocarbon reserves it is obligatory to align the results of well logging with laboratory tests for obtaining petrophysical relations.

The thickness of oil reservoirs and testing intervals are determined on the basis of reserves calculation – net pay thickness maps, structural maps by the top of sheshmian horizon, geological profiles.

Exploration well testing is performed in accordance with the guidance document²⁾. Sampling intervals are specified by the actual data of the core documentation and the optimal set of well logging at a scale 1:200.

Hydrodynamic surveys in wells are provided for intervals of testing wells.

They include recording of level recovery curve, temperature and reservoir pressure measurements, wellhead pressure, determining the location and velocity of the formation fluid influx, determining flow rates obtained during the tests of formation fluids.

On the test object for the inflow of heavy oil hydrodynamic studies first conducted in a natural regime, and then after steam stimulation to the oil reservoir.

During exploration works laboratory tests are performed of the core, selected from wells. Results of analyzes are crucial in determining oil-saturated intervals and calculation parameters of layers in accordance with conditional values. They also allow us to estimate reservoir properties (porosity and permeability) of reservoir rocks, oil-containing rocks and cap rocks for heavy oil deposits.

In accordance with established practice, in the interval of productive formation determined according to core sampling data and conclusions of optimal log set, core sampling to determine porosity and weight oil saturation is carried out every 0.2 m of the section, and to determine carbonate content, permeability and mineralogical density of the rock matrix – every 0.5 m.

In addition, the study of granulometric size composition of the oil reservoir is provided on the basis of studying each penetrated oil-saturated zones in wells.

In other coring intervals, a technique for sampling to carry out analysis is as follows:

- The determination of open porosity and permeability coefficient every 1 m;
- The determination of the weight oil saturation every 1 m;
- The determination of carbonate content every 1 m in the interval of cap rocks (“lingula clay”) and sand pack of sheshmian horizon.

The study of hydrocarbon composition and properties is to be implemented on a single unified program. It includes the determination of composition and properties of dry oil, density, viscosity, dynamic and kinematic at different temperatures, group, fraction, elemental composition, acid number, coking, pour point, etc. A quantitative assessment on the content of associated micro-components and sulfur is required.

If necessary, with the entry to the poorly studied uplift groups (deposits), drilling of exploratory wells with continuous core sampling around the trunk is planned in order to study the whole section and, in particular, dense differences and clay rocks, which are regional cap rocks overlying reservoirs. The study of cap rocks is carried out by a special program and methodology.

In addition, the study of physical and chemical composition of reservoir waters is provided.

3. The results of exploration works

As an example let us consider the results of exploration work on Tuymetkinsky, Ulanovsky and Varvarinkinsky deposits of heavy oil of sheshmian horizon in order to prepare them for commercial development.

Total 5 exploration wells were drilled on Tuymetkinsky deposit in 2014, one of which is a testing well. Total penetration of wells was 792.3 m, including 242.8 m of coring. The average core recovery from the sand pack was 86%. On Ulanovsky deposit 5 exploration wells were drilled in 2014, one of which is a testing well. Total penetration of wells was 912.7 m, including 394.7 m of coring. The average core recovery from the sand pack was 91.4%.

The value of core sampling interval in wells changed depending on the thickness of penetrated sand pack of sheshmian horizon, which ranged from 13.5 m to 33.4 m.

Since in the course of works gas shows, including intense, were observed on a number of deposits, the optimal set of well logs at a scale of 1:200 was supplemented by GGKp method allowing in combination with other methods to allocate gas-saturated and gas-containing rocks in the section.

Based on GGKp data gas and gas-oil-saturated (‘gas + oil’) sandstone intervals were identified in the upper part of heavy oil deposits and Tuymetkinsky and Ulanovsky uplifts. Thickness of gas-saturated intervals according to logging data varies from a few meters up to 18.4 meters (Ulanovsky uplift).

The average coefficient of verifiability of design effective oil-gas-saturated layers according to logging data for Tuymetkinsky and Ulanovsky deposits is 1.63 and 1.51 respectively.

Testing of penetrated productive formations is made in accordance with the work program at both deposits. Testing objects in wells were selected on the basis of core documentation, including photographs and logging results. HC inflows of varying water content and intensity were obtained as a result of the test wells in the natural regime and after steam stimulation on productive formations in well No. 5Tm and 2U1 (Table 1).

²⁾ RD-39-0147035-293-89R. Manual for testing bitumen wells. Bugulma: MNTK; BKO VNII. 1989. 40 p.

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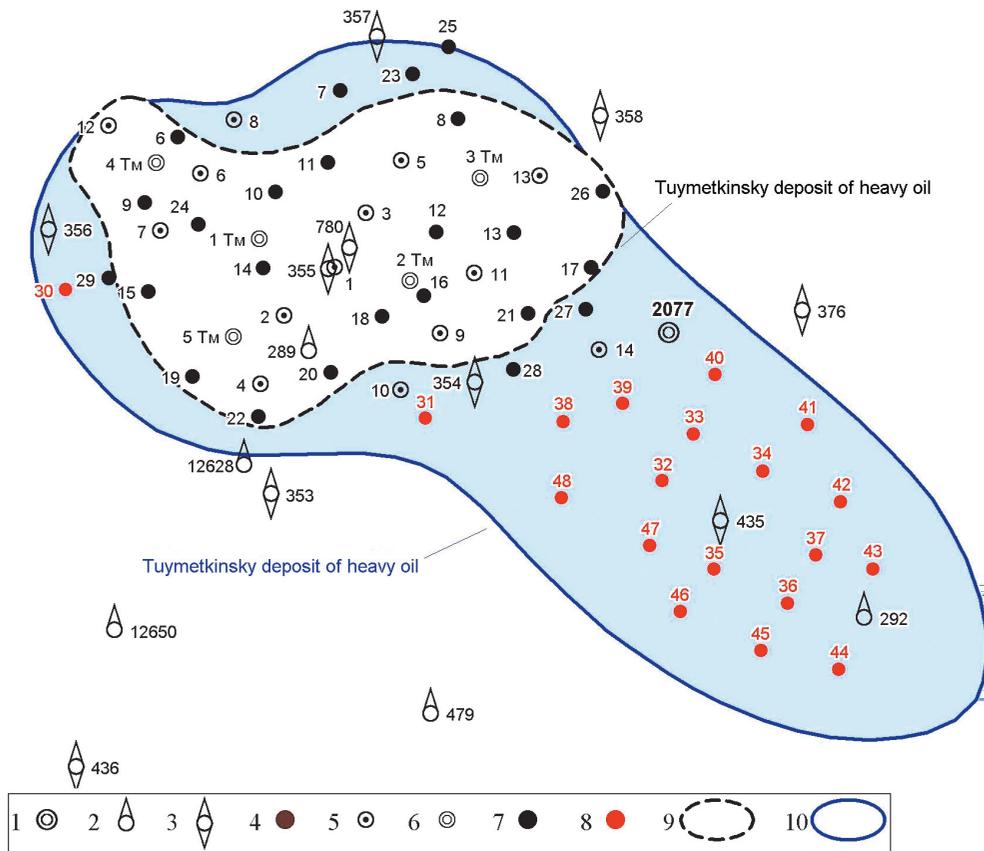


Fig. 1. Tuymetkinsky deposit of Sheshmian heavy oil. Legend: drilled wells: 1 – deep oil prospecting and operational, 2 – structural, 3 – prospecting-appraisal, 4 – prospecting-appraisal (Tatar Geological Exploration Department PJSC Tatneft, 2013), 5 – exploration, 6 – exploration (Tatar Geological Exploration Department PJSC Tatneft, 2014), 7 – appraisal (Tatar Geological Exploration Department PJSC Tatneft, 2014), 8 – appraisal-designed; deposit boundaries: 9 – before recalculation in 2014, 10 – after recalculation in 2014.

Well No. Depth, m	Geological and Geophysical data using materials of core-sample and geophysical well logging				Results of well testing	
	Core sample interval, m Core recovery from sand unit, %	Interval of optimal geophysical well logging complex conducting, m	Sand unit interval, m Thickness, m	Cumulative depth of gas and oil saturated layers according to geophysical well logging, m	Total fluid, m ³	Total hydrocarbon, m ³
Tuymetkinsky deposit of heavy oil						
1 148,0	98,5-148,0 94	19,3 -147,3	99,7-125,5 25,8	24,4	-	-
2 155,0	105,0-155,0 58	52,3-153,3	115,7-149,1 33,4	29,2	-	-
3 178,3	124,0-178,3 84	59,4-178,3	138,0-160,0 22,0	12,9	-	-
4 161,0	118,0-161,0 94	18,4-159,4	137,0-151,4 14,4	8,6	-	-
5* 150,0	104,0-150,0 100	30,3-154,3	111,1-130,3 19,2	19,2	10,2** 16,0***	film** 0,5***
Ulanovsky deposit of heavy oil						
1 197,3	142,0-197,3 94	18,9-193,9	147,5-176,0 28,5	14,6	-	-
2* 198	5,0-198,0 90	18,7-145,7	153,2-181,6 28,4	24	2,5** 3,04***	0** 0,76***
3 148,3	100,0-148,3 93	29,2-155,2	107,5-125,5 18,0	11	-	-
4 162,0	109,0-162,0 91	18,8-158,8	117,3-143,8 26,5	24,4	-	-
5 207,1	164,0-207,1 89,1	18,9-203,9	179,9-193,4 13,5	13,2	-	-

Table 1. The results of exploration works on Tuymetkinsky and Ulanovsky + Varvarian deposits of heavy oil. Note: * – well with the test; * – on a natural mode; *** – after steam stimulation.

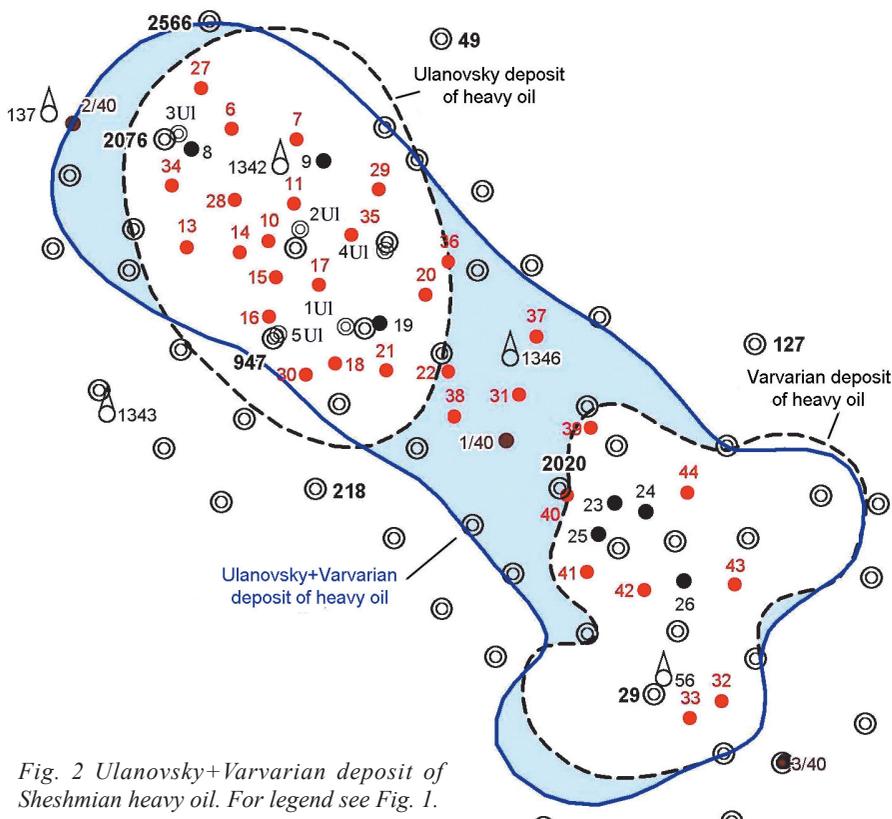


Fig. 2 Ulanovsky+Varvarian deposit of Sheshmian heavy oil. For legend see Fig. 1.

On the object tested for the inflow of heavy oil, hydrodynamic tests were conducted firstly in a natural regime, then after steam stimulation on the oil reservoir.

Laboratory studies of the composition and physico-chemical properties of hydrocarbons are made on samples taken after steam stimulation on the reservoir.

These geological and geophysical data on the wells allowed to specify the geological structure of sheshmian horizon uplifts and confined to them deposits of heavy oil. Clarified geological materials by uplifts (structure maps on top of the productive formation, maps of effective oil-saturated strata, geological profiles and others) were quickly built with the aim of designing layout of evaluation, observation, hydrogeological and operation wells with subsequent drilling.

In 2014 at the time of reserves recalculation in addition to 10 exploration wells, 31 evaluation wells – 24 and 7 wells of Tuymetkinsky and Ulanovsky deposits, respectively.

Removal of core from 29 wells drilled in 2014 on Tuymetkinsky deposit amounted to an average of 97% (96.4% of the productive part). At the time of reserves recalculation laboratory studies of core samples were carried out, selected from 22 wells. There were performed 1407 determinations of porosity (including oil-saturated part – 841), 1399 (619) determinations of oil saturation to the rock weight, 1314 (722) determinations of oil saturation to pore volume, 727 (493) determinations of mineralogical density, 500 (75) determinations of permeability parallel to bedding.

At the expense of 29 new-drilled wells, the area of oil-bearing deposits increased 2.72 times (Fig. 1). As a result of additional exploration, geological and recoverable reserves of C_1 category increased 3.57 times.

In 2012 in the Tatar geological management there was assessment of Permian heavy oil resources of C_3 category within the licensed area of Novo-Elkhovsky oil field through

the use of operating well stock (Sukhov, 2012). In the process of works 69 oil-bearing objects have been allocated.

One of the oil-bearing objects – No. 40 is confined to the structural uplift of the III order by the top of sheshmian horizon of sedimentary origin. It has a north-west strike and contoured by 15-meter isopach of sand pack. According to performed geological structures it was expected to have a single oil-bearing circuit for previously identified Ulanovsky and Varvarian deposits of sheshmian heavy oil.

In order to confirm this assumption, in 2013 prospecting and appraisal well No. 1/40 was drilled between Ulanovsky and Varvarian deposits, revealed the formation of oil-saturated sandstone with thickness 9.6 m.

Core recovery from 15 wells drilled on Ulanovsky and Varvarian uplifts in 2013-2014 amounted to an average of 91.2% (90.5% of the productive part). 816 (including from oil-saturated part – 184) determinations of porosity, 816 (184), determinations of oil saturation to the rock weight, 760 (149) determinations of oil saturation to the pore volume, 361

(46) determinations of mineralogical density, 649 (123) determinations of permeability parallel to the bedding were performed in cores recovered from the sand pack.

Drilled in 2014 wells confirmed the single oil-bearing single contour of Ulanovsky and Varvarian deposits, which when recalculating were combined into a single deposit – Ulanovsky + Varvarian.

When recalculating reserves, according to new data the oil-bearing area increased by 36% (Fig. 2). Due to the additional geological exploration of deposits, geological and recoverable reserves of C_1 category, including reserves of Ulanovsky deposit due to revaluation have increased by 2.1 times.

Furthermore, when testing well 5 Tm oil inflow was obtained with viscosity of 18260 mPa*s, and in well 2 UI – 15189 mPa*s, which in turn has a direct impact on the economic feasibility in the form of tax relief, namely discounts on the customs duty at the rate of 90%.

Thus, implementation of the projected program of geological exploration allowed us to specify regime calculation parameters and geological-engineering data of Tuymetkinsky and Ulanovsky deposits of Sheshmian heavy oil.

The results obtained in the course of works allowed us to recalculate reserves of additionally explored heavy oil deposits, clarify the dynamic viscosity of hydrocarbons and to make corresponding adjustments to the state balance reserves of oil of the Ministry of Natural Resources and Ecology of the Russian Federation as of 01.01.2015.

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Received February 09, 2016

