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## THE DESIGN OF GEOLOGICAL EXPLORATION WITH SIDE TRACK DRILLING

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## ПРОЕКТИРОВАНИЕ ГЕОЛОГО-РАЗВЕДОЧНЫХ РАБОТ МЕТОДОМ СТРОИТЕЛЬСТВА БОКОВЫХ СТВОЛОВ

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geological exploration, side track, 3D seismic exploration, structures, candidate wells, geodata, profile, land acquisition, "window" cutting, geophysical surveys, core sampling, reserves increase, field, costs.

The paper discusses the method of well reconstruction using sidetracks drilling as a method for searching prospective formations in Perm region. At the moment, there are small-size reservoirs of less than 100 thousand tonnes of resources included in located and prepared formations. Drilling of the reservoirs is unprofitable. Drilling a sidetrack from wells located near promising reservoirs can be more economical way to solve the problem.

Drilling of sidetracks has become one of the most investment-attractive technologies aimed at stabilizing and further increasing oil production from fields being developed. This method is used to intensify the system of field development, increase the rate of oil extraction from productive formations and actually replaces the compaction of the well grid. Appropriate technologies help to save a well as well as construction and development costs. In presence of candidate wells, including plugged and abandoned one, located near promising structures, it becomes important to search for them using sidetrack drilling as a method of geological exploration.

The paper describes the technology of side tracks construction and presents the algorithm of works designed. Well stock of LUKOIL-PERM LLC and geological structure of promising objects were analyzed. The technical possibility of well reconstruction by sidetracking was considered. Criteria for candidate wells and "window" kickoff intervals to be selected are defined. Calculation of profiles of second well bores for recommended wells was made, various aspects related to their construction were worked out. As a result of the work it was proposed to include these activities in the geological exploration program of LUKOIL-PERM LLC.

Results of the work have practical significance and can be used in production activities of oil and gas companies.

### Ключевые слова:

геолого-разведочные работы, боковой ствол, сейсморазведочные работы 3D, структуры, скважины-кандидаты, геоданные, профиль, отвод земли, резка «окна», геофизические исследования, отбор керн, прирост запасов, месторождение, затраты.

Рассмотрен вопрос использования метода реконструкции скважины путем бурения боковых стволов как способа для опискования перспективных структур на территории Пермского края. В настоящий момент в фонде выявленных и подготовленных структур числятся малоразмерные объекты с ресурсами менее 100 тыс. т, ввод в бурение которых экономически нерентабелен. Решением этой проблемы может стать более экономичный способ – бурение бокового ствола из скважин, расположенных вблизи перспективных объектов.

Бурение боковых стволов стало одной из наиболее инвестиционно привлекательных технологий, направленных на стабилизацию и дальнейший рост добычи нефти на разрабатываемых месторождениях. Данный метод служит для интенсификации системы разработки месторождений, увеличения коэффициента извлечения нефти из продуктивных пластов и фактически заменяет уплотнение сетки скважин. Соответствующие технологии помогают сохранить скважину и сэкономить затраты на строительство и освоение. При наличии скважин-кандидатов, в том числе консервированных и ликвидированных, расположенных вблизи перспективных структур, становится актуальным их опискование с помощью строительства бокового ствола как метода геолого-разведочных работ.

В работе описана технология строительства боковых стволов и представлен алгоритм проектируемых работ. Проанализированы фонд скважин ООО «ЛУКОЙЛ-ПЕРМЬ» и геологическое строение перспективных объектов. Рассмотрена техническая возможность реконструкции скважин бурением боковых стволов. Определены критерии выбора скважин-кандидатов и интервалов резки «окна». Произведен расчет профилей вторых стволов для рекомендуемых скважин, проработаны различные аспекты, связанные с их строительством. Конечным итогом работы стали предложения по включению данных мероприятий в программу геолого-разведочных работ ООО «ЛУКОЙЛ-ПЕРМЬ».

Результаты работы имеют практическую значимость и могут быть использованы в производственной деятельности нефтегазодобывающих обществ.

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## Introduction

Geological department of any oil and gas production enterprise is considered to be effective if it prepares necessary information for the development of long, medium and short time planning and geological exploration programs, which is the main criterion. In order to compensate oil production by increasing reserves through geological exploration today, it is necessary to intensify work both on the study of territories and formations that were not fully explored yet and on the development of new directions and ways of geological survey [1-7].

During the planning of exploration and appraisal drilling license obligations and terms in geological projects, which are subsequently laid into the program of geological exploration must be taken into account. Often, due to investment unattractiveness additional exploration can be postponed from one year to another.

Sidetrack drilling plays a significant role in development of oil and gas fields among the modern methods. Their use allows us to solve a large range of problems associated with the increase in oil production on fields that are at a late stage of development and the involvement of hard-to-recover hydrocarbon reserves. Appropriate technologies help to save the well and costs for its development [8-13].

### Sidetrack drilling technology

Sidetracking is an effective technology that allows increasing oil production at old fields and the coefficient of oil extraction from reservoirs, to return to operation oil wells that could not be returned to the existing stock by other methods. [14-16].

Sidetracking allows to involve reservoir areas that were not in production previously, hard-to-recover oil reserves, extraction of which was not previously been possible. Sidetracking technology contributes to increased oil recovery and actually replaces well grid compaction.

Besides, there are examples of additional exploration of missed deposits and local structures identified according to 3D seismic survey data [17].

Sidetracking consists of the following steps:

- selection of candidate wells for sidetracking;
- selection of structure, profile and calculation of the sidetracks' trajectory;
- elimination of a part of the wellbore;
- cutting the “window” in the casing;
- kickoff and drilling of sidetracks;
- fastening with a shank or filter;
- development and bringing the well on line of the influx of formation fluid.

Production columns above the cement bridge installation interval, according to the relevant instruments and pressure testing, must be technically efficient, trajectories of selected and neighboring wells must be sufficiently reliable to prevent the wells from crossing [18].

Well design in terms of reliability, manufacturability and safety should ensure:

1. Maximum utilization of the reservoir energy of the productive formation during operation due to selection of the optimal diameter of the production string and the possibility of achieving the design level of hydrodynamic communication of productive deposits with the wellbore.

2. Use of optimal modes of operation, maintaining reservoir pressure, heat exposure and other methods of enhanced oil recovery.

3. Conditions for safe work without accidents and problems at all stages of well construction and operation.

4. Required geological information on the open section.

5. Conditions for the protection of the subsoil and the environment due to the strength and durability of lining the well, the tightness of casing and annular spaces.

6. Maximum alignment by type of casing and wellbore.

Side trunks are designed to be drilled from wells cased with 146 mm diameters. For them,

casing of countersunk column liners with diameters 101.6 mm is recommended [19-22].

The main option of sidetracking is to cut the “window”. A wedge-diverter with an orienting device, which is installed on an artificial face, goes down the well. Work on the descent and installation of the wedge-diverter is performed in accordance with the technology of manufacturers.

Lowering the assembly on steel drill pipes is made with the measurement of the tool length, with a speed of not more than 0.2 m/s. In directional wells wedge-diverter should be installed approximately within  $\pm 90^\circ$  with respect to the azimuth of the main shaft curvature at the installation site [23].

After whipstock is installed the assembly with the suspension device and the telesystem rises, the assembly for cutting the “window” goes down.v.

### **Workover planning algorithm**

At the first stage, based on actual geological material on 3D seismic survey promising areas and structures was selected. It is proposed to use preserved and abandoned wells located close to the contour or set of prospective uplift as candidate wells. It is worth saying that approaches to well abandonment did not take into account the possible prospects for their bringing back to production when there is a change in ideas about a formation geological structure.

As an example of planning, southern dome of the Gubanovskaya structure, located in the southern part of the Veslyanskaya ridge-like zone in the Kokuyskoe field (Fig. 1).

The structure was ready in 2015 based on the results of seismic prospecting using the method of a common depth point of 3D at the Kokuyskoe field (SP 12/13). The amplitude of the structure in the reflecting formation II<sup>II</sup> is 14 m, dimensions – 1.5×0.8 km. The formation represents a tectonic-sedimentary uplift modified by Late Devonian organogenic structure, paleokarst in Tournaisian and Bashkir

sediments. There is Well 754 of the Kokuyskoe field drilled near by the structure.

In order to search for oil deposits, it is recommended to drill a sidetrack in Well 754-Kokuyskoe on Frasnian deposits. The recoverable resources on the passport are 328 thousand tons. Resources of the following complexes are estimated: Upper Devonian, Lower Carboniferous Carbonate and Visean Terrigenous. In addition, the structure falls into the zone of reserves of categories B1+C1 that have already been put on the balance of Middle-Carboniferous sediments.

At the second stage, the technical state of the well and possibility of overhaul are considered. On the basis of the regulations [24] and production experience of the company, the criteria for selecting candidate wells and sidetracking intervals are substantiated. Reasons why the well was subjected to temporary suspension/abandonment, oil production string tightness, open perforation intervals, test results and other aspects are considered (Table 1).

The main criteria for the selection of wells for their recovery by sidetrack drilling according to the analysis are (Fig. 2):

- absence of remaining reserves in a well;
- current bottomhole location does not exceed 700 m from the optimal (proposed) on the structure arch;
- leaktightness of the production string;
- borehole profile, allowing to carry out works on the second borehole (intensity of curvature less than  $5^\circ$  by 10 meters);
- absence of metal patches or cuffs from the pipes above the estimated point of the second sidetrack cutting (the maximum cutting depth of the “window” is 400 m above the roof of the formation);
- presence and quality of cement stone;
- absence of accidents in the well that led to its abandonment;
- no production drilling plans in the considered work area.

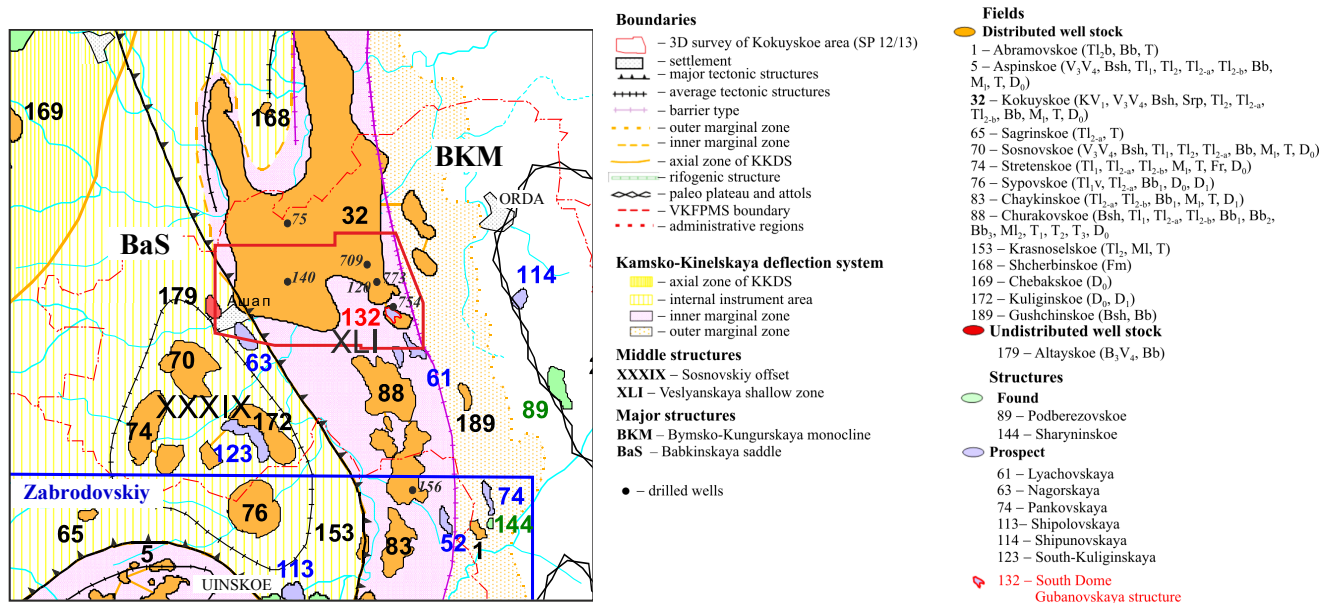


Fig. 1. Schematic map of the work area: KKDS – Kamsko-Kinelskaya deflection system; VKFPMS – Verkhnekamskoe field of potassium and magnesium salts

Table 1

Basic well information\*

Name	Value
Field (uplift)	Kokuyskoe (Gubanovskoe)
Well cluster	4
Well number	754
Altitude of the rotor table, m	215.24
Well category	Oil in suspension
Well category by hazard	2 <sup>nd</sup> (GF)
Operational formation	Bsh
Well construction:	
– surface Ø 426×11 mm	21 m, HCV to well head
– conductor Ø 299×9 mm	70 m, HCV to well head
– intermediate casing Ø 219×8 mm	498 m, HCV to well head
– production string Ø 146×8 mm	1825 m, HCV up to 220 m
Perforation intervals, m:	
– Bsh	1382.0–1392.0 m (not isolated)
– T <sub>1</sub>	1729.0–1735.0 m (isolated 10/22/1986)
Drilled bottom hole, m	1825.0
Artificial bottomhole, m	1810.0
Current bottomhole, m	1592.0
Maximum zenith angle, degree	29.25 degrees at a depth of 300 m
The state of the cement stone behind the casing	Satisfactory
Casing tightness, MPa, its residual strength	13.0 (defined 07/07/1976)
Presence of cross flows	–
The presence (absence) of pressure in the annular spaces, MPa	–
Underground equipment	–
Wellhead equipment	ETG 73 × 146
Well state	Suspension

Note: \* – information may be changed to maintain confidentiality; ULC – upper limit of cementing.

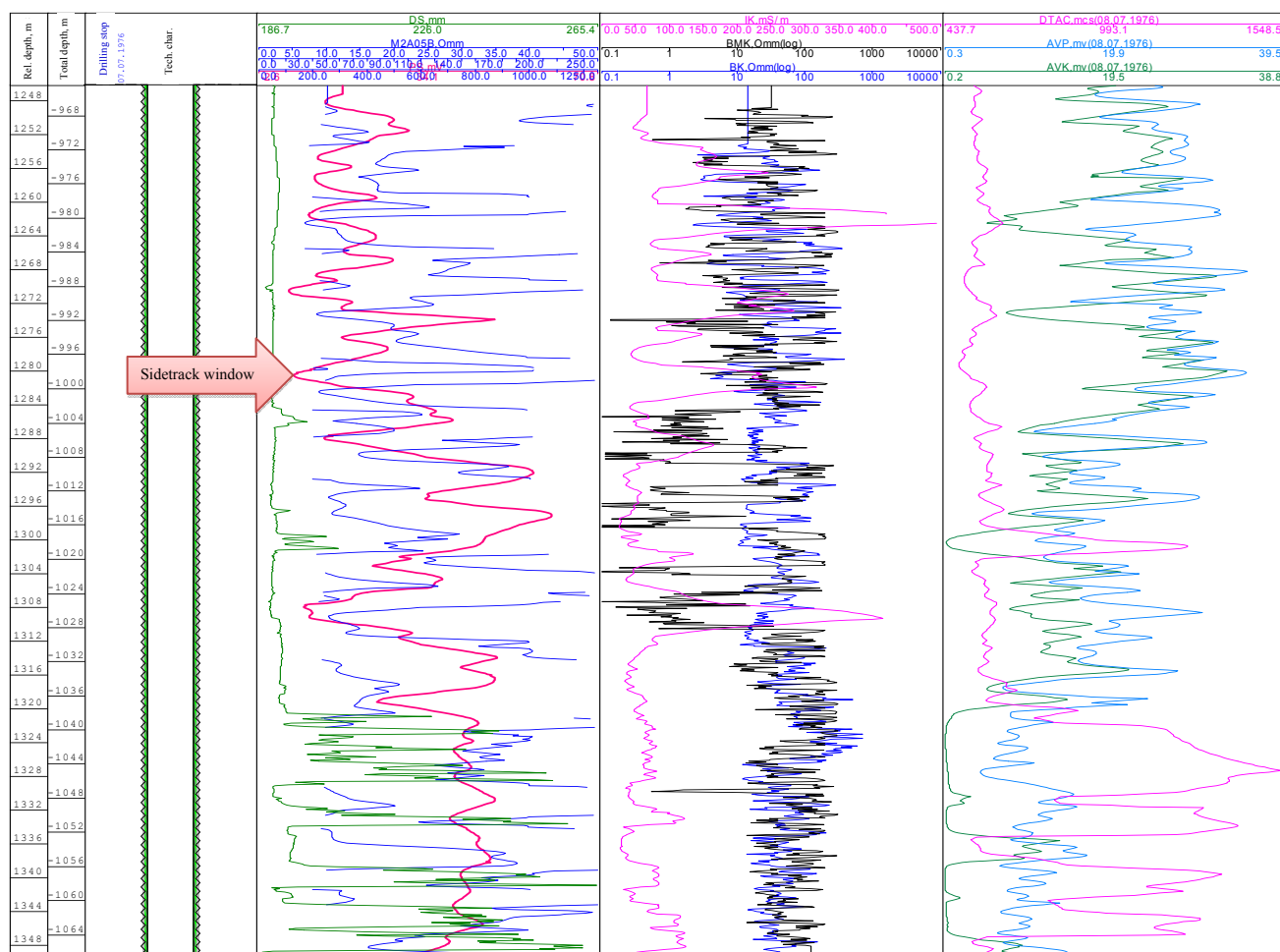


Fig. 2. Selection of the interval of drilling the well according to the logging data

When choosing a second wellbore interval, the following criteria are used [25]:

- depth from the well head to the upper edge of the last perforated interval, the second trunk is drilled 30-50 m higher accordingly;
- presence and quality of a cement stone behind the casing;
- well wall resistance and minimum rock hardness;
- maximum intensity of the curvature of the wellbore above the drilling interval (should not exceed 2-3° per 10 m);
- depth of clutches of the production string in the interval of the intended cut;
- tightness of the production string in the estimated interval;
- depth of the productive formation roof;
- deviation of the trunk from the vertical;

– radius of curvature in the section of zenith angle set.

The third stage includes preparation of drilling geodata. As a result of the calculation, the exact values of location, angles and preliminary depth of the sidetrack are determined. The current owner of the land on which the well is located is established. In the presence of a valid lease agreement for a land plot, it becomes possible to perform work without a long process of land acquisition and associated costs.

Based on geodata, profiles for recommended stems were calculated. The first consideration was the possibility of oblique drilling with a maximum zenith angle of up to 60° (Table 2). This solution is associated with the possibility of using clayless or thin mud, which will also reduce the cost of drilling [26-35]. Well profiles should take into

account the presence of a significant zenith angle drop along the section while drilling promising deposits [36, 37].

Profiles of sidetracks were constructed, allowing in three-dimensional form to represent the passage of the projected profile through structural surfaces (Fig. 3, 4).

Thanks to the received images, it is possible to check the correctness of profile construction and correct them for the most optimal posting.

Due to the fact that the sidetracks perform the functions of wildcat, appraisal and exploration wells, establishment of an optimal set of geological and geophysical studies is one of the most important points. In order to obtain high-quality geological information in the plan-order it is planned to include an expanded complex of well logs (Table 3). To study the

lithological characteristics of the layers and physical properties of reservoirs, clarify the stratigraphic boundaries, effective and oil-saturated thickness, the position of oil-water contacts, as well as laboratory studies in wells, core sampling is provided. Well test during the drilling process with the help of KII-92 equipment is also planned [38].

Core sampling is recommended to be carried out using the Security DBS 104/52 core drilling tool or its analogs with collet type core breakers providing 100 % core removal.

To study the lithology of the section and determine the oil content in it, sludge is sampled after 5 m of penetration, in productive intervals at 2 m. The control measurement of the tool should be carried out before coring and after reaching the design depth of the well.

Table 2

Well inclinometry report for 754 Kokuyskoe field  
(analysis range for the wellbore – from 1280 to 2552.33 m)

Well depth, m	Zenith angle, deg.	Magnetic azimuth, deg.	Azimuth true, deg.	Vertical depth, m	Absolute mark, m	Global displacement to the north, m	Global displacement to the east, m	Spatial intensity, degree/10 m	Angle of installation of the diverter, deg.	Zenith intensity, degree / 10 m	Azimuth intensity, degree/10 m
1280.00	8.75	137.13	137.13	1213.24	-997.90	50444.40	46472.63	0.152	-90.49	0.000	-1.000
1290.00	9.75	151.43	151.43	1223.11	-1007.77	50443.09	46473.57	2.507	66.49	1.000	14.300
1300.00	9.75	151.43	151.43	1232.97	1017.63	50441.61	46474.38	0.000	0.00	0.000	0.000
1455.08	56.81	223.20	223.20	1361.61	1146.27	50377.93	46433.10	3.500	78.25	3.035	4.628
1935.04	56.81	223.20	223.20	1624.34	1409.00	50085.14	46158.14	0.000	0.00	0.000	0.000
2552.33	2.37	223.20	223.20	2141.16	1925.82	49871.20	45957.25	0.882	-180.00	-0.882	0.000

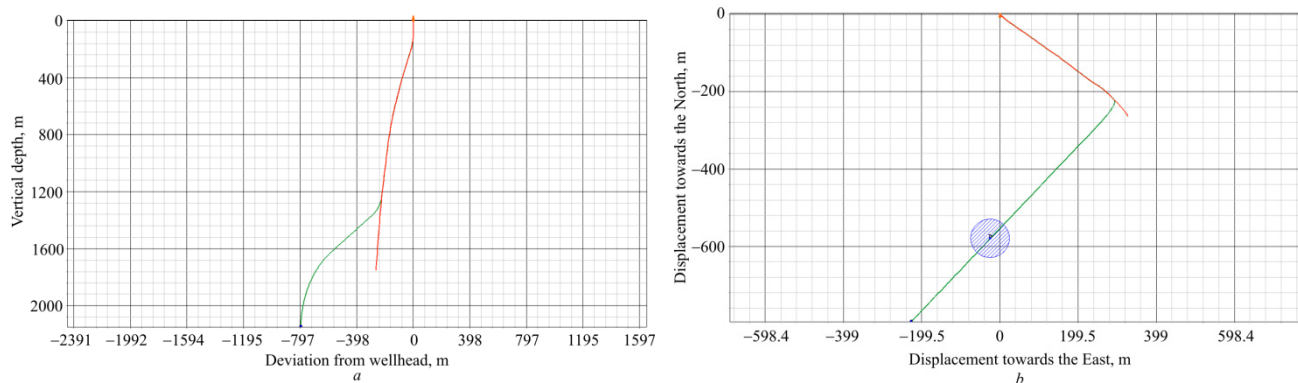


Fig. 3. Vertical (a) and horizontal (b) sidetrack projections

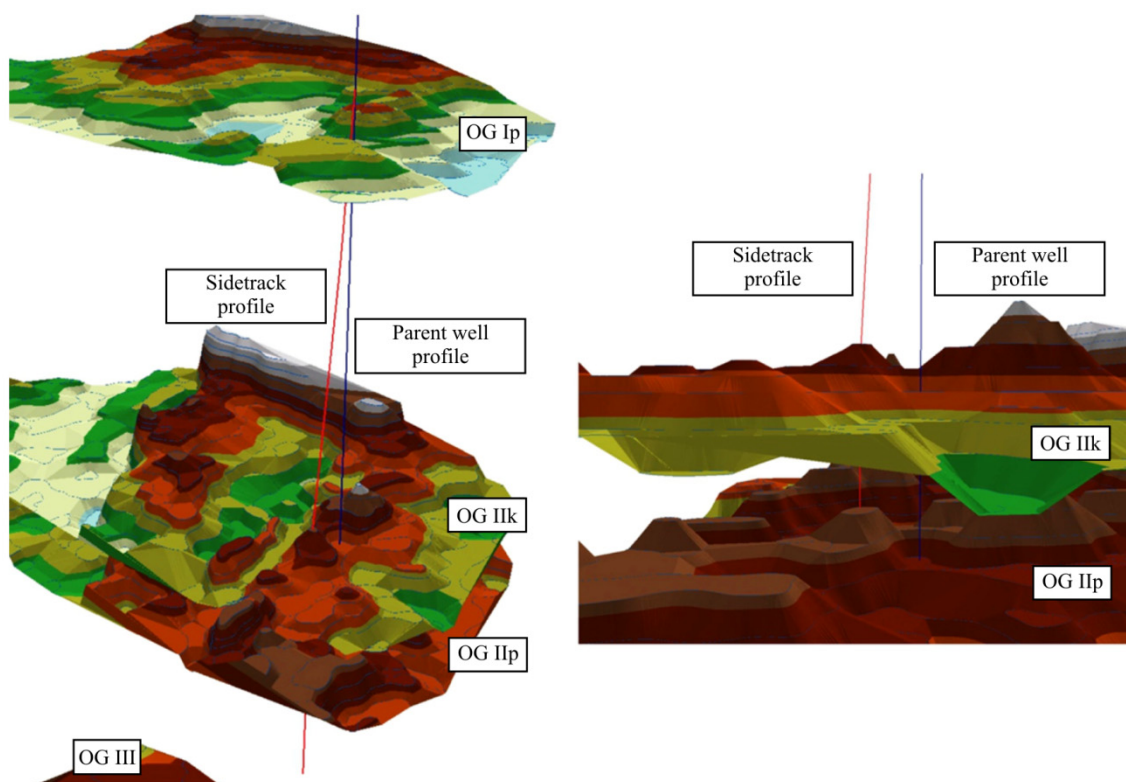


Fig. 4. Building a profile of the projected sidetrack relative to the main reflecting intervals

Table 3

### Well logging

Test type*	Recording scale	Notes
LG-5, GRL, NNL, IL, LL, AL ith VS, Caliper, GGRL-LDL, MP, MLL, EPTL, NGSL	1:200	Intermediate logging after subsurface coal deposits
GRL, NNL, AL with VS, Caliper, GGRL-LDL LG-5, IL, LL, MLL, MP, Caliper, GRL, NNL, AL ith VS, GGRL-LDL, EPTL, NGSL	1:500 1:200	After well drilling
GRL, NNL, Caliper	1:200	Binding logging before coring
GRL, NNL, LL, Caliper	1:200	Binding logging before reservoir testing by pipe testers
Complex of tests on control of technical condition of wells		
CBL, GRM (WGRDT), EMITM	1:500	Throughout the entire wellbore no earlier than 48 hours after the launch of the production string
CBL-S, GRM (WGRDT), EMITM	1:200	In the intervals of detailed studies

Note: \* – the list of acronyms of the types of studies is presented in the “Technical Instructions for Geophysical Research and Instrumentation on Cable in Oil and Gas Wells RD 153-39.0-072-01”, approved by the Ministry of Natural Resources, Order No. 134 of 07.05.2001.

The cost and payback period of capital investments for sidetracks construction is significantly lower than the similar rates of drilling a new well due to the use of a part of existing well and field infrastructure. The feasibility study revealed that the planned works satisfy the conditions for the effectiveness of

LUKOIL PJSC projects and can be recommended for implementation [39].

Thus, the implementation of proposals will minimize costs associated with reserves increase, and the time to enter into the development of newly discovered reserves will be reduced.

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