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Increasing Reservoir Productivity at Yuzhno Vyintoyskoye Field, Western Siberia

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Abstract

The new economic conditions characterised by the instability in the global oil and gas industry push market players to search for profitable and efficient ways of developing oil and gas deposits.

One of the key opportunities is Enhanced Oil Recovery projects in hard-to-recover reservoirs and formations. When planning the entire scope of development operations, well interventions and surveys, it is important to follow a strategy that would help successfully overcome the geological and engineering challenges facing the operators.

In this project, a geological feasibility study of the field development management was conducted with regards to the one formation of the Yuzhno-Vyintoyskoye field based on the data obtained using marker-based production surveillance in horizontal wells and flow simulation.

INTRODUCTION

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OBJECTIVES AND CHALLENGES ARISING DURING THE DEVELOPMENT OF THE YUZHNO-VYINTOYSKOYE FIELD

The formation of the Yuzhno-Vyintoyskoye field has a complex wedge-shape geological structure and is characterised by low permeability, high heterogeneity and clay content, a low net-to-gross ratio, and an extensive water-and-oil zone with high (40-60%) water saturation. The producing horizon consists of argillaceous sandstones interbedded with clays and siltstones, with the presence of some lithology substitutions.

The following table shows the profile and current state of the well stock in the reservoir zone under study. The three-dimensional view of the initial geological and flow dynamics models is shown in Figure 1.

Parameters	Area under study
Producing wells in operation	22
Average fluid production, ton/day	43.43
Average crude oil production, ton/day	11.52
Water cut, %	62.8
Reservoir pressure, MPa	21.56
Bottom-hole pressure, MPa	10.39
Injection wells in operation	8
Average intake capacity of one well, m3/day	71.7
Average well head pressure, MPa	28

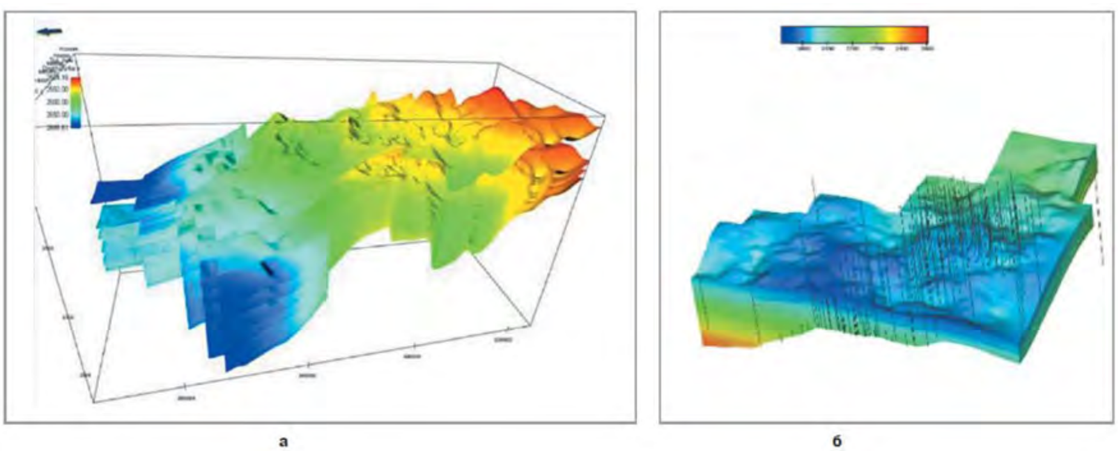

Figure 1—Three-dimensional view of the initial geological (a) and flow dynamics (b) models

The following key challenges arise during the development of this area:

- high water cut in wells, including in the initial period of development after hydraulic fracturing;
- reducing oil production due to the decline in reservoir pressure in the oil recovery zones;
- interference between producing horizontal wells given the extracted fluid is not properly compensated with injection.

In general, the reservoir area is characterised by non-uniform reserves recovery. Currently, water flooding outstrips oil production, which is the main problem with respect to the field development system improvement [8–11].

To accomplish the objectives set, the technology of marker-based production surveillance in horizontal wells was used in the field, where marked proppant was injected into horizontal producing wells in the course of multi-stage hydraulic fracturing and then production profile and flow composition along the horizontal wells were studied during long-term surveillance. Within the framework of this engineering solution, there is no need to deploy asset-heavy applications such as coiled tubing conveyed production logging tools. Instead, nanomaterials — quantum markers-reporters (Figure 2) that are high-precision flow indicators — are used to obtain a stream of data on horizontal wells' performance without well intervention for several years [1].

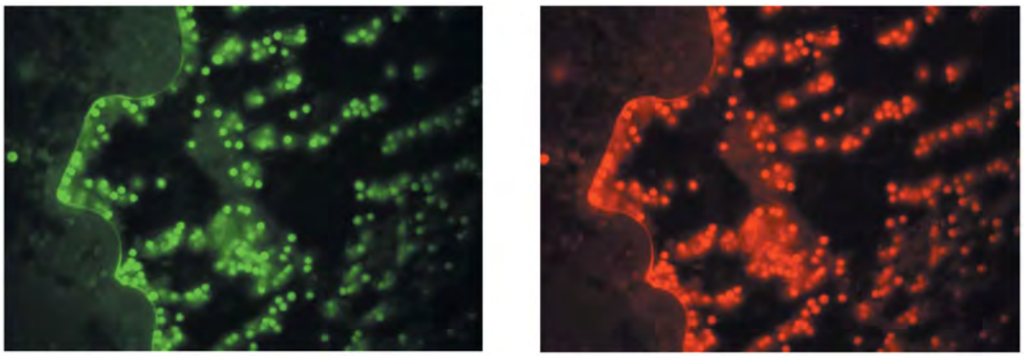

Figure 2—Quantum markers-reporters indicate the production profile and flow composition along the horizontal lateral

All wells were marked with inflow tracers. Obtaining the production profiling of each well and interpreting inter-well influence enables the client to better understand hydrodynamic interaction between the wells and better optimize water flooding [2].

PROPPANT MARKING TECHNOLOGY

The heart of the technology are the quantum dots – small semiconductor crystals 2-10 nanometers in size. High-quality quantum dots are well suited for optical encoding applications due to their durable structure, broad excitation profiles and narrow emission spectra. The use of quantum dots in GEOSPLIT® technology allows achieving high accuracy and efficiency of diagnostics. Quantum dots are used as part of markers-reporters. Marker-reporters are polymeric spherical particles containing large number of quantum dots (figure 3). Various combinations of six types of quantum dots inside those spherical particles allows to create 63 unique combinations - codes (or signatures) of the markers.

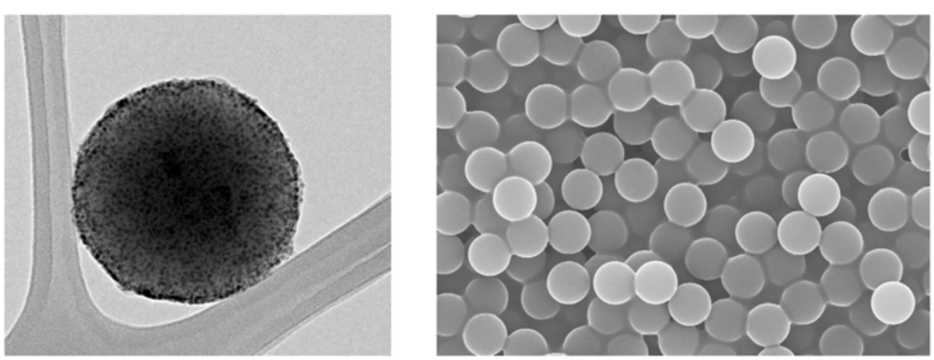

Figure 3—Microphotography of markers-reporters in transmission (left) and scanning (right) electron microscope.

Polymeric composite material containing marker-reporters is coated on ceramic proppant.When conducting multi-stage hydraulic fracturing, coated proppant is pumped into each stage, marked with a specific code, as the last proppant. This ensures the right coverage of the frac face and controlled release of marker reporters into the flow once the well is put on production. During the subsequent long period of the well performance, the marker-reporters are controllably released with water or oil and transported by the reservoir fluid flow to the wellhead. Marker-reporters are released both in the hydrocarbon and aqueous phases of the formation fluid. After the completion of the multi-stage fracturing operation and putting the well on production, periodic sampling of the formation fluid from the wellhead was carried out, after which the samples were taken to the laboratory for analysis.

To estimate number of markers in the sample, specific sample preparation is used. This sample preparation involves different physical and chemical processes. It markers tracing oil and water phases. The main purpose of those treatments to transfer markers from sample to deionized (distilled) water without contaminations or loss of marker reporters and be ready for analytical processing.

The main analytical tool for measuring and quantifying markers extracted from the samples – is flow cytofluorometric method. During flow cytometry, a sheath of fluid hydrodynamically focusses the markers-reporters suspension through a small nozzle such that only one particle passes the laser light at a time (Figure 4, left). A detector is placed in front of the laser beam such that it can capture the forward scattered light from the cells, while several detectors are also placed to the sides to measure the amount and intensity of fluorescent light that is different for each code.

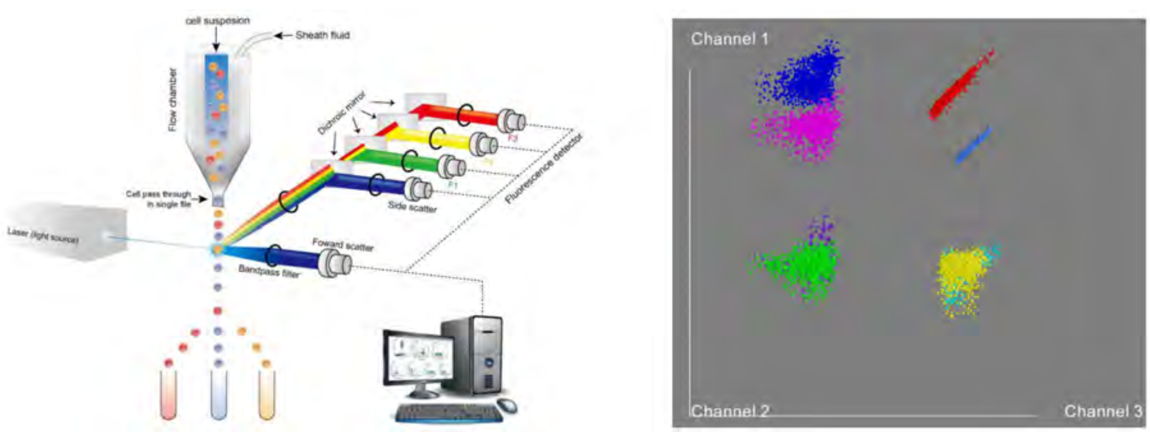

Figure 4—Principles of flow cytometry (left) and examples of data obtained from it (right).

Studies of multistage wells involve working with large amounts of data. For example, information on the identification of each marker-reporter is a point in a 25-dimensional coordinate space, so the manual calculation method will be very labour intensive. One of the key elements of the technology is using machine learning and neural networks methods to qualify and quantify data from flow cytometry. Consequently, the technology of marker diagnostics uses specialized intelligent software. It allows to provide comprehensive analysis and obtain high accuracy data in short period of time.

METHODOLOGY FOR GEOLOGICAL FEASIBILITY STUDY OF THE FIELD DEVELOPMENT MANAGEMENT USING DYNAMIC MARKER-BASED PRODUCTION SURVEILLANCE

The following was done during the project (Figure 5):

- Definition of geological structure:
  - Update of the geological and flow dynamics models based on the quantitative production profiling in horizontal wells;

- Lithological and facies analysis;
- Estimation of oil reserves.

- Analysis of the current resource recovery status:
  - analysis of the resource recovery dynamics and the current state of the well stock;
  - analysis of the reservoir pressure and related parameters (reservoir energy status);
  - analysis of the causes of low flow rates and well water cut.
- Analysis of reserves recovery.
- Analysis of water flooding pattern performance with an assessment of the hydraulic communication between the producing and injection wells.
- Geological analysis of the results of dynamic marker-based production surveillance in horizontal wells
  - analysis of the causes of changes in the production profile dynamics;
  - analysis of interference and a single hydrodynamic system.
- Development of a work plan to enhance the reservoir pressure maintenance system efficiency.
- Flow simulations of the displacement process using the conformance control method in injection wells with the forecast and appraisal of the engineering efficiency indicators.

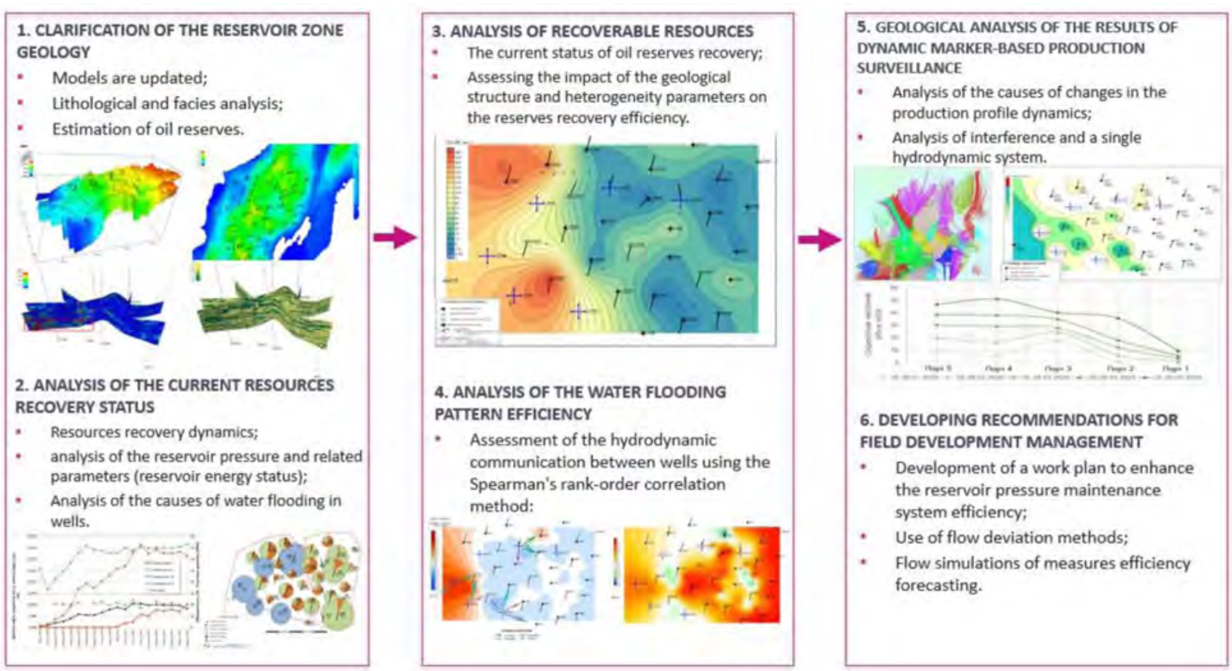

Figure 5—Methodology for the geological feasibility study of the field development management using dynamic marker-based production surveillance in horizontal wells

The project involved adjustment of the reservoir sector models, mapping the current and cumulative water cut along with current and cumulative water-oil ratios (WOR), the analysis of well interference using the Spearman's rank-order correlation method, modelling flow paths on the basis of the updated flow model to analyse well interference, etc. [3–5].

DEVELOPING RECOMMENDATIONS FOR OIL RECOVERY IMPROVEMENT

Upon analysing the causes of high water cut in the reservoir zone, three groups of wells were identified:

1) Wells with initially high water cut after multi-stage hydraulic fracturing
   Higher water cut observed at the early stage in a number of horizontal wells could have occurred due to the contribution of aquifers after the multi-stage hydraulic fracturing. There is also a possibility of water inflow from the overlying BV6 aquifer.
2) In wells where higher water cut was observed during their operation, the hydraulic fractures could result in a hydraulic communication between the oil and water-oil-saturated interlayers due to intensified drainage along the propagation through water-oil-saturated intervals.
   The water flooding sources pattern was clarified based on the analysis of the areal changes in the water cut dynamics across the reservoir zone area. The highest values of the above-mentioned water-oil factor and the rapid rate of production decline suggest that water is likely to inflow from the edge or bottom water.
3) In wells with low cumulative oil-water factor values, the most likely sources of flooding were considered to be the breakthroughs of the injected water through highly permeable intervals.

The analysis of the current development and recoverable reserves has shown that the BV7 formation area is characterised by non-uniform reserves recovery primarily due to the insufficient areal sweep efficiency.

The formation pressure maintenance system was analysed to obtain data on the degree to which injection impacts the production across individual flooding zones, and this data was used to identify flooding areas for the purpose of implementing conformance control activities [6, 7] with the aim to increase the vertical sweep efficiency and reduce the water cut in production wells (Figure 6).

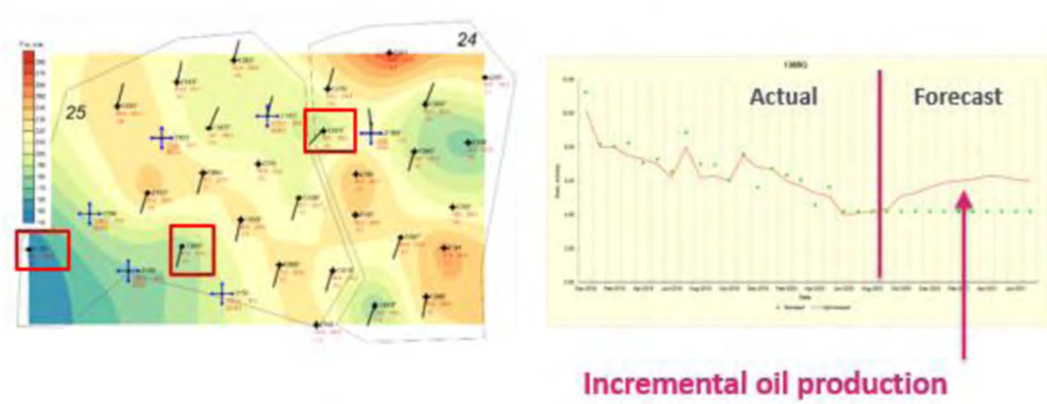

Figure 6—The effect of conformance control measures in injection wells

According to calculations and additional flow simulation of the displacement process using formation pressure maintenance technology in injection wells, this measure will result in total forecast incremental production of at least 1,900 tons, while the expected duration of the effect will be at least 8 months, and water cut in a number of wells will reduce by at least 20%.

Overall, based on the analysis, the following measures were developed and justified to adjust the field development system:

- Changing the operating modes of producing and injection wells across the reservoir area (bottom-hole pressure and injectivity reduction/increase);
- Changing the direction of seepage flows by blocking high-permeable water-conducting intervals in inhomogeneous formations through injection;

- Creating additional water flooding sources in the reservoir zone to improve the areal sweep efficiency;
- Infill drilling to intensify the development of remaining recoverable resources;
- Bottom-hole zone treatment to stimulate the oil flow from individual interlayers (bottom-hole treatment using mud acids).

RESULTS

In the course of the project, the geology of the formation zone was studied, the formation geological parameters, properties (porosity and permeability), and heterogeneity indicators were calculated and mapped, the areal and vertical patterns of productive formations distribution were obtained, the factors causing the changes in the production profiles were analysed along with well interference and the presence of a single hydrodynamic system.

The primary focus of this study is placed on determining the extent to which individual reservoir zones, productive layers and interlayers are involved in development. This task was addressed through qualitative and quantitative assessments of the status of oil reserves recovery.

The resulting list of recommendations for adjusting the reservoir development system is approved for implementation that will help achieve stable development parameters, improve areal and vertical sweep efficiency numbers, and bring earlier undrained reservoir zones into development.

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