Geological and Field Feasibility Study of Field Development Management Using Marker-Based Production Profiling Surveillance in Horizontal Wells: The Case Study of the Yuzhno-Vyintoiskoye Field

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This article is the first to propose a comprehensive strategy for the geological and field feasibility study of field development management using the data of dynamic marker-based production profiling surveillance in horizontal wells performed at the Yuzhno-Vyintoiskoye field. The project helped develop, substantiate and adopt for implementation a set of practical recommendations for improving the field development system efficiency. This will allow achieving stable dynamics of oil field performance, improving the vertical and areal sweep efficiency numbers, and involving earlier undrained reservoir areas in the development.

Keywords: *faield development, geological and field analysis, reservoir modeling, dynamic marker-based production profiling surveillance, quantum reporter-markers, horizontal wells.*

New economic environment marked by the instability in the global oil and gas industry pushes the market players to search for economic and efficient techniques for developing oil and gas deposits.

The key objective pursued during efficient field development, including hard-to-recover reserves, is to enhance oil recovery. When planning the entire scope of development operations, well interventions and surveys, it is crucial to follow a strategy that would help operators successfully cope with the geological and engineering challenges.

This project involved a geological feasibility study of the field development control at the BV7 formation of the Yuzhno-Vyintoyskoye field based on the data obtained using marker-based production logging in horizontal wells and reservoir simulation.

The BV7 formation of the Yuzhno-Vyintoyskoye field has a complex wedge-shape geological structure and is characterised by low permeability, high compartmentalisation and clay content, a low net-to-gross ratio, and an extensive water-and-oil zone with high (40-60%) chaotic water saturation. The producing horizon consists of argillaceous sandstones interbedded with clays and siltstones, with the presence of some lithology substitutions.

The table presents the profile and current state of the well stock in the reservoir zone under study, while a three-dimensional view of the initial geological and reservoir models is shown in Figure 1.

Структура и текущее состояние фонда скважин на исследуемом участке пласта

Параметры	Исследуемый участок (по состоянию на 2020 г.)
Действующий фонд добывающих скважин	22
Средний дебит по жидкости, т/сут Средний дебит по нефти, т/сут Обводненность, % Пластовое давление, МПа Забойное давление, МПа	43,43 11,52 62,8 21,56 10,39
Действующий фонд нагнетательных скважин	8
Средняя приемистость одной скважины, м^3/сут Среднее давление на устье, МПа	71,7 28

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

- high water cut in wells, even 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, reserve recovery is quite non-uniform across the reservoir area. Currently, flooding outstrips oil production, which defines the key objective with respect to the field development system improvement [8-11].

To accomplish the objectives set, the technology of marker-based production logging 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 long-term production profiling surveillance was performed to obtain data on the flow profile and composition along the horizontal boreholes. Within the framework of this engineering solution, there is no need to deploy asset-heavy applications, such as coil tubing conveying 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].

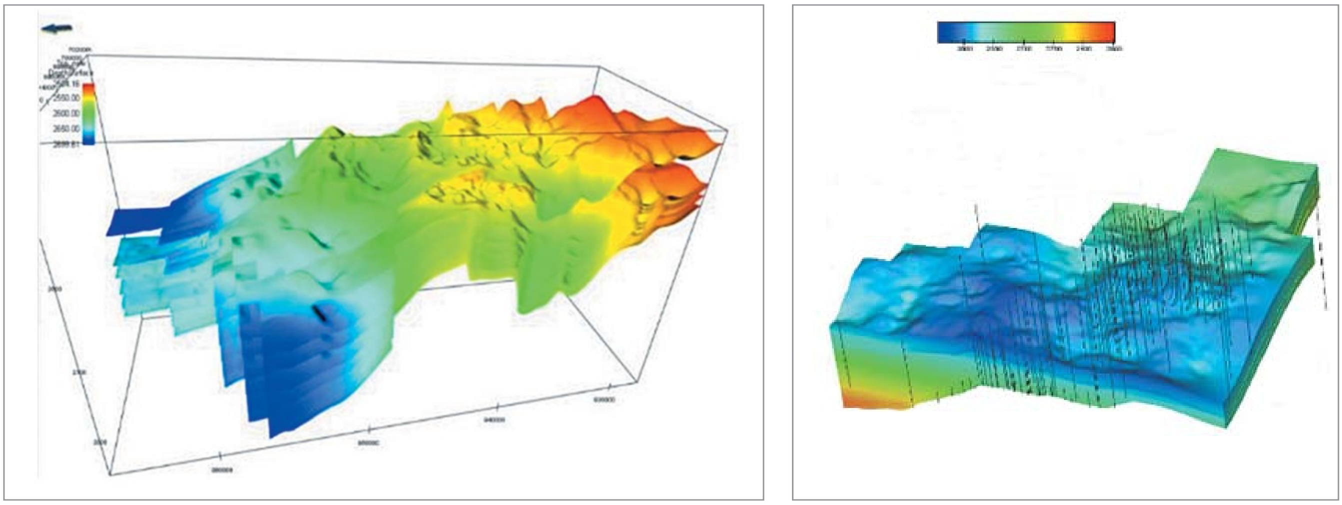

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Figure 1. Three-dimensional view of the initial geological (a) and reservoir (b) models

The solution is applied as part of an integrated approach, in which all wells were marked with flow tracers. Obtaining the production profiling of each well and interpreting well interference enable the client to better understand hydrodynamic interaction between wells and better optimise water flooding [2].

Methodology for geological and field feasibility study of the field development management using dynamic marker-based production profiling surveillance

The project involved the following activities (Figure 3):

- Defining the geological structure of the reservoir area:
  - Update of the geological and flow dynamics models based on the assessment of the quantitative production profiling in horizontal wells;
  - Lithological and facies analysis;
  - Estimation of oil reserves;
- Analysis of the current resource recovery state:
  - 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 flooding;
- Analysis of reserve recovery;
- Analysis of water flooding pattern performance with an assessment of the hydraulic communications 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;
- Reservoir simulations of the displacement process using the injectivity conformance control method in injection wells with the forecast and appraisal of the engineering efficiency indicators.

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

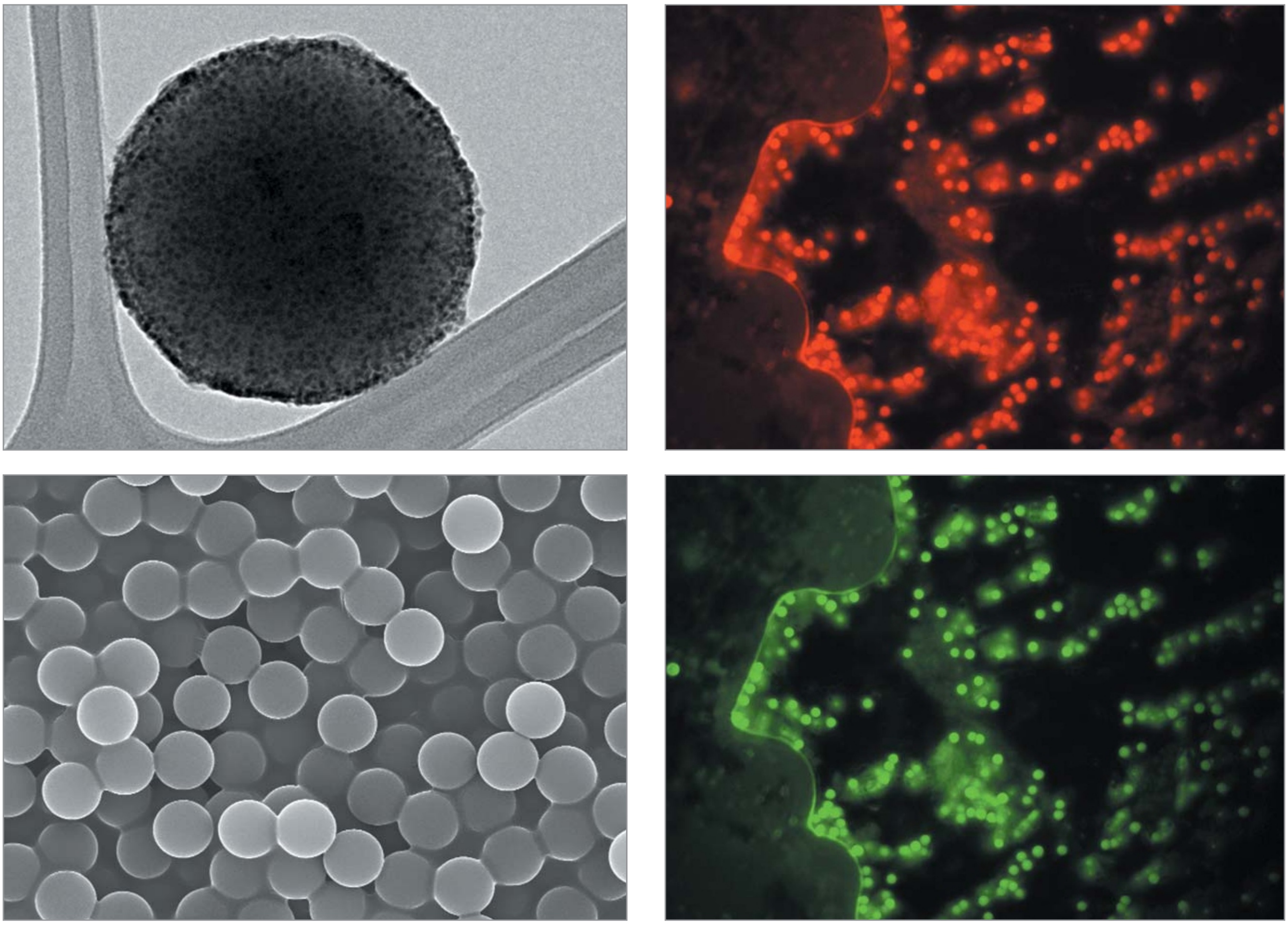

Figure 2. Quantum markers-reporters indicate the production profile and composition along the horizontal borehole

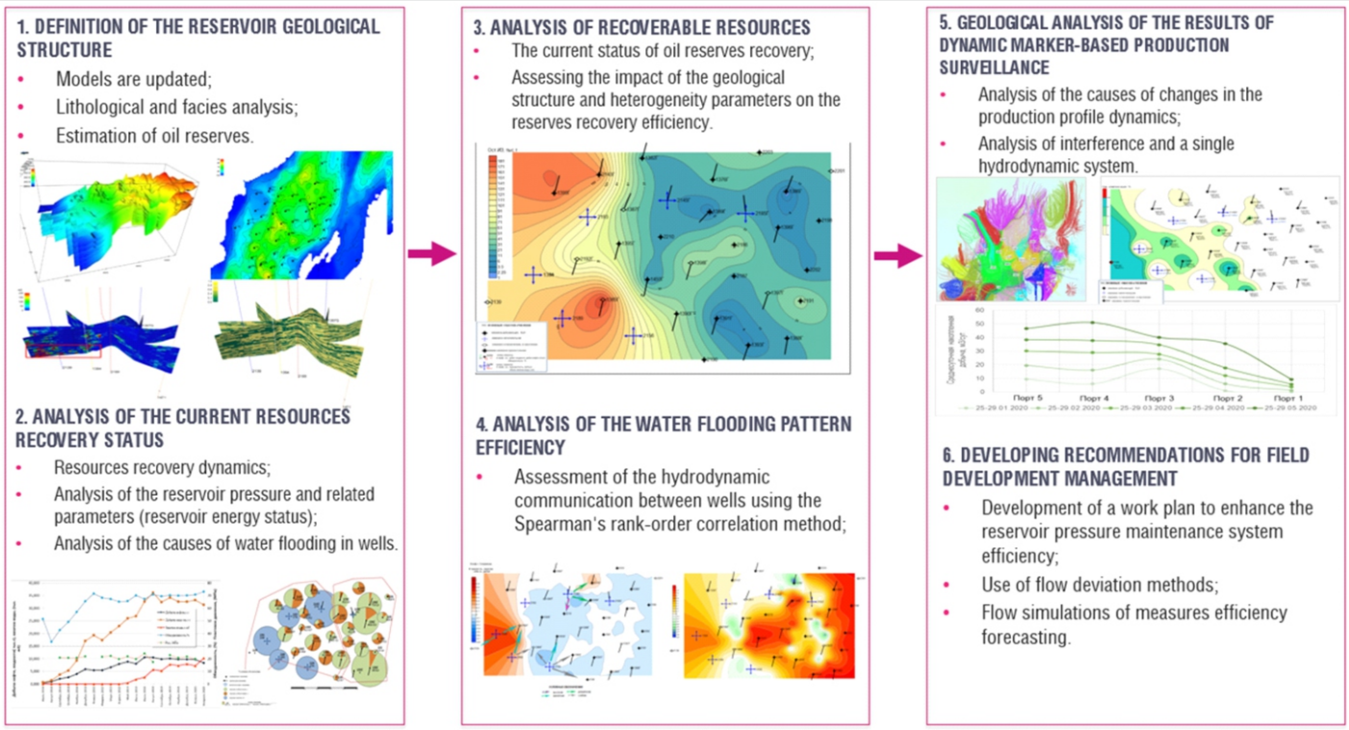

Figure 3. Methodology for the geological feasibility study of the field development management using dynamic marker-based production surveillance in horizontal wells

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

▪ Wells with initially high water flooding after multi-stage hydraulic fracturing.

Higher water flooding observed at the early stage in a number of horizontal wells could have been sourced by aquifers after the multi-stage hydraulic fracturing. There is also a possibility of water inflow from the upper BV6 aquifer.

▪ In wells where higher water flooding was detected during their operation, the hydraulic fractures could create hydraulic communications 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 flooding dynamics across the reservoir zone area. The highest values of the above-mentioned water-oil factor and the rapid decline in production suggest that water is likely to inflow from edge or bottom water.

▪ 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 BV7formation area is characterised by non-uniform reserves recovery primarily due to the insufficient areal sweep efficiency.

The formation pressure maintenance system was analysed to clarify to which extent injection impacts the production across individual flooding zones. The data obtained 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 encroachment in production wells (Figure 4).

According to calculations and additional reservoir 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% (Figure 5).

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 by injection;

▪ Creating additional water flooding sources in the reservoir zone to improve the areal sweep efficiency;

▪ Infill drilling to intensify the development of remaining oil in place;

▪ Treatment of the wells' bottom-hole zone to stimulate the oil flow from individual interlayers (bottom hole treatment using mud acids).

The above recommendations were adopted for implementation in 2020—2021.

Conclusions

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

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

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

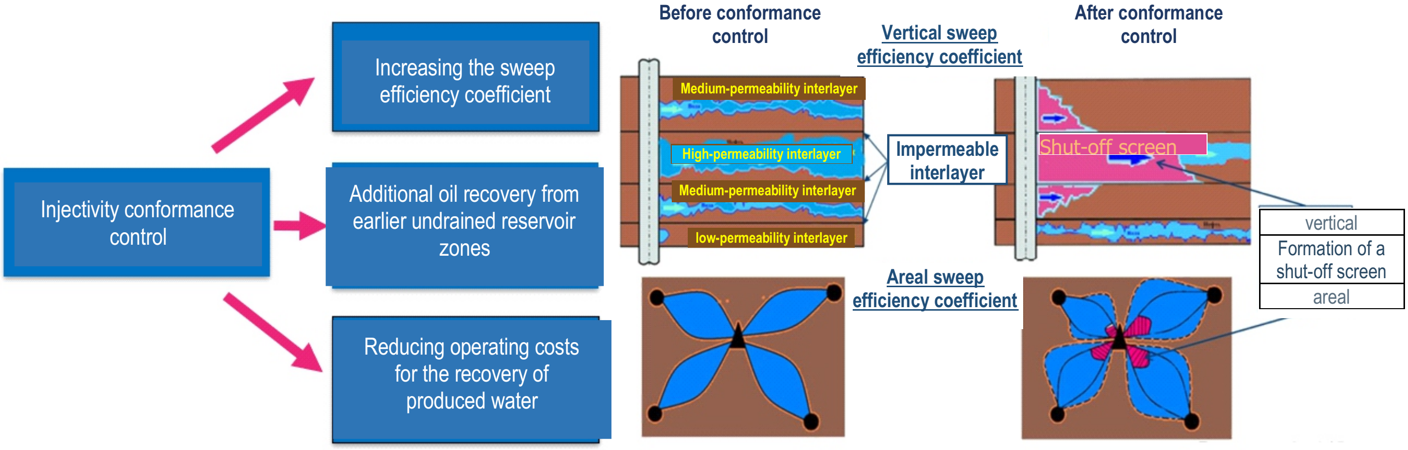

Figure 4. Mechanism for injectivity conformance control

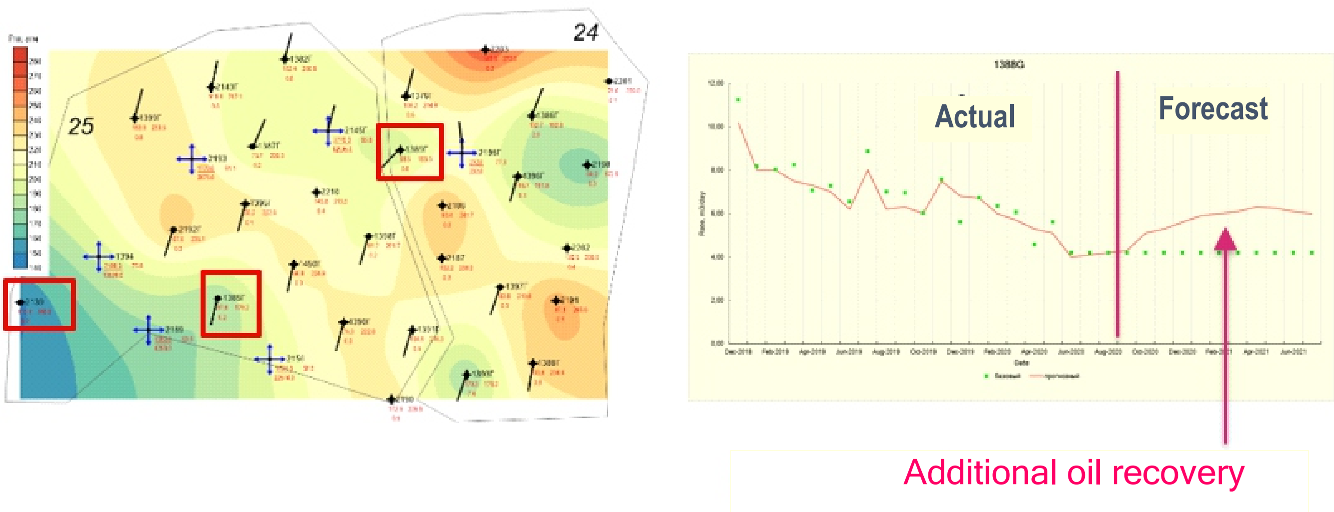

Figure 5. The effect of injectivity conformance control measures in injection wells

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