Contemporary development state of reservoir Yu1, the Verkh-Tarskoe oilfield (south of Western Siberia)

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Abstract. The paper provides results of the field-geological information analysis in order to evaluate the current development stage of reservoir Yu1 of the Verkh-Tarskoe oilfield. The main recoverable asset is currently in development phase III (declining production). The total well stock consists of 175 wells, of which 134 are producing. The monthly volume of water injection into the reservoir pressure maintenance (RPM) system reaches 100,000 m³, and fluid production is about 170,000 m³ with average water flooding of producing wells is 90.4%. The structures with complex geometry that formed within the hydrodynamic field where the deep pressure sinks are associated with production wells, and piezomaxima with injection wells. Given the multi-facies pattern of the sandstone depositional environments and secondary processes of rocks metamorphism during catagenesis, the target reservoir has a complex structure and its study in greater detail will require building a new geological model of the oilfield and more precise definition engineering to achieve maximum recovery.

Key words: hydrogeochemistry, exploitation, water content, reservoir pressure, Verkh-Tarskoe oilfield, Western Siberia

1 Introduction
Every oilfield goes through a certain life cycle, which can be broken down into several distinctive stages. Given that fluid filtration through a porous media is a complex phenomenon, it cannot be described as explicitly as e.g. principles of liquid flow within a conduit. Measuring the pipe’s diameter and length, as well as calculating its flow rate as a function of pressure is relatively simple. Whereas filtration flow through a porous media which is characterized by the absence of distinct current lines does not permit appropriate physical measurements [1-3].

Most recent methods employed in hydrogeological studies of petroleum basins are primarily based on the underlying principles of natural sciences. Appended by hydrochemical studies, their results are being increasingly utilized in the analysis and control of oil and gas fields development. Besides practical benefits of such monitoring, which is largely associated with its high informativeness, underpinned by the geochemical nature of technogenesis; as well as with the stratatal waters acting as indicator of cumulative human impacts; and with its significance for evaluation
of the environmental conditions and those of natural waters. A comprehensive lithohydrogeochemical concept occupies a cornerstone position in the theoretical framework of hydrogeochemical monitoring, which was the idea behind the research works of N. M. Strakhov, A. A. Kartsev, P. P. Timofeev, V. N. Kholodov, A. A. Makhnach, C. L. Shvartsev and others. Among the studies of hydrogeochemistry of petroleum basins, this research direction has received much emphasis in the works of A. A. Kartsev, A. N. Dmitrievsky, V. D. Poroshin, V. V. Mulyak, N. A. Popova and other researchers [4-7]. Besides, a huge body of factual evidence has been accumulated since the beginning of oil and gas exploration in Western Siberia [8-31]. The results of the study of different aspects of hydrogeochemistry of oil and gas-bearing deposits (including Upper Jurassic), were previously studied in detail in [32-36].

2 Results and discussion

The Verkh-Tarskoe oilfield is located in the north of Novosibirsk region (Fig. 1) within the Mezhov petroleum province in the southern portion of the West Siberian plate. The oilfield, which is ranked as the largest oil producing asset in Novosibirsk region, is located 340 km NW of Novosibirsk and 120 km N of Kuibyshev and is confined to the Verkh-Tara local structure detected by the seismic reflection method during the 1968-1969 field works. The exploration drilling in the Verkh-Tara area was started in 1970, with prospecting well #1 having struck oil in the crestal part of the structure. And thus that was the year when discovery of the Verkh-Tara oilfield was announced.

The oilfield comprises two oil accumulations within the oil and gas-bearing horizon (pay zone) at the contact zone (after E. E. Danenberg and A. E. Kontorovich, this is either the contact zone of Paleozoic and Mesozoic deposits or a multi-layered reservoir comprising deposits of different ages at the contact zone) and Yu1 (Upper Jurassic) representing both major pay zone and exploration and development target. 1998 est., oil reserves totaled 50.990/24.475 mln tons in C1 category (geological/recoverable), and 7.75/3.72 mln tons (C2). Development of the Verkh-Tarskoe (V-T) field commenced in 1994 by means of periodic operations of exploratory wells with the subsequent oil transportation from the field by road-tankers. At that time, the subsoil use rights were held by OOO Novosibirskneftegaz. In 2001, according to the CDP Protocol (Central Development Commission) No. 2743 dated 04.10.2001,
the oilfield development proceeded in accordance with the Amendment to the Improved Development Technology for the Verkh-Tarskoe Oilfield.

The Verkh-Tarskoe Oilfield Development Plan was approved in 2006. The Current Estimates of Oil and Dissolved Gas Reserves in the YuV1 reservoir of the Verkh-Tarskoe Oilfield as of 01.01.2009 was approved by the Federal Subsoil Resources Management Agency (Protocol No. 18/48 dated 06.02.2009). Presently, Novosibirskneftegaz company (AO NNG) is subsumed into joint stock company NK Neftis company. In 2017, NNG company was taken over by PITSI BINTEK under a business management agreement. As of 01.01.2018, oil reserves are total 39.980/10.898 mln t (A+B1 category: geological/recoverable) and 1.180 / 0.489 mln t (B2 category) [37].

Reservoir Yu1 is now almost completely drilled by production wells. As of January 2019, the total stock was 175 well, of which 134 are producing (Fig. 2). The production stock of 84 wells is divided into producing (54), observation (25) and idle (5) wells (Fig. 3). The injection stock ensuring the operations of the reservoir-pressure maintenance (RPM) system includes 91 wells, of which 29 are producing, 26 are observation and 36 are idle wells.

![Map of sandstones permeability (a) and isobars (b) of the YuV1 deposit of the Verkh-Tarsk oil field of January 2019.](image)

1 – contour of the deposit; injection wells: 2 - flowing, 3 - observation, 4 - idle; producing wells: 5 - flowing, 6 - observation, 7 - idle.

Porosity and permeability (P&P) properties of the YuV1 reservoir sandstones are marked by strong anisotropy. The permeability coefficient values vary from $1 \times 10^{-3}$ to $36 \times 10^{-3}$ $\mu$m$^2$. Localities with elevated P&P were recognized in the central and eastern part of the oilfield (Fig. 2a). The intake capacity of injection wells within the RPM system is also highly variable and ranges from 11 to 940 m$^3$/day, averaging 3,300 m$^3$/per day or about 100,000 m$^3$/per month for the reservoir.
The P&P anisotropy is dictated by the Yu1 reservoir structure, which includes dense layers composed of sandstones and siltstones with carbonate cement ranging from 1 to 8 in number (on average, 2-5) in its section. Acting as local impermeable beds, these divide the pay zone into separate layers (Yu1, Yu12) and interlayers (Yu1a, Yu1b) with varied reservoir properties, and, hence, the hydrogeological characteristics. The uneven drainage of Yu1 was confirmed by the data analysis results derived from the modular wireline formation tester (WFT) in the producer well [38].

![Graph showing production and injection well stocks dynamics](image)

**Fig. 3.** Production and injection well stocks dynamics (reservoir Yu1 of the Verkh-Tarskoe oil field)

Production well stock: 1 – operating, 2 – observation, 3 – idle wells, 4 – injection wells: A – operating, B – observation, C – idle wells.

A hydrodynamic field of complex geometry has distinctly formed within the bounds of the V-T oilfield in which the deep pressure sinks are associated with rows of production wells, and piezomaxima – with injection wells.

The reservoir pressure distribution pattern across the V-T oilfield area is illustrated by the isobar chart (as of January 2019). Reservoir pressures for individual blocks of the oilfield under development vary from 5 to 37 MPa (Fig. 2b). Reservoir pressures in the injection wells profiles range from 6.5 MPa to 30.5 MPa (on average, 22 MPa). Reservoir pressures are regularly measured in observation wells (51 wells in January 2019) drilled in the central, northern and southern parts, in order to control the oilfield development in the peripheral zones.

The production performance characteristics of hydrocarbon accumulation of Yu1 bed are as follows. The sandstones zones with elevated P&P are associated with regions of producing wells with high flow rates. As of January 2019, liquid flow rates for the currently valid production well stock vary from 8 to 279 m³/day, oil flow rates vary from 1 to 35 t/day, and associated gas from 63 to 4,162 m³/day. Monthly fluid production was about 170,000 m³ with water cut of oil producing wells averaging 90.4%. The degree of water encroachment into the oil generally varies from first percent to 99-100%. The most invaded zones are characteristic of the central and eastern blocks of the producing field.

### 3. Conclusion

The conducted rapid analysis (Quick Scan) of the available geologic parameters has shown that the basic targets of the Verkh-Tarskoe oil field is reservoir Yu1 which currently corresponds to stage III of development (declining production). A detailed geological model and reservoir properties analysis of
interlayers $Y_{U_1}^{i_a}$, $Y_{U_1}^{i_b}$ have enabled identification of oil accumulation zones which required different approaches to their development.

Acknowledgments

The research was financially supported by the FNI project № 0331-2019-0025 "Geochemistry, genesis and groundwater formation mechanisms in the sedimentary basins of Siberian Arctic ", by the Russian Foundation for Basic Research and the Government of Novosibirsk region in the framework of research projects № 18-45-540004 and 19-45-540006.

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