## Three-dimensional synthetic stochastic geological-hydrodynamic models

Since 2013, active drilling of productive formations in the northern part of the Priobskoye field has been carried out with a grid of production and injection wells. The reservoirs of the Gorshkovskaya area are low-permeable (0.1 - 1 mD) and heterogeneous (laterally disconnected).

In modern times, an essential task in designing hydrocarbon deposit development is to construct a geological and hydrodynamic model of the productive reservoir to obtain accurate production volume forecasts for various development scenarios. To account for geological heterogeneity, 3D stochastic models were utilized, as illustrated in Figure 1.

In order to make timely design decisions for new drilling locations, a considerable number of hydrodynamic models need to be constructed. These models are necessary to assess the efficiency of various development options while considering the geological properties of the reservoirs, which can be highly variable and heterogeneous. Unfortunately, the calculation of parameters for a single hydrodynamic model can take several hours or even days using high-performance computing clusters.

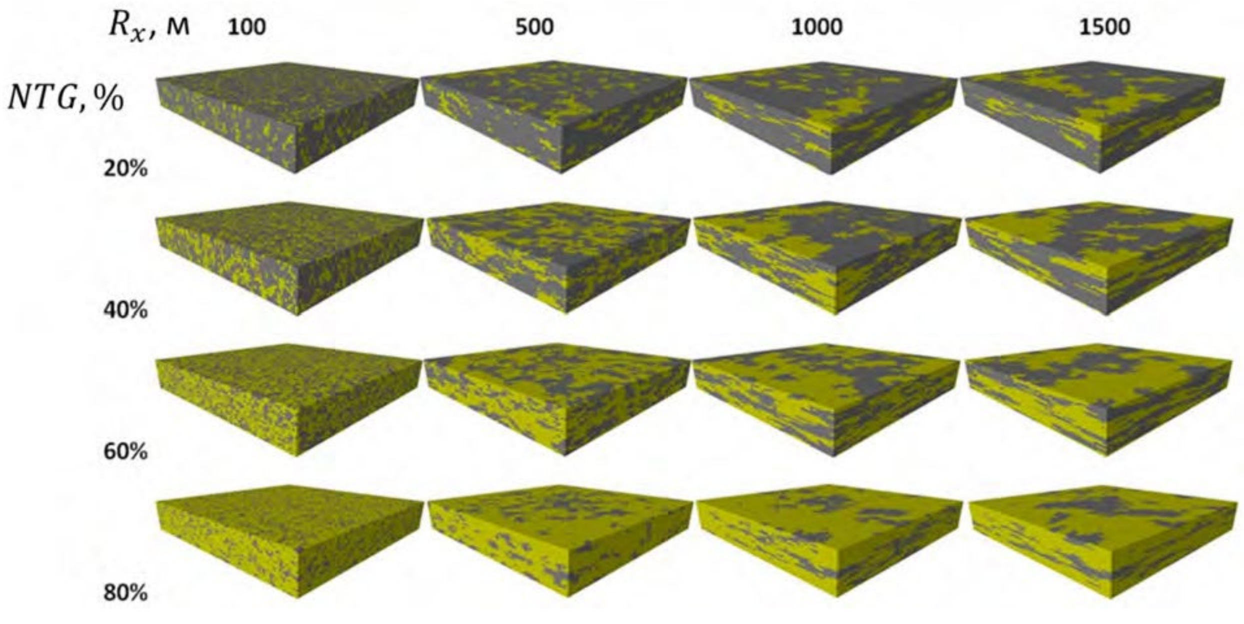


*Figure 1. An example of the distribution of sand bodies in stochastic geological models with different sand content coefficients (NTG) and different lateral sand body sizes (Rx).*

## Data desciption

The data used in this study consists of a table comprising 124,416 rows and 16 columns. Each row represents the calculation of a constructed hydrodynamic model, with the columns containing the key geological and technical parameters utilized in the calculations. The final column presents the outcome of hydrodynamic calculations, i.e., the oil recovery factor for the 100th year of development. A portion of the data table is depicted in Figure 2.

| | PORO | SW | KRW | system_number | NTG | RVAR | PERMX | l_horiz | param_x | n_frac | xf_prod | xf_inj | rotation_angle | switch_period | dFrac | КИН (100) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 0.17 | 0.3 | 0.15 | 9 | 0.60 | 250 | 2.00 | 0 | 300 | 1 | 50 | 150 | 0 | 1 | 0 | 0.4594 |
| **1** | 0.17 | 0.3 | 0.15 | 12 | 0.60 | 50 | 0.30 | 2000 | 100 | 20 | 50 | 300 | 0 | 3 | 100 | 0.2217 |
| **2** | 0.17 | 0.3 | 0.15 | 13 | 0.60 | 50 | 1.00 | 1500 | 100 | 15 | 50 | 150 | 0 | 6 | 100 | 0.4145 |
| **3** | 0.17 | 0.3 | 0.15 | 13 | 0.45 | 500 | 1.00 | 1000 | 200 | 10 | 50 | 150 | 45 | 6 | 100 | 0.3867 |
| **4** | 0.17 | 0.3 | 0.15 | 12 | 0.60 | 500 | 1.00 | 1000 | 300 | 10 | 50 | 300 | 45 | 3 | 100 | 0.4251 |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **124411** | 0.17 | 0.3 | 0.15 | 12 | 0.10 | 250 | 1.00 | 2000 | 200 | 20 | 50 | 150 | 0 | 3 | 100 | 0.1434 |
| **124412** | 0.17 | 0.3 | 0.15 | 12 | 0.30 | 50 | 0.30 | 1000 | 100 | 10 | 50 | 300 | 0 | 1 | 100 | 0.2301 |
| **124413** | 0.17 | 0.3 | 0.15 | 9 | 0.30 | 250 | 2.00 | 0 | 300 | 1 | 50 | 300 | 0 | 1 | 0 | 0.3809 |
| **124414** | 0.17 | 0.3 | 0.15 | 1301 | 0.10 | 250 | 0.05 | 1200 | 200 | 24 | 100 | 100 | 90 | 10000 | 50 | 0.0735 |
| **124415** | 0.17 | 0.3 | 0.15 | 13 | 0.10 | 1000 | 1.00 | 1500 | 200 | 30 | 50 | 50 | 45 | 6 | 50 | 0.3983 |

124416 rows × 16 columns

*Figure 2. Fragment of the table showing the results of multiparametric hydrodynamic calculations*

The primary parameters of the models analyzed in the study:

- **KIN (100)** – cumulative oil recovery factor (ORF) for the 100th year of development, units;
- **PORO*** – porosity;
- **SW*** – initial water saturation of the formation (SWATINIT);
- **KRW*** – Relative phase permeability of water at residual oil saturation (Krw(Sor));
- **NTG** - net-to-gross ratio;
- **RVAR** – variogram radius along the X-axis (lateral dimension of the sandbody), m;
- **PERMX** —permeability, mD;
- **l_horiz** - horizontal wellbore length, m;
- **param_x** - distance between wells, m;
- **n_frac** - number of hydraulic fracturing ports;
- **xf_prod** – hydraulic fracture half-length in producing wells, m;
- **xf_inj** – hydraulic fracture half-length in injection wells, m;
- **rotation_angle** – rotation of the grid of wells relative to the azimuth of the regional stress (330 $^{o}$);
- **switch_period** – period of oil injection wells development, months;

- **dFrac** – distance between hydraulic fracturing ports, m;

*An asterisk ( * ) denotes the parameters that were unchanged during the calculations.*

10 well placement systems were used for model calculation (Fig. 3):

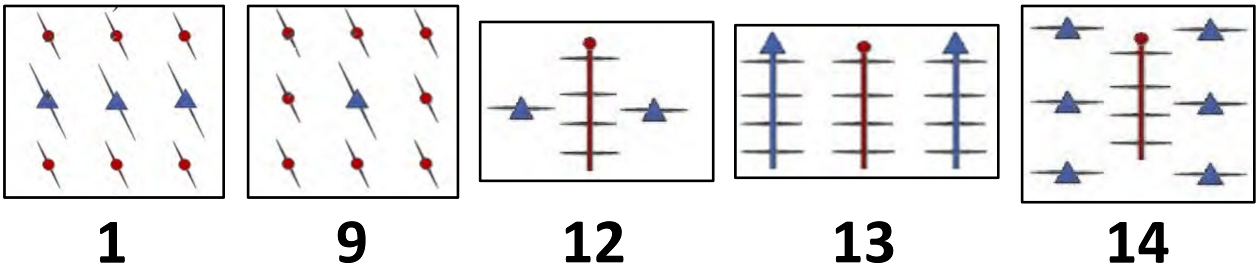


*Figure 3. Variation of well placement systems (producing wells are denoted in red, while injection wells are denoted in blue)*

**system_number** - well placement system number:

- **1** - frontal in-line; injection and producing vertical wells (VW) at a ratio of 1:1;
- **9** - nine-spot reversed; injection and production
- **12** - in-line; injection aircraft producing horizontal wells (HW) at a ratio of 1:1;
- **13** - in-line; injection HW, producing HW at a ratio of 1:1;
- **14** - in-line; injection VW, producing HW at a ratio of 2:1;
- **901** , **101** , **1201** , **1401** , **1301** - all presented well placement systems without injection wells (to account for well operation in depletion mode).

Filtration-permeability and phase properties are set according to the average values of the geological and physical characteristics of the Achimov formations of the Priobskoye field:

- Average porosity - 0.17;
- Viscosity of water in reservoir conditions - 0.35 mPa*s;
- Viscosity of oil in reservoir conditions - 1.44 MPa*s;
- Volumetric coefficient of water - 1.033 $m^3/m^3$;
- Oil volume factor - 1.2 $m^3/m^3$
- Initial reservoir pressure - 261 atm .;
- Saturation pressure - 125 atm .;
- Density of oil in surface conditions - 870 kg / $m^3$;
- Gas content of oil at saturation pressure - 55.1 $m^3$/t.;
- formation compressibility - 4 * 10-5, $atm^{-1}$ .;

Non-variable parameters of hydraulic fractures were obtained by averaging the data from the results of hydrodynamic well testing:

- hydraulic half fracture-lengths in the calculations varied in the range of 50-300 m;
- hydraulic width fracture – 0.005 m;
- proppant permeability - 50 D ;