Uncertainty analysis in sidetracking planning based on geological and reservoir simulation

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Abstract[1]

This work describes the stability analysis of simulation results of the adapted geological and hydrodynamic model depending on used stochastic realization, as well as sensitivity analysis of predicted technological parameters (oil flow rate, liquid flow rate, water cut) of the planned sidetrack to values of the initial parameters of geological and hydrodynamic model on the example of the oil-field Priobskoe.

1. Introduction

Sidetracking is one of the most effective ways to increase the production of residual recoverable oil reserves and to recover emergency, marginal and premature drowned wells [2].

Uncertainty of various kinds is an important problem in oil field development, since it can lead to errors during prediction of the technological parameters of the planned sidetrack and, consequently, to reduction of the oil recovery factor and loss of potential profits.

Uncertainty analysis in sidetracking planning based on geological and reservoir simulation is the main tool for risks of profit loss reduction [5].

2. Uncertainty analysis in sidetracking planning

The main uncertainties during planning of sidetrack are:

- Presence of residual stocks in the target area;
- Position of the injected waterfront;
- Position of the bottom hole;
- Technological parameters of the hydraulic fracturing at the planned sidetrack.

An effective tool to minimize the risks during the sidetracking is a three-dimensional geological and reservoir simulation [1].

The object for modelling in this paper is the spectral sector three-dimensional model of the oil-field Priobskoe with the target well. Geologically, the area is represented by three layers: AC10, AC11, AC12 (fig. 1). Layers AC10, AC11 refer to the shelf sediments which are characterized by well correlated interlayers, layer AC12 refer to deep-sea sediments which are characterized by high clay content, compartmentalization and extremely low permeability. However, this layer contains about half of the recoverable oil reserves.

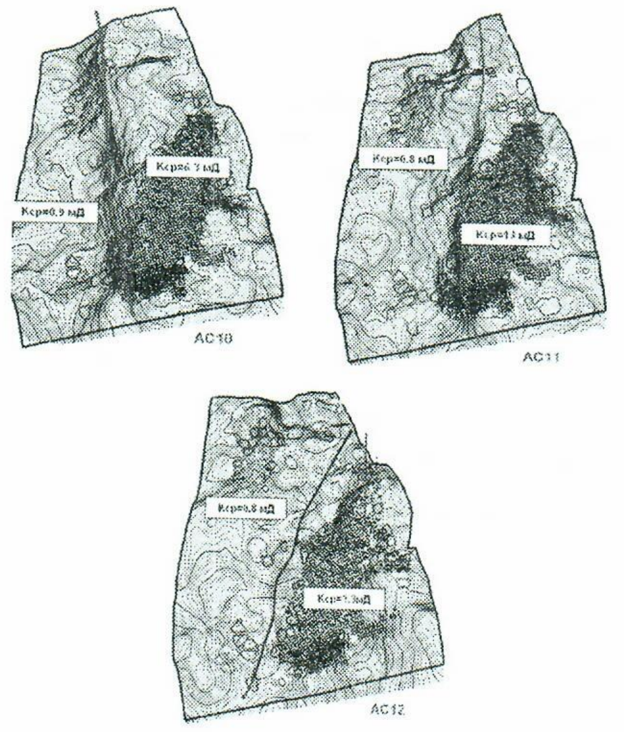

Fig. 1. The geological structure of the modeled area

Reservoir properties at the interwell space are random variables and are defined in the model by geostatistical simulation based on geological investigations of wells and core analysis conducted in the wellbore (fig. 2).

[1] **Proceedings of the 14th international workshop on computer science and information technologies CSIT'2012, Ufa – Hamburg – Norwegian Fjords, 2012**

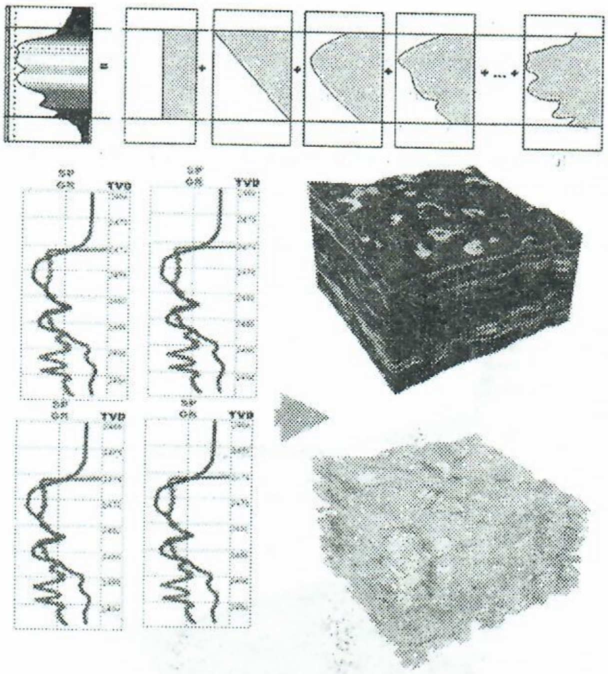

Fig. 2. Stochastic geology modeling

Model calculations were performed using the simulation package NGT BOS Core on the computational cluster of USATU. A feature of this package is the ability to model well fractures by the method of sources (fig. 3), which has the following advantages:

- Accounting for the geometry of the fracture without local grid shredding;
- Accounting for fracture permeability;
- Accounting for filtering of intermingled due to fracturing lenses, which were not initially connected with the wellbore.

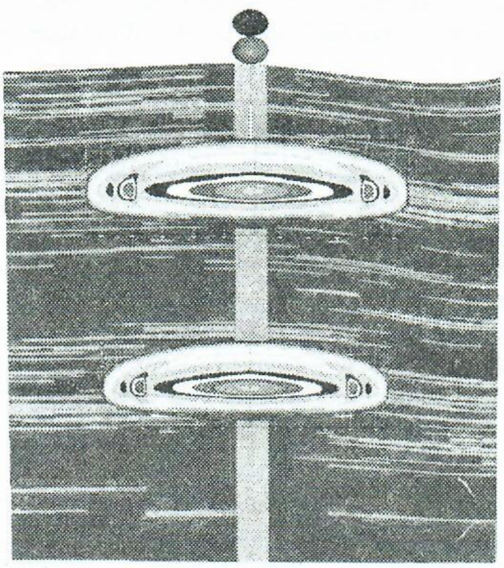

Fig. 3. Modeling of well fractures by the method of sources

The input data for modeling is: historical data of production, physico-chemical properties of reservoir fluids, hydraulic fracturing design data and results of the material balance analysis for the considered oil field.

Often in practice to predict technological parameters of the sidetrack only single implementation of the geological model is used. Consequently, the question of adequacy of the adapted geological-hydrodynamic model becomes urgent and the problem of the analysis of the stability of calculation results depending on the implementation of a geological model occurs. Also, certain difficulties in constructing models of such oil fields as Priobskoe are tremendous amount of production and geophysical data and high level of non-stationary (spatial variability) of physical and geological fields [6]. All this introduces an uncertainty to the values of technological parameters of the planned sidetrack, which are predicted using geological and hydrodynamic model. This fact explains the urgency of the problem of the sensitivity analysis of predicted technological parameters of the planned sidetrack to the values of the initial parameters of geological and hydrodynamic models.

Analysis of the impact of geological parameters (stochastic realizations, anisotropy, connectivity, "permeability-porosity" ratio) on the results of calculations of the adapted geological and hydrodynamic model conducted in this paper showed that model, in general, is robust to considered parameters. Deviations of integral calculated technological parameters in the model (oil production rate, liquid production rate, water cut) from the historical do not exceed 3% (fig.4).

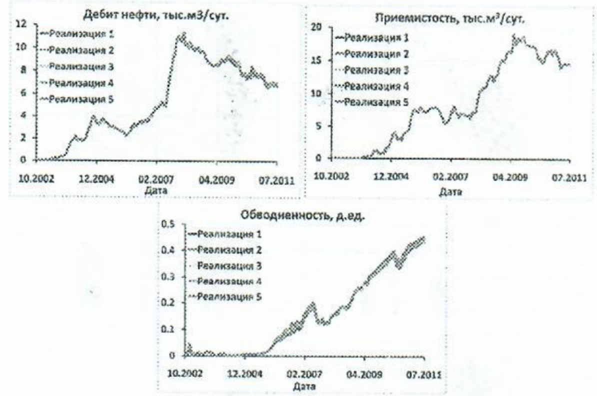

Fig. 4. Analysis of the stability of the geological model implementation

Further to analyze the impact of hydrodynamic parameters of the original model to forecast technological parameters of the sidetrack a single adapted implementation of geological and hydrodynamic model has been used (fig.5).

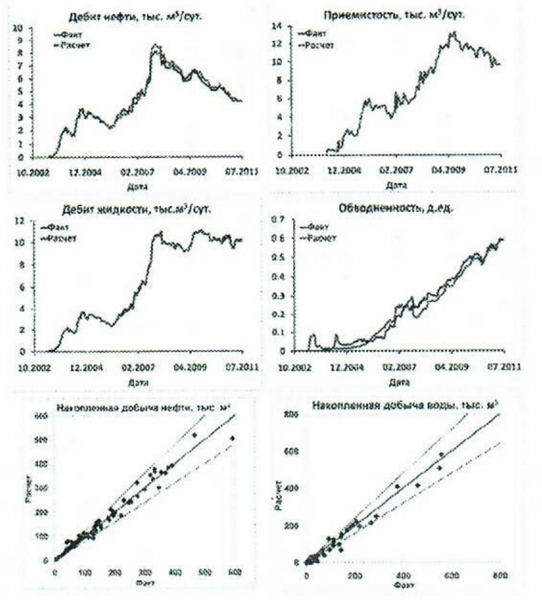

Fig. 5. Results of three-dimensional model adaptation

During the work probabilistic parameters of the geological and hydrodynamic model were determined, as well as their discrete probability distributions (fig.6).

Basic hydrodynamic parameters of the original model with uncertain values are [3, 4]:

- Position of the front of injected water;
- Position of the bottom hole of the planned sidetrack;
- Azimuth, half-length and permeability of the fracture of the planned sidetrack.

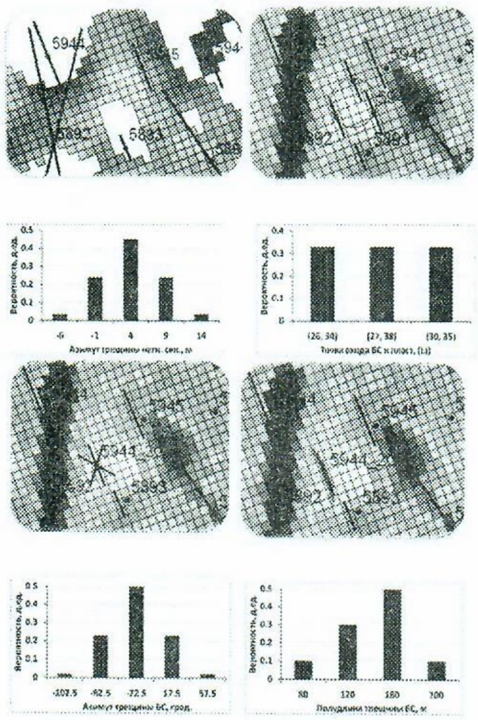

Fig. 6. Probabilistic parameters and their distributions

On the basis of selected hydrodynamic parameters multiple calculations were carried out. Results of these computations form probability surfaces and distributions of the sidetrack forecast technological parameters on which it's possible to make a conclusion about sidetrack future effectiveness (fig. 7).

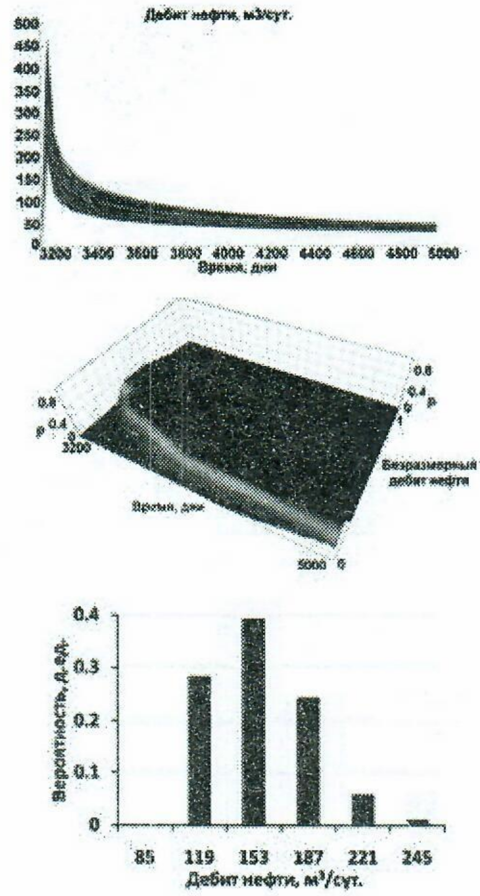

Fig. 7. Probability surface and distribution of the forecast technological parameter of the sidetrack

3. Conclusion

Development of computational tools provides possibilities of multiple geological and hydrodynamic calculations which help solving the problem of the sensitivity analysis of predicted technological parameters of the planned sidetrack to the values of the initial parameters of models. Results of these computations form probability surfaces and distributions of the sidetrack forecast technological parameters on which it's possible to make a conclusion about sidetrack future effectiveness.

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