REDUCING GEOLOGICAL UNCERTAINTIES OF A NEWLY DISCOVERED FIELD IN RUSSIA WITH SEISMIC INVERSION*

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A wide-azimuth 3D seismic survey was performed at the field with an explosive source, using a centrally symmetric observing system, with a fold of 144 and a maximum source-receiver distance of 5,056 m. Since the field is undeveloped, poorly studied and is in full autonomy, it is necessary to perform the most accurate forecast of the resources and reserves for the construction of optimal surface facility design. The main geological objects are deposits of Cretaceous and Jurassic. Deepwater marine sediments (from the Cretaceous period, also known as Achimov reservoirs) represent most of the resources of this licensed area. The traps are most often stratigraphic, or structural-stratigraphic. Task of the research was to perform attribute analysis and seismic inversion with the aim to obtain most accurate properties of the reservoir for further geological and infrastructural activities. In our case, since it is a new field, we had a small number of observations, and as a result, the absence of a representative sample of data for regression analysis. To resolve ambiguities and select an appropriate forecasting methodology for complex reservoirs, petroelastic modelling was performed.

Key words: rock physics, simultaneous inversion, Achimov reservoirs.

INTRODUCTION

Research area is located in Russia in the Khanty–Mansiisk Autonomous district of the Tyumen region. It is a Greenfield discovered in 2017.

Since the field is new, poorly studied and is in full autonomy, it is necessary to perform the most accurate forecast of the resources and reserves for the construction of optimal surface facility design. Avoid building too much or too little infrastructure and keep the project economical. This is especially challenging due to environmental conditions. Area where field is located has only roads during certain seasonal times – from December to March.

A wide-azimuth 3D seismic survey was performed at the field with an explosive source, using a centrally symmetric observing system, with a fold of 144 and a maximum source-receiver distance of 5,056 m. Four wells were drilled within the framework of the 3D seismic survey, three of them have sonic scanner and density well-logs from near surface level to total well depth.

The main geological objects are deposits of Cretaceous and Jurassic age. Most of the resources of this licensed area are represented by deep-water marine sediments and are confined to the Cretaceous period also known as Achimov reservoirs. The traps of such deposits are most often stratigraphic, or structural stratigraphic (Sidubaev *et al.*, 2019).

The main difficulties are prediction of pay thicknesses and determining the areal distribution of the reservoir, without which it is impossible to make an accurate forecast of the resources estimation. Task of the research was to perform attribute analysis and seismic inversion with aim to obtain most accurate properties of the reservoir for further geological and infrastructural activities.

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METHOD AND THEORY

Attribute analysis is a search for correlation between various attributes of a seismic data and the pay thicknesses/rock properties (such as porosity) of productive target objects. In the case of predictable dependency, a quantitative forecast of the properties of the target object can be calculated by converting the attribute to the forecast map according to the established dependency. The advantages of attribute analysis are the rapidity and simplicity of this method (Aki, Richards, 1980).

The basis for predicting the properties of reservoirs using seismic data is the existence of reasonable relationships between the elastic parameters of the section (the velocity of P and S waves, density and their derived quantities) and reservoir characteristics of various lithotypes of the studied section. In this regard, the completeness and quality of the log data is important. Since the data of well logging are carried out under the influence of the borehole environment (change in diameter, drilling fluid invasion, etc.), and seismic waves carry information about unaltered rocks, rock physics is the most important element in the implementation of seismic projects (Hilterman, 2001) to facilitate the modelling of elastic properties, necessary for (Fig. 1):

- Obtaining missing log curves;
- Filling the “gaps” in surveys of Vp, Vs, Rhob;
- Correction for the influence of the wellbore;
- Normalization of well data by area to obtain a consistent spatial model.

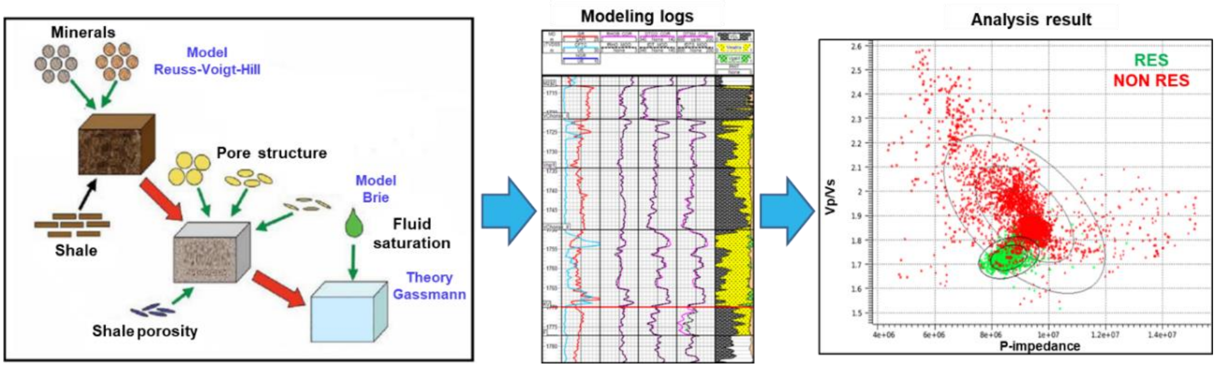

Fig. 1 – Algorithm of creation and probable results of Rock Physics (petro-elastic model).

Based on petro-elastic modelling, one can determine which seismic inversion method can be used to solve the geological problem and deal with uncertainties. In the simultaneous inversion of partial-multiple sums algorithm, several angular or offset seismic data are used simultaneously (Al-Otaibi, Hilterman, 2000). Using a set of seismic data stacked for different ranges of angles/offsets, it is possible to extract additional information by studying changes in reflection coefficients from the angle of incidence of seismic waves and three independent elastic parameters (P-velocity, S-velocity and density) (Fig. 2).

Based on the results of simultaneous inversion for several elastic parameters a more reliable forecast of reservoir properties in the field can be obtained by cross-correlation analysis.

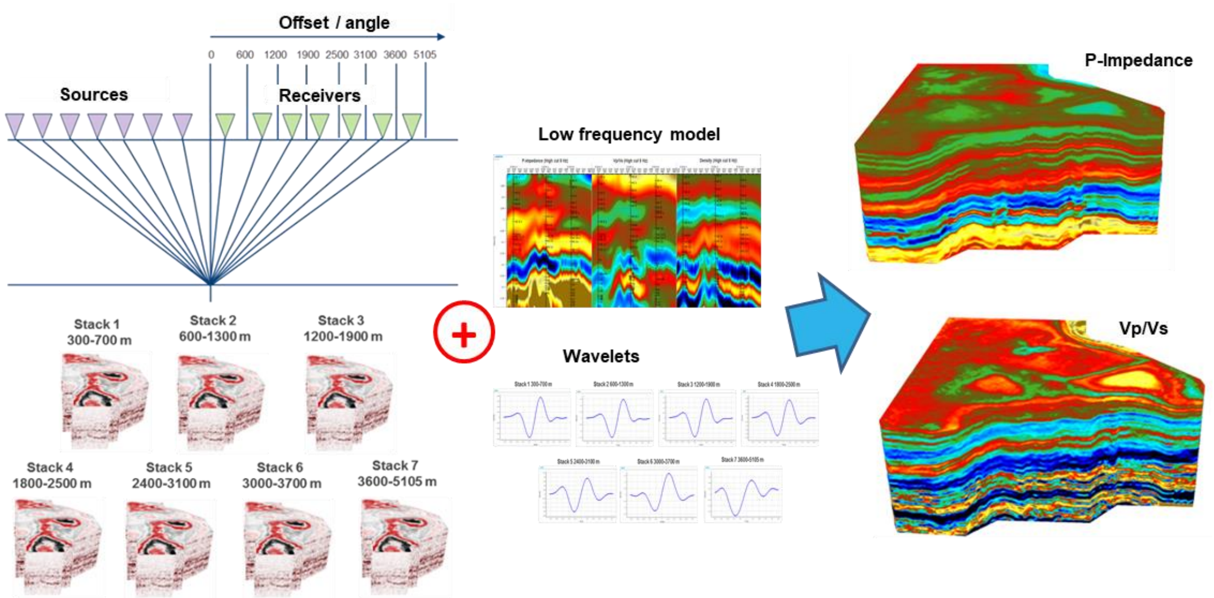

Fig. 2 – Algorithm of Simultaneous AVA Inversion.

RESULTS

One of the main challenges of the project under consideration is the prediction of pay thickness and areal distribution of reservoirs across the deep-water sediments that make up formations I and II (turbidity flows). In our case, since it is a new field, we had a small number of observations, and as a result, an absence of representative sample of data for regression analysis. That led to lack of reliable causal relationships between changes in predicted parameters (porosity, permeability, etc.) and changes in attributes and explicit multi-collinearity of predictors.

To solve this ambiguity and select the forecasting methodology for complex reservoirs I and II, petro-elastic modelling was performed. Following conclusions are obtained (Fig. 3):

- Reservoir and Non-reservoir are poorly separated in the P-impedance domain; a significant area of overlap is noted;
- Reservoir rock confidently determined in the Vp/Vs ratio domain;
- To predict the area of Achimov reservoirs, it is necessary to perform simultaneous AVA inversion.

From the seismic data, a set of seven partial offset stacks was generated. Deterministic simultaneous AVA inversion of partial offset stacks was calculated (Fig. 2). Prospective reservoir (Sweet spot) data points are located in area of reduced values of Vp/Vs and P impedance. Separating these points from the rest of the data set, distribution zones of reservoir I and II are highlighted (Fig. 4). This way, the key uncertainties in the distribution of sand bodies over the area for deep-water deposits of formations I and II are reduced.

For geological modelling and probabilistic estimation of reserves, we decided to use 2D trend modelling. Prediction of pay thicknesses is done according to their dependence on acoustic impedance, since it had the best correlation coefficient and the smallest error in the forecast. The distribution boundaries of the reservoir were determined by the cross-correlation analysis of elastic parameters.

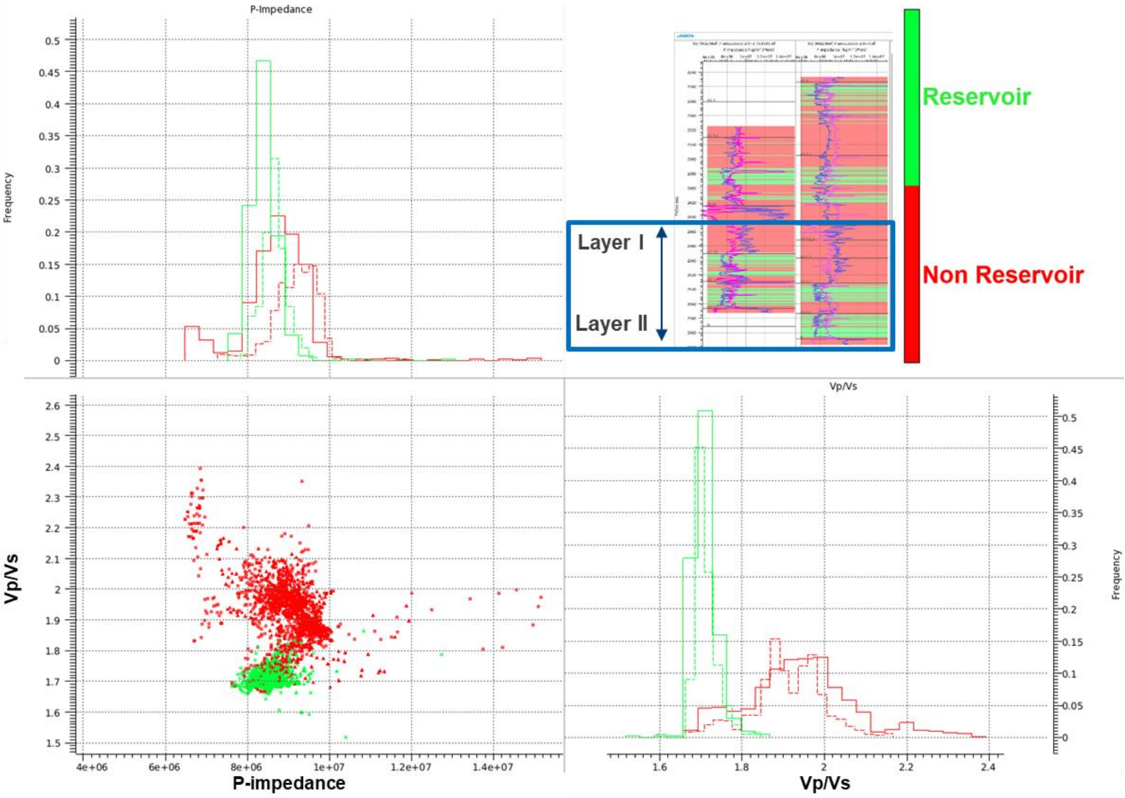

Fig. 3 – Results of Rock Physics. Distribution and histograms of reservoir and non-reservoir in P-impedance vs Vp/Vs cross-plot.

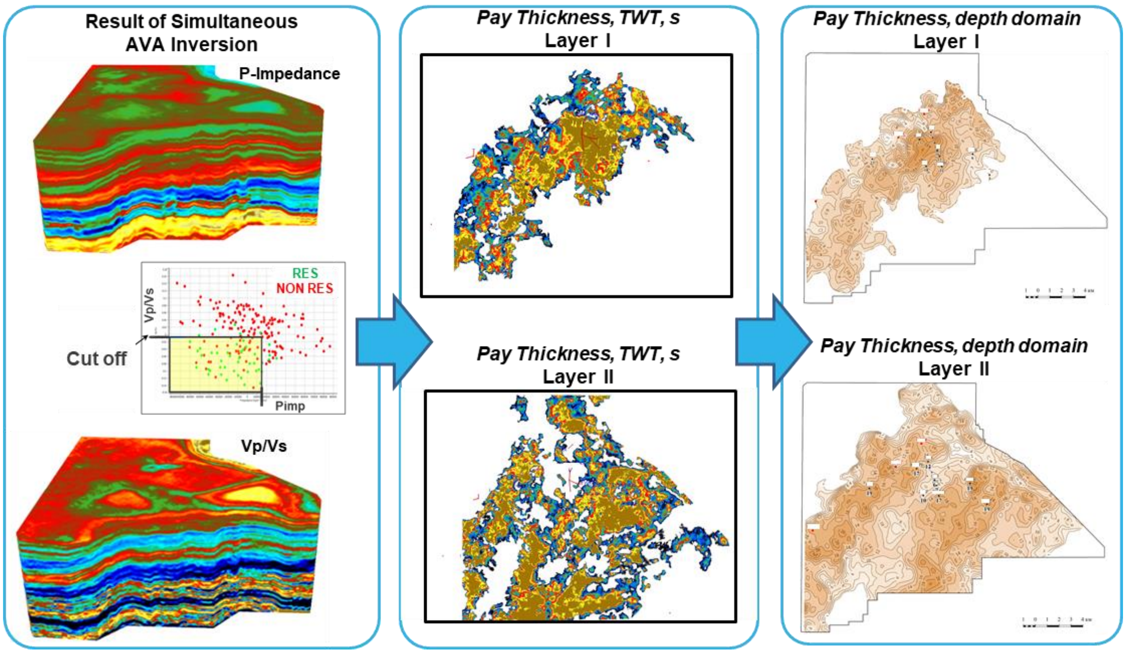

Fig. 4 – Method to create prediction of reservoir areas and pay thickness from results of Simultaneous Inversion.

The probabilistic estimation of reserves was performed using 3D modelling. As a result, 400 realizations of the geological model were created, based on which reserves P10-P50-P90 were determined; maps of the coefficient of variation for reserves and maps of the density of reserves were constructed. Based on these data, certain zones were determined that allow one to start production drilling without additional study. There are also zones with high potential for reserves, but with remaining uncertainties for pay thicknesses. For such zones, a program of additional exploration was formulated. This program includes drilling of pilot wells, and data acquisition with high-quality complex well-logs that would remove these uncertainties.

Based on the selected geological data that correspond to the reserves of P10-P50-P90, production profiles were calculated, the necessary surface facility were predicted, the project economics were evaluated, and a decision was made to build surface facility and start production drilling.

CONCLUSION

The results of the performed work on seismic inversion allowed us to:

- Perform quantitative forecasts for pay thicknesses and pay areal distribution for deep-water marine sediments (Achimov reservoir) that were previously not possible;
- Perform a probabilistic evaluation of reserves and to create an development program to decrease residual uncertainties;
- Make the decision on the construction of surface facility and early development drilling;
- Generalize and apply the experience to other fields with the same type of deposits (Achimov resevoirs).

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