FORECAST OF FRACTURING AND FLUID-SATURATING AREAS OF CARBONATE ROCKS OF THE RIPHEAN OF KUYUMBINSKY FIELD BASED ON SIMULATION OF ELASTIC-MECHANICAL PROPERTIES (PROCESSING AND INTERPRETATION OF 3D CDP SEISMIC MATERIALS FROM KUYUMBINSKY REPRESENTATIVE AREA OF THE KRASNOYARSK TERRITORY)

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Abstract. In this paper we consider a new approach to the forecast of increased fracturing areas of the Riphean carbonate rocks based on simulation of elastic and mechanical properties of well logging data, with the involvement of full-wave seismic acoustics. The main parameters used, characterizing the elastic and mechanical properties of the rock are the Poisson's ratio and Young's modulus. The forecast is made for fluid saturation of the Riphean strata on the basis of calculated cubes of basic elastic parameters λρ, μρ (Lame constants) and λρ / μρ, because they (the parameters) have the best ability to detect hydrocarbons. To evaluate the forecast quality monitoring wells were used that did not participate in the interpretation, which confirmed the forecasted model of the Riphean reservoir.

Keywords: seismic survey, Riphean deposits, fracturing forecast, elastic and mechanical properties, fluid saturation

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Site of seismic survey operations is located within Kuyumbinsky field in Eastern Siberia. Research objects are ancient deposits of the Riphean, the fluid saturation degree of which is controlled by fractured rocks.

Kuyumbinsky field was discovered in 1973 by drilling parametric wells K-1, which penetrated in the Riphean carbonate deposits gas reservoir with an initial daily flow rate of gas about 200 thousand m^3 (Kharakhinov, Shlenkin, 2011). In 1974 it was put on the state balance. The first commercial oil flow was obtained in 1977 in exploration well K-9; its production rate was 43.8 m^3/day. In the same year, oil was produced from the exploratory well K-2 with a maximum flow rate of 135 m^3/day (Kharahhinov, Shlenkin, 2011). Today, according to the value of the initial recoverable reserves of hydrocarbons, this field is classified as major. Oil in the field is light, with a low viscosity, relatively high gas content and saturation pressure, referred to the methane type.

Oil has low content of sulfur, resin, paraffine. Hydrocarbon deposits are confined to the ancient carbonate Riphean strata where fractures and caverns have a decisive influence on the formation of voids. Deposits are of tectonically shielded type, reservoir type – massive, fluid type – gas-oil, oil, gas condensate.

Kuyumbinskoye oil-gas-condensate field has a complex block structure and intensive disjunctive tectonics on Riphean deposits (Figure 1). The field is characterized by a high degree of litho-facies heterogeneity, variability of reservoir properties. In addition, a complicating factor for the study of the Riphean section of the interval is that the deposits are penetrated by wells at a shallow depth, and there is still no single common and approved scheme of stratigraphic subdivision of the Riphean deposits. Therefore, in the wave field stratification of reflectors in the Riphean section is based on the assumption that in the carbonate section the most stable reflections are formed from carbonate-clay strata (kopcherskian, dolgoktinskian, madrinskian, vedreshevskian formations).

In this connection, to successfully implement the exploration and development of such a complex and unique deposit, an in-depth analysis is required of all available information, in this case, the main focus is in the forecast of zones of increased fracturing,

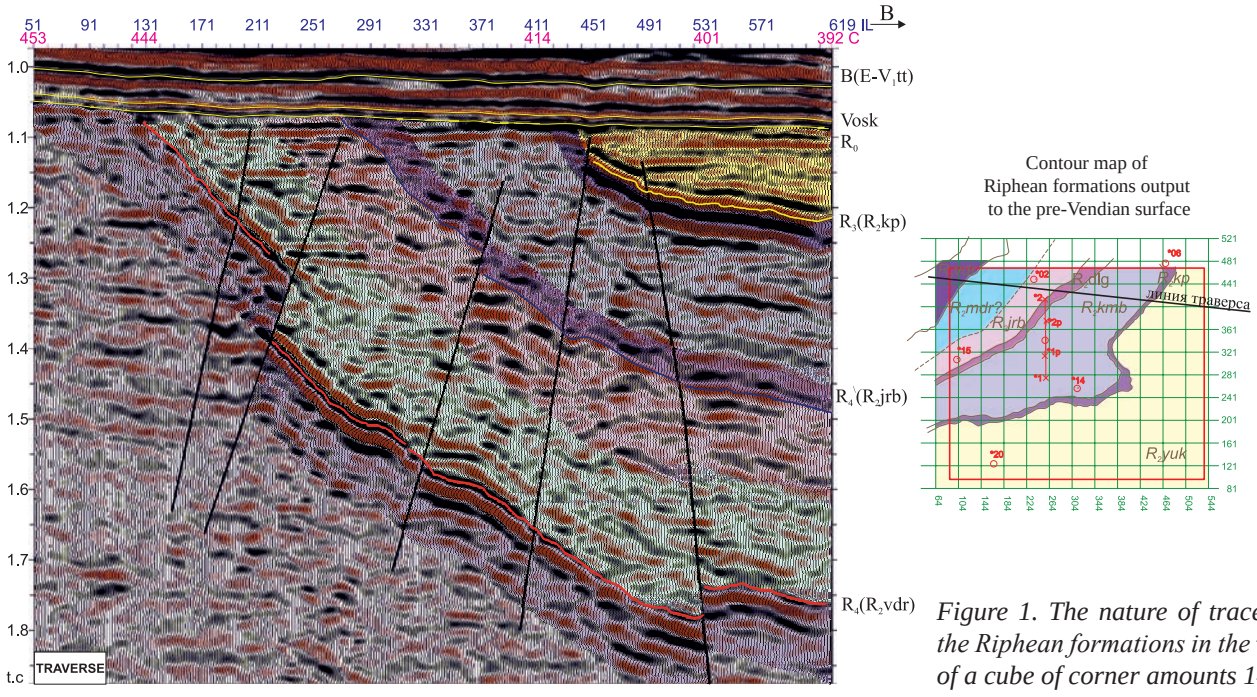

Figure 1. The nature of traceability of the Riphean formations in the wave field of a cube of corner amounts 14-26 o.

controlling fluid saturation degree using new seismic technologies.

Therefore, for the purpose of reservoir properties prediction, including areas of highly fractured Riphean deposits, a treatment was carried out with the implementation of time and depth migration and interpretation of seismic data in the amount of 100 km^2. Matched graph provided a good traceability of the main reflectors and yielded optimal resolution of seismic data in both vertical and lateral directions.

In addition, interpretation of well logging data was conducted. For lithologic and petrophysical characteristics of rocks the results of core analysis were used, including a description of thin sections, sludge; calculations, modeling was made of elastic and mechanical properties of rocks. On the basis of broadband acoustic data we calculated dynamic properties such as the ratio of interval times of the transverse and longitudinal waves, shear and Young's modulus, Poisson's ratio, shear and acoustic impedances, wave propagation speed (Dobrovolskaya et al., 2016).

In the interpretation process, fragility coefficients were calculated, the analysis of the changes of which together with the test results of formations, data of full wave sonic logging and FMI allowed to assume that rocks with fragility of more than 60% have an increased fracturing and may be the flowed. In addition, the intervals of increased fragility are characterized by high values of Young's modulus and low values of Poisson's ratio since zero values of Poisson's ratio correspond to absolutely fragile materials, and the maximum – to absolutely incompressible. More 'hard' rocks having high Young's modulus are more prone to cracking than rocks with low Young's modulus.

In the interpretation process in two well No.14 and 15 and the Riphean deposits we have found a discrepancy between the Poisson's ratios, calculated from the log data and the theoretical curves, which is probably due to the secondary voids of rocks.

Thus, the conclusions drawn from the interpretation of borehole material, have set the direction for further interpretation of seismic data.

To predict the most fragile and fractured zones in conditions of carbonate rocks a synchronous inversion was performed with obtain of cubes of Poisson's ratio and Young's modulus; a cross-plot analysis was conducted.

In addition, the fracturing assessment of the Riphean strata was carried out on the basis of Poisson's ratio cubes, calculated on the basis of multi attributive analysis using theoretical and calculated curves in the wells. The basis was the conclusion on the results of modeling of elastic and mechanical properties in wells about that intervals of fracturing rocks correspond to significant deviations in the direction of reducing the calculated values of Poisson's ratio from the theoretical ones. Analysis was performed within a small portion of pressure stabilization curve separately for each well; test intervals were adopted as analyzed intervals.

As a result on well sites where commercial oil, gas and gas condensate flows were obtained, we can observe in the histograms a significant deviation in the direction of reducing the calculated Poisson's ratios from the theoretical values. In the analyzed sections of wells, where no commercial inflows of hydrocarbons were obtained, calculated and theoretical values of Poisson's ratio are close enough (Figure 2).

Therefore, to identify promising areas with increased fracturing across the studied area cubic difference

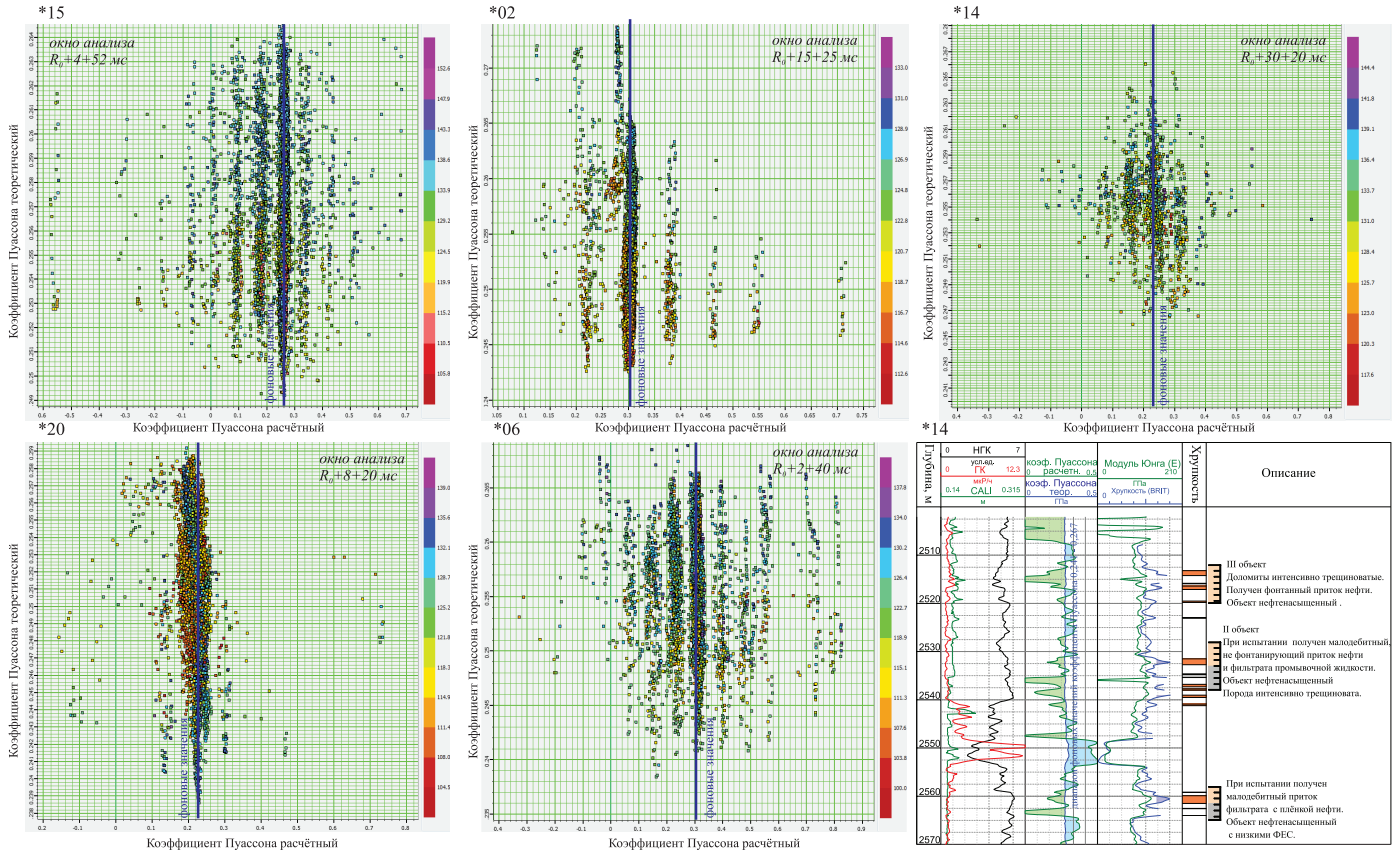

Figure 2. Evaluation of elastic and mechanical properties of the productive Riphean deposits using calculated and theoretical Poisson's ratios.

of Poisson's ratio was obtained; and the coefficients difference map was calculated for the upper range of Riphean deposits (analysis window is selected taking into account the test intervals in wells) (Figure 3). Potentially promising areas allocated for cubes 'ant-tracking' of the Young's modulus are characterized by a maximum difference of Poisson's ratio, which once again confirms their potentially high reservoir properties.

To predict fluid saturation of the Riphean strata, cubes of the basic elastic parameters λρ, μρ and λρ/μρ (Lame constants) were calculated, because they have the best ability to detect hydrocarbons (Voskresensky, 2001).

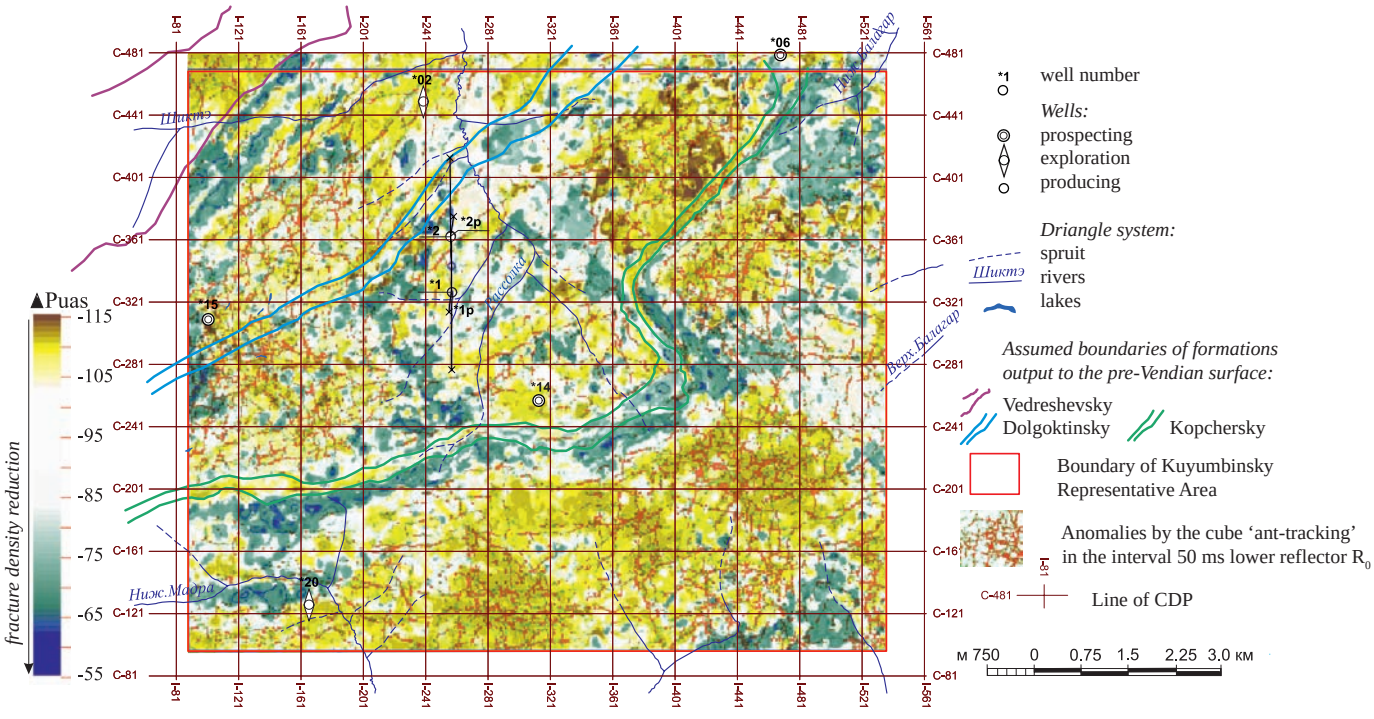

Figure 3. The difference map between the Poisson's ratios in the range of 20 ms below R_0, combined with anomalies by the cube 'ant-tracking'.

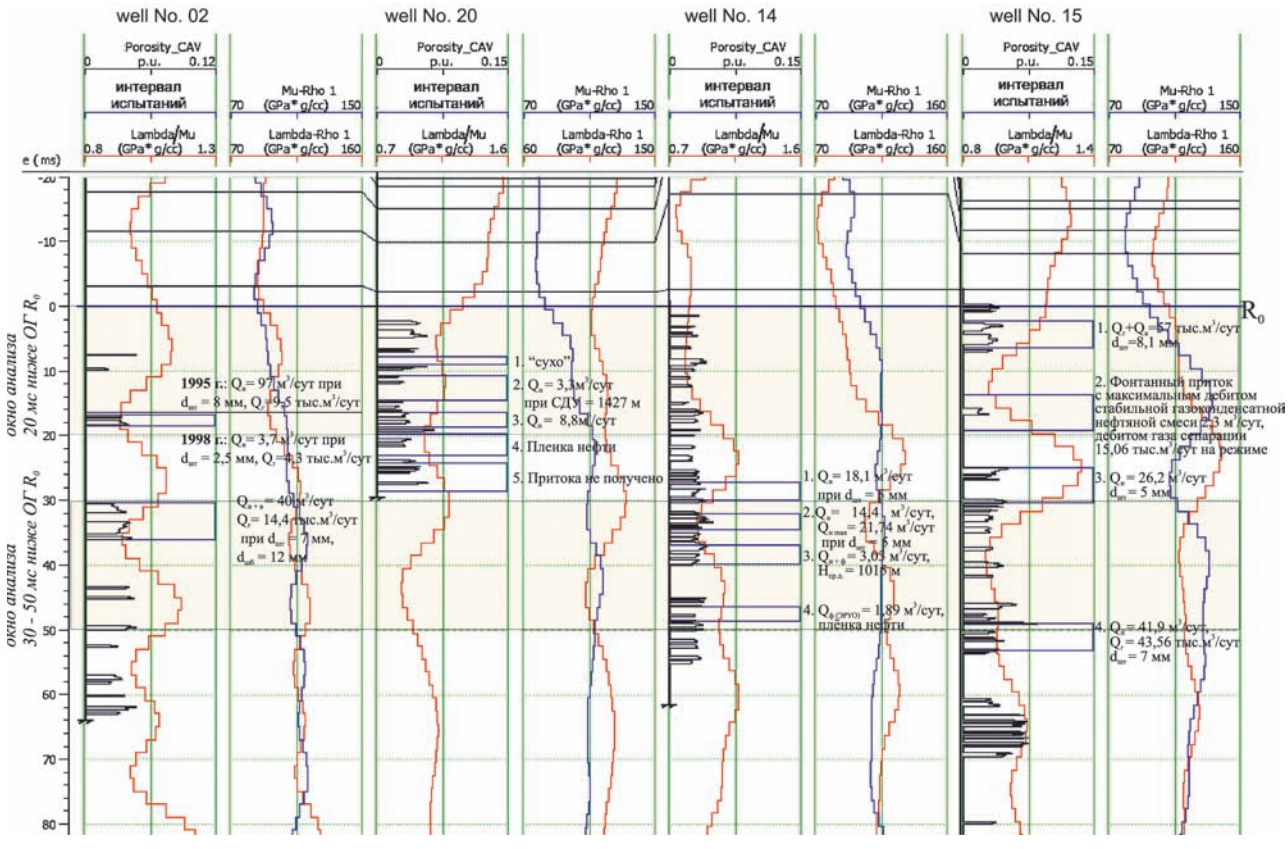

Figure 4. Change in the Lame constants curve shape and λρ/μρ parameter depending on saturation.

The module λ is the interesting to determine fluids. According to the research, set By Voskresensky for clastic rocks, gas-saturated sandstone is characterized by minimum values of parameters λ, λ/μ, shale – by maximum values, with the difference in percentage for parameter λ/μ is from 104 to 181 % and the maximum differences are inherent to low-speed strata. The above research results have been tested for high-speed strata of the Riphean carbonate deposits with the assumption that the differences will not be as significant. However, in the vertical sections of the cube low values of the parameter λρ correspond to the test intervals, in which commercial flows of oil and gas condensate were obtained.

Additionally, by the calculated cubes of λρ, μρ and

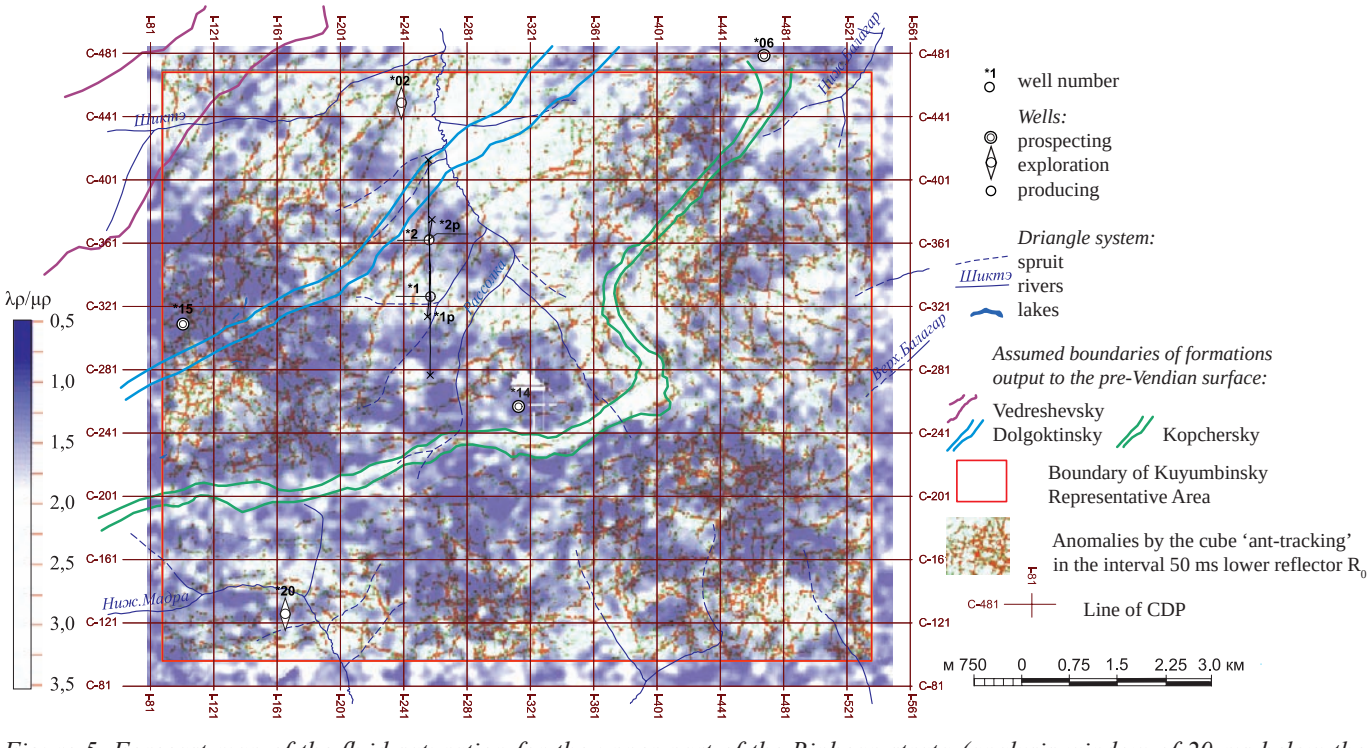

Figure 5. Forecast map of the fluid saturation for the upper part of the Riphean strata (analysis window of 20 ms below the reflector R_0).

λρ/μρ parameters, an analysis was conducted of changes in the shape of curves extracted from the attributive cubes with the test results in wells No 02, 20, 14 and 15 (Figure 4). As a result, it is noted that fluid saturation changes most strongly the shape of λρ/μρ parameter curve, curves of Lame constants also vary, but not so clearly. Therefore, by cube of λρ/μρ parameter maps were calculated in the windows of 20 ms (the upper producing interval in view of perforation intervals) and 30-50 ms lower of reflector R_0.

On the forecast map of fluid saturation, calculated for the upper interval of Riphean deposits, the most promising for the intensity of the observed anomalies is the zone allocated in the area of well No. 15 and further to the southeast (Figure 5). Additionally, the mapped area of output to the pre-Vendian surface of carbonate-clay suite kopcherskian formation, which in this region is the reference reflector that does not contain commercial hydrocarbon accumulations, is characterized by the absence of the low values of λρ/μρ and, therefore, is a screen for oil and gas deposits.

As a result, applied approach to the forecast zones of increased fracturing on the basis of modeling of elastic and mechanical properties in Riphean deposits according to the seismic data with the assistance of well information allowed us to achieve good results; monitoring wells were used in this case to assess the quality of the forecast, these wells did not participate in interpretive works that confirmed forecast model of the Riphean reservoir. Thus, the above approaches to forecast the reservoir properties of carbonate reservoirs on the basis of seismic data can be recommended for further use.

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