Comprehensive Analysis of Geological-geophysical Data and Development Parameters to Justify System of Bedded Deposits in Allochthon and Autochthon of Vuktyl Oil and Gas Condensate Field

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Abstract. Comprehensive analysis of injected 'dry' gas distribution and well production, composed correlation schemes of productive Artinian-Lower Carboniferous sediments, reservoir pressure distribution over sediments of various age revealed that the well-known massive deposit of Vuktyl field is characterized as a system of bedded deposits, apparently, with its own gas-water contact. This model allows the most efficient control and management of processes in the productive section when using the injection of 'dry' gas in allochthonous part of the field.

According to drilling and 2D, 3D seismic survey in the north of Vuktyl field an autochthonous fold with amplitude of up to 125 m is established in carbonate deposits of Lower Permian-Lower Carboniferous, to which bedded deposits may be confined, as evidenced by the abundant oil flow and oil and gas shows in drilled wells. Total resources of the autochthonous bedded deposits could reach tens of billions of cubic meters.

Keywords: Vuktyl field, section, allochthon, autochthon, well, gas condensate deposit, injection of 'dry' gas, seismic survey, productive deposits.

DOI: 10.18599/grs.18.2.2

For citation: Pankratova E.I., Yunusova L.V., Bogdanov B.P. Comprehensive Analysis of Geological-geophysical Data and Development Parameters to Justify System of Bedded Deposits in Allochthon and Autochthon of Vuktyl Oil and Gas Condensate Field. *Georesursy = Georesources*. 2016. V. 18. No. 2. Pp. 87-93. DOI: 10.18599/grs.18.2.2

The study and specification of the geological structure of Vuktyl oil and gas condensate field was carried out since it was discovered in 1964 in the exploration, development and commercial operation of the current development. Vuktyl structure is structurally complex swell-like high-amplitude asymmetric fold with submeridional two structural levels: the upper overthrust-allochthonous and lower low dislocation-autochthonous. The field with productivity level up to 1500 m and large size has unique in its reserves Lower Permian coal-gas condensate deposit, confined to allochthonous part. The deposit is considered to be a massive tectonically shielded with a common gas-water contact (Fig. 1).

In component composition Vuktyl formation gas belongs to a group with a high content of condensate, the value of which for the initial pressure and temperature conditions (reservoir pressure of 36.3 MPa) was 360 g/m^3. Development of the deposit up to 1993 was carried out in the depletion mode of natural energy of the reservoir. Extraction from formation was accompanied with reservoir pressure loss, resulting in a significant loss of liquid hydrocarbons in the formation. By this time, reservoir pressure passed the threshold of maximum condensation and decreased to 3.78 MPa.

To increase the condensate since 1993 the technology of active influence on the exhausted gas condensate deposit was being implemented on the field. The effectiveness of the technology used is determined by the achievement of maximum coverage of productive intervals by 'dry' gas and, as a result, production of hydrocarbons fell in the formation.

At present, the influence of 'dry' gas covered a large area of the field: injection is performed at the gas treatment plant-1, 2, 4, 8.

The control of injection and extraction processes realized on the basis of standard geophysical, gas condensate and gas-dynamic research complexes is conducted on two groups of wells: injection and production.

Analysis of geophysical researches of wells, which resulted in more detail studied geological sections of exposed deposits, allows determining the depth of productive horizons, their reservoir properties, including porosity, permeability, fluid saturation, and track gas yielding and absorbing intervals of production and injection wells, respectively.

According to the results of gas condensate research, as well as operational control over the component composition of gas by production wells, the ways of 'dry' gas productive deposits from injection wells to production were traced.

Based on the results of pilot projects two options were identified for promoting injected 'dry' gas into production wells. The first option – injection and extraction occur on deposits, confined to a single stratigraphic horizon; the second option – injection is carried out in the sediments of the same age, and production – in multi-aged deposits. This is facilitated by conducting tectonic violations established by drilling and seismic data (Pankratova, 2013). As an example, Fig. 2 shows geological profiles through wells in sites UKPG-1 and UKPG-2 (gas treatment plants), which displays options for promoting injected 'dry' gas.

On the basis of investigations balance calculations of hydrocarbons are carried out on the productive deposits, confined to different stratigraphic horizons. On the example UKPG-1, where Tyumen gas sweeps the entire productive interval, the distribution of Tyumen gas production and retrograde condensate for each well is shown.

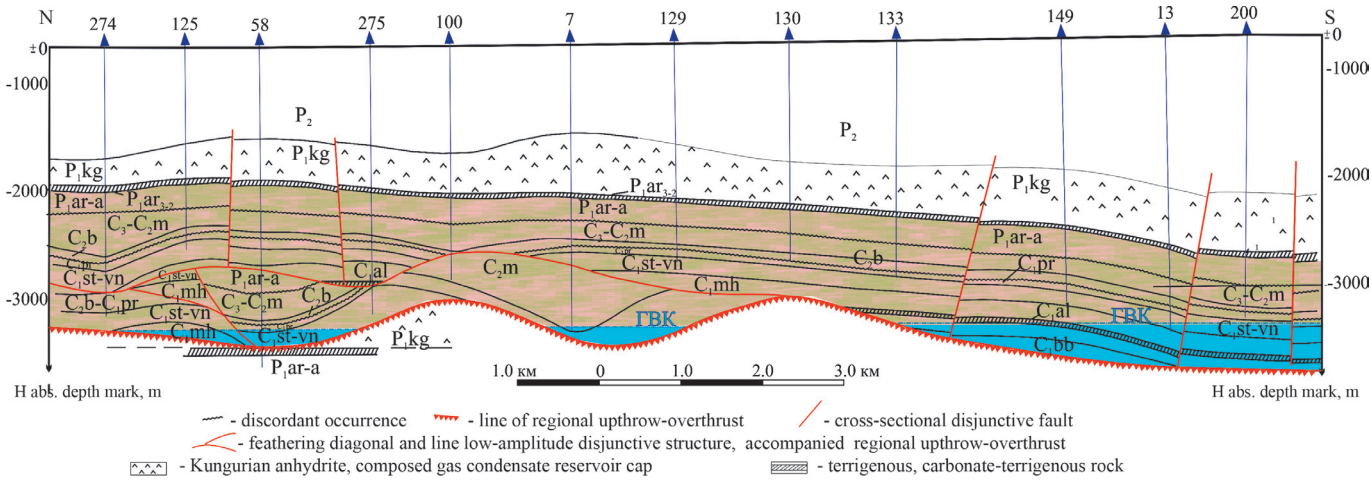

Fig. 1. Longitudinal profile of site of Vuktyl field.

Theoretically, it is assumed that in massive deposit precipitated condensate takes hypsometrically low depth. However, the authors of this article conducted analysis of retrograde condensate production from the beginning of injection. It showed that the deposited condensate is present in all productive deposits, regardless of the depth of their occurrence (P_1art-C_1) (Fig. 3).

In this regard, there was an assumption that the well-known massive deposit may have a different geological structure. On this basis, a more detailed analysis of the geological section of productive deposits is performed; the correlation scheme is made up for the Lower Permian, Upper Carboniferous, Moscovian, Bashkirian, Serpukhovian tiers (Fig. 4). Moscovian stage consists of three parts: the upper and lower characterized by the clays and clay varieties of carbonate rocks, the middle part with highly porous dolomites and limestones. A detailed comparison of sediments showed that the three packs of rocks are traced in all wells. According to the geophysical and petrophysical studies of core samples gas-saturated reservoirs were allocated with good reservoir properties, which are confirmed by test results. The top and base of the Bashkirian deposits also contain clay carbonates with thickness up to 15-30 m, between which limestones and dolomites lie (Pankratova, 2014).

According to the correlation of sections, the analysis of injecting 'dry' gas and product extraction it be assumed that the reservoirs of Moscovian, Bashkirian, Serpukhovian tiers are separated by confining beds, which are referred to clay

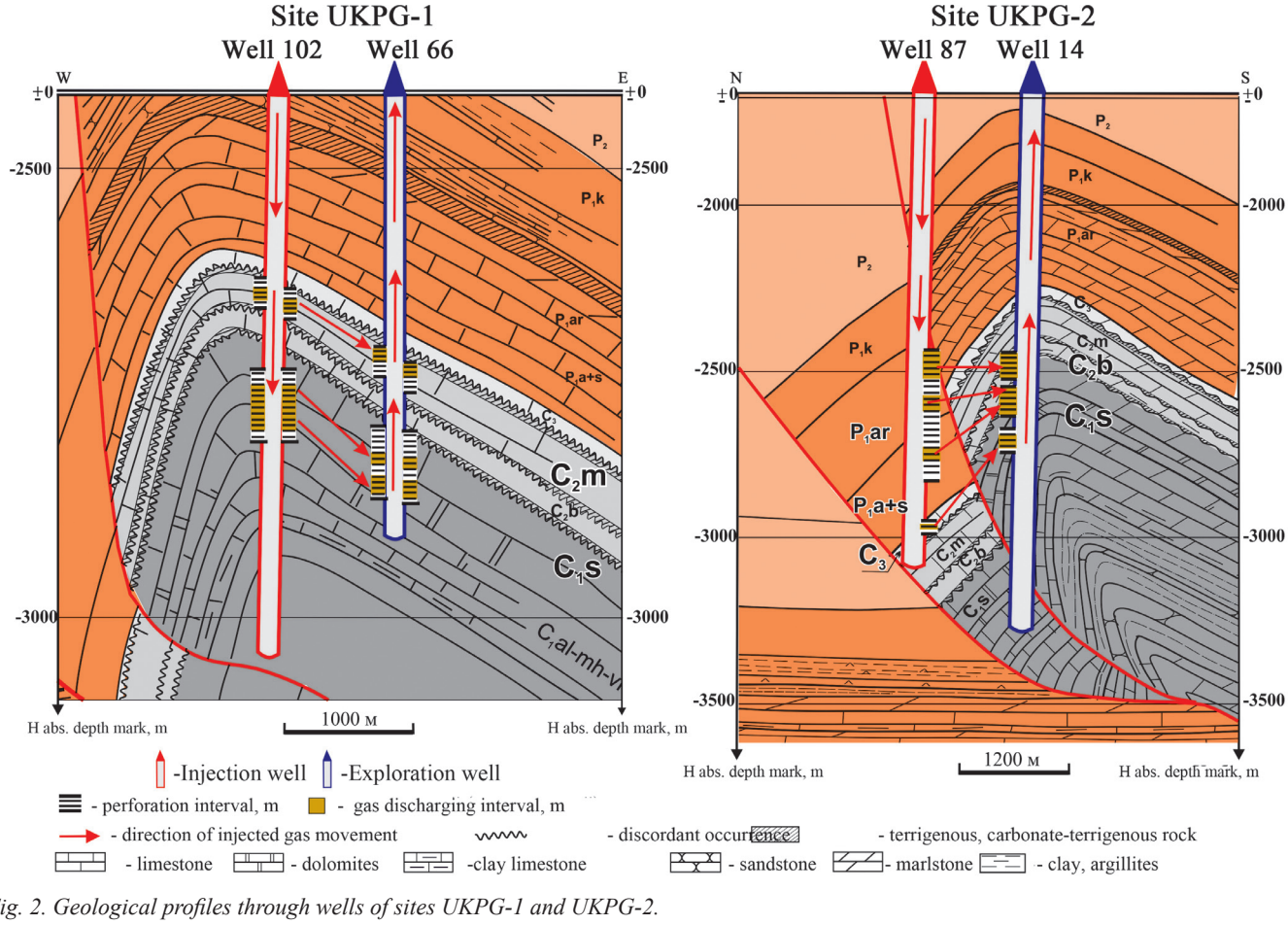

Fig. 2. Geological profiles through wells of sites UKPG-1 and UKPG-2.

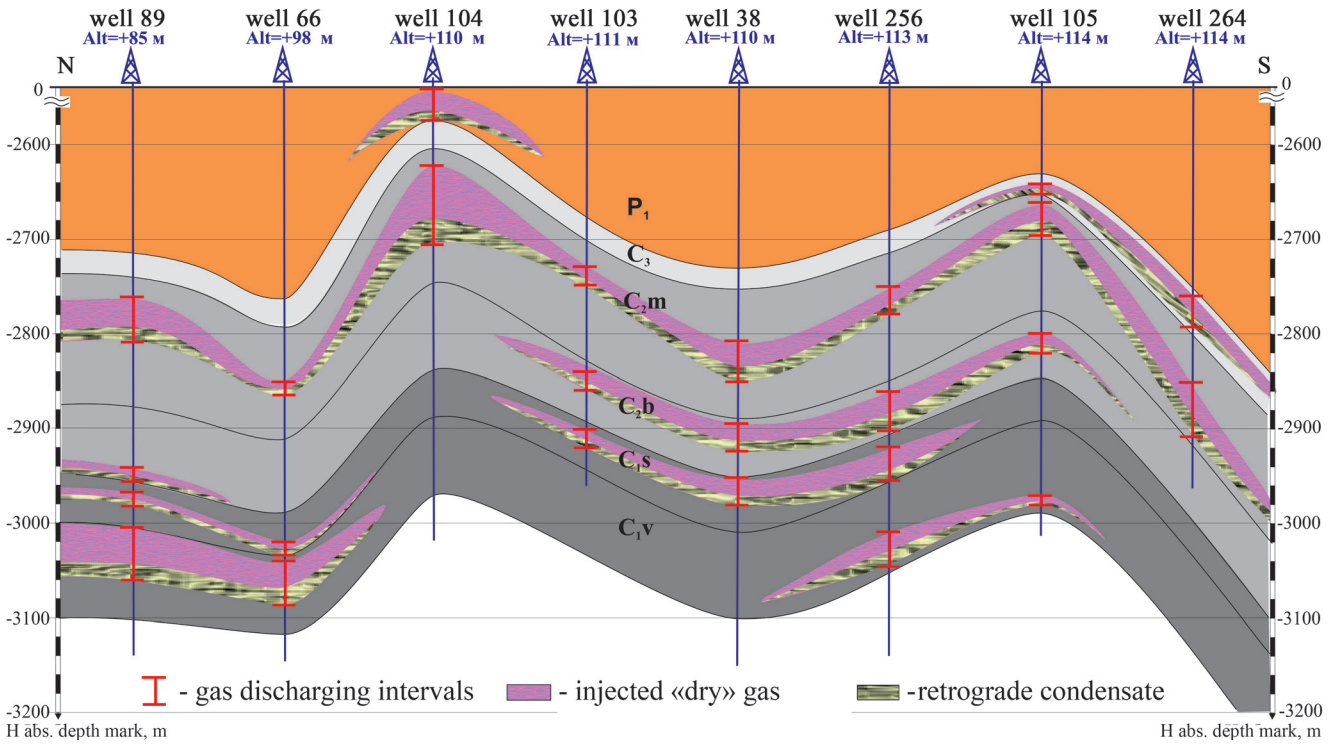

Fig. 3. Profile of the well through the area of Vuktyl field.

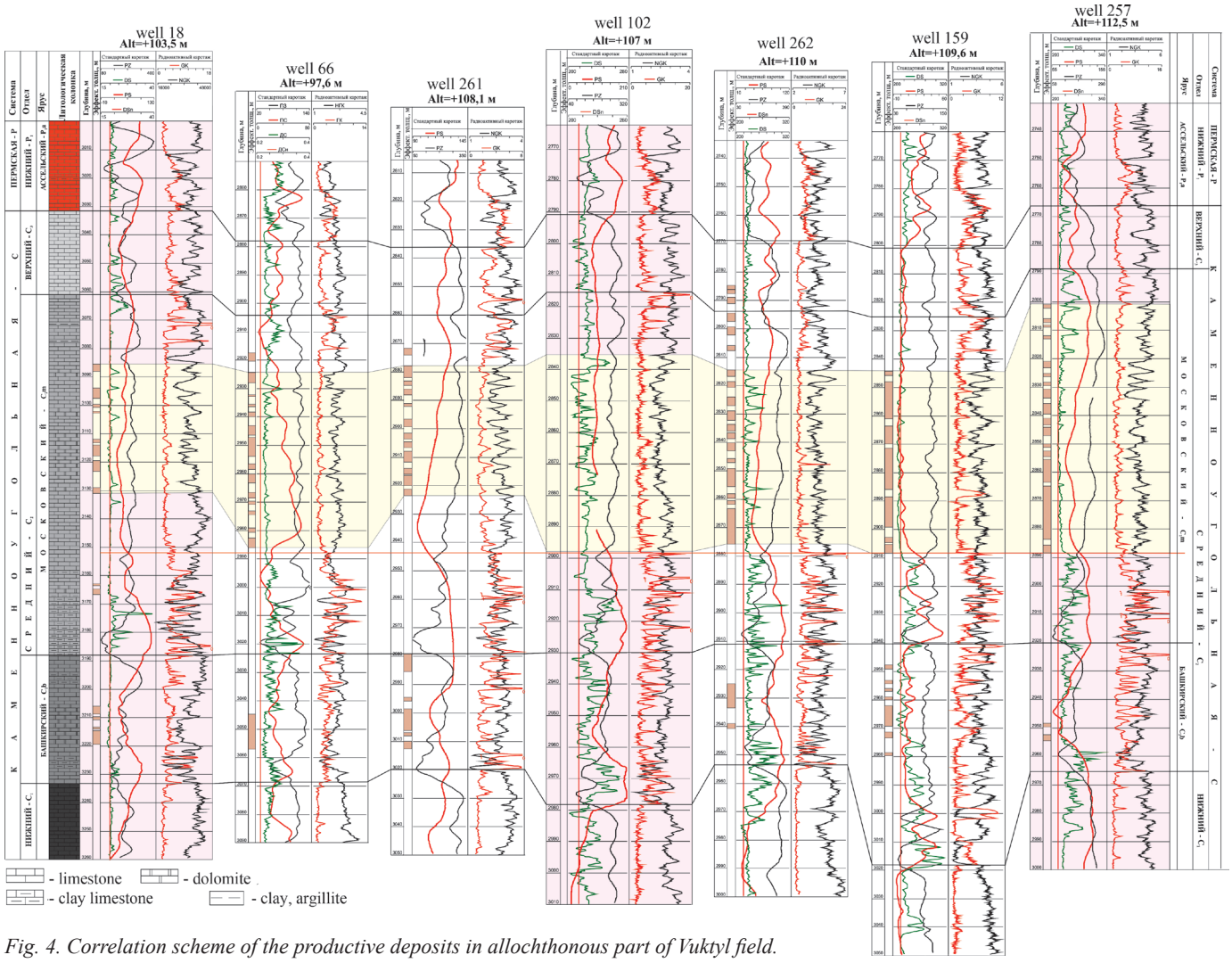

Fig. 4. Correlation scheme of the productive deposits in allochthonous part of Vuktyl field.

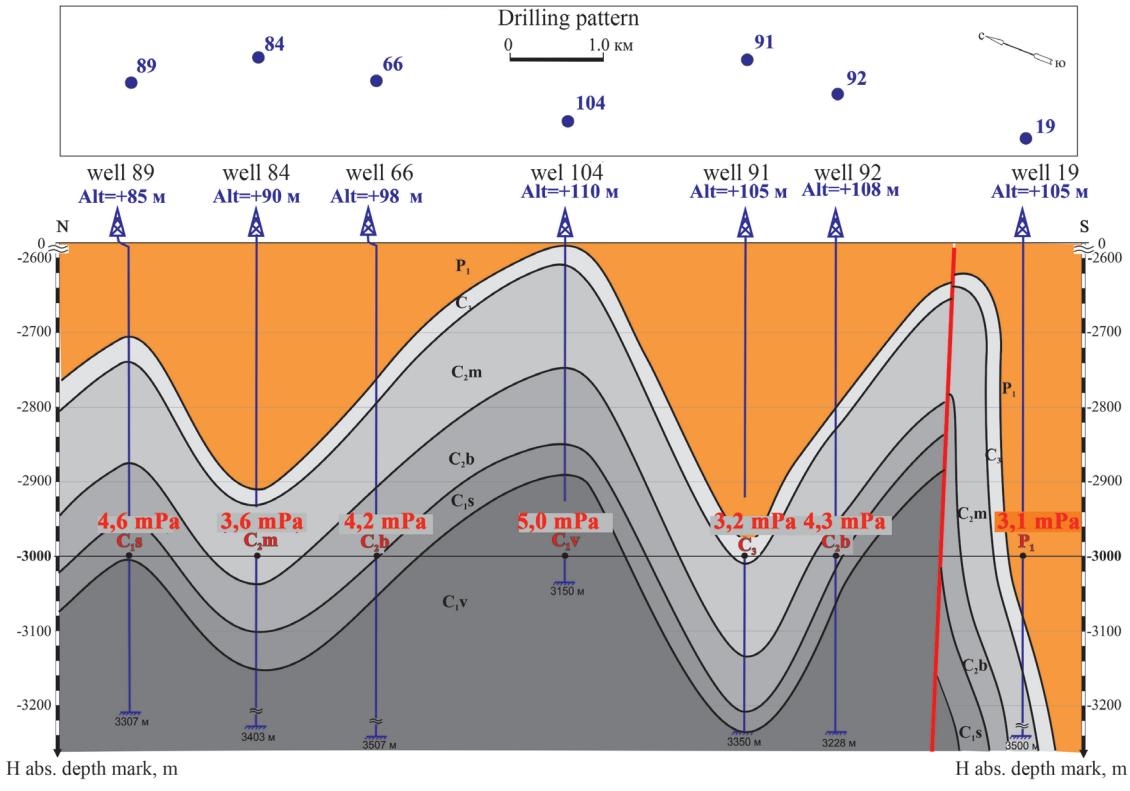

Fig. 5. The reservoir pressure distribution of productive deposits, reduced to an absolute marks of 3000 m.

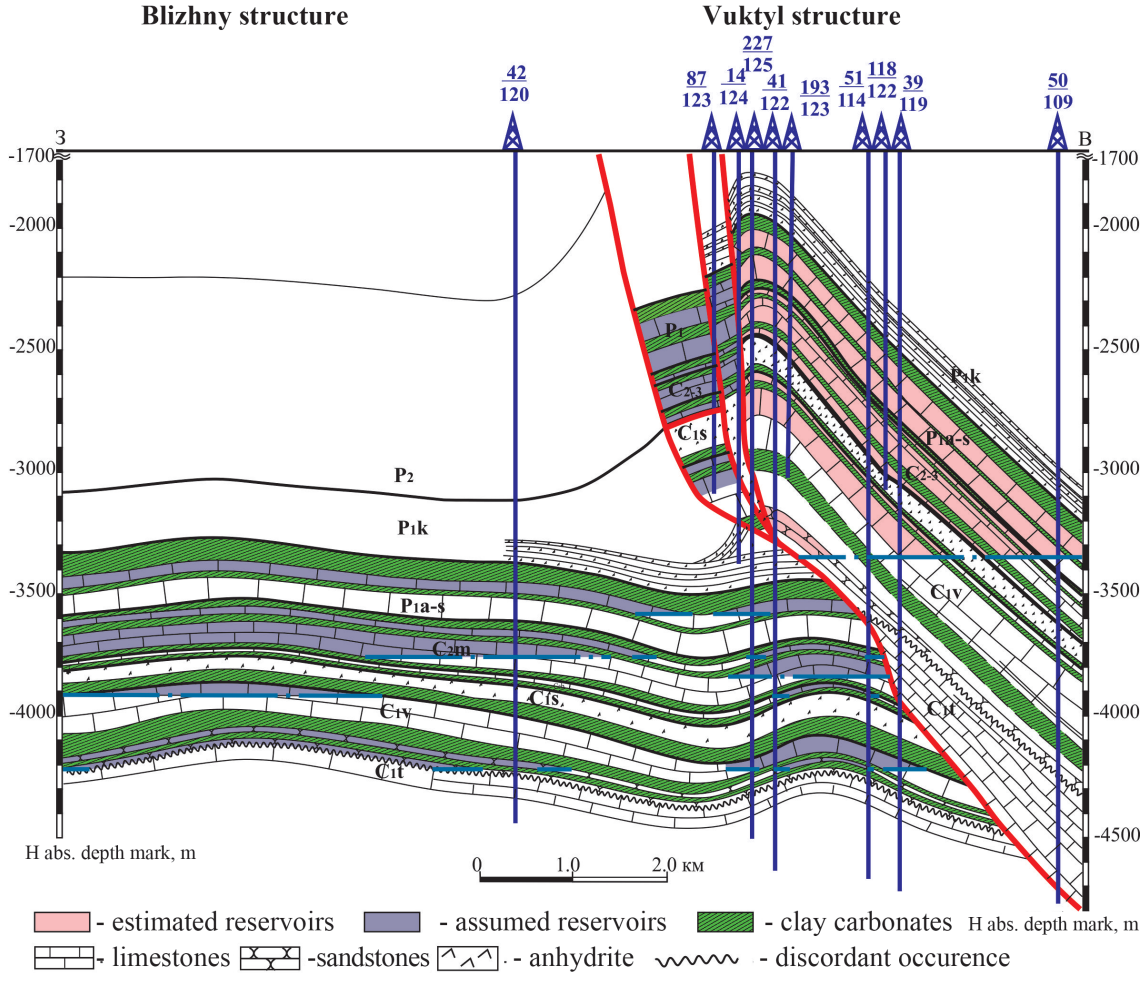

Fig. 6. Geological section with the system of reservoirs in allochthon and autochthone of Vuktyl field.

packs and argillaceous carbonates. And this, in turn, points to the fact that the Lower Permian – Serpukhovian reservoirs of Vuktyl field contain separated formations in the reservoirs of the Lower Permian, Moscovian, Bashkirian and Serpukhovian tiers.

Analysis, in which on the basis of measured wellhead static pressure and taking into account reservoir gas composition, pressure given on a single depth (for illustrative purpose) has been made for clarification of distribution pattern of reservoir pressure across a productive section from the Lower Permian to the Lower Carboniferous.

It should be noted that for the calculation data were taken for each well over the whole period of operation on the natural depletion mode. After analyzing the materials, it can be noted that each uneven pack of the same depth is characterized by its pressures.

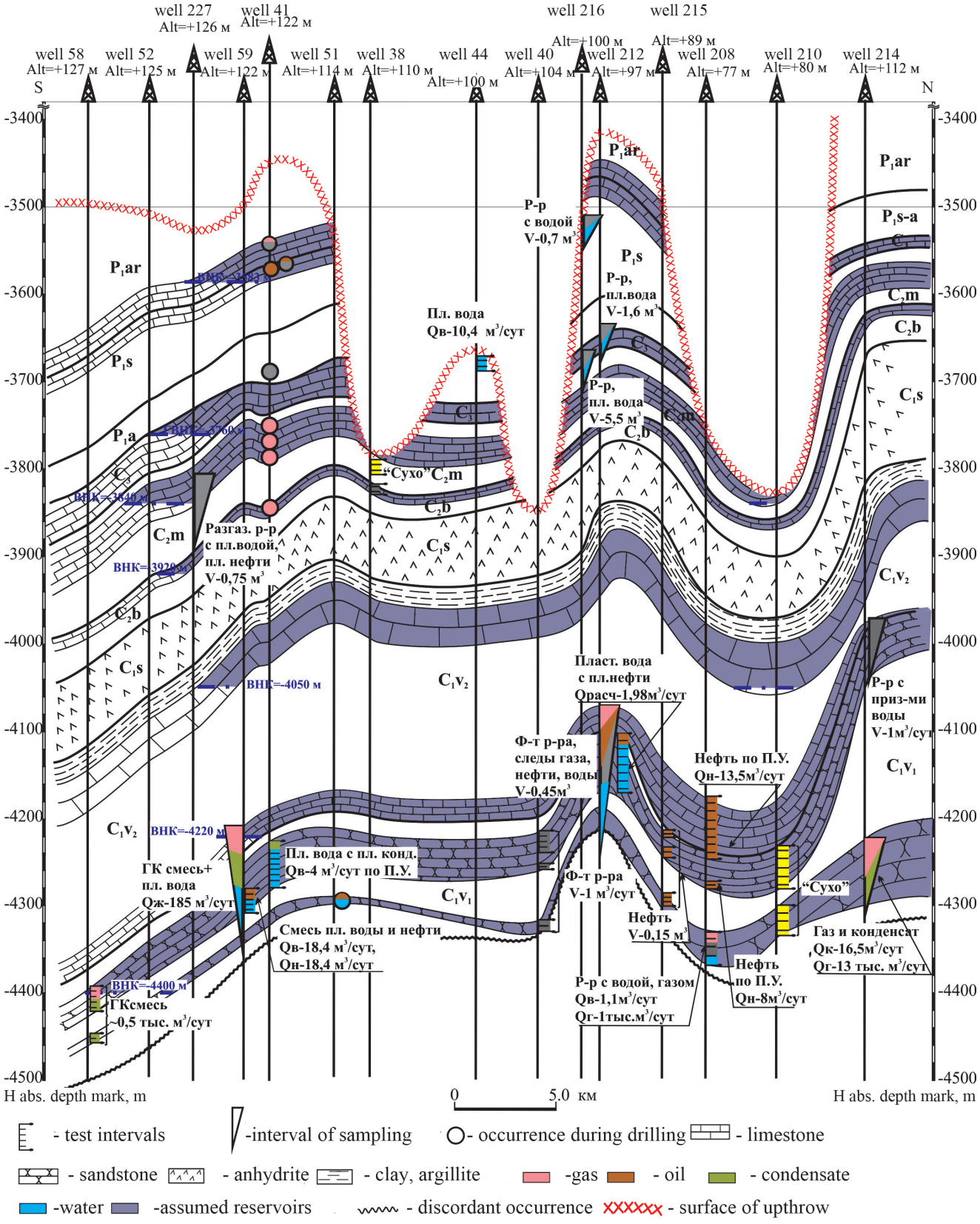

Fig. 7. Structure of hydrocarbon deposits in the autochthon of Vuktyl field.

The values of reservoir pressure are correlated with the reservoir properties of different horizons. For illustrative purpose the profile is drawn up by the line of wells for northern dome of Vuktyl structure that penetrated the entire productive interval (P_1art-C_1), which shows that reservoir pressure in the sediments of different ages have their own values (Fig. 5).

Thus, a comprehensive analysis of geological and geophysical data and parameters of Vuktyl field development allows us to offer its another geological structure and to prove that the deposit of allochthone considered to be massive deposit with a single hydrodynamic system, is characterized by formation of deposits, possibly with their gas-water contacts.

The analysis was a prerequisite to support oil and gas potential in Lower Permian – Visean sediments in the autochthonous part of the field.

For the geological analysis of autochthonous part of Vuktyl field, a correlation scheme has been drawn up of Carboniferous-Permian sediments, which indicated the presence of the reservoirs, separated by argillaceous carbonates and clays as confining beds, as has been shown by us for allochthone.

It should be noted that the productivity of Ordovician-Lower Permian sediments of autochthonous in Vuktyl fold was set a long time ago: T.G. Grinko in the manufacturing report notes that "in the autochthon of Vuktylsky area during drilling and testing of wells, almost throughout the section of Artinskian-Ordovician formations oil and gas occurrences were observed of different nature and intensity: from the degassing of the mud and increased gas values at gas logging to gas fountain. For example, in the Late Visean-Early Permian carbonates when drilling well No. 41 at a depth of 3690 m (Asselian) oil appeared; in 1.5 h 15 m^3 of oil came out with density of 0.95 g/cm^3. Oil films were observed in the solution during penetration of Asselian and Moscovian formations in well 42, Protvino-Bashkirian – in well 39, Early Artinskian and Sakmarian – in well 59.

Also oil shows are marked in two lithological packs of Yasnopolyansky clastic strata in underthrust of Vuktyl area – layers IIa and IIb. Deposits in these sediments are associated with both lithological and structural factors. They are isolated from each other and are associated with lenticular sandstones, replaced by dense clay rocks up to the rise in the monocline. Deposits of oil in the reservoir IIa are detected by well 225: when testing in the interval 4514-4487 m, a gushing flow (density 0.790 g/cm^3) is received with 40.1 m/day of light oil and 122 thousand m3/day of gas. The layer has also been penetrated by wells 224, 39, 42, 58, 59. In the preliminary assessment of oil reserves made in the software "Severgasprom" in 1987, the following parameters are taken for the calculation by category at the position of oil-water contact, on absolute elevation -4364 m, reservoir area of 2.9997 km2, height 76 m, average effective thickness -4 m, open porosity of 10%, oil saturation factor of 0.65.

Oil deposits in the formation IIb were penetrated in the well 51, where from the interval 4362-4375 m oil was produced with a low content of formation water (up to 25%), liquid flow rate of 22 m^3/day. Also they were penetrated by well 59, in which from a depth of 4428-4409 meters mixture of formation water and oil was extracted with total flow rate of 36.8 m^3/day (50% water, 50% oil). These oil fields are isolated from each other in the area between wells 51 and 41, where the layer II_b is almost completely replaced by dense siltstones and sandstones. According to preliminary estimates the area of deposits in the well 51 is 9.361 km^2, well 59 – 27.485 km^2, the other parameters of calculation are the same as for the formation II_a.

Perhaps the main points for new oil and gas potential of Vuktyl field are research results presented below. As a result of generalization of CDP-3D, 2D seismic survey, held in the northern part of Vuktyl structure, along the lines of seismic and geological profiles in the the autochthonous part of Permian-Carboniferous sediments we mapped anticline folds with amplitude up to 50-125 m at the size of 22 x1 m, petroleum prospects of which were not evaluated.

Based on the massive structure of the Permian-Visean deposits of Vuktyl field, the massive deposit in the autochthon will have a height up to 50-125 meters, and is unlikely to sustain geological-economic assessment for the development (Pankratova, Bogdanov 2014). However, based on the model with system of formation deposits (Fig. 6), we obtain a completely different geological and economic evaluation. With certain assumptions we can transform structural construction of OG IIv report on the interpretation of 3D-2D data into schematic structural maps of seven reservoirs, the size of each can make 22x1-3 km at amplitude of up to 125 m (Pankratova, Bogdanov, 2015).

Analysis of drilling wells that penetrated the autochthon of Vuktyl fold including oil and gas shows when conducting, and testing examined sediments, allowed us to make an overall model of Vuktyl oil and gas condensate field consisting of hydrocarbon reservoir systems in Artinskian-Sakmarian, Upper Carboniferous, Moscovian, Bashkirian, Serpukhovian and Visean autochthonous and allochthonous sediments (Fig. 6 and 7).

For each of the potential reservoir, resources were evaluated. The total resource estimate for the reservoirs of autochthon in the north of Vuktyl structure in Lower Artinskian, Asselian-Sakmarian, Upper Carboniferous, Moscovian, Bashkirian, Serpukhovian, Visean carbonate sediments can reach many tens of billions of cubic meters of gas, and tens of millions of tons of condensate.

Thus, the totality of the research led to the following conclusions.

1. Comprehensive analysis of the distribution of injected 'dry' gas and product extraction from wells, created correlation schemes of productive Artinskian – Lower Carboniferous sediment, distribution pattern of formation pressures at various aged sediments revealed that the well-known massive deposit of Vuktyl field has a different geological structure and is characterized as a system of formation deposits, apparently, with its own gas-water contacts.

2. This position of deposit type changing in Vuktyl requires additional confirmation in further work in the field, but we can already say that this model allows us to more effectively monitor and control processes in the productive section using injection technology of 'dry' gas in allochthonous part of the field. The results of complex analysis were taken into account when changing the system 'injection – production', as well as the justification of a dual injection for productive deposits. The Program of pilot projects to increase hydrocarbon recovery on Vuktyl oil and gas condensate field is approved in PJSC Gazprom.

3. According to drilling and 2D, 3D seismic survey in the north of Vuktyl field in carbonate deposits of Lower Permian-Lower Carboniferous an autochthonous fold is established with sizes up to 22x 1 to 3 km, at an amplitude of up to 125 m, to which seven of reservoirs can be confined with total resources tens of billions of cubic meters. Based on paleo-facies conditions the best reservoir properties are projected in autochtone.

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Manuscript received April 15, 2016