ANÁLISE FACIAL DE DEPÓSITOS PRODUTIVOS DENTRO DO MORRO PYMSKIY

FACIAL ANALYSIS OF PRODUCTIVE DEPOSITS IN THE BORDERS OF THE PIM SHAFT

ФАЦИАЛЬНЫЙ АНАЛИЗ ПРОДУКТИВНЫХ ОТЛОЖЕНИЙ В ПРЕДЕЛАХ ПИМСКОГО ВАЛА

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RESUMO

Na bacia de rochas sedimentares da Sibéria Ocidental, espera-se a descoberta principalmente de pequenos depósitos de hidrocarbonetos, cujas reservas totais podem cobrir apenas uma pequena quantidade de produção atual de hidrocarbonetos. No entanto, até o momento, os recursos potenciais dos sedimentos mesozoicos foram transferidos para categorias industriais em não mais que 25-30%. Consequentemente, existe uma certa reserva de depósitos de hidrocarbonetos ainda não descobertos. Para sua identificação bem-sucedida, é necessário alterar a fundamentação metodológica e as abordagens metodológicas para previsão, estimativa de recursos e reservas e para a realização de explorações geológicas que se formaram até o momento. É necessário transferir a atenção de grandes complexos de petróleo e gás para formações e poços específicos. Provavelmente, o cálculo das reservas geológicas iniciais de hidrocarbonetos deva ser feito para poços específicos. Ao mesmo tempo, as operações de exploração de campos de petróleo e gás devem ser acompanhadas por um estudo detalhado de materiais de perfuração profundos e estudos geofísicos usando técnicas modernas de processamento e interpretação geológica de materiais geológicos e geofísicos primários. Um dos métodos mais eficazes é a análise paleofacial de depósitos produtivos.

Palavras-chave: *reservatório, situação de sedimentação, análise paleofacial, método eletrométrico, identificação, fácies*.

ABSTRACT

In the West Siberian sedimentary-rocky basin, it is projected to open mainly small hydrocarbon deposits, the total reserves of which can cover only a small amount of current hydrocarbon production. However, to date, the potential resources of Mesozoic deposits have been transferred to industrial categories by no more than 25-30%. Consequently, there is a certain reserve of undiscovered hydrocarbon deposits. For their successful detection, it is necessary to change the methodological justification and methodological approaches to the forecast, the estimation of resources and reserves, and the geological exploration work that has developed to date. It is necessary to shift attention from large oil and gas-bearing complexes to specific strata and wells. It is also possible to calculate the initial geological reserves of hydrocarbons for individual wells. At the same time, geological exploration and oil and gas production should be accompanied by a detailed study of deep drilling and geophysical research materials using modern processing techniques and geological interpretation of primary geological and geophysical materials. One of the most effective methods is the paleofacial analysis of productive deposits.

Keywords: *layer, sedimentation environment, paleofacies analysis, electrometric technique, identification, facies.*

АННОТАЦИЯ

В Западно-Сибирском осадочно-породном бассейне прогнозируется открытие главным образом мелких залежей углеводородов, суммарные запасы которых могут покрыть лишь незначительный объем текущей добычи УВ. Однако на сегодняшний день потенциальные ресурсы мезозойских отложений переведены в промышленные категории не более чем на 25-30%. Следовательно, имеется определенный запас еще неоткрытых залежей УВ. Для их успешного выявления необходимо менять методологическое обоснование и методические подходы к прогнозу, оценке ресурсов и запасов, проведению геологоразведочных работ, сложившиеся к настоящему времени. Необходимо перенести внимание от крупных нефтегазоносных комплексов к конкретным пластам и скважинам. Возможно и подсчет начальных геологических запасов углеводородов следует производить по отдельным скважинам. При этом геологоразведочные и нефтегазопромысловые работы должны сопровождаться детальной проработкой материалов глубокого бурения и геофизических исследований с использованием современных методик обработки и геологической интерпретации первичных геолого-геофизических материалов. Одной из наиболее эффективных методик является палеофациальный анализ продуктивных отложений.

Ключевые слова: *пласт, обстановка осадконакопления, палеофациальный анализ, электрометрическая методика, идентификация, фация.*

INTRODUCTION

The geological section of the area in the Pim Shaft area is represented by a thick stratum of sedimentary terrigenous rocks of the Mesozoic-Cenozoic orthoplatform cover (on average about 3200 m) and effusive-sedimentary metamorphosed rocks of the Paleozoic basement (Lobova and Isaev, 2009; Kulishkin *et al.*, 2012). Higher in the section, the Jurassic, Cretaceous, Tertiary and Quaternary deposits were discovered. To recreate the conditions for the formation of reservoir rocks, GIS methods were used for exploratory and production wells drilled within the Pim Shaft.

The roof of layer UC_2 is well marked on the bottom of a pack of low-resistance clays and is characterized by a sharp increase in resistance, which is distinguished by the methods of BC and IR. The sedimentary complex of the UC_2 reservoir with a total thickness of about 50 m has a three-member structure (the elements of which are packs UC_2^1, UC_2^2,and UC_2^3) reflecting three stages of its formation (Kuzin, 2006; Kontorovich *et al.*, 2014). Since the sand bodies belonging to the allocated subcomplexes are composed of washed sediments of the previously formed continental strata, as well as the sediments of the repeatedly inverting water basin, the boundaries of the isolated packs are rather conditional. The lower, most clayey, part of the section is allocated as a bundle of UC_2^3.The formation of this part took place under conditions of inadequate deposition of the sand mass, which led to extreme incontinence and a small thickness of the sandstones (Kuzin, 2004; Isaev, 2004; Isaev, 2008). The average pack of UC22 was formed under transitional conditions. It is represented by glacial-siltstone rocks with thin interlayers of sandstone, opened in sections of almost all wells.

The main oil reserves are concentrated in reservoirs of the reservoir BC_1. The same layer is characterized by better filtration-capacitive properties and high productivity in comparison with other layers. Further, these indicators are followed by deposits of the layers AC_8 and UC_2. Above, the seam is blocked by a regional forty-meter clay layer, the so-called Pim clay. The thickness of Pimskoye clays within the deposit amounted to around 40 m. The roof of the seam is opened at a depth of 2092-2040 m. The layer is sufficiently monolithic, especially at the top of the section. Interlayers of clays and silts have subordinate inportance. Unlike the underlying objects, the section is less complicated by the presence of carbonitized rock differences (Karogodin *et al.*, 2000; Borodkin and Kurchikov, 2011; Borodkin and Kurchikov, 2010). The dissection is generally 2.27, the sandiness is

0.80. Non-homogeneity in layers is 0.31, in zones 0.34. The effective thickness of the reservoir ranges from 2.8 to 13.6 m. The reservoir has an area distribution. In a number of wells in the plantar part of the reservoir deterioration of reservoir properties is noted due to greater claying of the section. On the map with the types of the PC curves for the BC_1 formation, the zone of development of the improved reservoir rocks is well traced.

Plast AC_8 was discovered at a depth of 1880-1927 m. The reservoir of the AC_8^1 formation is confined to the upper part of the reservoir, the AC_8^2 deposit to the lower part. The separation of two separate deposits in the reservoir is caused by differences in the reservoir characteristics of rocks from its upper and lower parts (Nezhdanov *et al.*, 2000; Borodkin *et al.*, 2007; Belozerov *et al.*, 2018). A regionally inherit clayey section between the upper and lower parts of the formation is absent. In a number of cases, when the roof of the AC_8^2 layers is clayed, this part of the section can pass into the lover part of the AC_8^1 formation. Consequently, they represent a single hydrodynamic system. The upper boundary of the AC_8 formation is clearly traced along the bottom of the clays separating the highly porous sandstones of the AC_7 formation. The thickness of the clay between the water-bearing sandstone AC_7 and the layer AC_8 is 3-5 m. The lower boundary of the AC_8 formation is not so definite as the upper one (Strakhovenko *et al.*, 2018; Ganchala *et al.*, 2018). This is due to the presence of thin sandstone lenses in a clay pack separating the AC $_9$ layer from the AC_8, especially in the wedging zone of the sand pack AC_8^2.

A bundle of AC_8^2 in the zone of its maximum development is characterized by better collection properties. It is rather monolithic and rarely has more than 2 sandy pro layers. By facies genetic typing, the sandstones of the bundle AC_8^2 can be attributed to the regressive stage of formation (ie, associated with the retreat of the sea). The bundle AC_8^1 is opened by all wells. Sandstones and siltstones, which are reservoir rocks, have a heterogeneous structure and can be considered as lithotypes with layered clayeyness (Sapyanik *et al.*, 2018; Kanygin *et al.*, 2016; Podobina, 2017). If the formation of sandstones of the bundle AC_8^2 is associated with the regression of the sea, the formation of the upper part of the AC_8^1 formation is, in all probability, due to its transgressive stage.

The nature of the distribution of oil in the AC_8 formation was affected by the insignificant thickness of the clay division (2-4 m) between the water-bearing sandstone of the AC_7 formation and the AC_8 layer, and also the "hazel" type reservoir of the upper part of the AC_8 formation (Lukin and Shestopalov, 2018; Isaev *et al.*, 2016). As a consequence, in most of the wells, the upper part of the AC_8 formation – the bundle AC_8^1 – is characterized by lower IR values.

The total thickness varies from 3.0 to 20.0 m on the bundle AC_8^1 and from 0.8 to 12.8 m on the bundle AC_8^2. The average oil-saturated thicknesses are 3.1 and 3.7 m, respectively. The neatness of the packet AC_8^2 (0.87) is much larger than in the packet AC_8^1 (0.31) and the subdivision is lower (1.52) compared to the dissection in the packet AC_8^1 (3.04). The heterogeneity in permeability, both layered and zonal in the bundle AC_8^2, is somewhat higher than in the bundle AC_8^1: layered – 0.09 in the bundle AC_8^2 and 0.06 in the bundle AC_8^1, zonal – 0.70 and 0.22 respectively.

MATERIALS AND METHODS

The justification of the facies nature of sand bodies is of prime importance in the search for lithological traps with oil and gas, and also allows the forecasting their spatial location, the position of the zones of wedging and changes in reservoir properties of rocks.

In our study, the electrometric technique of V.S. Muromtsev was used to diagnose facies complexes. (Muromtsev, 1984). It is the most popular method among Russian geologists for conducting the facial analysis. V.S. Muromtsev proposed: 1) to delimit the sedimentological facies of sandy rocks at five levels of paleohydrodynamic regimes of their formation, which is reflected in the lithological and granulometric composition of rocks; 2) use a quantitative assessment of the relationship between samples of terrigenous rocks and GIS methods.

The method of electrometric models of facies is based on the following. The sedimentation features that remain in the rock reflect the dynamics of the sedimentation environment, among which the granulometric and material composition, the nature of contacts, thickness, structures, textures, etc. are the main ones. Study of these features on a cut and plain allows detecting changes paleo-hydrodynamic modes (levels) in depositional environment The developed system of diagnostic features makes it possible to establish the facial nature of the sediment not only as a result of the study of the rock but also according to their electrometric characteristics. In this sedimentation-facies analysis, electrometric characteristics were used- the values of α_{PC}, corresponding to certain paleohydrodynamic levels (regimes) of sedimentation, according to which an electrometric model of a particular facies was constructed.

The electrometric facies model is a segment of the PC curve formed by one or more geophysical anomalies linked to the boundary values α_{PC} and reflecting changes in the lithophysical properties of the rocks due to the characteristic sequence of the change in the paleohydrodynamic levels of the sedimentation enviroment (Muromtsev, 1984).

RESULTS AND DISCUSSION:

2.1. Results of paleofacial analysis of stratum AC_8

Stratum AC_8 was opened by wells and submitted sandstones and fine-medium-grained siltstone, layered clay, moderately sorted (heterogeneous structure) with a high content of soluble in 5% – HCl components. After studying the available information on the mineral composition of the reservoir rocks, the quality of their sorting, stratification and the determination of the facies zone in the shape of the PS curves for which the dependencies between the hydrodynamic activity of the environment and the shape of the PC curve (the so-called electrometric models) were established, Four rhythms of sedimentation were singled out (Figure 1).

1. **Subfacies of the transgressive circumferential shaft.** The electrometric model is formed by an inclined roofline, complicated by a denticulate or dissected, and a horizontal straight plantar line. Parameter α_{PC} varies within 1,0-0,6.This type of PC curve is typical for subfacial deposits of a transgressive along-the-roll shaft. Transgressive shafts at the beginning of the regression are in a zone of high hydrodynamic activity and subject to intense erosion.

2. **Subfacies along the coastal washout.** The PC curve is located in the zone of positive deviations ($\alpha_{PC} \leq 0.4$) and is a non-isosceles trapezium. Roofing line inclined straight or serrated, lateral vertical straight or wavy, flat horizontal straight line. Maximum values α_{PC} fixed in the upper part subfacies and the minimum – the bottom of the anomaly. This electrometric model is similar to the delineations of the subfacies of the bar lagoons and the gullies, but unlike them, the subfacies along the coastal rain rills are formed in conditions of a still undefined part of the sea, limited only by the coastal shaft.

3. **Subfaciation of beaches.** Because of the lack of core material and distortion of the PC curve in most wells, the subfacies are determined from above and below subfacies. The value α_{PC} = 0.8-0.6 (does not reach 1.0). According to V.S. Muromtsev's electrometric model of this subfacies represents two merged right-angled triangles, the acute-angled vertices of which are located in the zone of negative deviations of the PC. The largest negative deviation of the curve is noted in the upper part of the anomaly. This type of Pc is observed only in several wells. The energy level of sedimentation is high, the hydrodynamic activity is intermittent. The beach sediments are formed on the seashore in the space between the wave breaking zone and the maximum zone over the splash. The input of terrigenous material on the beach is carried out due to its transport by waves and alongshore currents, and the sorting of grains by their size and density also takes place. The supply of terrigenous material to the beach is carried out due to its transport by waves and alongshore currents, and the sorting of grains by their size and density also takes place. In general, this part of the reservoir is composed of a coastal-marine complex of facies, formed during the transgression of the sea (Muromtsev, 1984).

4. **Subfacies of the washouts of discontinuous currents.** The layer is monolithic and rarely has more than two sandy interlayers, it is characterized by the best reservoir properties. Complicated with grained sandstones, well sorted, low-clayey also has increased content of soluble in 5% – HCl components. According to the mineral composition, the reservoir rocks of this polymeric cladding are dominated by fragments of rocks, which are mainly clay minerals-kaolinite, hydromica, and chlorite. The cement marked as calcite, ferruginous and titaniferous formation, and generational quartz.

Such a lithology affects the filtration-capacitive properties of the plate. The electrometric model of the interlayer is an anomaly in the form of an elongated rectangle, often complicated in the lower part by one or more small teeth. These teeth are a reflection on the electrometric model remains of bar sands, washed gullies in the discontinuous flow. The anomaly is located in the zone of negative deviations of PC (α_{PC} to 0.8-0.6).

Roofing line is horizontal straight, lateral vertical straight or wavy or slightly toothed, plantar line horizontal straight, often with complications. In a comprehensive analysis of the PC curve, it was concluded that the bottom of the reservoir AC_8 represents subfacies from discontinuous flows. The complication of the plantar line and the smaller width of the anomalies are characteristic features that help to distinguish this electrometric model from the channel facies models. The sedimentological model of the subfacies deposits of the rifts of the discontinuous currents is characterized by relatively stable paleohydrodynamic conditions for the accumulation of sand deposits due to the intensive operation of unidirectional water flows (Muromtsev, 1984). This subfacial refers to the regressive stage of reservoir formation. All the above-listed subfacies refer to the coastal-marine complex of facies. Representations of the phases of facial formation of the AC_8 formation are shown in Figure 2.

2.2. Results of paleofacies analysis of the formation BC_1

The reservoir BC_1 is sufficiently monolithic, especially in the upper part of the section. The layers of clay and silt are subordinate. The dissection is generally 2.27, the sandiness is 0.80. Unlike the underlying objects, the section is less complicated by the presence of carbonized rock differences. Heterogeneity of the layers is 0.31, zonal 0.34. Effective layer thickness ranges from 2.8 to 13.6 m. The average oil-saturated thickness is 8.2 m, the water-saturated thickness is 2.1 m. The reservoir has an area development. In a number of wells in the plantar part of the reservoir deterioration of reservoir properties is noted due to greater claying of the section. A scheme for the separation of deposits of different facies for a given formation is shown in Figure 3.

The lower part of the reservoir BC_1 was accumulated in a facial situation, typical for estuary bars. Deposits subfacies of estuarine bars are formed at the confluence of river water in the saltwater pool. When leaving the riverbed, the flow of fresh water, spreading over the surface of salty sea water, having a high density, loses its speed and deposits the terrigenous material that it attracts in the shallow coastal part of the sea - a shallow belt is formed.

The sedimentological model of the subfacies of the wellhead bar will first reflect an increase in the paleohydrodynamic activity of the sedimentation environment, then their stabilization follows, and at the end of the bar formation, a gradual weakening of the dynamics of the environment. In this connection, the electrometric model of this subfaction will be a complex anomaly located in the zone of negative deviations of the PC, which for some geometrical formalization resembles an isosceles trapezium. Roofing line of an anomaly – inclined straight or wavy, plantar – inclined straight or dentate.

The subfacies of the lagoons precede the emergence between the shore and the growing bar of the coastal gully. Lagoons are shallow pools, often stretched along the sea coasts and separated from the open sea by sand shallows (bars). The conditions of sedimentation within the lagoons are characterized by a limited area, small depths, and stagnation of the aquatic environment. As a result, predominantly silt with a high content of organic matter or chemogenic or carbonate precipitates are accumulated in them.

With the regressive development of the sea basin, when the coast line moves towards the sea, the sediments of the marginal parts of the lagoons located on the border with the land, moving towards the sea, overlap the previously deposited sediments of the central parts of the lagoon. As a consequence, the sedimentological model of subfacies will be characterized by a gradual increase in the dynamic activity of the aquatic environment from a reduced hydrodynamic level as low and medium. In this connection, the electrometric model of this subfacies is a simple anomaly that has the form of an unpaired trapezoid and is located in the zone of positive deviations of the PC. The sloping roofline is notched; lateral – straight, wavy; plantar – horizontal.

Subfacies along the coast bars. In the conditions of the regressing sea basin, the movement of the crest of the bar follows the retreating sea and the zone of sedimentation of coarse granular sediments formed at high hydrodynamic levels moves towards the sea, overlapping the earlier more fine-grained sediments. Therefore, the sedimentological model of the regressive bar will reflect an increase in the activity of the sedimentation environment from the low and very low hydrodynamic levels, characteristic of the initial stages of its formation, to high at the final stages of formation of the sand body.

The increase in the dimension of detrital material and the decrease in clayiness upwards along the section of the sand body, caused by the dynamic conditions of accumulation of bar deposits in the regressing sea basin, is reflected on the electrometric curves. The facies formation model is shown in Figure 4.

2.3. Results of paleofacial analysis of the formation UC_2

The electrometric subfacies model is a simple anomaly in the form of a rectangular triangle located in the zone of negative deviations of the PC. The roofline is horizontal, plantar inclined and is most often complicated by denticles, there is no lateral line (Figure 5).

The electrometric model is an anomaly of the PC curve, which has the form of a quadrilateral and is located in the zone of negative deviations. The largest deviation α_{PC} reaches 0.8-1.0. Such an electrometric model is typical for the subfacies of channel banks of rectified and bounded-meandering rivers (bundle UC_2^1) (Muromtsev, 1984).

The upper part of UC_2 has the best collector characteristics. Formation of sandstone is associated with an environment close to alluvial. It is represented by sandstones with medium-fine-grained, slightly and moderately clayey, well sorted, poly-microscopic. Siltstones are less common, are represented by coarse-grained differences, well and medium sorted, moderately clayey, polymictic.

On the strike channel channels of the straightened rivers form isolated lenticular-curved, sometimes difficultly constructed sandy bodies that have oval outlines in plan and are staggered along the paleorubel of the river.

The electrometric model of the next interlayer is an elongated rectangular triangle formed by an inclined roofing, dentate and directional horizontal plantar lines and located at an acute angle in the zone of negative deviations of the PC. The maximum value of α PC, reaching 0.5-0.6, when it is connected to the lower part of the anomaly. This type of curve PC describes the subfacies of the coastal shafts (bundle UC_2^2). With a decrease in the dynamic activity of the aquatic environment, the amount of clay of the clayey material increases along the section (Muromtsev, 1984).

The sediments of this subfacies are formed during periods of floods when the meltwater of the river carrying a large amount of material enters the floodplain beyond the limits of the river bed, they lose speed and deposit the sand material carried by them on a narrow strip, forming a shoreline.Sedimentaion of this subfacies limits the outer edge of the river floodplain, separating it from the channel sediments. The sedimentological model is characterized by the presence of increased hydrodynamic activity in the initial period of their formation and a sharp subsequent weakening.

The deposits are clayey-aleurolite with rare and thin interlayers of sandstone, which is present in the section of almost all wells. Subfacies are composed of fine-grained, uniform sands. The middle pack was formed in transitional conditions, it is represented by clayey-siltstone rocks with thin interlayers of sandstone, which is present in the section of almost all wells.

Subfacies of flood plains (bundle UC_2^3).The sediments of this subfaciation accumulated in the areas of floodplains temporarily flooded with hollow waters and dried during the low periods.

The electrometric model of this facies is a triangle located in the zone of positive deviations of the PC curve. The highest value of $\alpha_{PC} \leq 0.4$ is noted in the anomaly base, indicating a low hydrodynamic activity of the sedimentation environment. With a regressive occurrence, the clayey sediments of the river floodplain were eroded by riverbeds of later stages (Muromtsev, 1984). Figure 6 depicts a conceptual model of facies accumulation for the UC_2 formation.

Lower – the most clayey part of the layer, the formation of which occurred in conditions of insufficient supply of sandy material, which led to extreme inconsistency and low thickness of sandstones.

The beds of ancient rivers, made with sandy-pebble formations and overlain by clayey sediments, represent a favorable combination of well permeable and impermeable rocks, which is necessary for the formation of hydrocarbon accumulations (Muromtsev, 1984; Barrabshin, 2011; Izotova *et al.*, 1993; Shilov and Jafarov, 2001; Chernov, 2004; Biju-Duval, 2012; Leader, 1986; Pettijón *et al.*, 1976; Sellie, 1981; Sellie, 1989).

CONCLUSIONS:

The definition of the paleofacial nature of the sediments under study allows the reconstruction of the physical and geographical settings of the past, revealing the patterns of spatial distribution of deposits of a given genesis, and, consequently, the forecast of their development within a certain territory, i.e. the method of genesis of deposits by electrometric models of facies makes it possible to establish general patterns of the propagation of permeable sand bodies. The optimality and convenience of using GIS data for obtaining information about paleogeographic conditions of sedimentation are the basis for predicting the development zones of improved reservoir materials.

As a result of the paleofacies analysis, the following results were obtained:

1) the strata AC_8 and BC_1 are characterized by the coastal-marine complex facies;

2) deposits of the UC_2 layer have a continental genesis;

3) deposits of four subfacies are distinguished in the AC_8 layer: the transgressive along-the-roll, along with the coastal washouts, the beaches and the clefts of the discontinuous currents;

4) in the BC_1 formation, sediments of three subfacies are identified: a wellhead bar, lagoons, and alongshore banks;

5) sediments of three subfacies were diagnosed in the UC_2 layer: channel banks of rectified and limited-meandering rivers, coastal shafts and temporarily flooded plains.

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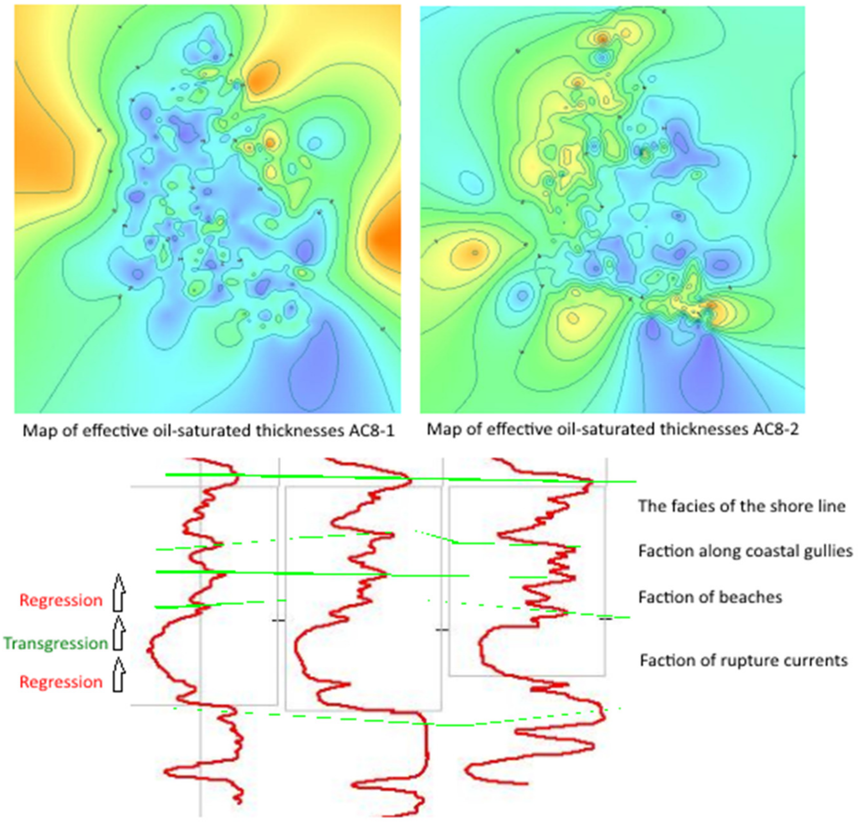


Sedimentation environment	Facies complex	The formalized electrometric model of the group of facies	Faction	Sign of deviation s ps	The maximum value of a ps	The real electrometric model	The real electrometric model of the facies The nature of the elements of the electrometric model of the facies				The position of the maximum value of a ps	The position of the maximum value of a ps	The position of the maximum value of a ps	morphology of sand bodies collectors Area spread		
							Roofing line	Lateral line	Botom line	Width of anomaly, m				The form		Size, km
Marine	Coastal-marine		Shore-kine bars (regressive) and the marginal shafts	-	1.0 - 0.8		Horizontal straight	Absent	Inclined straight line	Units and tens	At the top	1.0 - 0.8 (very high)	↓		Linear-elongated	Dozens and hundreds, sometimes thousands
Marine	Coastal-marine		Lagoons and alongshore washouts	+	< 0.4		Inclined or notched	Vertical straight or wavy	Horizontal straight	Units	At the top	0.4 - 0.2 (low)	↓		Oval Extension	Hundreds and thousands
Marine	Coastal-marine		Beaches	-	1.0 - 0.8		Horizontal straight	Absent	Inclined, serrated or dissected	The units	At the top	1.0 - 0.8 (very high)	↓		Linear-elongated	Tens and hundreds
Marine	Coastal-marine		Washouts of discontinuous currents	-	0.8 - 0.6		Horizontal straight	Vertical wavy or notched	Inclined, serrated or dissected	Units and tens	Slightly expressed in the lower part of the anomaly	0.8 - 0.6 (high)	↑		Linear-elongated, branching	Tens

***Figure 1**. Scheme for isolating the deposits of facial complexes in the AC_8*

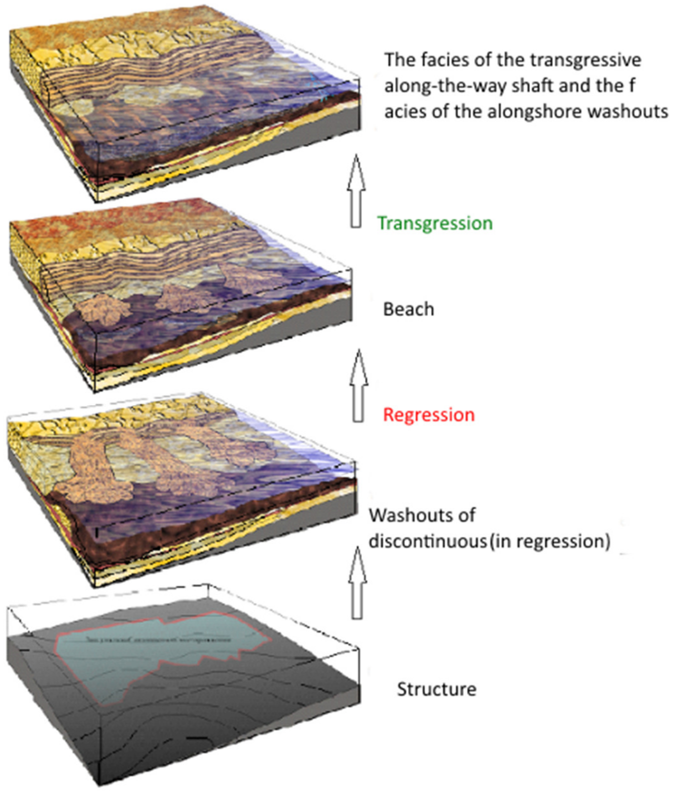


***Figure 2**. The generalized scheme of sedimentation of a layer AC_8*

Sedimentation environment	Facies complex	The formalized electrometric model of the group of facies	Faction	Sign of deviation s_{ps}	The maximum value of a_{ps}	The real electrometric model	The real electrometric model of the facies The nature of the elements of the electrometric model of the facies: Roofing line	Lateral line	Bottom line	Width of anomaly, m	The position of the maximum value of a_{ps}	The position of the maximum value of a_{ps}	The position of the maximum value of a_{ps}	Morphology of sand odies - collectors. Area spread: The form		Size, km
Marine	Coastal-marine		Delta bars	-	0.8 - 0.6		Inclined straight, wavy or notched	Vertical wavy	Inclined straight or notched	Units and tens	In the middle	0.8 - 0.6 (high)	↕		Isometric	Tens and hundreds
Marine	Coastal-marine		Lagoons and alongshore washouts	+	< 0.4		Inclined or notched	Vertical straight or wavy	Horizontal straight	Units	At the top	0.4 - 0.2 (low)	↓		Oval Extension	Hundreds and thousands
Marine	Coastal-marine		Shore-kine bars (regressive) and the marginal shafts	-	1.0 - 0.8		Horizontal straight	Absent	Inclined straight line	Units and tens	At the top	1.0 - 0.8 (very high)	↓		Linear-elongated	Dozens and hundreds, sometimes thousands

***Figure 3**. Scheme for isolating the deposits of facies complexes in the reservoir BC_1*

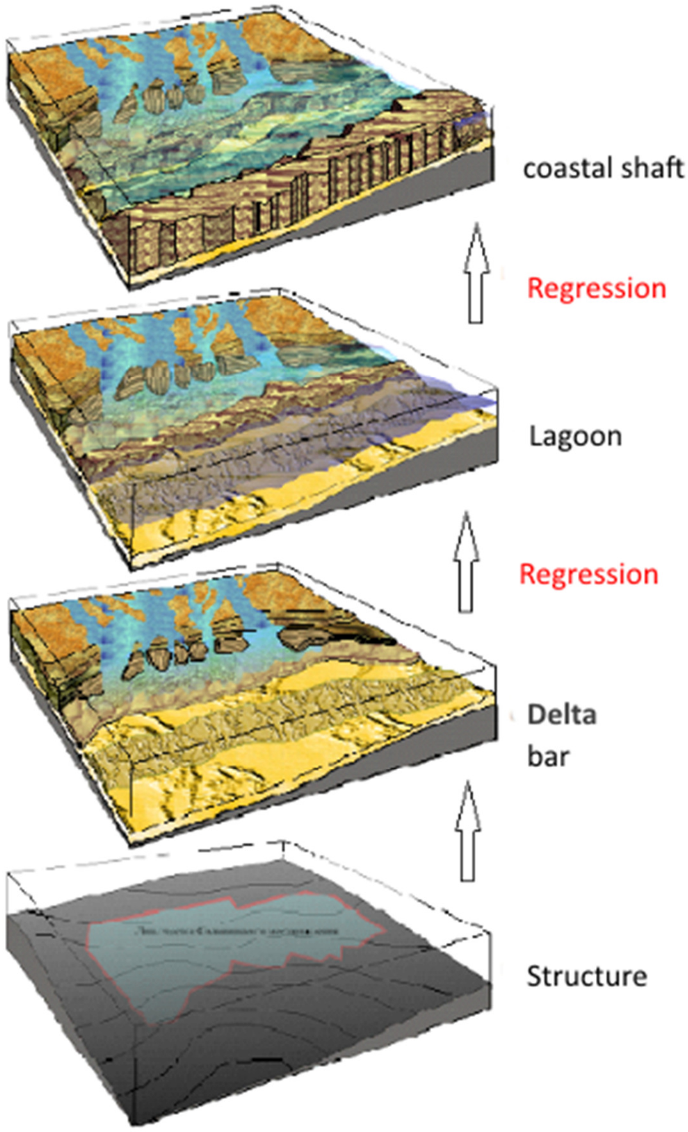
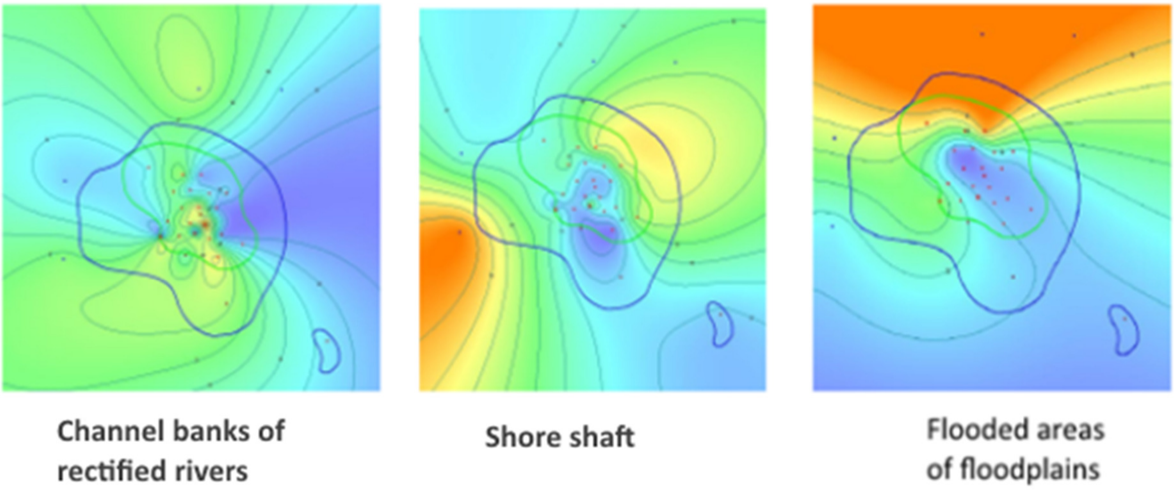
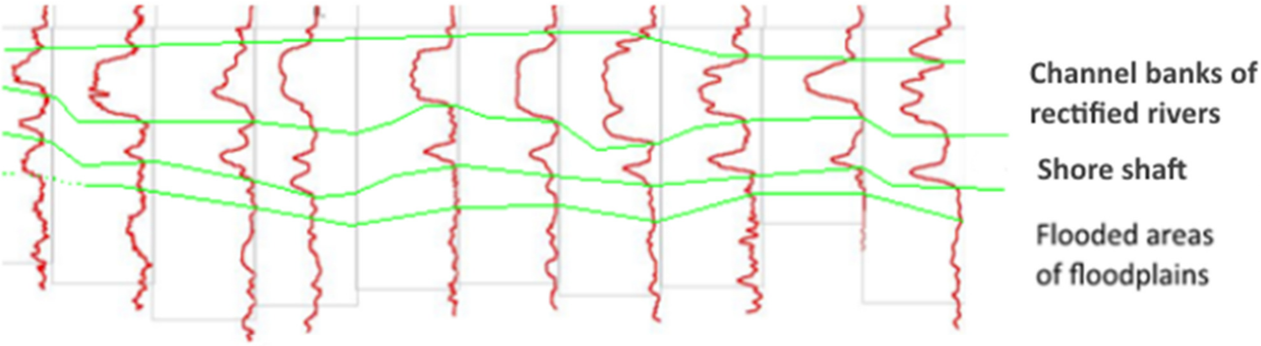


***Figure 4**. The generalized scheme of sedimentation of BC_1*





Sedimentation environment	Facies complex	The formalized electrometric model of the group of facies	Faction	Sign of deviation s ps	The maximum value of a ps	The real electrometric model	The real electrometric model of the facies The nature of the elements of the electrometric model of the facies				The position of the maximum value of a ps	The position of the maximum value of a ps	The position of the maximum value of a ps	Morphology of sand bodies - collectors Area spread		
							Roofing line	Lateral line	Bottom line	Width of anomaly, m				The form		Size, km
Marine	Alluvial		The shallows of the fluctuating rivers (mountain type) and temporary streams	-	1.0 - 0.6		Horizontal straight	Vertical dissected or notched	Horizontal straight	Units and tens	Throughout the anomaly, but especially in its lower part	1.0 - 0.8 (very high)	↑		Linearly extended branching	Hundreds of thousands, for temporary flows - hundreds
Marine	Alluvial		Shore Shafts	-	0.6 - 0.5		Inclined straight, serrated or inclined	Absent	Horizontal straight	The units	At the bottom, sharply expressed	0.6 - 0.4 (medium)	↑		Narrow linear elongated, sometimes oval	Units and tens
Marine	Alluvial		Temporarily flooded plots of floodplain	+	b 0.4		Horizontal straight	Absent	Inclined straight line, serrated or dissected	The units	In the lower part	0.4 - 0.2 (low)	↑		Linearly extended, with a complex contour	Hundreds and thousands

***Figure 5**. Scheme for isolating the deposits of facial complexes in the UC_2*

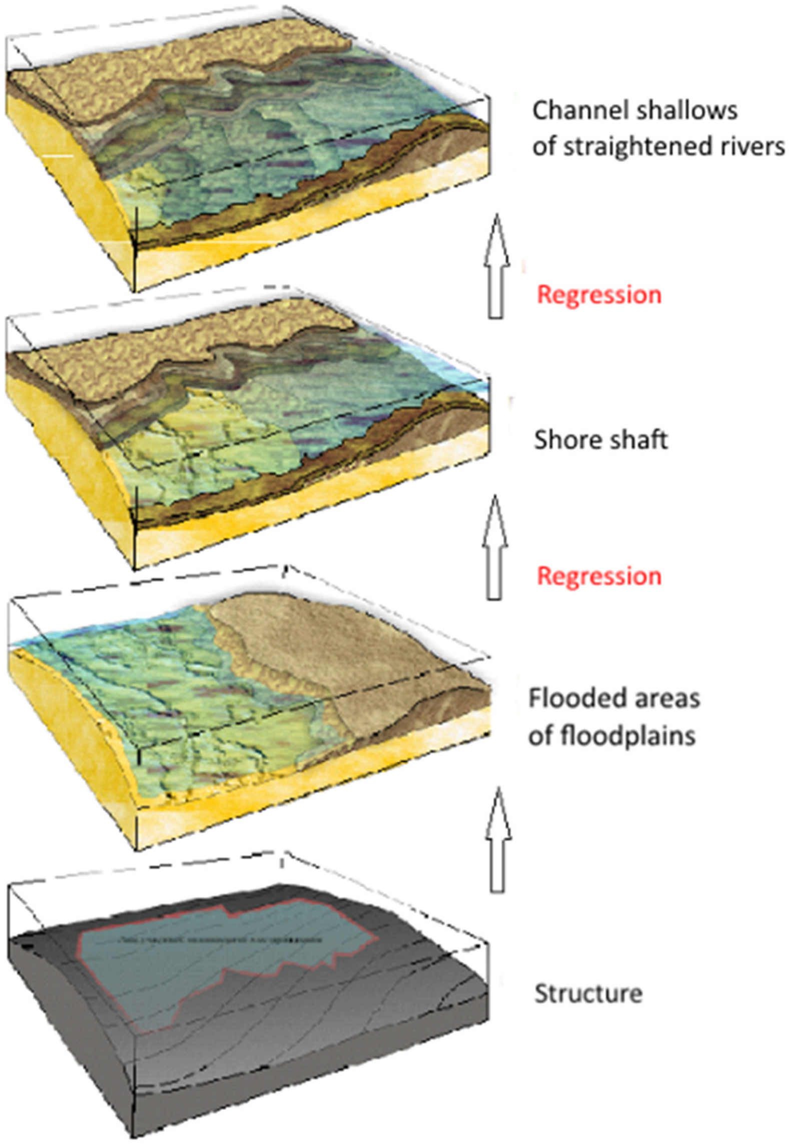


***Figure 6**. The generalized scheme of sedimentation of the UC_2*

PERTINÊNCIA PALEOFACIAL DAS ROCHAS RESERVATÓRIO DA FORMAÇÃO ROCHOSA VASIUGANSKAYA DA BACIA DE PETRÓLEO E GÁS NATURAL DA SIBÉRIA OCIDENTAL

PALEOFACIAL ATTRIBUTION OF COLLECTOR MINERALS OF VASYUGAN SUITE OF THE WESTERN SIBERIAN OGB

ПАЛЕОФАЦИАЛЬНАЯ ПРИНАДЛЕЖНОСТЬ ПОРОД-КОЛЛЕКТОРОВ ВАСЮГАНСКОЙ СВИТЫ ЗАПАДНО-СИБИРСКОГО НГБ

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RESUMO

O campo petrolífero de Fainskoye está localizado no distrito de Surgut na região autónoma de Khanty-Mansiysk (Okrug Autônomo de Khantia-Mansia – Yugra), entre os rios Bolshoy Yugan e o canal Pokamas, perto dos campos produtivos de Yuzhno-Surgutskoye e Vostochno-Surgutskoye. A análise das características da estrutura geológica dos depósitos produtivos do horizonte US1 do campo de Fainskoye foi realizada, bem como a identificação dos complexos paleofaciais. O artigo apresenta os resultados da aplicação do método eletrométrico de V. S. Muromtsev. Três zonas paleofaciais, diferentes em termos de características capacitadoras de filtração, foram identificadas: depósitos de inundação de canal, depósitos sublitorais e depósitos de lagoas e zonas estagnadas. Isso permite uma abordagem mais diferenciada para a escolha da estratégia ótima para o desenvolvimento de reservas de hidrocarbonetos.

Palavras-chave: *depósitos, ciclito, condições de sedimentação, complexos paleofaciais, método eletrométrico.*

ABSTRACT

The Fain oil field is located in the Surgut district of the Khanty-Mansiysk Autonomous Okrug (KhMAO-Yugra), in the interfluve of the Bolshoy Yugan river and the Pokasam canal, near the South Surgut and East Surgut deposits being developed. The features of the geological structure of the productive deposits of the US_1 horizon of the Fainsk deposits are analyzed, and paleofacial complexes are identified. The results of the application of the electrometric method of V.S. Muromtsev. Three paleofacial zones, differing infiltration, and capacitance characteristics are distinguished: channel-floodplain deposits, sublittoral deposits, and sediments of lagoons and stagnant zones. This allows for a more differentiated approach to choosing the optimal strategy for the development of hydrocarbon reserves.

Keywords: *sediments, cyclite, sedimentation environments, paleofacies, electrometric methods.*

АННОТАЦИЯ

Фаинское месторождение нефти расположено в Сургутском районе Ханты-Мансийского автономного округа (ХМАО-Югра), в междуречье реки Большой Юган и протоки Покамас, вблизи разрабатываемых Южно-Сургутского и Восточно-Сургутского месторождений. Выполнен анализ особенностей геологического строения продуктивных отложений горизонта $ЮС_1$ Фаинского месторождения, выполнена идентификация палеофациальных комплексов. В статье приведены результаты применения электрометрического метода В.С. Муромцева. Выделены три различные по фильтрационно-емкостным характеристикам палеофациальные зоны – руслово-пойменные отложения, отложения сублиторали и отложения лагун и застойных зон. Это позволяет более дифференцированно подойти к выбору оптимальной стратегии освоения запасов углеводородов.

Ключевые слова: *отложения, циклит, обстановки осадконакопления, палеофациальные комплексы, элетрометрическая методика.*

INTRODUCTION

The Fain oil field is located in the Surgut district of the Khanty-Mansiysk Autonomous Okrug (KhMAO-Yugra), in the interfluve of the Bolshoy Yugan river and the Pokasam canal, near the South Surgut and East Surgut deposits being developed.

The deposit was discovered in 1981 and five years later it was put into development. According to the size of the initial recoverable reserves (Mukhametshin *et al.*, 2015), the deposit belongs to the category of medium size, and according to the geological structure – to the complex structures because of the strong macro- and microinhomogeneity of productive deposits.

Tectonically, it represents a single dome-shaped elevation of the sublatitudinal strike, located in the Faina Basin separating the southeastern wing of the Surgut arch from the Nizhnevartovsk arch. The geological section of the deposit is represented by a thick layer of sedimentary terrigenous rocks of the Mesozoic-Cenozoic orthoplatform cover (an average of about 3200 m) and effusive-sedimentary metamorphosed rocks of the Paleozoic basement (Betkher and Vologdina, 2007; Volozh and Leonov, 2004). Productive sandstones are confined to the upper Vasyugan Formation (horizon UC_1) (Petrova *et al.*, 2018; Starikov and Kozlova, 2010; Sokolov *et al.*, 2006a; Kuznetsov, 2016; Khabarov *et al.*, 2010).

Deposits of the formation have been opened almost all the wells drilled within the field. The total thickness of the Vasyugan suite varies from 72 m in the most elevated part to 84 m on the wings of the structure. There is a tendency for a slight decrease in capacity from the east to the west of the field. The Formation section within the region under consideration are four sandy-argillaceous cyclitis indexed upwards like UC_1^4, UC_1^3, UC_1^2 and UC_1^1. All objects are complex, heterogeneous. They are characterized by an extremely uneven distribution of filtration-capacitive properties due to strong paleofacial heterogeneity. Riverbeds and floodplains are the most promising for oil and gas.

MATERIALS AND METHODS

Deposits of cyclites UC_1^4 and UC_1^3 within the Faina deposit are mainly claystones and only in the eastern part are individual lenses of siltstones. The mudstones are dark gray, unevenly sandy, calcareous, micaceous, and dense with the inclusion of carbonated plant residues. Siltstones are gray, clayey, sandy, mica, sometimes calcareous, with the inclusion of plant remains. The total thickness of the cyclites varies from 35 m in the east to 20 m in the west of the deposit.

Cyclite UC_1^2 is composed similarly to the lower ones, and likewise the character of the power that changes in direction from east to west changes in a similar way.

The upper part of the Vasyugan Formation is mainly sandy, the industrial oil bearing layer UC_1^1 is confined to it. The sandstones of the productive stratum are finely -and medium-grained, unevenly-clayey, firmly cemented, in the clay interlayers strongly compacted (Figure 1). Interbeds of dark gray siltstones and argillites occur in sandstones, in which carbonized plant remains are noted. When testing sand deposits of the UC_1^1 formation, industrial oil inflows were produced with a flow rate of 20-100 m^3/day.

The analysis of the filtration-capacitance properties of the deposits (Sheriff, 1989; Gutorov, 2012) of the UC_1 horizon of the Faina deposit was carried out, which showed that their differentiation is observed both in plan and in the section, due to the variegated development of paleofacial zones in the Faina field.

RESULTS AND DISCUSSION:

Results of typification of well sections by the forms of curves of GIS methods by electrometric method of V.C. Muromtsev (1984) suggest that at the time of formation of the Vasyugan cyclists, a "genetic set" of sedimentation environments at the Fainsk field was a coastal belt that included both shallow water and the weakly dissected continental plain adjoining it, intersected by streams of meandering rivers that supplied terrigenous material in shallow water (Shimanskiy, 2011).

Based on the results of the correlation, several paleofacial zones have been identified in the area of the main deposit (Figure 2), and, presumably, the area of development of the mouth bar.

It should be noted that the boundaries of the selected areas are of a conditional (diffuse) nature, which is due to the influence of insignificant fluctuations in sea level and the constant migration of paleostreams, so that the coastal belt of precipitation, in shallow water, has undergone significant processing and redeposition. The boundary regions of the paleofacial zones, which are the result of repeated transgressive-regressive processes, are combined into a transitional facies group (Petrova *et al.*, 2018; Starikov and Kozlova, 2010; Sokolov *et al.*, 2006a; Alexandrov *et al.*, 2005; Sokolov *et al.*, 2006b; Nikiforova, 2015; Syzrantsev *et al.*, 2018; Kriswandani, 2012). In some cases, in the general field of the selected sub-facies, individual wells opened a different type of cut. In order to avoid unnecessary diversity, these local zones are included in the general field of the predominant paleofacial zones. In those cases, when there were no GIS data in the wells, the boundaries of the paleofacial zones were calculated taking into account the area patterns of the change in effective thicknesses (Filina *et al.*, 1984).

At the time of the formation of the UC_1 horizon, the entire western and northwestern parts of the structure represented vast lowland covered with a network of shallow rivers. In the west of the main deposit, four regions of alluvial-bed deposits have been identified (Surkov, 2005; Osintseva, 2016). A characteristic feature of channel sediments is the absence of area correlation (Ngah, 2000). This is due to the meandering nature of the channel flows. At close distances, the wells open up channel sediments both in the roof part of the upper-Vasyugan subsuite, and in the lower part. Sometimes the upper channel cuts into the underlying older riverbed, forming the maximum sandy body (boreholes No. 14R, 113, 502, 114, 503, 107, 13R).

The smallest area of channel sediments is found in the northeast of the area. In the area of wells No. 1780, 1782, 9084, 1794 and 1792, the presence of a channel is well traced. The thickness of sandstones in these wells is more than 20 m. In the surrounding wells, characteristic sections are marked, which can be attributed to the surrounding alluvial-channel complex.

In the central part of the deposit structure, the riverbed of the river of the submeridional strike is traced (Omosanya *et al.*, 2014). From the north to the south, typical channel sediments are noted along the line of wells No. 1722, 1719, 9017, 9025.1750, 9051, 1759, 358, 386 and further, with some deviation to the southwest (wells No. 441 and 615).

The same nature of the meandering channel is noted in the northwestern part of the structure, which is also represented by channeled facies. The movement of the water flow occurred from the north-west to the southeast. The position of the channel sediments is most clearly seen from the map of effective thicknesses and is identified with the zones of maximum increase (Shpilman *et al.*, 1999). Wells No. 100, 180, 502, 183, 187 and 120 opened the deposits of the delta canal, and in the surrounding wells, the type of incision characteristic of alluvial-bed deposits is identified (Figure 3).

At the western end of the structure, a small number of wells also revealed delta deposits. These are wells No. 515, 220, 160, 222, 161, 161a and 223. The presence of channel facies is in good agreement with the sharp increase in the thickness of sandstones. This region is studied by the formation of a coastal bar at the mouth of the river, which is separated on the map by effective thicknesses by their local magnification and by the specific type of the PC curve (Gorbunova, 2017; Volchenkova, 2009; Sirotenko, 2009). In general, the area of development of channel facies on the map of effective thicknesses is characterized, first of all, by their sharper changes. The maximum thicknesses (25-32 m) are associated with the filling of the main channel, and the areas of medium and minimum thickness – with the floodplain part of the channel flow.

Between the channel-alluvial complex and the sublittoral deposits, one can distinguish the transitional facial zone, which is the cumulative result of repeated transgressive-regressive processes. It is characterized by the shape of the PC curve typical for the sublittoral region, but, in contrast to the sublittoral, it has in its section more restrained and less clayey sandstones.

The largest part of the area is occupied by sediments of the sublittoral type. Apparently, during the formation of the sandstones of the horizon UC_1, the most elevated part was located in the northwestern part of the deposit, where the sedimentary material was brought to the open sea, located in the southeastern part of the study area. As a consequence, the entire southeastern part of the deposit is represented by subglacial deposits of the sublittoral, characterized by the presence of good traceability, even relatively low-power interlayers at a distance of 2-3 km (Figure 4).

Wells No. 410, 432 and 626, located in the southern part of the Faina deposit, are represented by a thin alternation of interlayers (low-power type of reservoir rocks – sawtooth records by the PC method). It can be described as a "rear" area facing the continent with a predominance of the low-energy environment of sea bays, lagoons, coastal plains where there was no active accumulation of reservoir rocks due to a shortage of large-grained detrital material. On the map of effective thicknesses, this region is characterized by the area development of 4-6-meter thickness of sandstones.

The southern part of the Faina field, previously allocated as a separate reservoir, after the 1994 reserves were calculated, was combined into a single reservoir. This uplift is composed of sediments of the lagoonal subfacies and is characterized by a sufficiently sharply outlined curve for the PC. In the southern part of this uplift, a specific type of incision is also presented with slightly differentiated curves of PC and GK, correlated with stagnant zones of sedimentation and characterized by increased clay content. Apparently, these are shallow-marine formations, which, in turn, under the influence of coastal shoreline movements were subjected to erosion and destruction. The facies of the stagnant zone differ from the remaining facies by the total absence of correlation of the deposits. In Figure 5 there is a paleo-profile that passes through the southern end of the Faina deposit, where sediments of stagnant and lagoon zones are represented.

In the West-Faina structure, the concept of the paleofacial composition of the constituent deposits is very conditional. Apparently, this area is a continuation of the stagnation zone, discovered in the southern part of the deposit.

CONCLUSIONS:

As a result of the studies carried out in the field of paleofacies analysis, the following conclusions can be drawn on the deposits of horizon UC_1. Conditionally, the entire area of the Faina deposit can be divided into three paleofacial zones generalized by filtration-capacitive characteristics:

1. Channel-floodplain deposits are characterized by good reservoir properties along the vertical, but weak hydrodynamic connection along laterals. This area is developed on the entire northern and northwestern part of the main reservoir.
2. Sublittoral deposits – lower reservoir properties, but the good hydrodynamic connection between wells by area. This area occupies the entire eastern part of the main reservoir.

Deposits of lagoons and stagnant zones have the lowest collector properties and the weak connection between sandstone interlayers along laterals. Partially central and the entire southern part of the main deposit, as well as the West Faina deposit, are characterized by the presence of this type of sediments.

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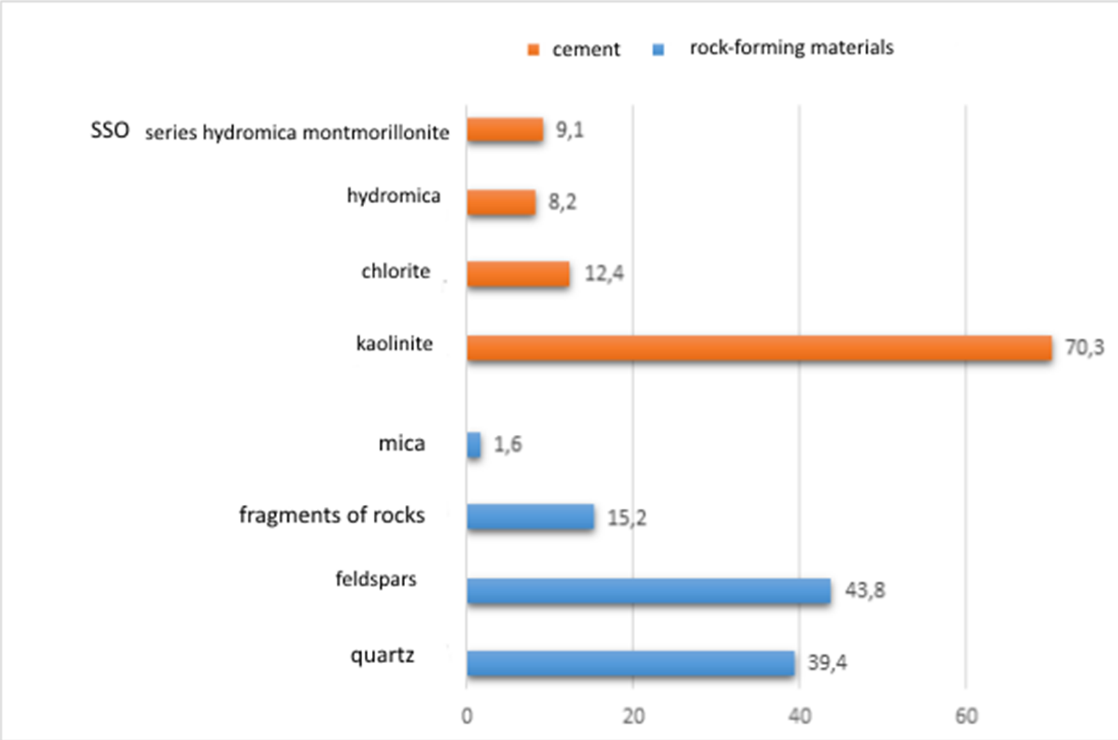

Figure 1. *Characteristics of the mineralogical composition of the rocks in the UC* $_1$[1]

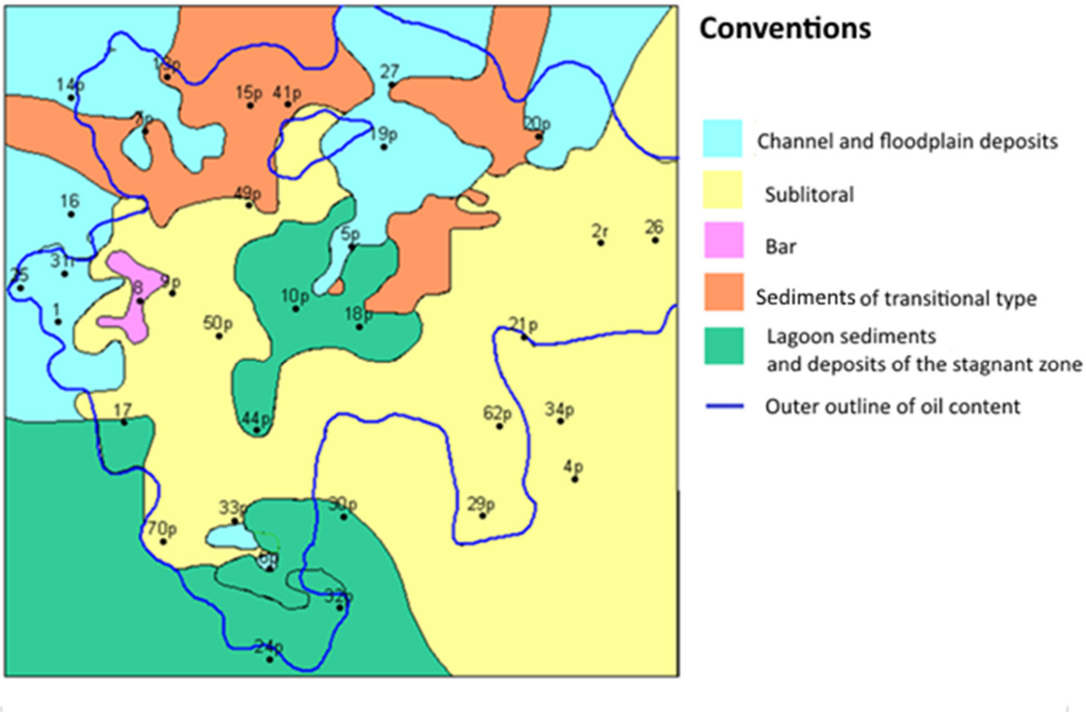

Figure 2*. Scheme of development of paleofacial complexes in the horizon of UC* $_1$

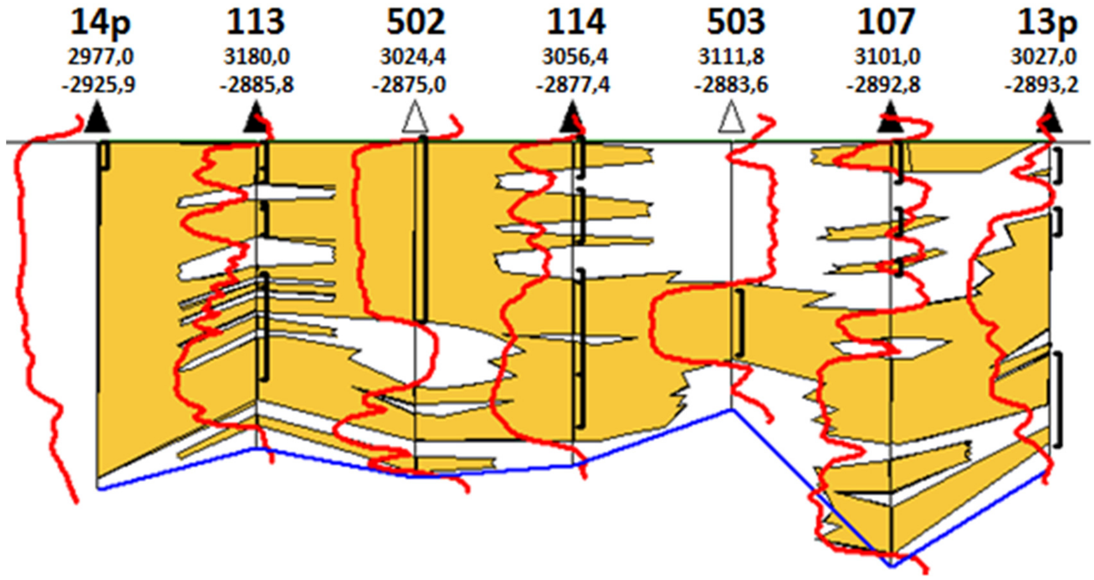

Figure 3. *Scheme of the development of sediments of channel-floodplain subfacies in the northwestern part of the Faina deposit*

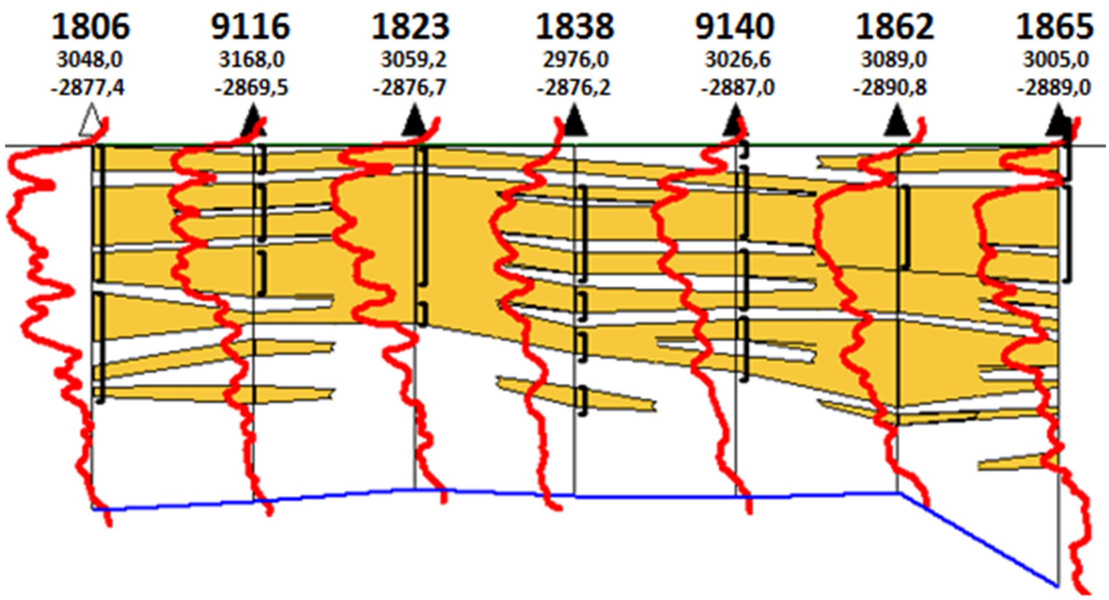

Figure 4. *Scheme of development of sediments of the subfacies of the littoral of the Faina deposit*

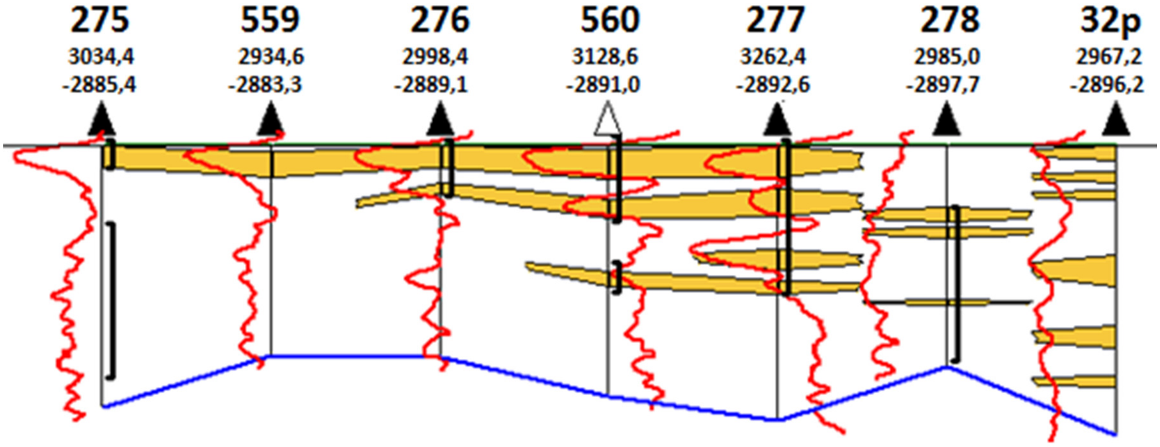

Figure 5. *Scheme of development of sediments of subfacies of lagoons and stagnant zones in the southern part of the Faina deposit*