TIPOLOGIA GENÉTICA DOS DEPÓSITOS DE FORMAÇÃO ROCHOSA TANOPCHINSKAYA

GENETIC TYPES OF DEPOSITS OF THE TANOPCHINSKY SUITE

ГЕНЕТИЧЕСКАЯ ТИПИЗАЦИЯ ОТЛОЖЕНИЙ ТАНОПЧИНСКОЙ СВИТЫ

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RESUMO

Reduzir a incerteza no cálculo das reservas geológicas iniciais de hidrocarbonetos é possível melhorando a qualidade dos modelos geológicos de várias dimensões. Foi criado um modelo de sedimentação conceitual de depósitos da formação rochosa Tanopchinskaya, usando métodos de análise de litofácies. O modelo de fáceis possibilitou predizer as áreas de desenvolvimento de zonas de rochas reservatórios melhoradas. A construção do modelo de fáceis baseia-se na utilização do método de análise de fáceis cíclica, que consiste em estudar a gênese dos depósitos e sua morfologia no espaço geológico. Duas macrofácies foram distinguidas: depósitos da costa da lagoa de inundação e de zona intertidal. A construção de um modelo conceitual (de fácies) permite um nível qualitativo completamente novo para realizar a modelagem geológica tridimensional de objetos geológicos complexos.

Palavras-chave: *campo, rochas reservatórios, cerne, análise de fácies, situação de sedimentação.*

ABSTRACT

Reduction of indeterminacy in the calculation of initial geological reserves of hydrocarbons is possible due to the improvement of the quality of geological models of different dimensions. The conceptual sedimentation model of the deposits of the Tanopchinsky suite using lithology-facies analysis methods was created. The facies model allowed to predict the development areas of improved reservoir rocks. The construction of the facial model is based on the use of the method of facies-cyclic analysis, which consists in studying the genesis of sediments, their morphology in geological space. Two macrofacies were identified: sediments of the lagoon-lagoon coast and tidal band. The construction of a conceptual (facies) model allows for a completely new

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qualitative level to perform three-dimensional geological modeling of complex geological objects.

Keywords: *deposit, reservoir rocks, core, facies analysis, sedimentation situation.*

АННОТАЦИЯ

Уменьшение неопределенности в подсчете начальных геологических запасов углеводородов возможно за счет повышения качества геологических моделей различной размерности. Была создана концептуальная седиментационная модель отложений танопчинской свиты с применением методов литолого-фациального анализа. Фациальная модель позволила спрогнозировать области развития зон улучшенных пород-коллекторов. Построение фациальной модели основано на использовании метода фациально-циклического анализа, который состоит в изучении генезиса отложений, их морфологии в геологическом пространстве. Было выделено две макрофации: отложений заливно-лагунного побережья и приливно-отливной полосы. Построение концептуальной (фациальной) модели позволяет на совершенно новом качественном уровне осуществлять трехмерное геологическое моделирование сложнопостроенных геологических объектов.

Ключевые слова: *месторождение, породы-коллекторы, керн, фациальный анализ, обстановка осадконакопления.*

INTRODUCTION

Deposits of the Tanopchinsky Suite of the Yamalo-Gydan oil and gas region are one of the main productive complexes in which a significant part of hydrocarbon reserves are concentrated (Fedorova *et al.*, 2010; Skorobogatov, 2006). The productive interval is characterized by a complex structure, the study of which requires the integration of the initial geological and geophysical information (Kopeev *et al.*, 2003; Petrova *et al.*, 2018). The Tanopchinsky suite is transgressively overlapped by the Yaron suite (Albian stage), which is composed of clay argillite-like, gray and dark gray, from finely stretched to silty, bioturbated areas, with interlayers of sandstones and siltstones. At the base of the formation, a layer of sandstones with sites of clayey material, glauconites, calc-siderite concretions is established. Accumulation of deposits of the suite occurred in relatively deep sea conditions, with a passive hydrodynamic regime (Kozlov *et al.*, 2015).

Paleofacial studies of geological objects consist of studying and retrospectively recreating the conditions of sedimentation in a specific interval of geological time, as well as obtaining a certain set of data for the subsequent creation of a geological model (Fielding, 2015). Ideally, in order to obtain the most reliable result, it is necessary to identify the conditions for the accumulation of each layer of rocks in a section (Verdugo-Perona *et al.*, 2016; Li and Zhao, 2014), to track in time and in area the change in these conditions, and to determine the characteristic features of the direction of sedimentation and the causes that led to this process. Under the sedimentation conditions, the whole sedimentation cycle is understood, including the methods of transport and deposition of the material, the hydrodynamic activity and the geochemical regime of the sedimentation basin, as well as the ecological and landscape conditions in which sediments are formed (Adams *et al.*, 2014; Boggs, 2014; Novikov, 2010). These circumstances are especially important for productive deposits, characterized by strong lithologic-facies heterogeneity both laterally and vertically (Oyanyan *et al.*, 2012). As an object of our research, we selected the rocks of the Tanopchinsky suite, a detailed study of which allows us to specify the genesis of sedimentary geological bodies in "transitional" conditions.

MATERIALS AND METHODS

The most important principle in the methodology of lithological-facial analysis and the creation of a conceptual geological model is the system approach, which implies a complex analysis from the smallest structural units (mineral) to large (sedimentary-rocky basin) (Figure 1). Paleo-facial constructions, as part of the basin analysis, begin with the description and reconstruction of sedimentation conditions for large stratigraphic units, then establishing the cyclicity of the rock layers and further distinguishing the largest geological bodies composing the main parts of the sedimentary-rock basin (Wang, 2016; Cook, 2015).

In accordance with the principle described above, the basis of lithologic-facies analysis is the determination of the conditions for the formation of the rock on the basis of diagnostic features already in the selection of core material and further detailing of characteristics in the subsequent processing of materials (Vackiner, 2013).

A detailed analysis of the core sampled in 19 wells was performed. The identification of sedimentation environments and subsequent subfacies was carried out in accordance with the classification of V.P. Alekseev (Table 1). By subfacies, we mean something similar to the deposition of a given facies in the conditions of existing knowledge.

Based on the results of a detailed layered macroscopic description of the core from the section of the Tanopchinsky suite, several subfacies were identified that are combined into macrofacies (Alekseev, 2014).

1. Macrofacion of the sediments of the lagoon-lagoon coast:

1.1. Subfacies of silty-clay sediments of central parts of bays and lagoons;

1.2. Subfacies of sandy-aleuritic sediments of coastal parts of bays and lagoons.

2. Sediment macrofacies of tidal band:

2.1. Subfacies of clayey-aleuritic sediments of the silty zone of the tidal flats;

2.2. Subfacies of sandy-argillaceous sediments of the mixed zone of the tidal flats;

2.3. Subfacies of sandy sediments of sandy tidal flats;

2.4. Subfacies of silty-clay deposits of brackish-water lakes and marshes;

2.5. Subfacies of sand deposits of channel gullies (canals).

When carrying out the facial analysis using the method of V.S. Muromtsev (1984) in the form of GIS diagrams, a model "with a thinning of sediments upwards along the section" was identified, which indicates the following situations:

- damped sedimentation phenomena, such as gravitational flows;
- successive displacements of the depocenter farther from the section under study (transgressive deposits);
- a consecutive decrease in the energy of the environment at the place of sedimentation (sediments of the channel).

This kind characterizes the alluvial atmosphere of sedimentation. Further, according to the existing standard forms PC and GC specific sedimentary environments of the group in question, their facial diagnosis is performed according to well logging: throughout the wells defined shape log curves SS and SC are sets of change in the sequence, pattern location section of the same type of anomalies and the nature of their rhythmic alternation. The diagrams of GIS methods in the sections of wells were used to identify the cycles, determine their types, and measure the capacities. Based on the results of the sedimentological description of the core and the electrofacial analysis, an array of typical electrometric models of subfacies was compiled (Alekseev, 2011; Izotova *et al.*, 1993; Shilov and Jafarov, 2001; Kontorovich *et al.*, 2014; Biju-Duval, 2012).

The electrometric model of the subfacies (macrofacies) of the bed is characterized by sandy deposits with a gradual decrease in grain size (an increase in the clay constituent) upwards along the cut, thus increasing the values of the PC and GC methods to the roof of the channel body.

The electrometric model of the subfacies (macrofacies) of the coastal plain is the deposition of aleuritic-argillaceous rocks of tidal flats and floodplains with thin coal interlayers and sandstone interlayers (small channels that dissect tidal banks), thereby increasing the values of PC and GC in clay and sharp decreases in values in the carbonaceous interlayers.

THE SEDIMENTS OF THE ALLOCATED SUBFACIES IN THE TANOPCHINSKY SUITE:

3.1. Macrofacion of the deposits of the lagoon-lagoon coast

For macrofacions, all the characteristics of closed sedimentation reservoirs are inherent. In the study of ancient bays (lagoons) diagnose the facies important features are the presence of siderite nodules bioturbation and having textures formed in the outside of an active influence. According to the section of the Tanopchinsky suite, two subfacies were identified:

1. Subfacies of silty-clay sediments of central parts of bays and lagoons.

2. Subfacies of sandy-aleuritic sediments of coastal parts of bays and lagoons.

Subfacies of silty-clay sediments of central parts of bays and lagoons. A typical electrometric model of sediments of this subfacies is presented in Figure 2. The deposits of the subfacies have a silty-clay composition and are represented mainly by massive, rarely thin-layered and microlenses-laminated moderately bioturbated argillites and clayey siltstones. Characteristically, the presence of strata and interlayers of pelitomorphic siderite and sideritized argillite (Figure 3A), as well as the texture of the introduction, landslides (Figure 3B). The aleurite-clay composition of sediments, the presence in them of a varied number of benthic courses, indicate their accumulation with predominantly quiet sedimentation conditions favorable for sedimentation of suspended fine-grained sediment fractions.

Subfacies of sandy-aleuritic sediments of coastal parts of bays and lagoons. A typical electrometric model of deposits of this subfacies is presented in Figure 4. Subfacial deposits are mainly represented by siltstones of fine-grained clayey lenticular-layered and hollow-undulating with interlayers and lenses of fine-grained sandstone (Figure 3C). In sandstones, a thin oblique layering of ripples of various types is developed: wave, combined and flowing. This subfacies are characterized by the presence in a small amount of carbon detritus, the remains of carbonated plant roots, syneresis cracks, siderite concretions, and bioturbational textures.

3.2. Sediment macrofacies of tidal band

A typical electrometric model of deposits of this macrofaction is presented in Figure 5. The tidal band is formed along the shallowly submerged coasts, where tidal currents operate, a fairly large amount of sedimentation is formed and there is no destructive effect of the waves. It can be formed in estuaries, lagoons, bays or behind barrier islands or sandbars. Deposits of the tidal band are divided into supralittoral (lakes and marshes) tidal band (silt, sand, and mixed shoals) and sublittoral zone (channel scours and sand bars). Sedimentation of tidal bands is represented mainly by fine-grained silt, silts, clays, and fine-grained sand.

For depositions of macrofacies in the tidal band, five subfacies are identified within the work area:

1. Subfacies of clayey-aleuritic sediments of the silty zone of the tidal flats.

2. Subfacies of sandy-argillaceous sediments of the mixed zone of the tidal flats.

3. Subfacies of sandy sediments of sandy tidal flats.

4. Subfacies of silty-clay deposits of brackish-water lakes and marshes (wattles, marches).

5. Subfacies of sand deposits of channel gullies (canals).

Subfacies of clayey-aleuritic sediments of the silty zone of the tidal flats. Subfacial deposits are mainly represented by clayey siltstones with thin interlayers and lenses of coarse silt, more rarely fine-grained sandstone (Figure 6A). These sediments are characterized by a depleted composition of bioturbational textures and the presence of numerous remains of plant roots.

Subfacies of sandy-argillaceous sediments of the mixed zone of the tidal flats. A typical electrometric model of sediments of this subfacies is presented in Figure 7. Subfacial deposits are represented by the hollow-wavy and lenticular-wavy interspersing of fine-grained sandstone with siltstones and mudstones (Figure 6B). In the sandstones, there is an oblique and fine oblique stratification, accentuated by the carbonaceous-argillaceous and detrital material. The layering of the rock is often disturbed by concedimentary deformations, traces of bioturbation and carbonized roots of plants.

Subfacies of sandy sediments of sandy tidal flats. A typical electrometric model of sediments of this subfacies is presented in Figure 8. Subfacial deposits are represented by fine-grained sandstones, less often fine-grained, slightly bioturbated with numerous clay and detrital puffs forming a flasher, fine, oblique, hollow-wavy and lenticular-wavy layering (Figure 6C).

Subfacies of silty-clay deposits of brackish-water lakes and marshes (wattles, marches). A typical electrometric model of subfacies is shown in Figure 9. Deposits of this subfacies are represented by mudstones, carbonaceous argillites, clayey siltstones, and coal (Figure 10). The rocks are massive, less often horizontally layered and microlincoid-laminar, with numerous carbonated rootlets of plants, with single fine pyrite scales. They were accumulated in the supralythoral zone of the tidal band. This is a strip of land located above the littoral, characterized by high humidity due to frequent splashes of surf and splash of waves.

Subfacies of sand deposits of channel gullies (canals). The electrometric model of sediments of these subfacies is presented in Figure 11. The sediments of the channel gullies, which occupy most of the sublittoral zone, are composed of fine-to medium-fine-grained sandstones with shallow oblique, often flasher, oblique and hollow-wavy discontinuous stratification formed by organic material (Figure 12). In addition, clayey intraclasts, shell fragments, sideritized pebbles, as well as fragments of carbonized wood can be found in the plantar part (bed of the washings). Sandstones, as a rule, are poorly bioturbated (Arenicolites, Teichichnus, Thalassinoides, Paleophycus).

CONCLUSIONS:

In the course of the studies, fundamentally new results were obtained. Typing of heterogeneous deposits of the Tanopchinsky Suite was performed. Two macrofacies were identified: sediments of the lagoon-lagoon coast and tidal band. They include the rocks of seven subfacies, differing in material composition, texture-structural features and filtration-capacitive properties: 1) aleurite-clay sediments of the central parts of bays and lagoons; 2) sandy-aleuritic sediments of coastal parts of bays and lagoons; 3) clayey-siltstone sediments of the silty zone of the tidal flats; 4) sandy-argillaceous sediments of the mixed zone of the tidal flats; 5) sandy sediments of sandy tidal flats; 6) aleurite-argillaceous deposits of brackish-water lakes and swamps (marches); 7) sand deposits of channel gullies (canals). The construction of a conceptual (facies) model allows for a completely new qualitative level to perform three-dimensional geological modeling of complex geological objects.

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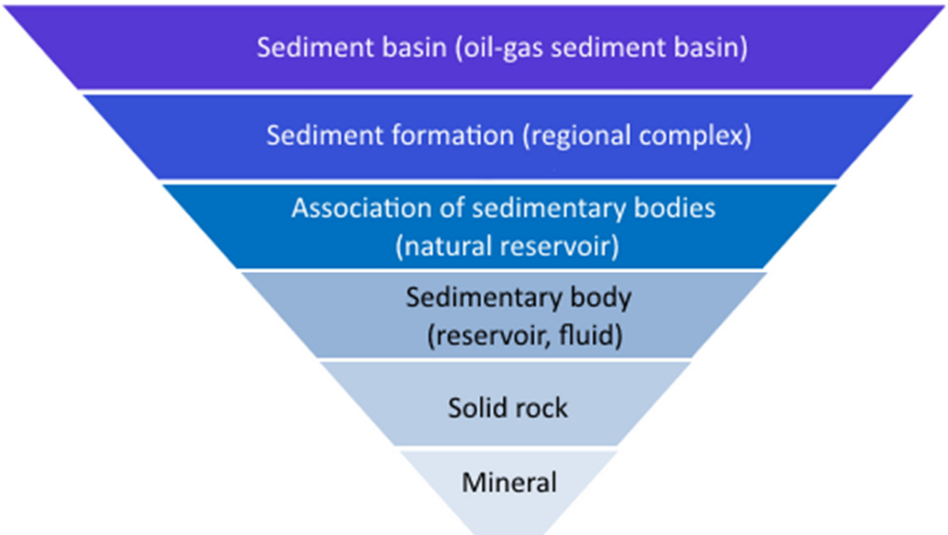

***Figure 1**. The hierarchy of natural geological objects*

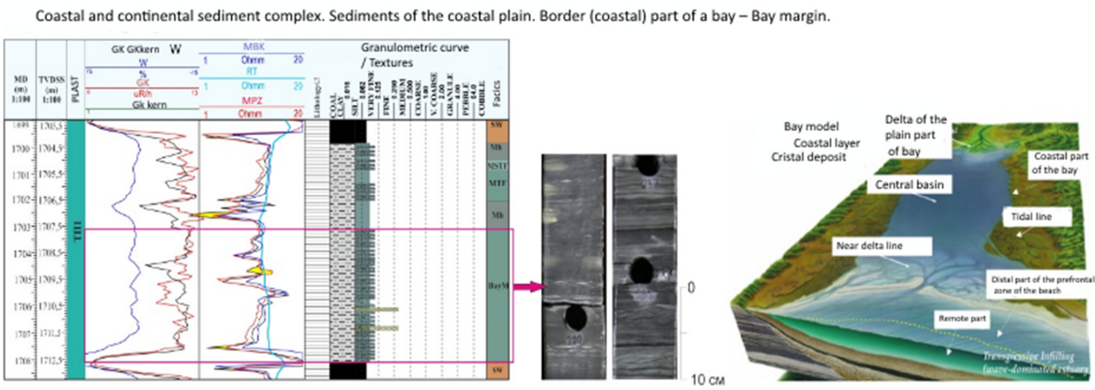

***Figure 2**. Electrometric model of deposits of the facies of aleuritic-argillaceous sediments of the central parts of the lagoon-lagoon coast*

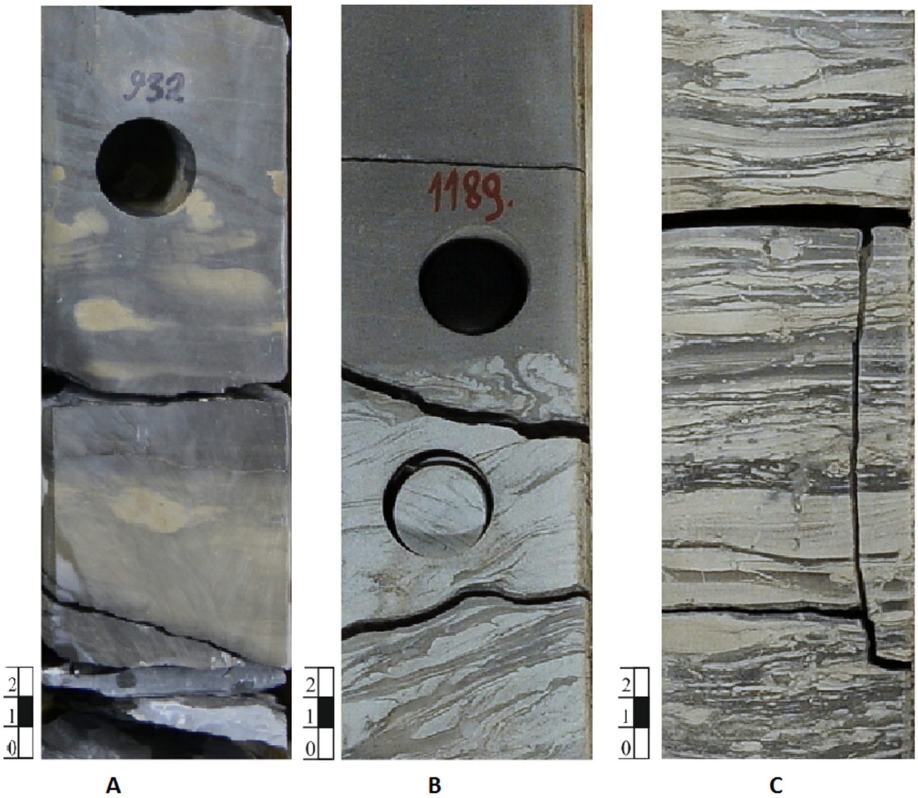

Figure 3. *Textural features of the deposits of the lagoon-lagoon coast. A – aleuromargillite with concretionary concretions of pelitomorphic siderite by stratification; B – in the upper part: large-fine gravelly well sorted massive siltstones, in the lower part: fine-grained sandy-wavy-bedded sandstone well sorted deformed by slipping; C – sandstone fine-grained well sorted small-layered with hollow and lenticular-wavy layering*

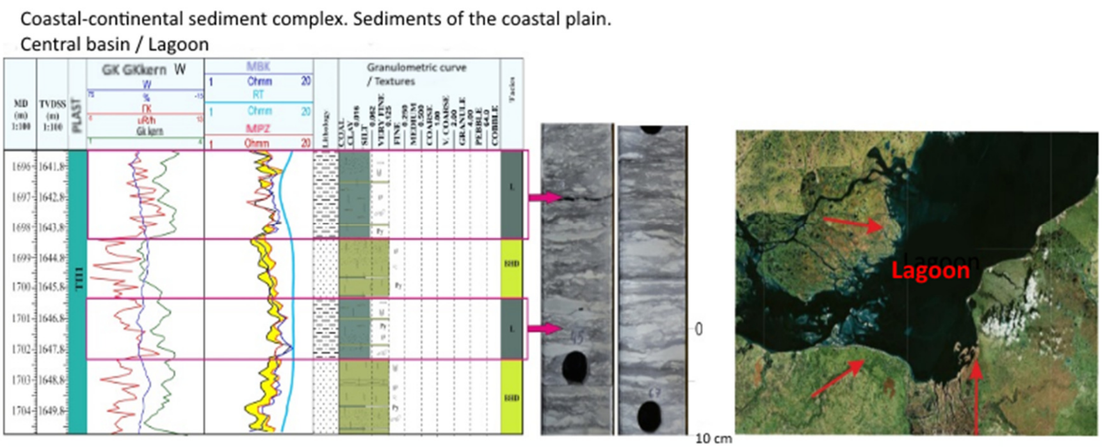

Figure 4. *Electrometric model of deposits of the facies of sandy-aleuritic sediments of coastal parts of bays and lagoons*

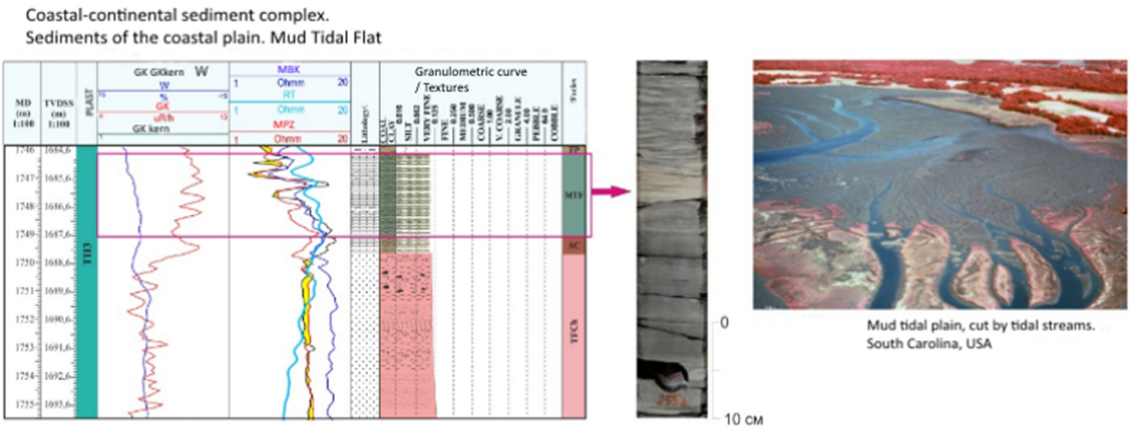

***Figure 5**. Electrometric model of macrofacies deposits of clayey-aleuritic sediments of the muddy zone of the tidal flats*

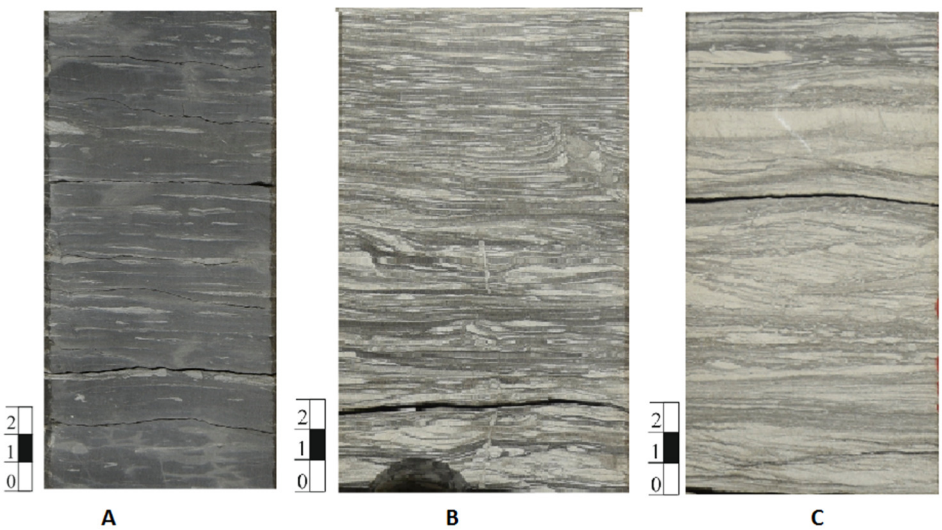

***Figure 6.** Textural features of sediments of the tidal zone. A – siltstone fine-grained clayey with microlensic lamination, caused by lenses of siltstone coarse-grained, the texture of the rock is poorly disturbed by single traces of bioturbation; B – hollow-wavy and lenticular-wavy interbedding of siltstone fine-grained clay and sandstone fine-grained. The stratification of the rock by the sections is disturbed by the vertical trajectories of the bioturbation, by consedimental deformations; C – fine-grained sandstone well sorted with a hollow-wavy layering due to pockets of carbonaceous-clay material and interlayers of fine-grained siltstone. The layering of the rock is intensely disturbed by bioturbation (Planolites, Arenicolites)*

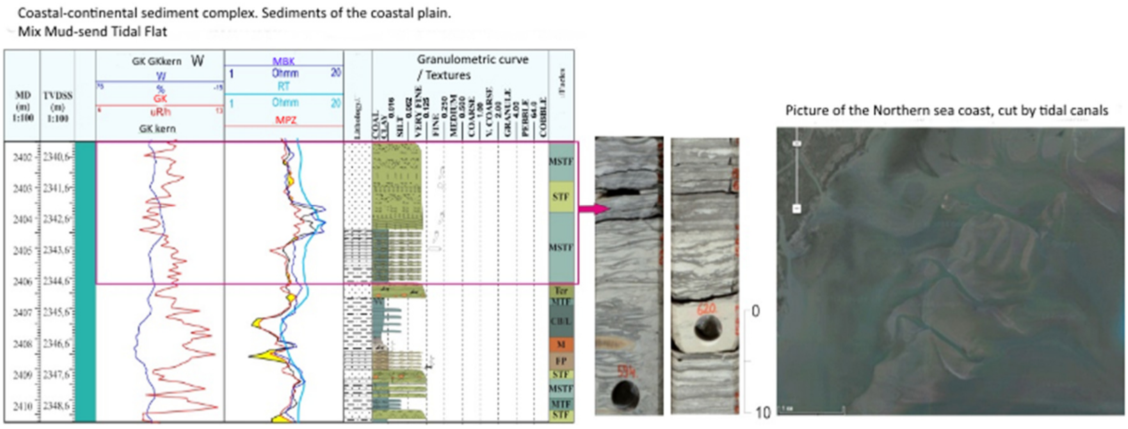

Figure 7. *Electrometric model of subfacies deposits of sandy-argillaceous sediments of the mixed zone of the tidal flats*

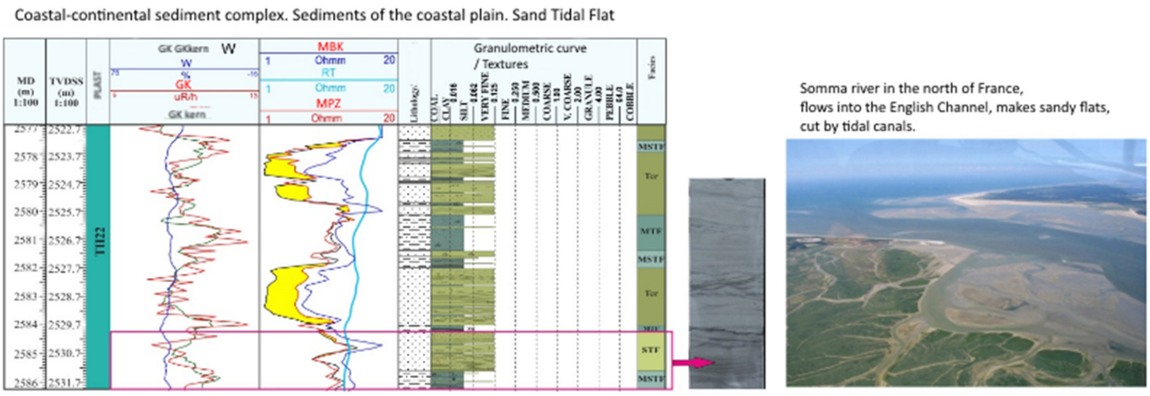

Figure 8. *Electrometric model of sediments of subfacies of sandy sediments of sandy tidal flats*

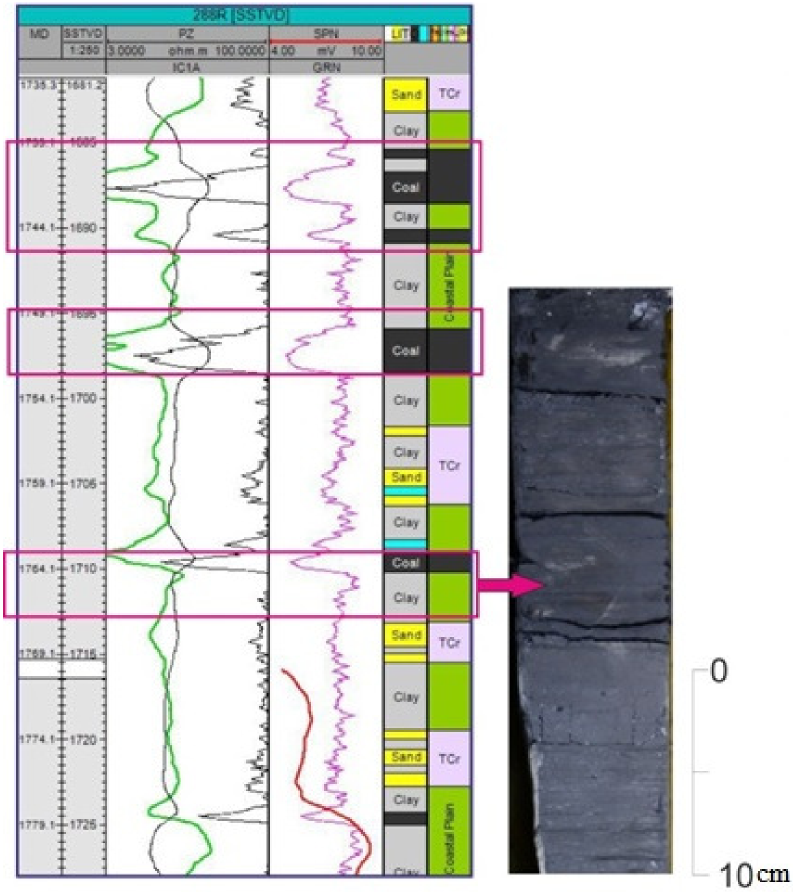

Figure 9*. Electrometric model of subfacies deposits of silty-clay sediments of brackish-water lakes and marshes (watt, marches)*

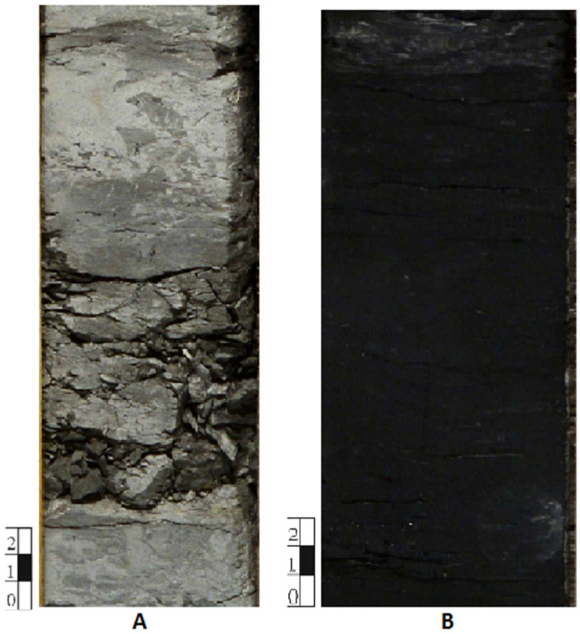

Figure 10*. Textural features of deposits of the supralittoral zone of the tidal band (lakes and marshes). A – aleurogarhillitis with unclear lumpy stratification, disturbed by numerous plant roots; B – carbonaceous argillite.*

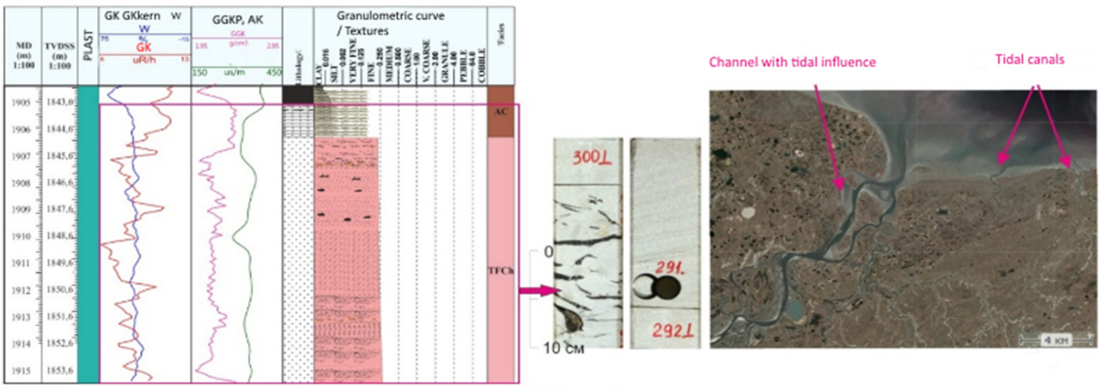

***Figure 11**. Electrometric model of sediments of subfacies of sand deposits of gullies (channels)*

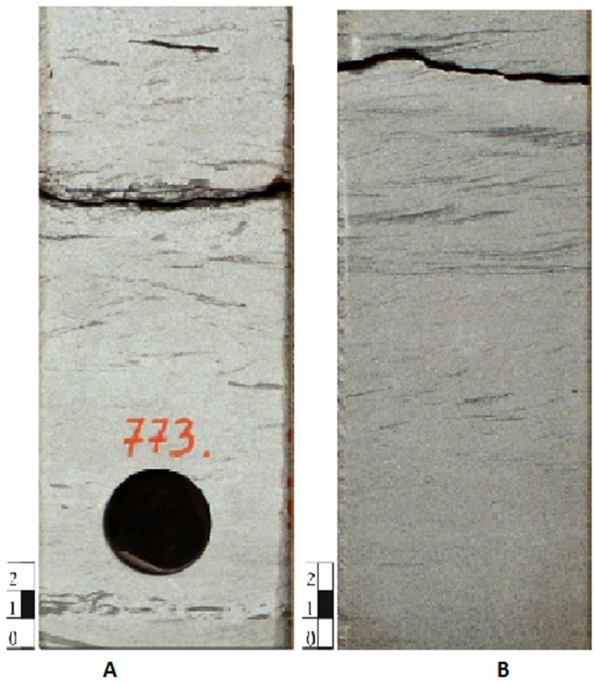

***Figure 12**. Textural features of deposits of the sublittoral zone of the tidal band (channel gullies). A – fine-grained sandstone, medium-fine-grained middle sorting in the upper half of the layer, with fine oblique multidirectional stratification, in the bottom of the layer – fine intracalsts of argillite by layering; B – fine-grained sandstone with fine oblique and oblique-wavy lamination formed from an organic material*

Table 1*. Classification of sedimentary facies (Alekseev, 2003; Alekseev, 2014; Botvinkina et al., 1956; Timofeev, 1969)*

Group	Subgroup	Macrofaction	Faction
Basin	Shallow-basin	The sediments of furthest part of the basin from the coast	Clay-carbonate sediments of the open part of the basin
			Alevret-clay sediments of the open part of the basin
			Sand-siltstone sediments of the open part of the basin
		Deposits of open, mobile, shallow water	Aleuritic-sandy sediments of mobile shallow water
			Sand sediments of highly mobile shallow water
			Intercalation of clay-aleuritic-sandy sediments of mobile shallow water
		Deposits of semi-isolated inactive shallow basin shallow water	Sandy-aleuritic sediments of inactive shallow water
			Aleurite-clay and carbonate sediments of inactive shallow water
			Aleuritic-sand sediments of small accumulative forms
			Clayey-aleuritic sediments of the tidal zone
			Clayey-aleuritic sediments of coastal lakes
	Transitional	Deposits of the underwater part of the delta	Aleuritic-sandy sediments of the advanced part of the delta
			Sand sediments of the cones of river carry-over
			Gravel-sand sediments of the central parts of the cones of carry-over
			Gravel-sand (pudding) sediments of the bases of cones of river carry-over
		The sediments of the lagoon-bay coast	Aleurite-clay and carbonate sediments of the central parts of the bays and lagoons
			Sandy-aleuritic sediments of coastal parts of bays
			Clayey-aleuritic sediments of semi-isolated parts of the coast of bays and lagoons
Continental	Alluvial	Deposits of small coastal watercourses	Gravel-sand sediments of channels of shallow coastal streams
			Clayey and sandy-aleuritic sediments of the floodplain of small coastal streams
		Riverbed sediments of river valleys	Sandy sediments near the mouth of the flat rivers

		Gravel-sand sediments of the bed of large flat rivers
		Sand-gravel and pebble sediments of the channel of mountain rivers
		Aleurite-sand sediments of the channel of small rivers and channels of large flat rivers
	Floodplain sediments of river valleys	Aleuritic-sandy sediments of the near-river part of the floodplain and its flood waters
		Clayey and sandy-aleuritic sediments of the low-flow part of the floodplain
		Clayey-aleuritic sediments of stagnant and vegetated old courses and secondary reservoirs of the floodplain
Lake	Sediments of open lake ponds	Clayey-aleuritic sediments of comparatively deep-water parts of large lakes
		Aleuritic-sand sediments of open mobile shallow water
		The sand sediments of the cones of carry-over
		Sandy and clayey-aleuritic sediments of semi-isolated shallow waters of large lakes
		Clayey and sandy-aleuritic sediments of small lakes
	Deposits of stagnant and swamping lakes	Sandy-silty sloughy sediments of flowing sections of vegetating lakes
		Clayey-aleuritic weakly-clayey sediments of stagnant and weakly flowing sections of vegetating lakes
		Clayey sediments of stagnant sections of lakes
		Coal and clayey-aleuritic sediments of swamping lakes and silting sites of peat bog
	Deposits of peat bogs and sapropel lakes	
	Proluvial deposits	Sand-gravel and pebble sediments of streams of cones of carry-over
		Sandy-aleuritic-argillaceous sediments of cones of carry-over
	The deluvial deposits	Sediments of the upper slopes
		Sandy-aleuritic-argillaceous sediments of the slopes