ANÁLISE DETALHADA DA INFLUÊNCIA LITOLÓGICA E DE FÁCEIS DE DEPÓSITOS PRODUTIVOS DA CAMADA Y_1^1 COMO PROBLEMA DE GEOLOGIA DO PETROLEO E GÁS NATURAL

DETAILED LITHOFACIES ANALYSIS OF PAY ZONES OF LAYER Y_1^1 AS A TASK OF PETROLEUM FIELD GEOLOGY

ДЕТАЛЬНЫЙ ЛИТОЛОГО-ФАЦИАЛЬНЫЙ АНАЛИЗ ПРОДУКТИВНЫХ ОТЛОЖЕНИЙ ПЛАСТА $Ю_1^1$ КАК ЗАДАЧА НЕФТЕГАЗОПРОМЫСЛОВОЙ ГЕОЛОГИИ

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RESUMO

A definição de fácies pela composição do material e pelas características estruturais e texturais das rochas contribui para a definição de minerais. Portanto, os autores estudaram a análise da influência litológica e de fáceis de depósitos produtivos da camada U1, que é necessário para a geologia do petróleo e gás natural. Uma análise sedimentológica foi realizada no trabalho, as fácies foram determinadas (indexadas) com base no método de V. P. Alekseev, as folhas de registo de sistema de informação geográfica (GIS) foram analisadas e foram realizadas a análise paleotectônica, análise de fácies sísmicas. Ao realizar os estudos especiais, foi construído um modelo facial conceitual de depósito sedimentar U11 em um dos depósitos localizados na parte sudeste da bacia da Sibéria Ocidental de petróleo e gás natural (região de Tomsk). Um detalhado estudo litológico das rochas do reservatório produtivo foi realizado para esclarecer suas características. O zoneamento da área de estudo foi realizado com base na identificação das zonas paleofaciais selecionadas.

Palavras-chave: *sedimentação, banco, praia da lagoa, regime de mar raso, depósitos de argila*.

ABSTRACT

The determination of facies by material composition and structural and textural features contributes to the determination of minerals. That’s why it was studied lithofacies analysis of pay zones of the Y_1 layer, which is necessary for petroleum field geology. The sedimentological analysis was carried out in the research, facies were indexed based on V.P. Alekseev’s method, logging cased wells log sheets were analyzed, paleotectonic, seismo-facial analyses were carried out. In the course of carried out special studies a concept facies model of sedimentary deposits of the Y_1^1 layer at one of the fields located in the Southern-Eastern part of the West Siberian petroleum basin (the Tomsk region) was built. A detail lithologic study of the species of payable basin to specify their facies belonging was carried out. Zoning of studied territory based on the identification of revealed paleofacies zones was conducted.

Keywords: *deposition of sediments, unit, lagoonal beach, shallow marine mode, argillaceous deposits.*

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АННОТАЦИЯ

Определение фаций по вещественному составу и по структурным и текстурным признакам пород способствует определению полезных ископаемых. Поэтому авторами был изучен литолого-фациальный анализ продуктивных отложений пласта $Ю_1$, что необходимо для нефтегазопромысловой геологии. В работе был проведен седиментологический анализ, определено (индексировано) фации на основе методики В.П. Алексеева, проанализировано каротажные диаграммы ГИС, проведен палеотектонический анализ, сейсмофациальный анализ. В процессе проведенных специальных исследований построена концептуальная фациальная модель осадочных отложений пласта $Ю_1^1$ на одном из месторождений, расположенном в юго-восточной части Западно-Сибирского нефтегазоносного бассейна (Томская область). Выполнено детальное литологическое изучение пород продуктивного резервуара с целью уточнения их фациальной принадлежности. Произведено районирование изучаемой территории на основе идентификации выделенных палеофациальных зон.

Ключевые слова: *осадконакопление, пачка, лагунный пляж, мелководно-морской режим, глинистые отложения.*

INTRODUCTION

The upper Jurassic petroleum play was chosen as a subject of the research. The permeable part of the play is composed of a sand bed of horizon Y_1, and argillites of Georgiev and Bazhenov groups are hood.

According to the scheme of oil-and-gas zoning of south-east districts of the West Siberian province the research site confined to the southern part of Vasyugansky petroleum region (Pudinsky petroleum region). In this region, the horizon Y_1 has trimerous structure and is divided into three lithofacies members (bottom-up): *sub-coal* (layer Y_1^5, $Y_1^{3\text{-}4}$), *inter-coal* (layer Y_1^M) and *percarbonic* (layers Y_1^1 and Y_1^2). The main part of hydrocarbon reserves is concentrated in sand layer sY_1^1 and Y_1^2, which are the main exploitation target.

The formation of considerably argillaceous deposits distinguished as Nizhnevasuygansky sub-suite took place in the second half of late Bathonian and early Callovian when the expansive marine transgression that began in the late Bathonian attained a maximum in Callovian (Figure 1). The depth of transgressed sea in the deepest part is 200-400 m.

At the end of Bathonian and the beginning of Callovian ages, there was a coastal plain on the studied territory, which was from time to time covered by the sea. The distribution of sedimentary material was mainly conditioned by the relief of bottom-living forms (Baimakhan *et al.*, 2008; Yentsov, 2015; Starosvetskov *et al.*, 2017).

Thus, according to regional paleogeographical reconstructions the following are the important factors determining the general regularities of the formation of upper Jurassic layers of the studied deposit (Sokolov, 2018):

1) deposition of sediments in transitional, marginal-marine and shallow marine depositional environment;

2) inflow of terrigenous material from the continent (from East and south-east of the region) and redistribution of sediments deposited on the bottom by wave action and longshore currents;

3) changing the hydrodynamics of environment – the role of currents and disturbances in the formation of diverse accumulative bodies;

4) tectonic movements of the bottom and adjacent land;

5) climatic conditions, characterizing with a moist warm climate;

6) conditions of global transgression.

METHODOLOGY

The following types of researches were carried out to reconstruct the conditions of formation and building of the conceptual sedimentation model of sedimentation of the pay zone Y_1^1 of studied deposit:

1. Sedimentological analysis of the photographs of the core by 21 well and its by-layer description from the 31 well. The total core recovery made up 1858,1 m. Moreover, the results of a lithologic-and-petrographic study of the core carried out in core warehouses of TomskNIPIneft OJSC and TyumenNIIgiprogas

LLC were attracted. They are represented by 18 lithological columns, in which main textural-structural and lithologic characteristic of well columns (Guseinova and Khuduyeva, 2016), different inclusions and secondary alteration of materials are reflected.

2. Determination and indexing of facies based on the V.P. Alekseev's method (Alekseev, 2007). As a result of studying the core and determination of its structural-material and textural features facies breakdown of the well column was carried out and formation conditions for each layer are determined. An ichnofacies analysis was carried out (according to S.G. Pemberton). Thus, 18 main lithologic-genetic types of sediments (lithofacies) united into 7 macrofacies were identified. Their transgressive-regressive sequence was revealed.

3. Building by each well with the core of lithofacies surveys sheet, which reflects connection of the core material with LOGGING CASED WELLS data, facies breakdown of the well column, the characteristic image of facies according to core data and the main set of ichnofossils for each facies (Khisamov *et al.*, 2017).

4. The analysis of LOGGING CASED WELLS log sheets by the electrometric method of V.S. Muromtsev (1984). A genetic image of each facies is determined by the results of combination sedimentological study and geophysical curves.

For a facial breakdown of well columns, logging cased wells methods (gamma-ray logging, compensated neutron log, density gamma-gamma logging, acoustic log, waterlogging) were attracted. Due to drilling on mineralized wash liquid, the self-potential curve in many wells is culled. As diagnostic signs of facies, the following were considered: the form of the anomaly of curves (roof, volar, and lateral lines), anomaly width, extreme (minimum and maximum) values.

Wells, in which facial belonging of some part of the layer is determined by core data, are taken to determine deposition environment by geophysical data. Out of all possible options of facial interpretation of curve shape the option which was confirmed by lithofacies core examination was chosen. Based on this, the type assignment of borehole logs in each well was carried out. In total, 244 wells were analyzed on the deposit.

5. The next stage included the analysis of facies in two intervals – spatial (studying the regularities of the distribution of facies across the area for limited stratigraphic range) and temporal (studying the facies change by the section). The stage result – revealing paragenesis of facies environment.

For studying dissemination and persistence of facies fields by area schematic facial profiles reflecting the periodicity of upper Jurassic stratigraphical complex formation were built.

6. Carrying out of the paleotectonic analysis. The roof of Georgiev suite was taken as leveling surface as an indicator of plain surface of the deep sea. By means of deduction from the surface spall of planation of the roof of marker horizon «U_{0-1}» a map of paleorelief of sedimentation area bottom at the moment of Y_1^1 layer formation was obtained (Figure 2). According to paleotectonic reconstructions, the distribution of sea deposits depended on the intensity of paleobasin bottom downward – in lower parts of the structure, there was more sedimentary material, while in elevated parts there was less material. The values of isopachous line increase in the direction of offshore to the central parts of the basin with sufficient compensation of downward with the incoming terrigenous material. The absence of accumulated thickness in the elevated parts of paleo-elevations and, as a consequence, pinching-out indicate the presence of coastline as a borderline of different facial zones.

7. The use of data of seismo-facial analysis to determine the main borders of facial areas. The forecast maps $N_{эф}$ and $K_{песч}$ served as a trend to build lithologic and facies maps, especially in interwell space.

8. The lithofacies scheme by the pay zone Y_1^1 was built at the final stage of facies researches. Supporting materials were used to build the scheme: the maps of general and net oil pay of the zone, the maps of sand content, the maps of seismic facies, regional paleogeographical schemes (Kontorovich *et al.*, 2013; Belozerov, 2007; Belozerov, 2008; Dainenberg, 2006).

The obtained lithofacies schemes reflect the main conditions of deposition of sediments and distribution of sand package in the space and allow tracking the regularities of the development of zones of most high-capacity reservoir units within the studied territory (Kazhdan *et al.*, 2013). The offered conceptual model is used as a basis for building a three-dimensional geological model of deposit.

RESULTS AND DISCUSSION:

3.1. Regional characteristics of deposition conditions

By the beginning of the Jurassic epoch, Western Siberia was an elevated, poorly broken high land with benchmarks 200-500 m (Kontorovich *et al.*, 2013; Belozerov, 2007; Belozerov, 2008; Dainenberg, 2006; Danilin *et al.*, 2016). The main areas of sedimentation were depression parts of the relief: cavities, depressions, defiles. Deposition of sediments occurred in the conditions of damp climate with the formation of the crust of weathering on the massif massive material of pre-Jurassic age.

During the Bajocian Age, the western part of the basin was subject to intensive downward. The considered exploration area was located in a typical continental depositional environment – lowland aggradation plain (Figure 1), where expansive lake water bodies and bottom-lands of river valleys with intense processes of peat accumulation were developed. At the time, the Middle-Jurassic layers of Tyumen suite $Y_{5\text{-}6}$ and coal benchmarks "U_6"-"U_{10}" of low and average subsites of Tyumen suite were depositing.

In the Bathonian age the conditions of continental lacustrine-alluvial plain stayed the same, however, the downward of the Western Siberian geosyneclise continued. In the Bathonian age, the layers $Y_{3\text{-}5}$ of Tyumen suite were accumulating.

The existing late Callovian sea was differed by quite a complex environment in term of hydrodynamics. The growing regression had a step-by-step nature – short-term transgression and regression characterized the repeated change of continental mode of sedimentation with the marginal-marine mode. Main facial bodies were confined to flood-plain, lacustrine-boggy, channel, delta, beach and bar deposits (Aitaliev *et al.*, 2005; Durkin *et al.*, 2017).

At the turn of Callovian and Oxfordian, transgression was changed by regression, which arraigned a maximum by the end of early Oxfordian (Figure 1). This time in the south-eastern part of Western Siberia sand layers $Y_1^{3–4}$ and so-called inter-coal members as a part of upper Vasyugansk sub-suite in the phase of intense compensation of shelf sea incoming from the south and south-east terrigenous material were depositing. During the formation of cyclite sediment $Y_1^{3–4}$ the conditions of formation of terrigenous deposits corresponded to the transition of the subcontinental environment to marginal-marine and shallow marine environment (Popov and Ponomareva, 2013).

At the end of the early and beginning of the middle Oxfordian regression was changed by transgression, as a result of which the sand layers of the coal-overlaying unit formed. This time semiarid climate prevailed in the territory. Y_1^2 and Y_1^1 layers were deposited in shallow marine conditions and the conditions of bay-lagoonal seaside (sand bodies represented transgressive bar structures).

At the end of late Oxfordian, a new largest in the Jurassic epoch long transgression began. It was marked by the formation of thin but well matured by the area and very widespread basal layer Y_1^0 – Barabinsk unit. In Kimmeridgian constant sea, the regime was established, which conditioned the accumulation of monotonous clayed stratum of Georgiev suite.

By the Volgian Age, the late Jurassic transgression in the Western Siberian paleobasin attained its maximum – offshore zone occupied the largest part of the territory. As the sea depth increases, saturated with sea organics black and brownish black carbonic-silicious-loamy sediments of Bazhenov suite accumulated in its deep-water part.

The principle diagram of the formation of upper Jurassic layers of Vasyugansk suite in the territory of the deposit is shown in Figure 3. According to this diagram, among shallow marine environment, there are facies of far, the prefrontal area of beach and actually beach (low and upper); as a part of the marginal-marine environment – tidal flat, marshes, paralic swamps, and lagoons.

According to the results of carried out correlation of wells, two layers were determined as a part of a coal-overlaying unit of Vasyugansk suite – Y_1^2 and Y_1^1, which are divided into smaller units. The layer Y_1^1 is divided into three parts – low (unit "v" – Y_1^{1v}), middle (unit "b" – Y_1^{1b}) and upper (unit "a" – Y_1^{1a}).

In the section of sediments of units, "a" and "b" of the Y_1^1 layer transgressive formation is observed since the marginal facies of paralic swamps of the $U_{0\text{-}1}$ layer are overlaid with carbonate- argillolith-sand deposits, which in turn underlie the sediments of the stone bind of the unit "a" of the Y_1^1 layer.

The "a" and "b" units of the Y_1^1 layer are represented with the sediments of the bay-lagoonal complex – argillites and calcareous stone binds with the interlayers of shell limestone. The marginal-marine genesis of massive material is confirmed by numerous faunal remains of shell bivalves and shelly detritus, up to the formation of shelly limestone interlayer. In the layer section the facies of offshore parts of the lagoon, lagoon beach and semi/isolated parts of lagoons are determined.

The deposits of the facies of semi-isolated lagoons are represented by argillites with the intermixture of siltstone material with matured horizontal (cross) bedding with the traces of slump, with the inclusion of shelly detritus up to the pieces of whole shells of bivalves, sideritization is typical. Completely isolated lagoons are characterized by dark-gray argillites with massive texture, thin cross-bedding and sideritic belts (Figure 4).

The alternation of argillites and shell deposits records the change of hydrodynamical environment of a water body and the degree of its isolation as a result of the change of storm conditions of the seaside to the calm (possibly, with barrier bar), isolated lagoon.

The depositions of the offshore part of lagoon beach are represented by limestone- shell deposits and carbonated stone bind with convoluted and swaley bedding (Figure 4). Such diverse development of calcite organics may indicate the conditions of the semiarid climate existed that time. Supposedly, beaches on directed to the sea slopes of barriers limiting the lagoon were the source of shells.

Permeable sand streaks and lenses of light-gray very fine sandstone can be met in the central part of stone bind (*type 1b*, Figures 4 and 5). They probably were a sand channel of the lagoon or were deposited in the periods of storms as a result of wave setup when activating wave activity of the seaside (Formalev *et al.*, 2018). Higher in section the interlayer of shell deposits of the facies of lagoon beach were replaced with clay and siltstone-clay massive material of semi/isolated sections of the lagoon with a typical cross, lenticular and undulating bedding (*type 1a*, Figures 4 and 5).

The further replacement of lagoon facies with facies of foreshore indicates the migration of sand barrier bars (islands) under conditions of bar seaside.

3.2. The results of making up a lithofacies model of Y_1^1 layer

By the beginning of Y_1^1 "a" unit formation, the territory in the north-west and west parts of studied uplift had started experiencing another deflection that witnessed the beginning of upper Jurassic transgression (Figure 2).

General transgressive development of late Vasygansk sedimentary basin has defined a change of lagoon sediments up to the section to sediments of foreshore, which, probably, represents a massive depositional feature of barrier bar that separates the lagoon from the sea.

Surfaces of the south-west and south slope of the structure remained uplifted. In this uplifted part of paleorelief layer, Y_1^1 is absent within sections of major part of wells (*type 2*, Figures 4 and 5), since its surface was situated above sea level – here was the border of shoreline and prevailed transitional and marginal-marine sedimentations. Up to swampy area, there is frontal thinning (of sub-lateral course) of layer Y_1^{1a}.

By that time in central and north parts shallow-water maritime sedimentation regime prevailed, which promoted accumulation of transgressive sandy-aleuritic deposits of layer Y_1^{1a} within the environment of active wave activity. In the present territory, the layer is being commonly developed (*type 1a*, Figures 5 and 6) except the area near well No. 147 that is being structurally higher than adjoining territory. This area is characterized by a reduced thickness of the Y_1^1 layer in general.

Deposits of the foreshore of Y_1^1 layer's "a" unit are formed with gray and light-gray medium- and fine-grained sandstones of mesomictic quartzous composition with a savor of coarse-grained material, the degree of lithification of which varies from poorly- to closely-cemented; there are also rare carbonized interlayers (Figure 4). The sandstones differ with solid texture and aclinal-undulating, cross-wave stratification added with clay material and carbonized vegetative detritus.

By the end of Y_1^1 layer's "a" unit formation, the offshore zone has taken up the major part of the territory against the background of the global late Jurassic cycle of the West-Siberian paleo-basin transgression.

With the increase of sea depth, the territory has acquired features of outer shell characterized by calm conditions of sedimentation below the base level of storm surges with limited addition of fragmentary material. In such circumstances, clay-sandy-carbonate rocks (Feyzullayev *et al.*, 2018; Kuznetsova *et al.*, 2014) had been forming. These rocks are characterized by specific outlook and detected by scattered, lumpy and heavily bioturbated texture (*"Zoophycos"*, shell fragments, belemnite snouts). Numerous inclusions of authigenic minerals, such as glauconite, phosphoritic and sideritic noddles, as well as inclusions of shells and belemnite snouts also witness the deficit of fragmentary material and extensive development of deep-water fauna.

The maximum of transgression in the studied territory is defined with deep-water dark-gray massive argillites of Georgiev suite with single inclusions of belemnite snouts (Figure 7).

CONCLUSIONS:

The paper provides results of sedimentological examination of core selected from upper Jurassic deposits. The structure of producing layer Y_1^1 has been significantly specified, facial inhomogenuity of percarbonic stratum sediments within the deposit has been determined.

As a result of conducted works, we can conclude that upper Jurassic sediments within the studied deposit are represented with complex of sediments of shallow-water and marginal-marine facies formed under the influence of wave tidal activity.

We have made up a lithofacies scheme reflecting space distribution of main facies within the studied territory with an account of forecasting expansion of pay container rocks in the areas where drilling is not performed. The results of well testing confirm the accepted model of facies distribution along the horizontal of the deposit.

The suggested conceptual model has been used upon making up a three-dimensional geological model of pay sediments.

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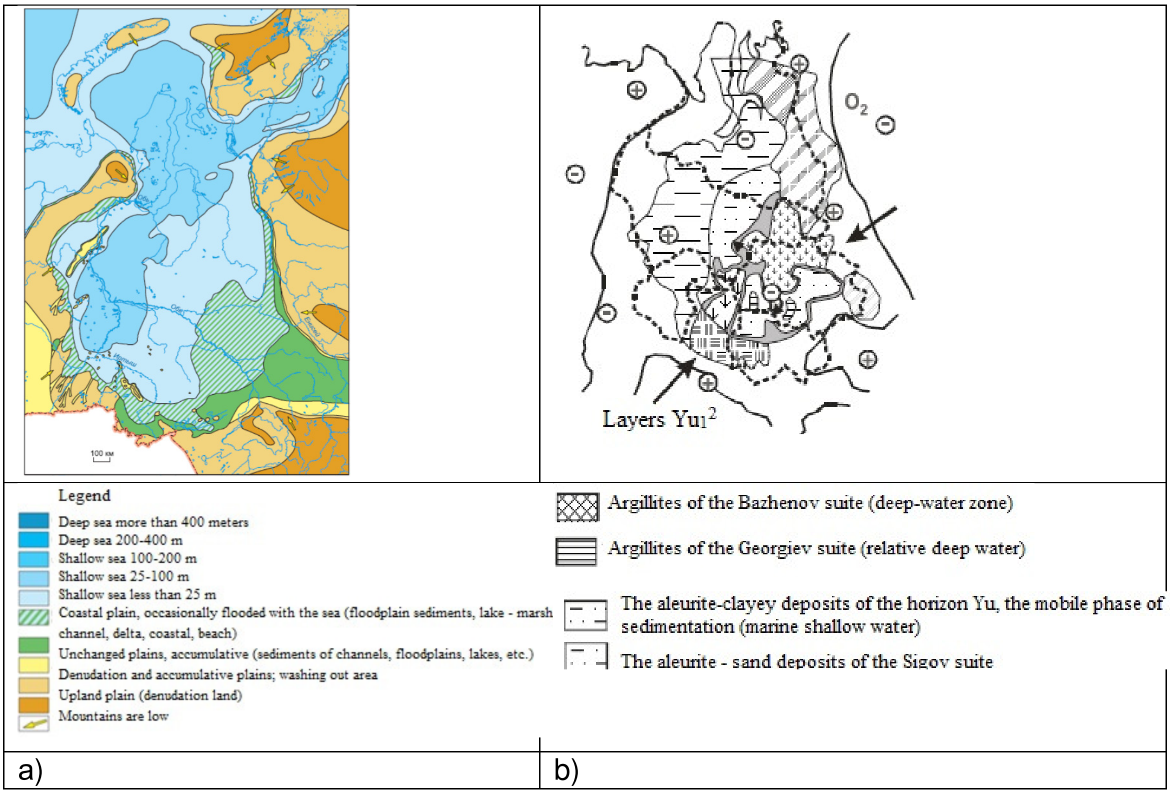

Figure 1. *Paleogeographical schemes reflecting the conditions of accumulation of Oxfordian deposits of Western Siberia: a (Kontorovich et al., 2013); b (Belozerov, 2008)*

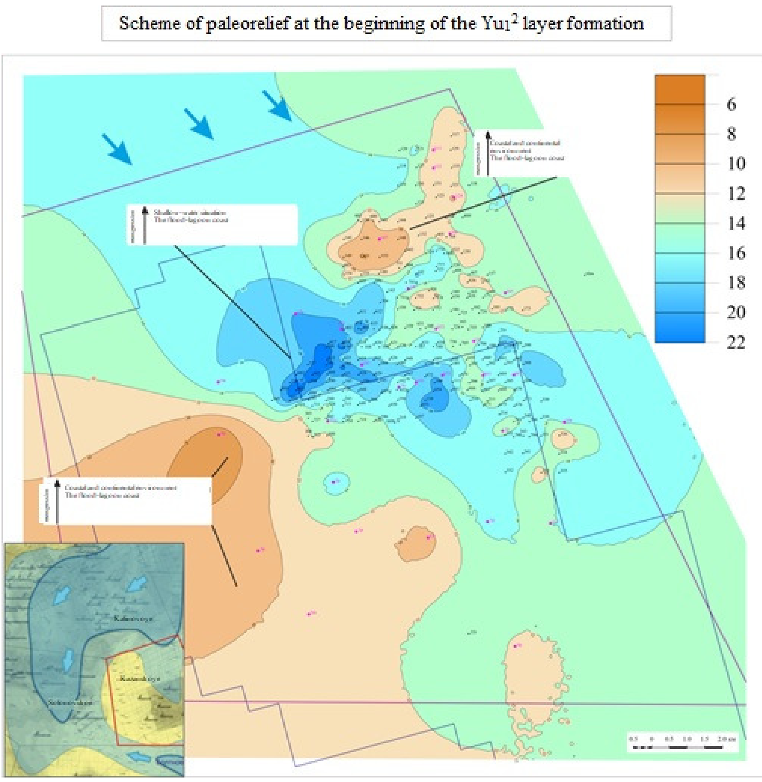

Figure 2. *Paleorelief scheme as of the beginning of Y_1^1 layer's formation. The transgressive stage of territory development*

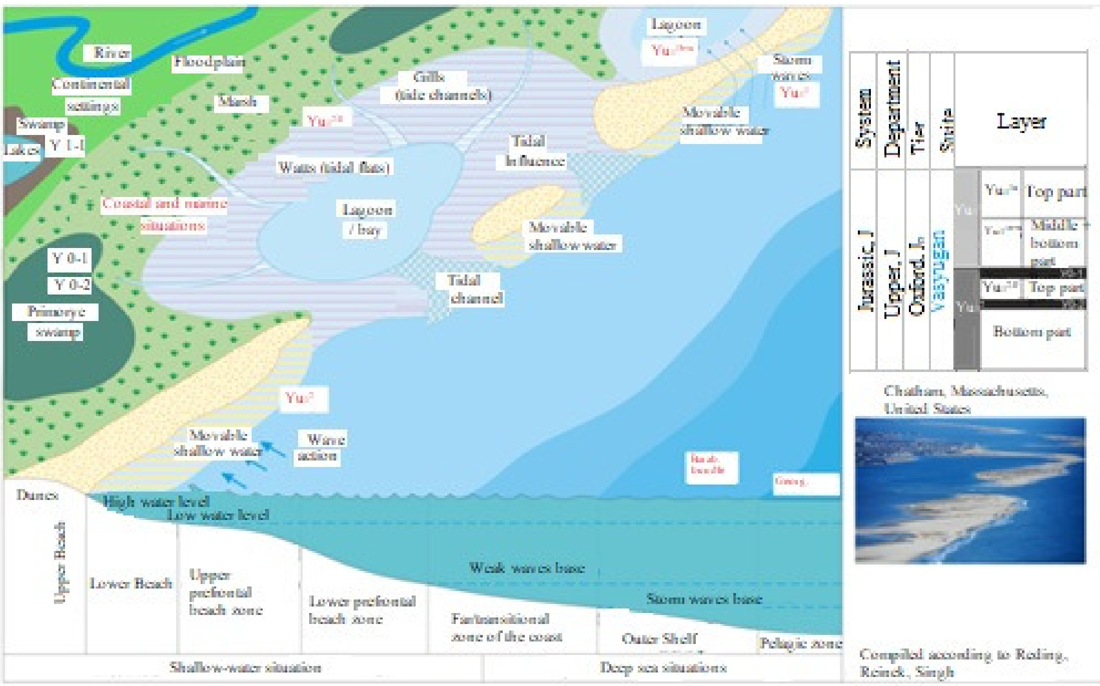

Figure 3. *Paleogeographical schemes of the formation of Vasyugansk suite layers (Reading, 1990; Reinek and Singh, 1981)*

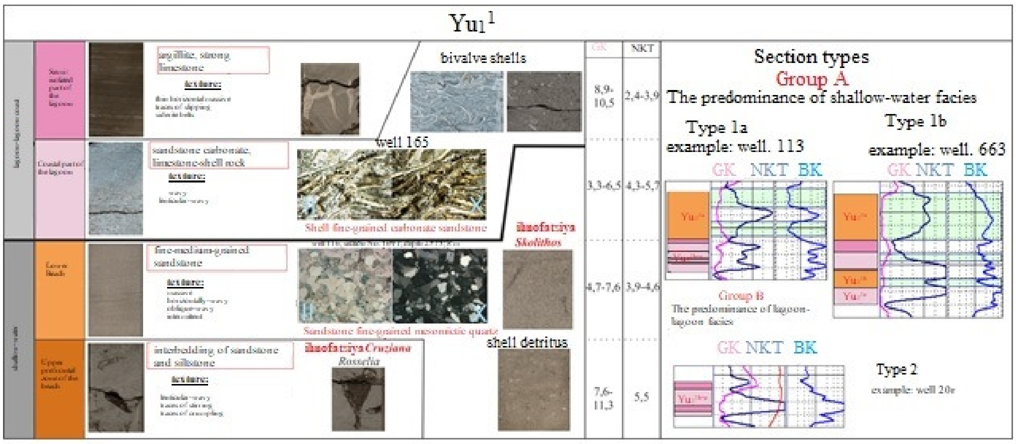

Figure 4. *The Litho-genetic outlook of facies and types of facial logs as for layer Y_1^1*

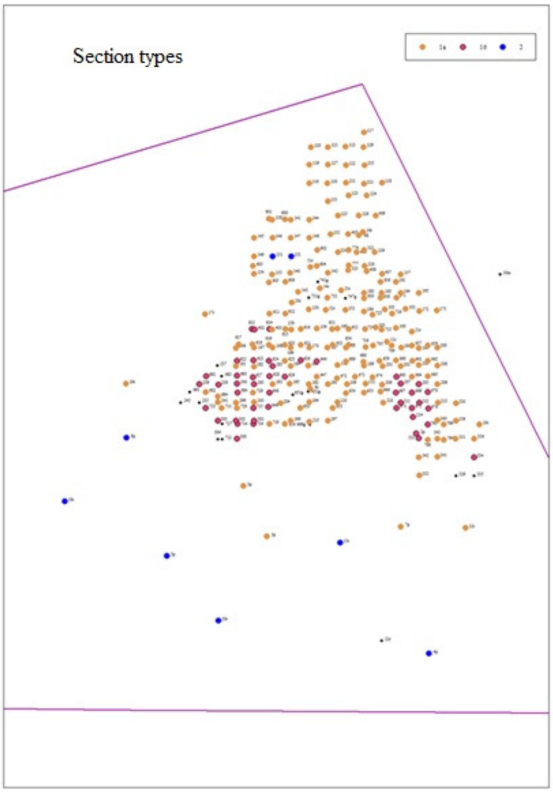

Figure 5. *Facial types of Y_1^1 layer's logs*

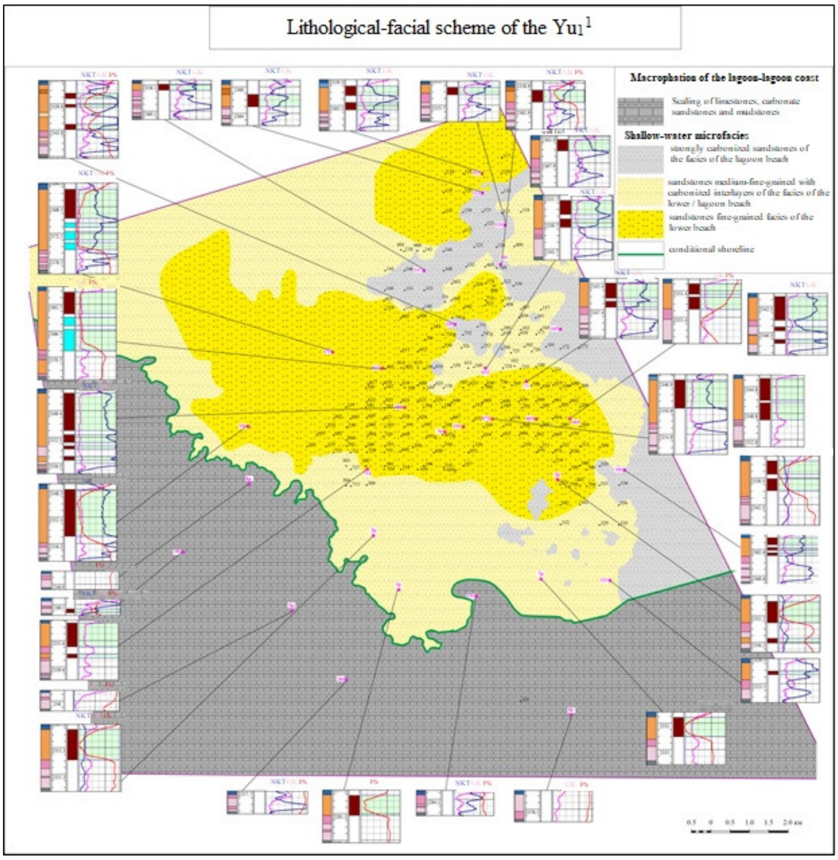

Figure 6. *A Conceptual facial model of Y_1^1 layer*

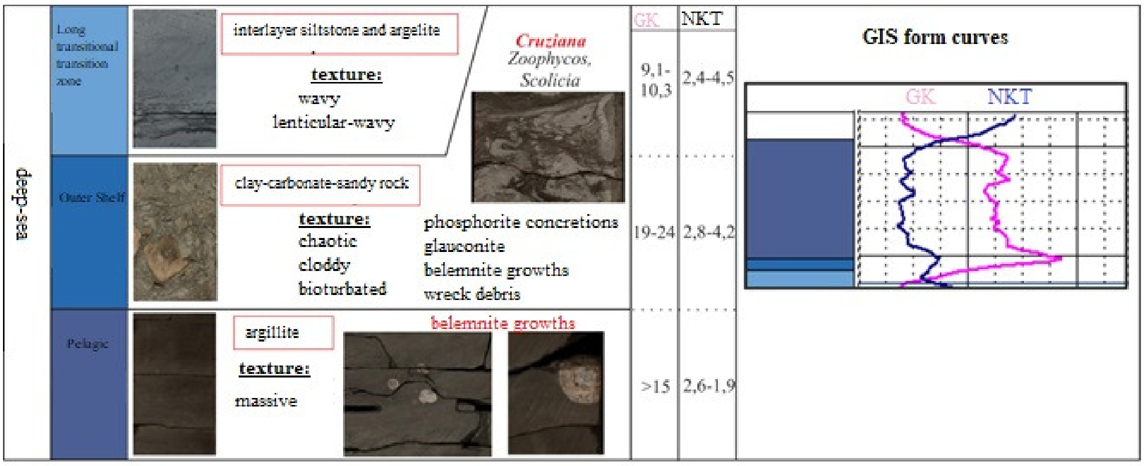

Figure 7. *The Litho-genetic outlook of facies and typification of geophysical well logging curves for deep-water deposits of Georgiev suite*