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The Berriasian–Aptian of the Western Gydan Peninsula (West Siberia): Biofacies and Lithofacies Models

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Abstract—Well logs and core analyses of Berriasian–Aptian petroliferous sediments from the western Gydan Peninsula are used to model their biofacies and lithofacies and to reconstruct the respective sequence stratigraphy. The sedimentological and palynological data, along with logging results, provide constraints on the history of transgressive and regressive events and make a basis for paleogeographic reconstructions for the Lower Cretaceous deposition of reservoir sand beds.

Keywords: Lower Cretaceous, sequence stratigraphy, biofacies analysis, lithofacies analysis, northern West Siberia

INTRODUCTION

The Gydan Peninsula in the northern West Siberian Plate has had very poor drilling coverage, and the available data on the lithofacies of Mesozoic sediments in the Gydan petroleum province remain scarce and fragmentary. According to recent estimates of 2003 and 2012 (Borodkin and Kurchikov, 2014), hydrocarbon discoveries can be expected mainly from Lower Cretaceous reservoirs. These, however, are less explored than the overlying Cenomanian formations that store commensurate amounts of resources. The new large industrial complex of Yamal LNG constructed in Sabetta (Yamal Peninsula, Ob Gulf coast) will require production enhancement from nearby gas fields, including those of the Gydan Province.

Complex structure of Lower Cretaceous deposits has evoked different point of views on their geological features and conditions of their formation. These problems were studied by V. Borodkin, F. Gurari, S. Ershov, O. Zaripov, V. Igoshkin, V. Kazanenkov, Yu. Karogodin, V. Kislukhin, N. Kulakhmetov, A. Kurchikov, G. Myasnikova, A. Naumov, A. Nezhdanov, I. Nesterov, L. Trushkova, I. Ushatinskii, V. Shimanskii, and many other specialists.

For studied area, we should note the paper of Skorobogatov and Stroganov (2006) presented a synthesis of local geology and reservoir potential of the Gydan Petroleum province and provided a generalized data of Berriasian-Aptian deposition environments and sediment lithologies. Until recently the atlas of lithological-paleogeographic maps edited by Nesterov (1976) was among the most often cited paleogeographical reconstructions. New maps imaging the Cretaceous deposition history in the West Siberian Basin were compiled in 2014 by a team from Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk (Kontorovich et al., 2014). In addition, the work in the Gydan Peninsula has been resumed lately, and yielded more results on paleogeographic reconstructions for paleogeographic data for some Lower Cretaceous intervals (Generalenko and Bardachenko, 2017). However, the published palynological evidence from the Gydan Mesozoic sediments is rare (Strepetilova et al., 1982; Strepetilova, 1994) and restricted to overall taxonomic compositions of the Berriasian-Valanginian, Valanginian, Hauterivian, Barremian, and Aptian spore-pollen assemblages, while microphytoplankton has never been studied at all.

We report biofacies and lithofacies models based on new lithological, palynological, well-log, and seismic data for the Lower Cretaceous Akha and Tanopcha formations, that were stripped by drilling in the Geofizicheskoe oil-gas-condensate field and partly characterized from core samples (Fig. 1).

MATERIALS AND METHODS

Cretaceous sediments were stripped by drilling, logged in fifteen wells, and core-defined within the 955 to 3502 m depth intervals in twelve wells.

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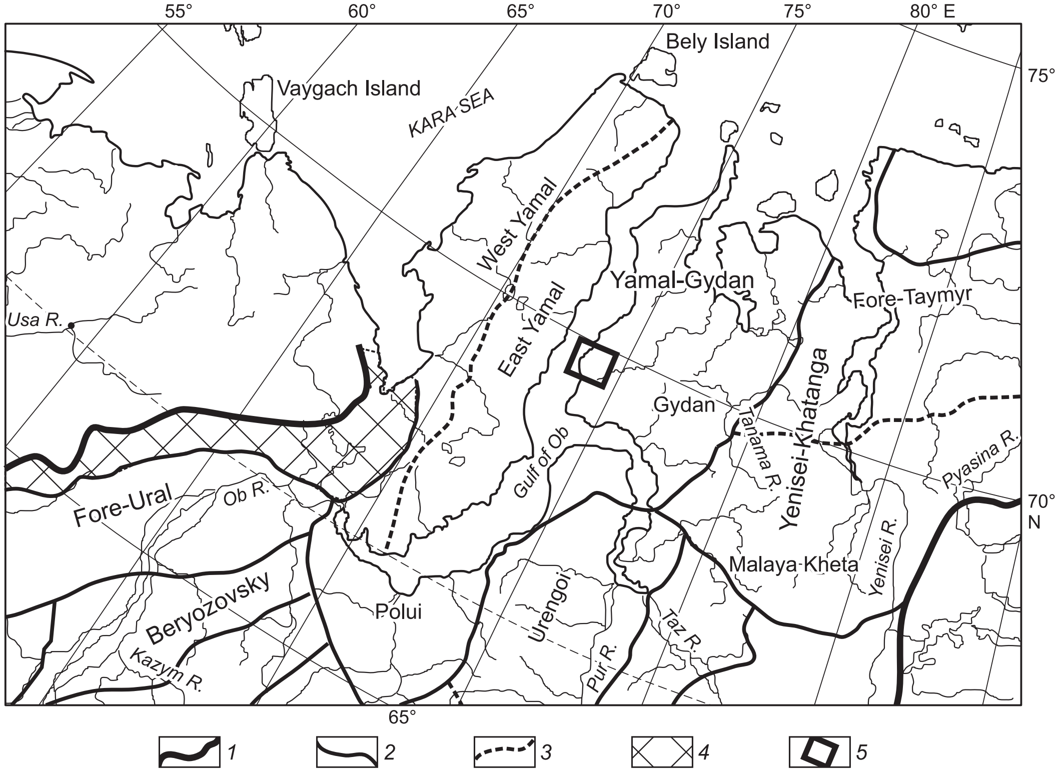


Fig. 1. Map of Berriasian–Aptian section types in West Siberia (Interdepartmental Stratigraphic Committee, 2006). Boundaries of West Siberian Basin (1), regions (2), subregions (3), basement exposures (4), study area (*5*).

Division and correlation of sections was based on biostratigraphic and sequence stratigraphic approaches with reference to seismic exploration and wireline well logging results. Terrestrial and marine pollen assemblages found in core samples (Pestchevitskaya, 2018), including stratigraphic marker taxa, revealed two biostratigraphic successions: spores-pollen and dinocysts. The stratigraphic succession of palynological samples collected from different boreholes was determined taking into account geophysical and lithological data as well as subdivision of geological section into the beds. This allows the analysis of taxonomical changes in the assemblages of microphytoplankton and terrestrial palynomorphs in the Hauterivian – Lower Albian of studied area.

The methods of sequence stratigraphy have been described in many publications (e.g., Vail et al., 1991 and references therein). We used the model of Vail et al. (1991) for the hierarchy of the sedimentary section, with sequences of six orders that differ in duration and types of boundaries. The first- and second-order sequences are called mega- and supersequences, respectively.

The Mesozoic sediments of the Geofizicheskoe field comprise sequences of the first, second, third, and fourth orders, including the 15.1 myr Neocomian (Berriasian-Barremian) and 12.0 myr Aptian supersequences in the Berriasian–Aptian range (Figs. 2, 3), separated by a gap. The Neocomian supersequence has a clinoform structure produced by lateral filling of a relatively deep basin as a result of avalanche sedimentation (Ershov, 2018). Within the Yamal-Gydan facies area, where the studied area is located, Neocomian sequence corresponds to the Akha Formation (Berriasian – Upper Hauterivian) and lower part of the Tanopcha Formation, and Aptian sequence corresponds to the upper part (Aptian) of the Tanopcha Formation. The two supersequences consist of nine third-order sequences, with high- and lowstand systems tracts (HST and LST, respectively) and maximum flooding surfaces (MFS). The resulting sequence stratigraphic framework was used then for detailed correlation of lower Cretaceous strata and paleogeographic reconstructions.

The Lower Cretaceous deposition environments were interpreted proceeding from continuous detail description of the core, petrographic analysis of the thin sections, spore-pollen and microfossil data, and well logs (standard and gamma logs).

The lithofacies analysis of core was performed with special focus on lithology and textures of sediments and their lateral and vertical variations. The sedimentary environments were reconstructed using paleontological and mineralogical indicators and trace fossils analysis. The specific methods for studies of shales deposited in different environments were largely reported (Botvinkina, 1962; Reineck and Singh, 1973; Frey and Seilacher, 1980; Muromtsev, 1984; Frey and Pemberton, 1985; Reading, 1986; Pemberton et al., 1992; Einsele, 2000; Alekseev, 2014). Facies features of

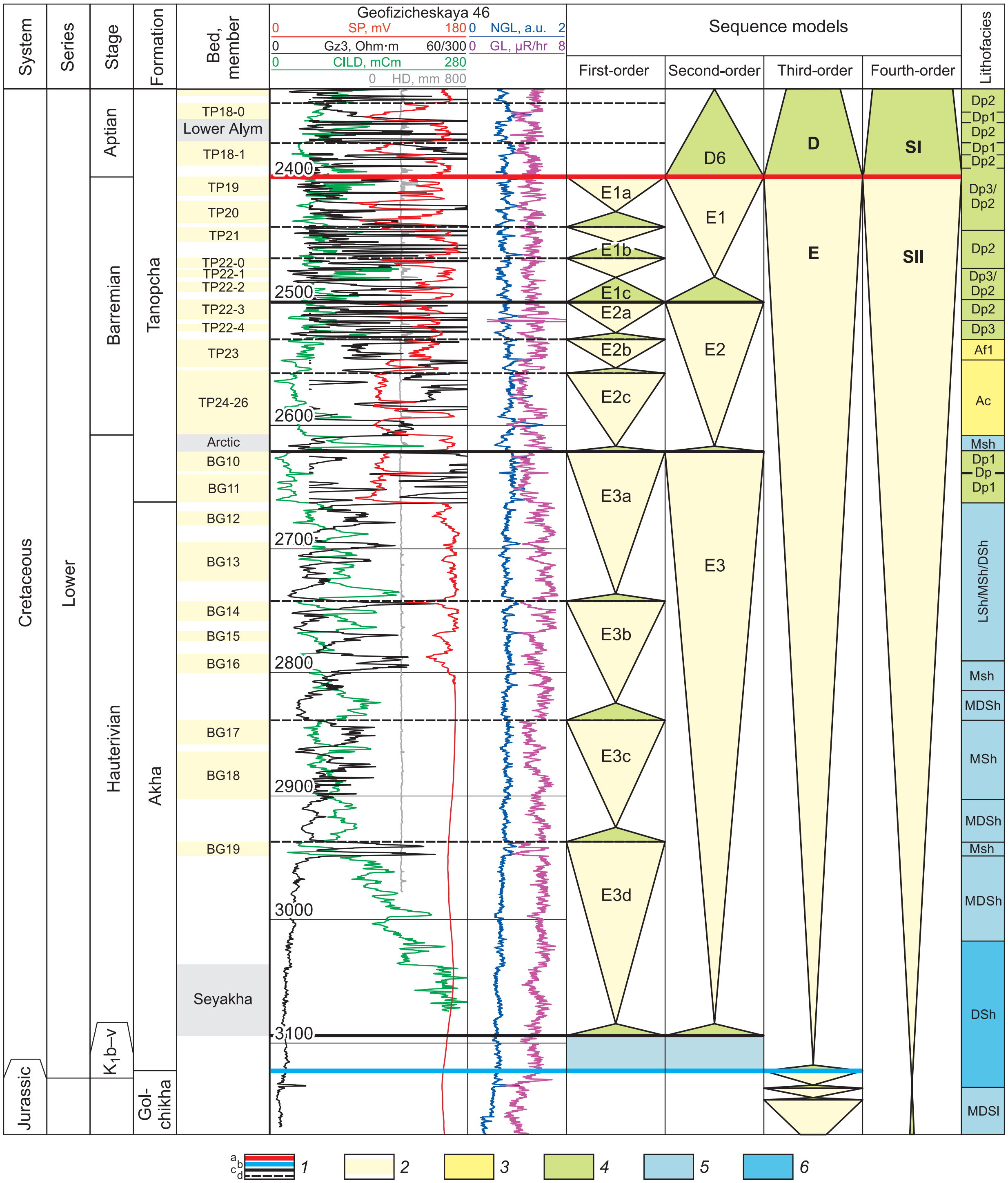


Fig. 2. Sequence stratigraphic and lithofacies models of Neocomian deposits. *1*, boundaries of sequences of different orders: first-order (a), second-order (b), third-order (c), fourth-order (d); *2*, sand beds; 3–5, continental (3), transitional (4), and shallow to deep shelf (5) facies; *6*, deep-sea facies. Abbreviations stand for lithofacies names: Ach, alluvial channels; Af, floodplain (Af1, point bars and flooding sands, Af2, floodplain, Af3, swampy floodplain); Dp, delta plain (Dp1, delta channel, Dr2, space between channels, Dr3, delta bay), Lt-Ts, coastal lithofacies (lagoons, tidal, and supratidal plains), LSh, lower shelf, MSh, middle shelf, MDSh, moderate deep shelf, DSh, deep shelf.

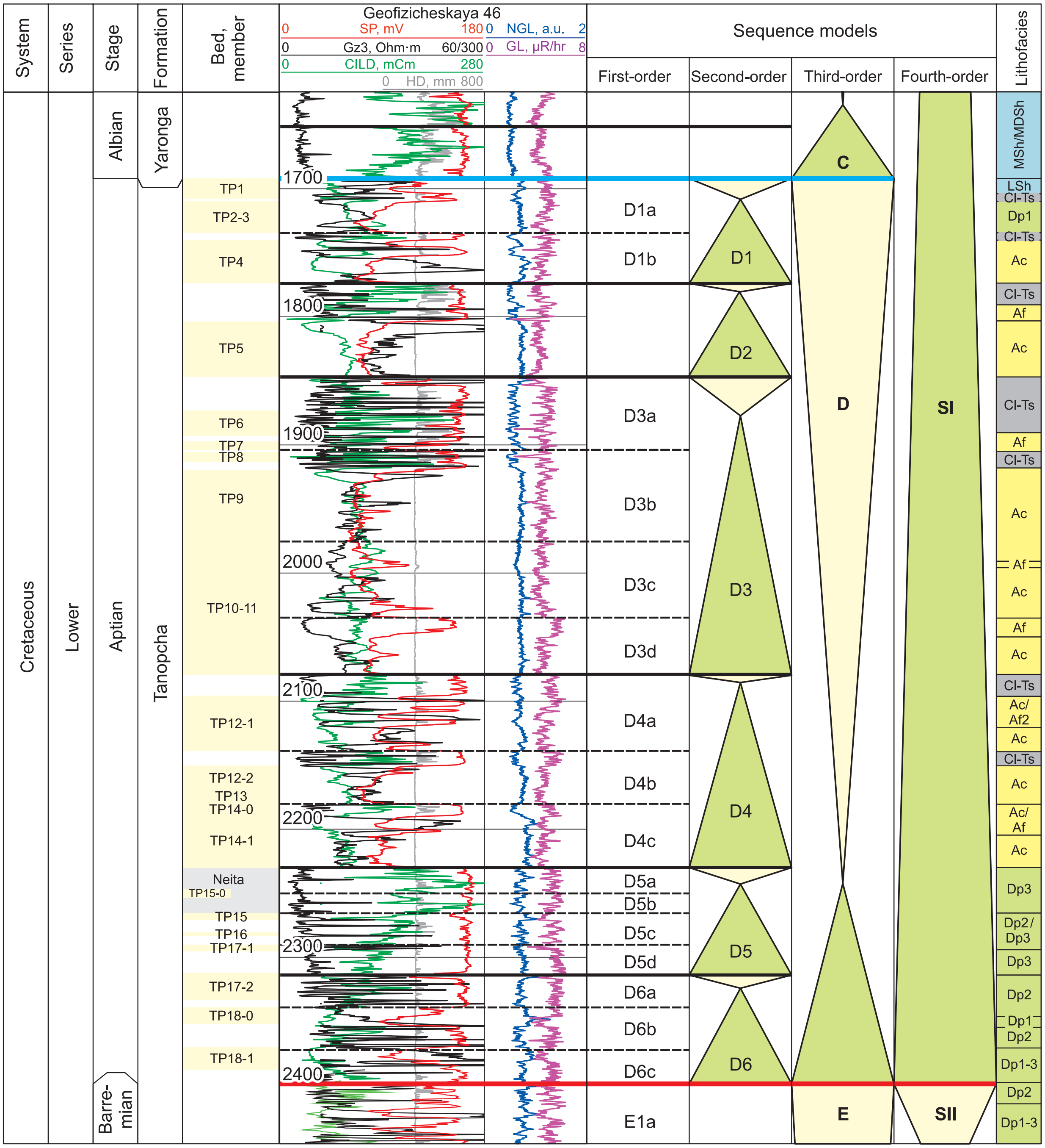


Fig. 3. Sequence stratigraphic and lithofacies models of Aptian deposits. Legend same as in Fig. 2.

certain taxa of spores, pollen, microphytoplankton, and their groups were regarded to reconstruct palaeoenvironments from palynological data (Pestchevitskaya et al., 2012).

BIOFACIES AND LITHOFACIES

Specialists from IPGG SB RAS define twenty sequences of the third order in the Berriasian–Barremian of West Siberia (Ershov, 2018). Three lowermost Berriasian sequences belong to the Tithonian-Berriasian supersequence and the other seventeen sequences to the Neocomian supersequence (Fig. 2). Most of the Neocomian supersequence within the Geofizicheskoe field consists of three Hauterivian-Barremian third-order sequences (E1–E3) and the distal part of sequence E4 in the southeastern part of the area. Other thirteen Berriasian-Lower Hauterivian sequences (E5–E17) make up a 20–30 m shale unit at the base of the clinoform complex. As mentioned above, the Neocomian supersequence includes the Akha and lower Tanopcha formations.

The ***Akha Formation*** (Berriasian–Upper Hauterivian) has a clinoform structure in the lower part and horizontal bedding in the upper part. The lowermost 20–45 m unit includes a thin compact bed and fondotheme of one of the Lower Hauterivian third-order sequence (E4). This part of the section mainly consists of clays with rare lenses of sandy silts and comprises the Under-Achimov, Achimov, and Over-Achimov members. At the base of the Hauterivian, core material derives from black and brownish mudstone with few silt intercalations. The sediments are massive with vague horizontal lamination; they contain *Phycosiphon* ichnofossils and pyrite concretions. The deposition occurred mainly in a low-energy environment, with episodic inputs of silt material.

The greater upper part of the Akha Formation falls within third-order Hauterivian sequence E3 corresponding to a 5–30 m poorly pronounced transgressive systems tract (TST) and a 470–545 m HST (Fig. 2). The lower part of the sequence, which includes the maximum flooding surface (Seyakha Mb.), is composed of black and brownish mudstone with few layers of clayey siltstone. The sediments are massive with vague horizontal lamination, sometimes with *Phycosiphon* trace fossils, with sporadic pyrite and siderite concretions. The sediments were deposited in a moderate deep shelf, with periodic anoxic events. Storms brought silt and clay material into the basin from time to time (forming distal turbidites).

According to palynological data, the middle Lower Hauterivian corresponds to the middle part of neritic zone: the assemblages are dominated by marine palynomorphs including abundant dinocysts (mainly Gonyaulacaceae and Areoligeraceae) (Fig. 4).

The upper part of Hauterivian sequence E3 is composed of alternating silt-clay and silt-sand (BG_{10}–BG_{19}) progradation beds, from a few meters to 40 m thick.

Member between beds BG_{18} and BG_{19} are separated by a 19–40 m seal which has a homogeneous shale composition according to well logs. The core samples are composed of brownish mudstones with fine lenticular and wavy bedding produced by the distribution of silty material. The sediments are characterized by thin bioturbation and, they contain numerous trace fossils (Chondrites) and foraminifers. The thicker silt layers show cross-wavy lamination. The sediments in the northern and northwestern parts of the area were deposited on a middle shelf (offshore) below storm wavebase (SWB). The basin became shallower in the southeastern direction. Palynological data show that shallow water and nearshore neritic environments occurred in the eastern area judging from low percentage of microphytoplankton and dinocysts (Fig. 4).

Bed BG_{18} (13–47 m) is composed of fine sandstone and light-gray coarse siltstone often alternating with thin or very thin silt-clay layers. The sediments are heavily bioturbated and bear signatures of small-scale contortion and erosion, till lumpy structures, with occasional traces of symmetrical ripples. They contain ichnofossil taxa of *Schaubcylindrichnus* (*Terebellina*) and *Teichichnus* (*Cruziana* ichnofacies), sporadic coaly plant detritus (fine or less often coarse), and sporadic pyrite and siderite concretions. The sediments in the north and northwest of the area were deposited on the distal part of middle shelf – proximal part of moderate deep shelf. Clay particles were settling in low-energy conditions, and the sediments underwent intense bioturbation. According to spore-pollen data, the southern and eastern parts of the area were still characterized by more shallow environments.

Member between beds BG_{16} and BG_{17} are separated by 16 to 39 m of progradational alternating siltstone and mudstone with scarce thin sandstone layers. The sediments are strongly bioturbated and contain abundant *Phycosiphon* and *Teichichnus* and less abundant *Chondrites* and *Schaubcylindrichnus* (*Terebellina*) ichnofossils. The structure and composition of this interval record progradation of shelf environments.

Bed BG_{16} (8–49 m) likewise has a progradation structure. It is composed of alternating contorted and bioturbated siltstone and mudstone, with lenticular-wavy bedding, in the lower part and of light gray fine sandstone, with variable clay contents and with a mottled texture produced by bioturbation, in the upper part. The sediments enclose thin layers of outsize siltstone with quasi-horizontal lamination and ripple marks and bear few traces of *Cruziana* and microfossil assemblages. The bed was deposited under general basinward advance of coastal sedimentation systems while the environments changed from middle to lower shelf (transitional – shoreface zones).

The 9–29 m layer between beds BG_{15} and BG_{16} consists of progradational alternating siltstone and less abundant mudstone. The siltstone layers show thin wavy cross lamination and ripple marks and contain authigenic pyrite and siderite. The sediments are heavily bioturbated and contain microfossils, as well as *Phycosiphon, Chondrites* and *Schaubcylindrichnus* (*Terebellina*) trace fossils. They were deposited in shelf conditions at below SWB (offshore) and below FWB (transitional zone) sea depths.

According to well-log data, silt-sand beds BG_{12}–BG_{15} formed as sand bars on a shelf above FWB, while the mudrock layer between them formed in offshore and transition zones.

Palynological data show that the upper Akha Formation in the central and eastern parts of studied area was deposited in a shallow neritic zone near the shore. The spore-pollen assemblages are dominated by spores and pollen of terrestrial plants while microphytoplankton (mainly prasinophytes *Leiosphaeridia*) is within 5–20%. Upward the section, the percentage of microphytoplankton decreases, especially dinocysts which only include the taxa that survive in nearshore conditions (simple forms of *Gonyaulacaceae* (*Escharisphaeridia-Sentusidinium*) and Areoligeraceae (*Circulodinium*)) that is in consistence with developing regression. The quantity and diversity of microphytoplankton and dinocysts periodically increased evidencing short transgression episodes.

The composition of spores and pollen of terrestrial plants demonstrates that input of terrigeneous material derived

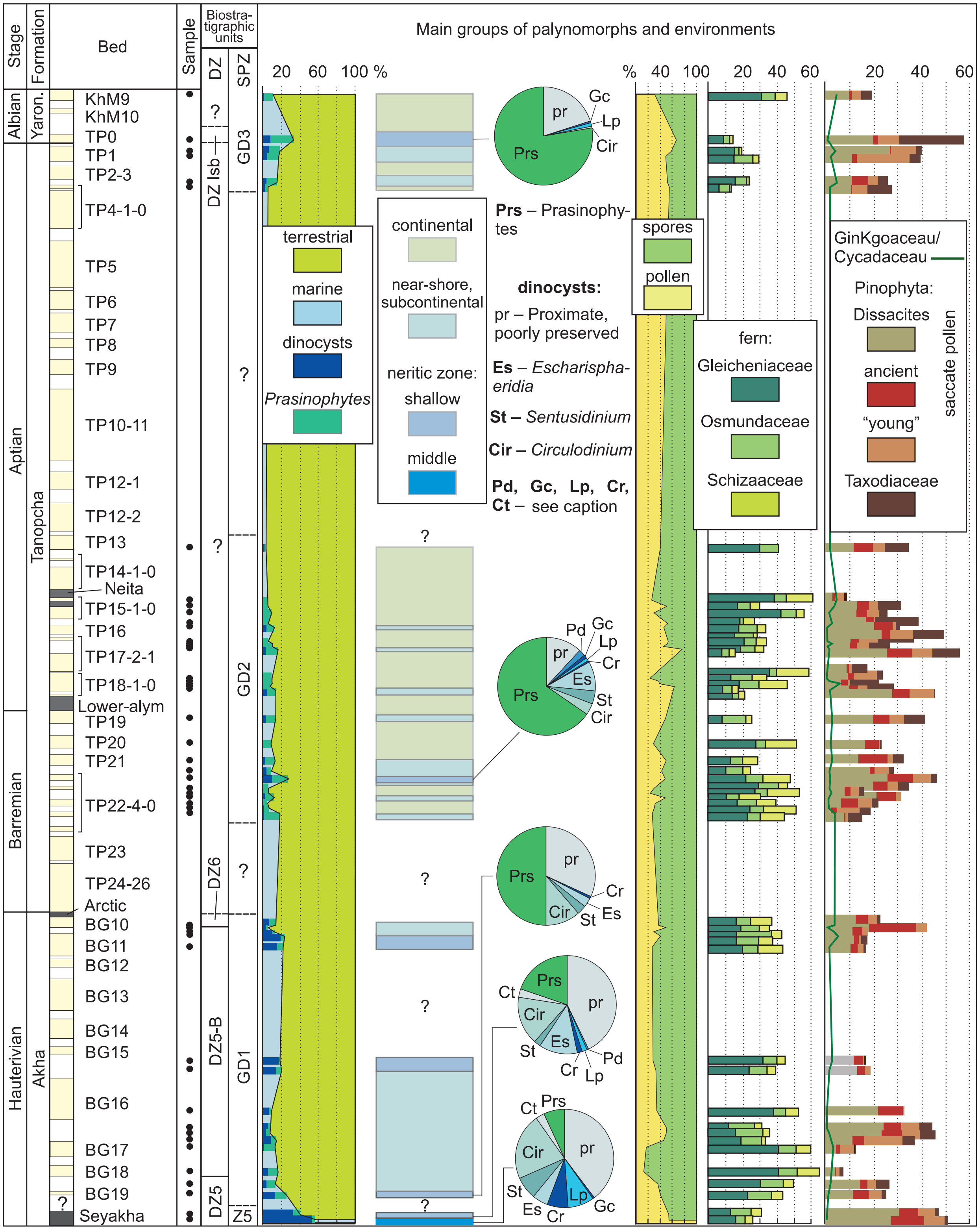


Fig. 4. Hauterivian-Albian biostratigraphy and main spore-pollen assemblages. DA, layers with dinocyst assemblages, SPA, layers with spore and pollen assemblages, Pd, Pareodinioideae, Gc, Gonyaulacoideae, Lp, Leptodinioideae, Cr, Cribroperidinioideae, Ct, Ceratiaceae.

from the land areas mainly occupied by forests with conifers and admixture of ginkgoaleans, growing in wet and moderately warm climate. The spore-pollen associations contain considerable percentages of poorly preserved saccate pollen of ancient conifers (5–24%) Alisporites-Pseudopicea group (2–20%), as well as pollen of "younger" morphology mostly represented by Piceapollenites (1–8%) along with Ginkgocycadophytus (2–7%), and Taxodiaceae (2–5%). The associations also include the species, which are widespread and in other boreal zones: *Protopinus subluteus*, *Pseudopicea magnifica*, *Piceapollenites mesophyticus* and others. *Classopollis* spp. indicating a hot and dry climate are only 0–4%. Wetter areas near the sea and rivers were occupied by cyatheaceous and dipteridaceous ferns: smooth trilete spores of Cyathidites-Biretisporites (12–41%) are the most abundant among the spores. The higher percentages of these spores are observed in northern and north-eastern regions, while coniferous pollen is more typical for the western and southern parts of studied area.

The Upper Hauterivian–Aptian ***Tanopcha Formation*** section begins from beds BG_{11} and BG_{10} in the upper part of sequence E3. BG_{11}, 18–29 m thick, is composed of light gray fine sandstone with different contents of silt, up to silty sandstone and coarse siltstone. The clastic material is of medium to good sorting and is mainly angular. The bedding is low-angle cross or cross-wavy, produced by aggradation of coaly-clayey and often sideritic material. The sediments enclose contorted and bioturbated thin layers and lenses of mudstone locally intercalated with siltstone. The deposition occurred in laterally migrating large delta channels, in periodically forming settings of within-delta bays and plains. Short marine ingressions are reconstructed for northern areas on the basis of palynological data: the percentages of microphytoplankton increase in the association including rare dinocysts.

Beds BG_{10} and BG_{11} are separated by unit of unevenly intercalated siltstone and mudstone, often contorted and bioturbated, containing *Planolites* and *Thalassinoides* trace fossils, with fine cross-wavy stratification and wave ripples in the siltstone layers. The sediments enclose fine plant detritus and siderite concretions. The deposition occurred in a prodelta with clastic inputs by periodic storms.

Bed BG_{10}, 10–18 m, consists of light grey coarse or locally outsize siltstone in the lower part, with low-angle cross or locally plane, wavy, or cross-wavy stratification, delineated by coalified plant detritus and siderite concretions. This part of BG_{10} formed in a setting of a sand bar by unidirected flow of material under a relatively stable hydrodynamic regime. The upper part of the bed is composed of medium to fine sandstone that fill a delta channel incised into the underlying sediments as a result of continuing delta progradation. The coastal areas in the north of studied region were periodically flooded during small transgressions that is evidenced by the presence of dinocysts in palynological associations.

The Neocomian supersequence is completed by two Upper Hauterivian–Barremian third-order sequences E1 and E2 in the lower part of the Tanopha Formation (above BG_{10}), 225–250 m of total thickness.

Upper Hauterivian–Lower Barremian sequence E2 (TP_{22}^{3}–TP_{26}), 120–130 m thick is represented by the Arctic Member of marine clays in its base and deposits of continental group in its upper part. Core material derives from the bed TP_{23} and overlying clay bed. The bed TP_{23} is composed of light grey fine or medium-fine sandstone, locally with high percentages of carbonates, massive or with rare low-angle cross or quasi-horizontal stratification produced by alluvial inputs of plant detritus. The sediments were deposited in a river channel. Few thin layers of thin plane-bedded mudstone may be relict floodplain facies redeposited by migrating channels of a meandering river. TP_{23} and TP_{22}^{4} are separated by dark gray massive mudstone with thin discontinuous layers of clayey siltstone, which were possibly deposited in low-energy conditions of a delta plain or an alluvial floodplain.

Upper Barremian sequence E1, 100–125 m thick, encompasses beds TP_{19}–TP_{22}^{2} of fine or less often medium-grained massive or cross-bedded sandstone, locally silty sandstone and coarse siltstone, with sporadic fine current ripple and quasi-horizontal or low-angle wavy flaser bedding. The sediments enclose fine and coarse plant detritus, with variable amounts of siderite in some layers. Clay or less often coal intraclasts are present at some levels. Siltstone layers contain *Skolithos* and *Ophiomorpha* ichnofossils. Silt-clay layers between sand beds, sometimes carbonaceous, contain quite abundant rhizoids and medium- to well-preserved plant prints. The zones of alternated thin or very thin layers of siltstone and mudstone are contorted or less often bear signatures of local erosion and gravity deformation. The sediments contain frequent siderite concretions. This part of the section was deposited mainly in a delta environment. Sands accumulated in fluvial delta channels while siltstone and clay material was deposited in swampy areas between the channels or less often in bays.

The Neocomian sequence completes the Upper Triassic-Barremian megasequence and records the end of a regression event.

The Aptian supersequence spans the respective stratigraphic range represented by ***upper part of the Tanopcha Formation*** of 660–725 m thick. The supersequence comprises six third-order sequences (Fig. 3). The characteristic feature is small thickness of HST intervals. The maximum flooding surface is defined in the middle of the Neita Member. The lower part of the Aptian sequence (from the Aptian base to the top of the Neita Mb.) in northern West Siberia has been traditionally considered jointly with the Berriasian–Lower Aptian reservoir, since the Neita Mb. and the Koshai Mb., its age equivalent, are regional seals. The upper part of the supersequence has been commonly attributed to the Aptian-Cenomanian reservoir.

The Aptian supersequence consists of sand-silt beds TP_{1}–TP_{18}^{0-1} (up to 102 m thick) irregularly alternated with thicker or thinner layers of silty shales and very few thin coal layers or lenses. Sandstone present in core samples is most often massive, mainly fine- or fine to medium-grained, or locally silty, grading into siltstone. Fine or coarse plant detritus, sometimes sideritized, produces cross stratification. The sediments contain well preserved plant detritus and clay or coal intraclasts at some levels. The sand-silt beds are separated by intercalating more or less clayey siltstone, mudstone, and clay, with plant detritus, siderite concretions, rhizoids, and coal. The sediments were deposited in a large alluvial plain with meandering rivers, except for the deltaic and coastal uppermost Tanopcha Formation (TP_1, $TP_{2\text{-}3}$ and sediments between them). The latter units appear as progradation successions; the wavy-bedded silt-clay members contain glauconite, detritus of bivalve shells, and scarce rhizoids.

Palynological data also record alternating continental and pericontinental settings in the Barremian and Aptian section. Microphytoplankton is of low abundance (5–28%) and mostly consists of *Leiosphaeridia* prasinophytes. Small transgression events in the middle Barremian and at some levels in the Aptian are marked by the appearance of dinocysts.

The spore-pollen data indicate gradual variations in the vegetation in the land areas providing the input of terrigenous material that was due to both evolution processes and environmental changes. Coniferous forests became dominated by pinaceous gymnosperms produced saccate pollen similar to the present species, and taxodiaceous trees. The Aptian is characterized by the appearance of first angiosperms, which gradually become one of the main component in the plant communities of later epochs in the Cretaceous. Meanwhile, the percentage of spores of schizaeaceous ferns increases in the Barremian that is probably related to the growth of river network and related formation of wet but well drained and sufficiently light zones along rivers. Gradual abundance increase of sphagnaceous spores in the Aptian was possibly caused by swamp expansion. Palynological data from the upper Tanopcha and lowermost Yaronga formations confirm periodic occurrence of nearshore marine environments (Fig. 4).

DISCUSSION

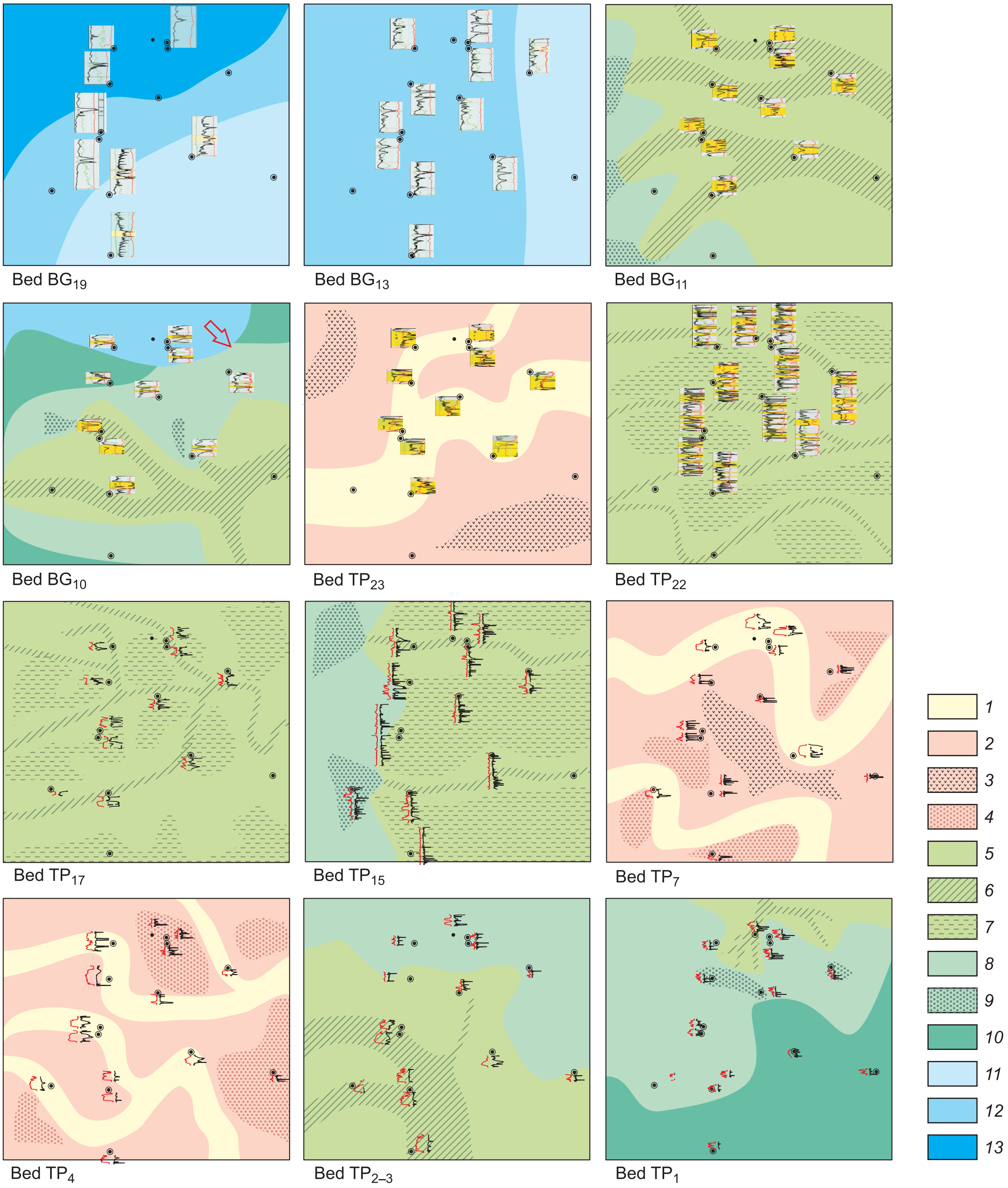
Thus, the biofacies and lithofacies analysis of Berriasian–Aptian core samples from the Geofizicheskoe oil–gas-condensate field revealed six assemblages of sedimentation settings: the alluvial, coastal-continental, nearshore-marine, deltaic, shallow water marine, deep water marine assemblages of sediments, which were united into three groups - continental, transitional, and marine ones. In addition, nineteen types and subtypes of sedimentation settings were defined as part of these assemblages (Figs. 2, 3). The studied section begins with relatively deepwater marine facies (lower part of the Akha Formation) overlain by assemblage of marine lithofacies of shallow water, middle and moderate-deep shelf (upper part of the Akha Formation) (Fig. 5). The lowermost Tanopcha Formation (BG_{10} and BG_{11}, uppermost Hauterivian) is composed of deltaic lithofacies. The Barremian and lower Aptian sediments (below the Neita Mb.) were deposited mainly on a delta plain (bays, channels, and spaces between them). The TP_{23} – $TP_{24–26}$ interval includes alluvial lithofacies. Most of the Aptian sediments are of continental origin, deposited on alluvial plains. The Aptian section is completed by sediments formed in coastal continental and near-shore marine settings.

The succession of transgressive and regressive events is easily reconstructed from palynological records (Fig. 4) which show a prominent regression trend: Early Hauterivian more deepwater environments of the neritic zone sharply changed to mainly nearshore marine facies in the middle and latest Hauterivian. The basin underwent further shoaling in the Barremian and Early Aptian when it became filled with coastal, subcontinental, and continental settings, with small ingressions indicated by dinocysts. Shallow-marine environments reappeared only in the latest Aptian.

Now, consider the relationship between the patterns of changes in sedimentation facies of studied Berriasian-Aptian deposits and evolution of sedimentary basin in the north of Western Siberia demonstrated in new paleogeographic maps (Kontorovich et al., 2014). In the Berriasian, the territory of the peninsula was located at sea depths 200–400 m, nevertheless some researches suggest that the depth of the Berriasian palaeobasin in the Gydan region was no more than 160 m, and less than 120 m in the Geofizicheskaya paleo-uplift area (Ershov, 2016). The climate at that time was warm and wet, and the connection of the basin with the boreal sea maintained normal seawater salinity (Kontorovich et al., 1975). In the Early Valanginian, the shallow sea zone extended, the water became slightly less saline, and the average water temperature was +15 °C (Golbert et al., 1968). In the Late Valanginian, the deep-water zone was restricted to the northeastern part of the area, while the remainder of the peninsula was in a shelf environment (100 to 200 m). Further regression in the Hauterivian did not lead to considerable re-distribution of marine zones within the territory. The global regression, which continued in the Barremian, completed the major Upper Triassic–Barremian transgression-regression cycle. At that time, the whole Gydan Peninsula was an intermittently flooded coastal plain. The Early Aptian transgression began the new Aptian-Paleogene transgression-regression cycle recorded in the respective megasequence. The territory was still a costal plain, with a wet and warm, to subtropical, climate (Kontorovich et al., 1975), and coal deposition resumed under general climate wetting. The latest Early Aptian transgression was accompanied by the deposition of the Neita Mb. marine clay and was followed by another regression event in the Late Aptian, while the sea limits did not change and the Gydan Peninsula remained in the coastal plain zone flooded from time to time.

Thus, the Lower Cretaceous reservoirs in the Gydan Peninsula formed in diverse sedimentary environments that changed progressively from deep-sea (Valangianian–Hauterivian) to mainly continental (Aptian) conditions.

In the Neocomian supersequence, the lowermost level of sand reservoirs beds is located in the Achimov Mb. of the Akha Formation and represented by a series of lenses characterized by relatively deep water genesis. They are deep-sea fans fans that formed at the foot of an aggradation slope within the Gydan Peninsula, and are coeval to shalow sea beds BG$_{10}$–BG$_{37}$ (Ershov et al., 2018), but only equivalents of BG$_{17}$–BG$_{20}$ were deposited in the study area.


Bed BG$_{19}$ Bed BG$_{13}$ Bed BG$_{11}$

Bed BG$_{10}$ Bed TP$_{23}$ Bed TP$_{22}$

Bed TP$_{17}$ Bed TP$_{15}$ Bed TP$_{7}$

Bed TP$_{4}$ Bed TP$_{2–3}$ Bed TP$_{1}$

Fig. 5. Paleogeographic model: Lower Cretaceous deposition of sand beds. *1*, channel alluvium; *2*, floodplain; *3*, swampy floodplain; *4*, sand bars and fans; *5*, space between delta channels; *6*, delta channel; *7*, delta bay; 8, distal part of delta front; *9*, sand bar; *10*, prodelta; 11, shallow-water tidal plain with sand shoals, bars, and microdeltas; *12*, lower shelf and middle shelf; *13,* deep shelf. Red arrow shows brief ingression episodes; circles are boreholes; red and black curves are wireline logs (self-potential and apparent resistivity logs, respectively); scale 1:10 000.

The BG_{16}–BG_{19} sandy covering beds of the Akha Formation formed in shelf conditions of sequence E3 (Fig. 2). Deposition of BG_{12}–BG_{15} reservoir beds in the latest Hauterivian mainly accumulated at a shallow sea depth and gave way to deltaic deposition of BG_{10}–BG_{11}. Sand beds TP_{19}–TP_{26} of Barremian sequences E1 and E2 are mostly of deltaic origin, though some (TP_{23} and $TP_{24–26}$) are alluvial.

Most of the Neocomian reservoirs in West Siberia, including those in the Gydan Peninsula, formed during regressions as noted by many researchers (e.g., Shpilman et al., 1979; Nezhdanov, 1988; Karogodin et al., 1996). According to sequence stratigraphy, they are confined to high system tracts. This applies not only to shallow water, but also to deepwater beds of the Achimov Member (Ershov, 2018). In the sequence stratigraphic hierarchy, the reservoir beds in both Neocomian and Aptian supersequences are associated with fifth- or rarely fourth-order sequences.

The sand beds of the transgressive and regressive units of the Aptian supersequence differ in deposition environments and in relation with systems tracts. The Early Aptian TP_{15}–TP_{18} beds were deposited in high-stand prograding delta systems, like Barremian sequences E1 and E2. These sediments, jointly with the underlying Berriasian-Hauterivian strata, are attributed to the major Berriasian-Aptian reservoir confined by the regional Neita clay member, since the lower Aptian section in northern West Siberia has the same structure as the Barremian section of the Neocomian.

The sedimentary environment in the western Gydan Peninsula changed dramatically during the regression phase of the Aptian supersequence, when the reservoir beds were forming. Most of them are alluvial channel filling and floodplain lithofacies, and some (e.g., TP_6 and TP_8) were deposited in coastal and restricted shelf settings. Furthermore, the reported data from the study area show deltaic origin of beds $TP_{2–3}$ and a shallow environment for TP_1. In terms of sequence stratigraphy, continental sand beds are distinguished in LST (channel incisions) and TST intervals. The TP_1 reservoir and some sand lenses of TP_6 can be reliably attributed to HST.

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