Stratigraphy and Geological Correlation, Vol. 12, No. 1, 2004, pp. 58–84. Translated from Stratigrafiya. Geologicheskaya Korrelyatsiya, Vol. 12, No. 1, 2004, pp. 67–93.

New Data on the Marine Paleogene of the Southwestern Siberian Plate, Paper 1

M. A. Akhmet'ev*, G. N. Aleksandrova*, V. N. Beniamovskii*, D. I. Vitukhin*, Z. I. Glezer, Z. N. Gnibidenko***, V. D. Dergachev****, Zh. A. Dolya****, N. I. Zaporozhets*, G. E. Kozlova*****, I. A. Kul'kova***, I. A. Nikolaeva**, M. N. Ovechkina******, E. P. Radionova*, and N. I. Strel'nikova*********

**Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, Moscow, 119017 Russia*
***All-Russia Research Institute of Geology, St. Petersburg, Russia*
****Joint Institute of Geology, Geophysics, and Mineralogy, Siberian Division, Russian Academy of Sciences, Novosibirsk, Russia*
*****Omsk Expedition for Geological Prospecting, Omsk, Russia*
******All-Russia Research Institute of Petroleum Prospecting, St. Petersburg, Russia*
*******Moscow State University, Moscow, Russia*
********State University of St. Petersburg, St. Petersburg, Russia*
Received January 14, 2002

Abstract—The Paleocene–Eocene marine deposits recovered by two reference boreholes (011BP and 9) in the Omsk depression, the southwestern Siberian plate, have been comprehensively studied in various paleontological aspects. Geology of the depression and associated Chany basin, which are structural elements of the Barabinsk lithologic–facies zone, is briefly described. Zonal assemblages of radiolarians, diatoms, ostracodes, benthic and planktonic foraminifers, organic-walled phytoplankton, spores and pollen are characterized. Biostratigraphic data are supplemented with lithological description of regional formations and with results of the electric logging and magnetostratigraphic study of Paleogene deposits that has been carried out for the first time in the West Siberian plate.

Key words: Paleogene, Eocene, Paleocene, West Siberian plate, foraminifers, dinocysts, radiolarians, diatoms, ostracodes, magnetostratigraphy, polarity zones, Gan'kino, Lyulinvor and Tavda formations.

INTRODUCTION

In addition to all the materials summarized in the correlation part of the unified regional stratigraphic scheme for Paleogene deposits of West Siberia [1], systematization of available paleontological data was used to substantiate the regional scales of the scheme. The results were published in a collective work by members of the Commission on the Paleogene System of the Interdepartmental Stratigraphic Committee [2] who emphasized that elucidation of time-and-space relations between the Gan'kino, Lyulinvor, and Tavda sequences and synonymous formations widespread in the study region is the key problem of the marine Paleogene stratigraphy. Unfortunately, the results of multidisciplinary study of boreholes 011BP and 9 drilled by the Omsk Expedition for Geological Prospecting in the south of West Siberia have not been timely considered in the full measure at the preparation time of the scheme and above publication. The paleontological study of both core sections has been accomplished recently, and the results obtained are presented in this paper. The members of scientific team who studied various groups of fauna and flora were G.E. Kozlova and D.I. Vitukhin (radiolarians); Z.I. Glezer, N.I. Strel'nikova, and E. P. Radionova (diatomaceous algae); I.A. Nikolaeva (ostracodes); G.N. Aleksandrova, N.I. Zaporozhets, and I.A. Kul'kova (organic-walled phytoplankton); V.N. Beniamovskii (foraminifers); and M.N. Ovechkina (nannoplankton). V.A. Krasheninnikov examined rock samples bearing planktonic foraminifers. Zh.A. Dolya and V.D. Dergachev were charged to select the borehole sites, to control the drilling and logging operations, and to compile and document the core sections. Z.N. Gnibidenko was responsible for the paleomagnetic research and magnetostratigraphic characterization of both reference sections drilled for the first time throughout the marine Paleogene of West Siberia and correlated with the time scale by Berggren *et al.*, [3]. M.A. Akhmet'ev and V.N. Beniamovskii headed the team and coordinated investigation in general.

A GEOLOGIC OUTLINE OF THE STUDY AREA AND RECOVERED CORE SECTIONS

Borehole 011BP has been drilled 1.5 km northeastward of the Achair Settlement, the Irtysh River bank

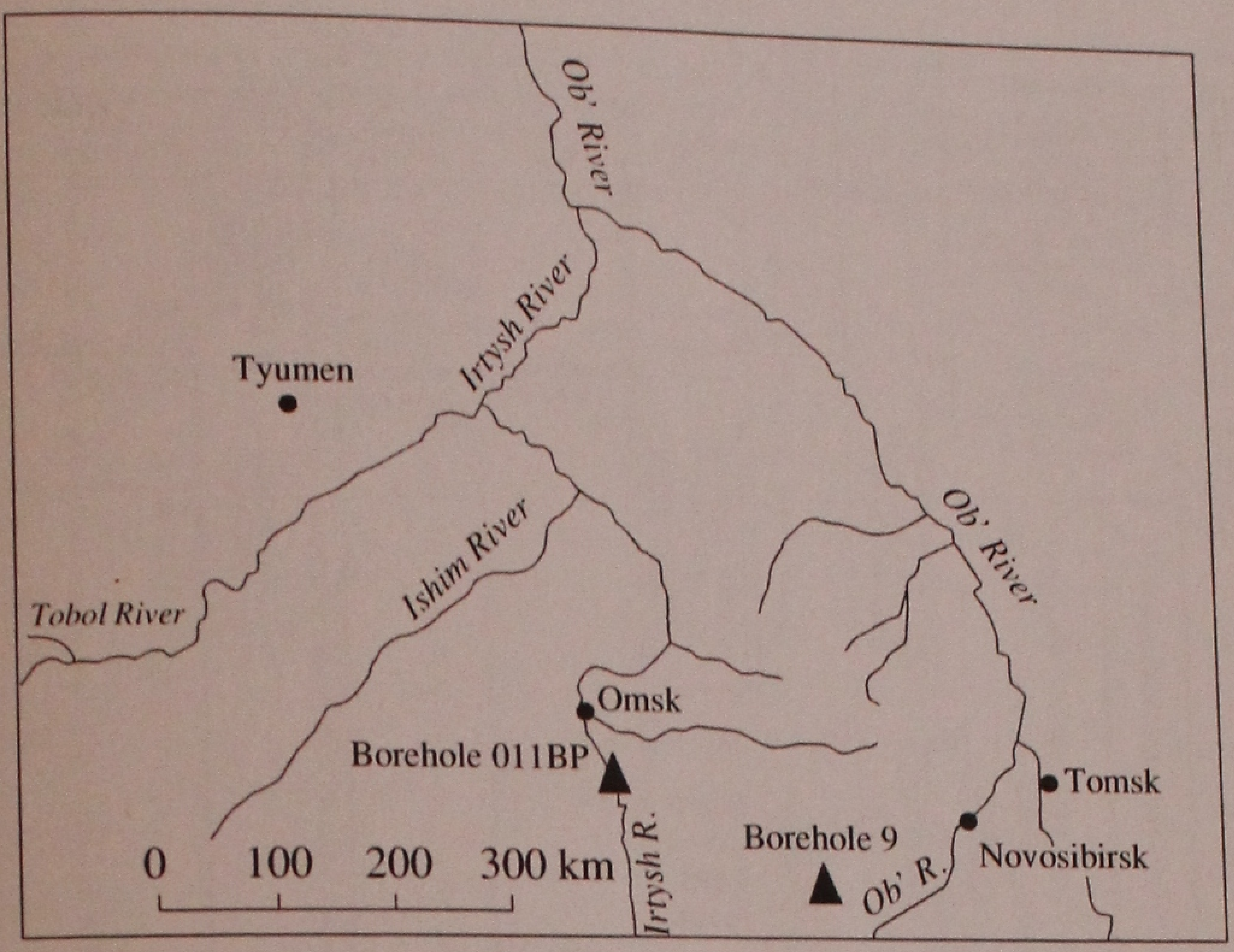


Fig. 1. Geographic localities of studied boreholes.

35 km upstream of Omsk, and Borehole 9 is situated near the Orlovka Village 25 km southeastward of Chistozernoe station (Omsk–Kulunda railway) at the southwestern coast of the Chany Lake (Fig. 1). The boreholes are drilled within the spacious Barabinsk lithologic-facies zone (or region) distinguished in the south of the West Siberian plate. In terms of tectonics, the greater zone part corresponds to the Omsk depression [4], and both boreholes are in the southern limb of the latter. The depression formation took place since the Mesozoic time. The Chany basin development within this large structure of the plate is recorded since the later Eocene time. The upper Lyulinvor Subformation and Tavda Formation are nearly as thick in the drilling area as in the most downwarped parts of the plate. The depth level of boundaries between the Paleogene lithostratigraphic subdivisions undulates depending on auxiliary local uplifts and downwarps (Chistozernoe depression, Kupa swell, etc.), development of which continued throughout the Paleogene [5]. Borehole 011BP is drilled near the Chany basin axis oriented parallel to the Irtysh River valley, where the crust downwarped most intensively during the Eocene. In the southern part of the Chistozernoe depression, where Borehole 9 is drilled, the depth to the Paleogene base ranges from 520 to 600 m. The situation around the Borehole 011BP is likely the same, although the Paleogene base has not been penetrated here. The depth to the Tavda Formation top is within the range of 250–280 m, and the total thickness of Paleogene marine deposits in the Chany basin is from 270 to 300 m.

The lithostratigraphy and biozonation of recovered sections are illustrated in Figs. 2–4. Drilling at the site 011BP was terminated at the depth of 498 m, and borehole penetrated here the complete Tavda Formation and the greater interval of the upper Lyulinvor Subformation. Borehole 9 reached the upper Maastrichtian clay of the Gan'kino Formation at the depth of 521 m. Oriented rock samples for paleomagnetic measurements have been taken with intervals of 0.5 to 1m in between.

The recovered core sections are lacking rocks of the Talitsa Formation, and the Paleogene sequence begins at both sites, like in many other areas of the Barabinsk lithologic-facies zone, with opoka and sandstone beds of the lower Lyulinvor Subformation. The latter is overlain with a hiatus by the basal horizon of glauconite sandstone of the upper Lyulinvor Subformation. The horizon penetrated in the depth interval of 492.5–490 m is 2.5 m thick. In the core section 9 that is stratigraphically more complete, the upper subformation is divided in two members: the lower one composed of gray diatomaceous and opoka-like clay with rare opoka interlayers, and the upper member of greenish clay beds, which are less siliceous, bearing fish remains, and yield the diverse assemblages of diatoms, radiolarians, silicoflagellates, and dinocysts. Formerly, Shatskii [6] regarded the upper member as the individual Nyurol'ka Formation. In the core section 011BP, this member is almost completely eroded. Separate interlayers of greenish glauconite sandstones occur sporadically at different stratigraphic levels in both members. One of them most distinct in the core section 9 and confined to the boundary between the gray and greenish clay beds was penetrated in the depth interval of 451–450 m.

In the upper 2- to 3-m-thick interval of the upper Lyulinvor Subformation, clay is enriched in silty and sandy material prevailing over the clay matrix at the subformation top, especially in the core section 9. In the same section, the contact between Lyulinvor and Tavda formation is most distinct. At the base of the latter, there is a bed of glauconite sandstone and siltstone, which is 10 m thick and clearly depicted in the log, being correl-

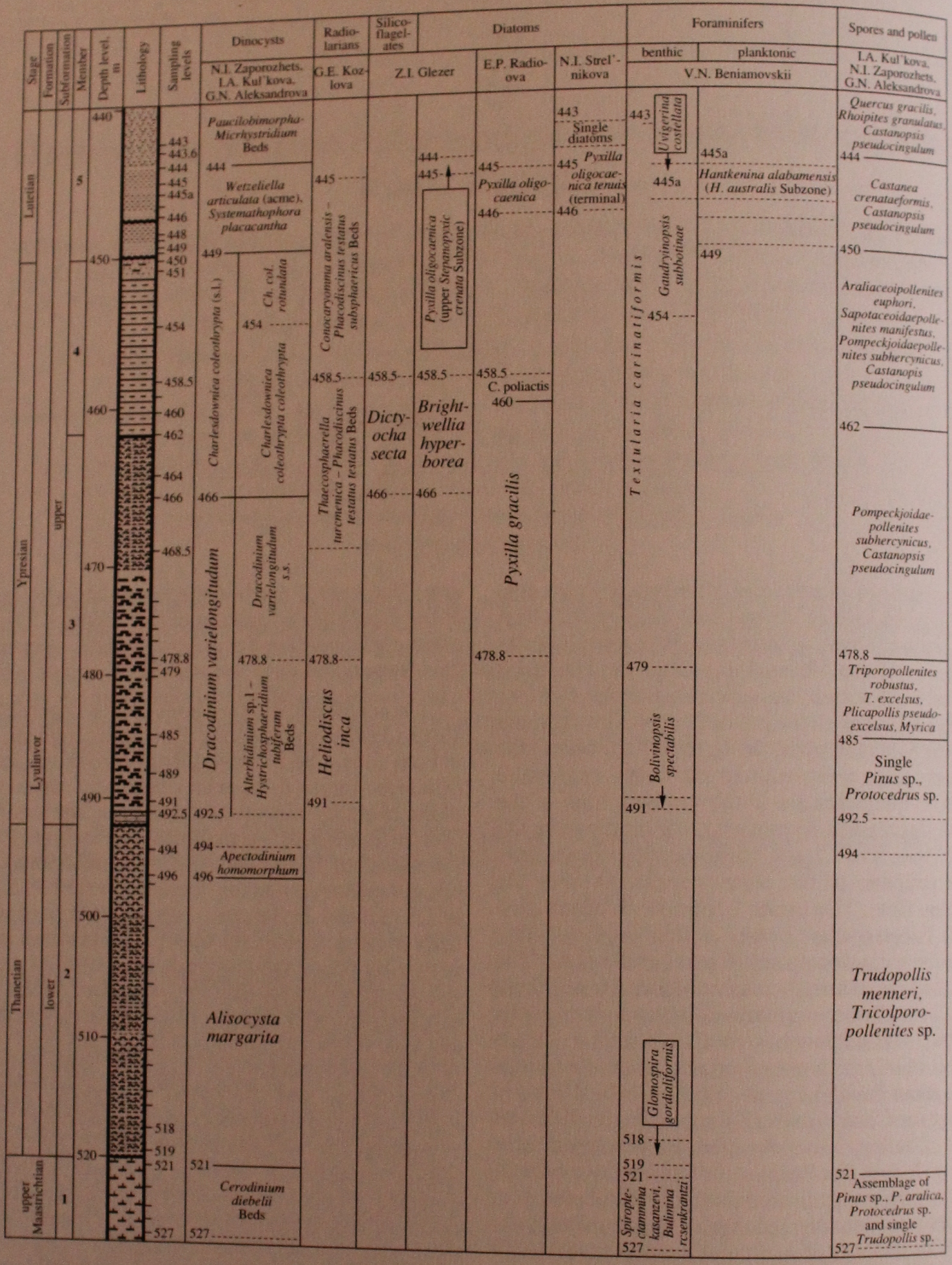


Fig. 2. Lithology and correlated biostratigraphic scales, Borehole 9, depth interval of 527–440 m (symbols as in Fig. 3).

ative with the regional logging marker "T." The rounded detritus of Lyulinvor clay occurs in the matrix of basal sands. In the core section 011BP, the contacts between formations and especially the Tavda basal member look differently. The latter is also 10 m thick but composed of greenish gray grumous aleurite with irregularly distributed clusters of clayey and silty particles. The member grades into overlying clay, and this transition looks gradual in the logging record as well.

The Tavda Formation is composed predominantly of clay with irregularly distributed admixture of silty material and with siderite interlayers and nodular seg-

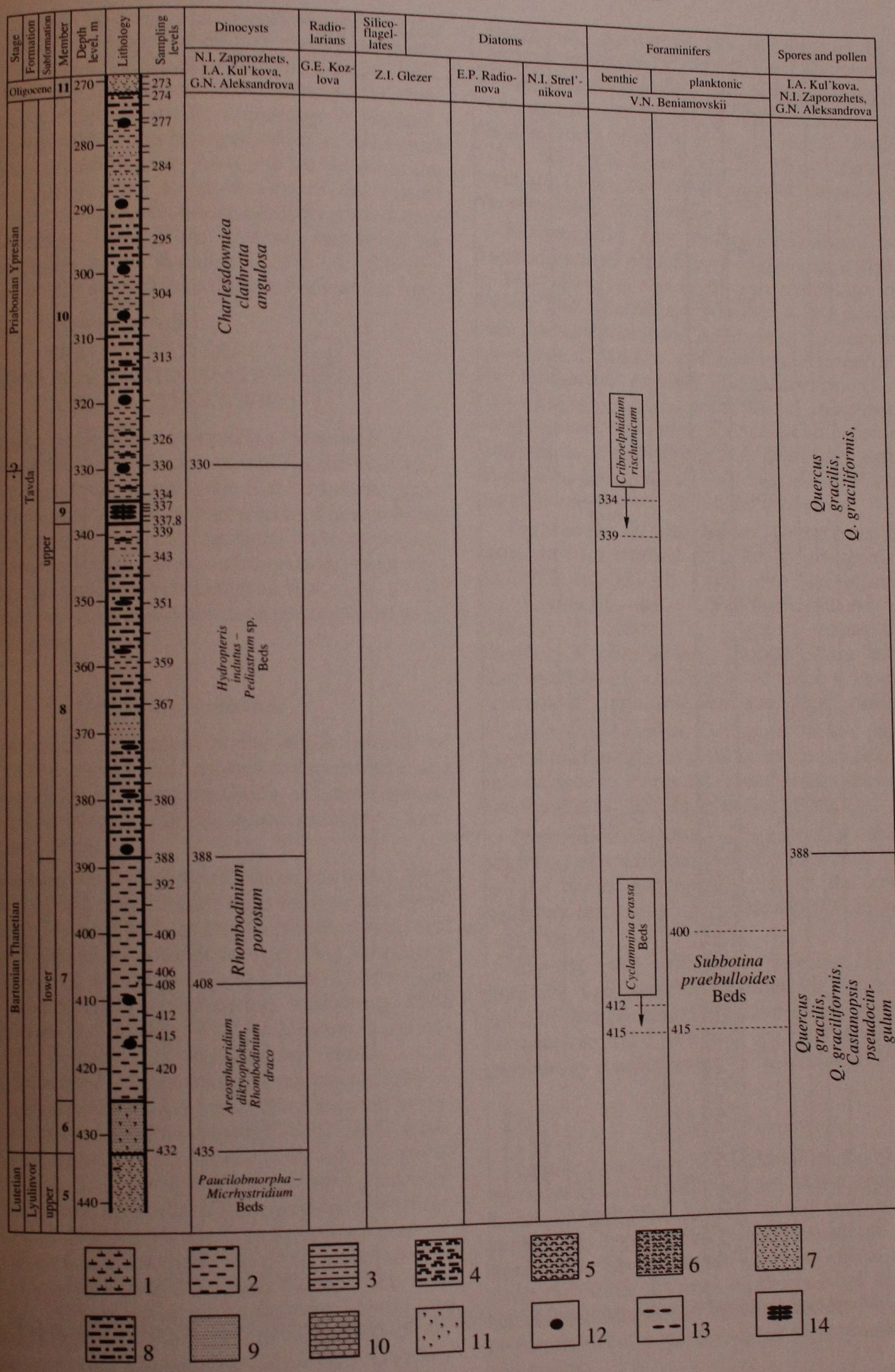


Fig. 3. Lithology and correlated biostratigraphic scales, Borehole 9, depth interval of 440–270 m: (1) calcareous, (2) non-calcareous, (3) siliceous, and (4) opoka-like clays; (5) opoka; (6) opoka-like sandy and (7) silty to sandy clays; (8) clayey siltstone or silty–sandy clay; (9) silty sand; (10) sandstone, siltstone; (11) glauconite; (12) septarian nodules of siderite; (13) marcasite; (14) leaf impressions of aquatic fern *Azolla vera* Krysht.

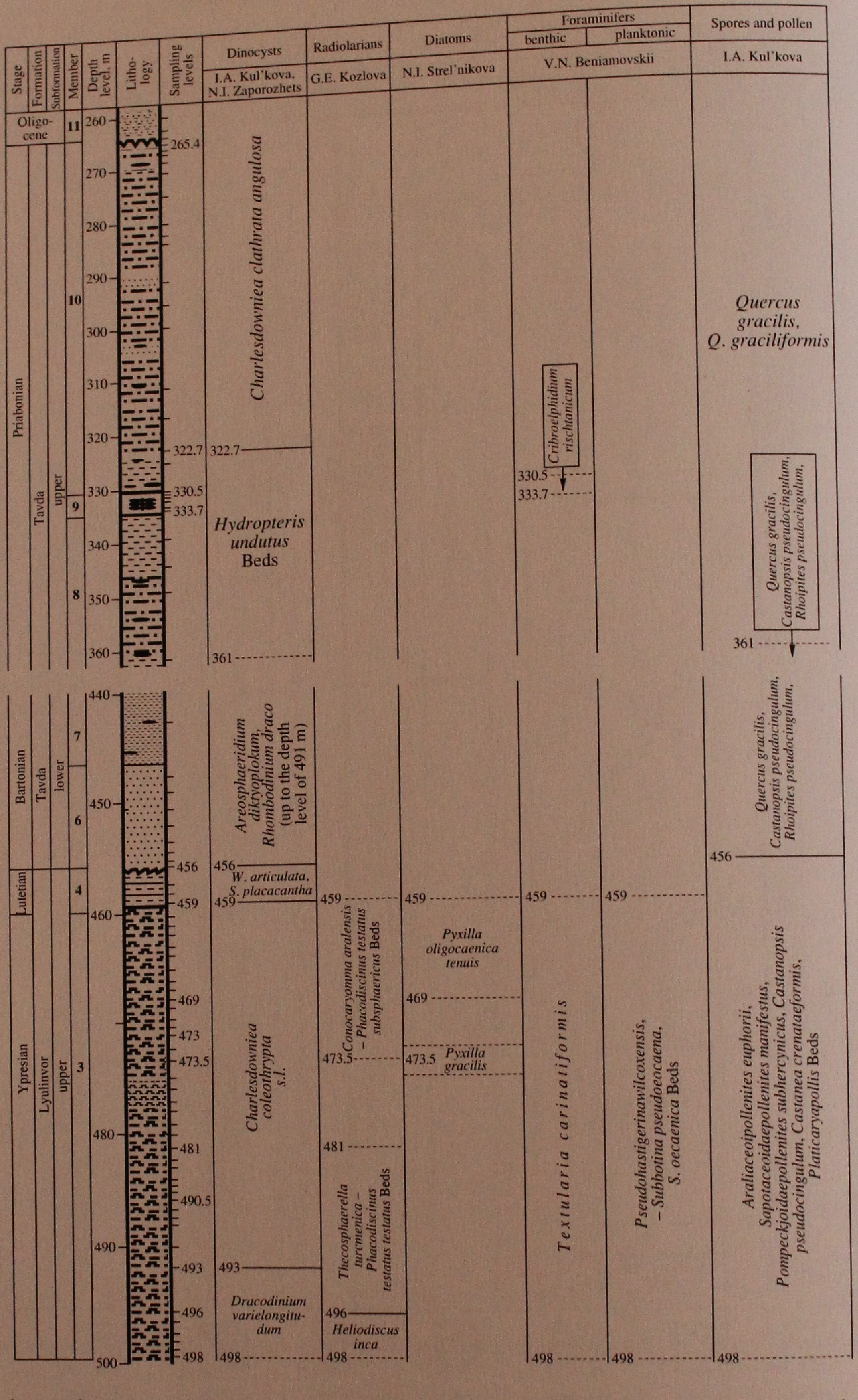


Fig. 4. Lithology and correlated biostratigraphic scales, Borehole 011BP, depth interval of 498–260 m (symbols as in Fig. 3).

regations. The purer clay is characteristic of lower and upper parts of the formation sequence, which characterize the true marine facies of the lower and upper Tavda subformations. Between these clay members, there is the middle one composed of silty clay. The three-member structure (if the basal sand bed penetrated by Borehole 9 is excluded) is readily distinguishable in both core sections. The Tavda Formation of the West Siberian plate used to be divided in two subformations, the upper of which includes the middle and upper members. We followed this tradition in our work as well. Nevertheless, the middle member composed of shallower facies yielding a specific assemblage of organic-walled phytoplankton can be regarded as an individual biostratigraphic subdivision. As it will be shown in the next our paper devoted to discussion of the results obtained, the core sections under consideration do not differ essentially from other sections recovered by nearby boreholes in the Barabinsk zone. All the sections are also very similar in parameters of electric logs.

PALEONTOLOGICAL AND MAGNETOSTRATIGRAPHIC CHARACTERIZATION

In order to compact presentation of materials, every lithostratigraphic subdivision, except for the Gan'kino Formation and lower Lyulinvor Subformation penetrated by Borehole 9 only, is characterized below based on data obtained for two core sections. Paleontological materials are uniformly presented beginning from data on the organic-walled phytoplankton that is of a high stratigraphic resolution and has been encountered in all studied samples.

Gan'kino Formation

The formation penetrated in the depth interval of 527–521 m is composed of massive to laminated clays bearing fragmented molluscan shells, echinoid spines, organic-walled phytoplankton, nannoplankton, foraminifers, and ostracodes.

The organic-walled phytoplankton (samples from depth levels of 525.5 and 522.5 m) is represented by 30 dinocyst species and by 8 species of prasinophytes and acritarchs (Table 1), which characterize the *Cerodinium diebelii* Beds of the mid-upper Maastrichtian. The dinocyst assemblage includes the following taxa: *Phanerodinium ?sonciniae, Ph. ?veligerum, Lacinia-dinium* cf. *firmum, Trythirodinium evittii, Kallosphaeridium* spp., *Membranosphaera maatsrichtica, Hystrichosphaeridium tubiferum, Microdinium ornatum, M. dentatum, M. kustanaicum, Chatangiella granulifera, Chatangiella* spp., *Fibradinium* sp., *Cerodinium speciosum, C. diebelii, Cerodinium* sp.1, *Isabelidium* sp., *Xenikoon australis, Connexrimura fimbriata, Pal eoperidinium pyrophorum, Exochosphaeridium* cf. *bifidum, Exochosphaeridium* sp., *Glyphanodinium facetum, Cordosphaeridium funiculatum, Parallecaniella* sp., *Achomosphaera ramulifera, Areoligera* sp.?, *Chlonoviella* sp., *Pterodinium cingulatum, Glaphyrocysta ordinata, Tanyosphaeridium* sp., *Alterbia?* sp., *Leberidocysta?* sp., *Cyclonephelium* sp.1, and *Hystrichostrogylon coninkii. Cerodinium* sp.1 present in the assemblage is close in morphology to *Deflandrea galeata*, being distinct from the latter by a large standard deltoid archeopyle characteristic of the genus *Cerodinium*. Acritarchs are represented by *Fromea chytra, F. laevigata, F. fragilis*, and *Micrhystridium* sp.

Nannoplankton is typical of the uppermost Maastrichtian zone CC26. About 50 species have been identified in rock samples from the depth levels of 527, 525.5, 524, 522.5 and 521 m. Most characteristic of them are *Lithraphidites quadratus, Micula mura*, and *Neophrolithus frequens*.

Foraminifers (the *Spivoplectammina kasanzevi–Bulimina rosenkrantzi* Zone of the upper Maastrichtian in West Siberia) represent an assemblage of benthic forms. The assemblage consists of the following species *Spiroplectammina kasanzevi, Gaudryina rugosa spinulosa, Dentalina cylindracea, Astacolus omskiensis, Globulina lacrima subsphaerica, G. veronica, Gyroidinoides obliquaseptatus, G. turgidus, Valvulinoides umovi, Eponides sibiricus, Cibicidoides bembix, Brotzenella pseudospinulosa, Cibicides gankinoensis, Anomalinoides pinguis, Bolivina plaita, Pseudouvigerina plummerae*, and *Bulimina thrihedra*.

Ostracodes of the Upper Cretaceous have been found in four studied samples (depth levels of 525.5, 524, 522, and 521 m). These are *Cetherella temporabilis, Cetherella* sp., *Pseudobythocythere verganica, Cythere (?) sibirica, Xestoleberis saratoensis, Krithe simplex, K. bronnemai, Bairdopillata simplicatilis, Curfsina notabilis, Clithrocytheridea schweyeri, Physocythere virginea*, and *Pterigocytheiris pallensa*.

Spores and pollen. Dominant in the palynological assemblage are *Pinus aralica* in association with other archaic species *Pinus* spp. and *Pseudocedrus* sp. Pollen *Trudopollis* sp. occurs as single grains.

Magnetostratigraphy. The normal and reversed polarities of rocks have been established respectively for the lower and upper parts of the clay member (apparent thickness 7 m) at the top of Gan'kino Formation (Fig. 5).

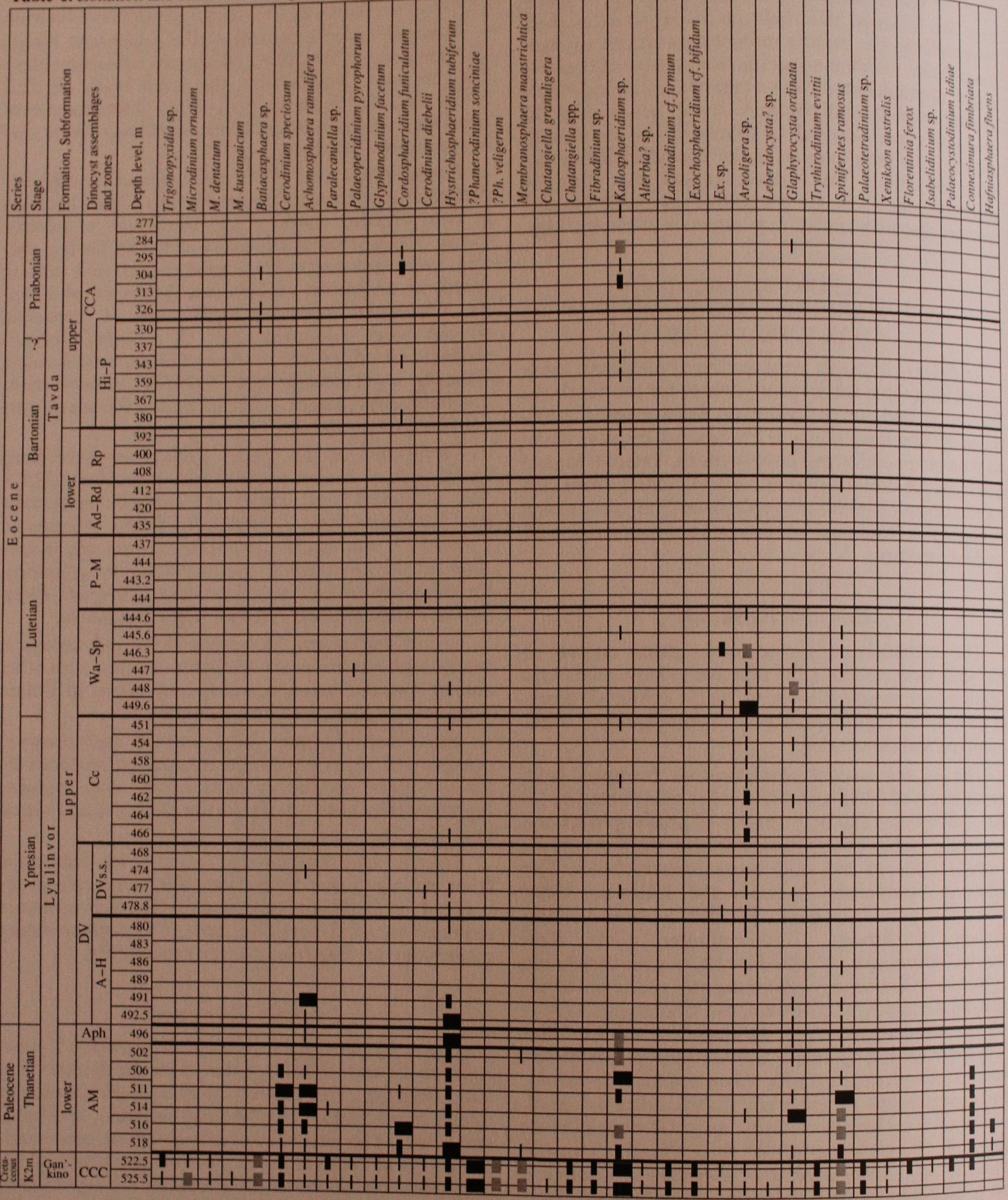
Electric and gamma-ray logging. In distinction from the Lyulinvor Formation, the more calcareous rocks of the Gan'kino Formation reveal a higher natural radioactivity of 8 versus 4 mr/h. The corresponding gamma-ray reading is less differentiated (Fig. 6).

Lyulinvor Formation

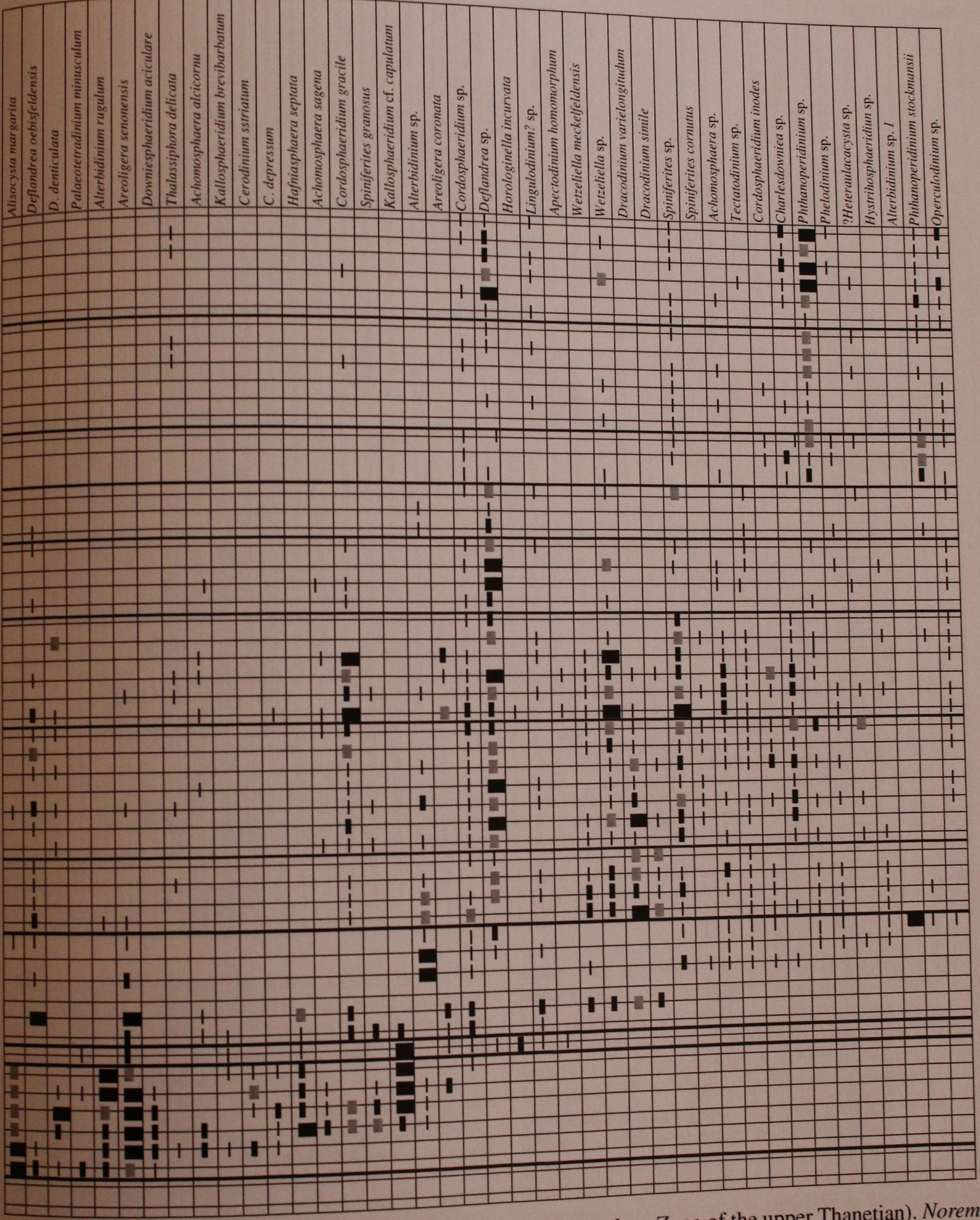
Lower Lyulinvor Subformation. Borehole 9 penetrated rocks of this subformation in the depth interval of 520.5–493 m. The unit is composed of alternating opoka, clay (opoka-like and diatomaceous), and sandstone beds. The basal bed of clayey bioturbated sandstone (1.5 m thick) rests on the erosion surface of the Gan'kino Formation. Organic remains are represented by foraminifers, organic-walled phytoplankton, spores, and pollen.

Organic-walled phytoplankton is macerated from 8 samples, the depth levels of 518, 516, 514, 511, 506, 502, 496, and 494 m. Over 40 dinocyst species and 8 prasinophyte and acritarch taxa are identified within the

Table 1. Zonation and distribution ranges of dinoflagellates in the section penetrated by Borehole 9



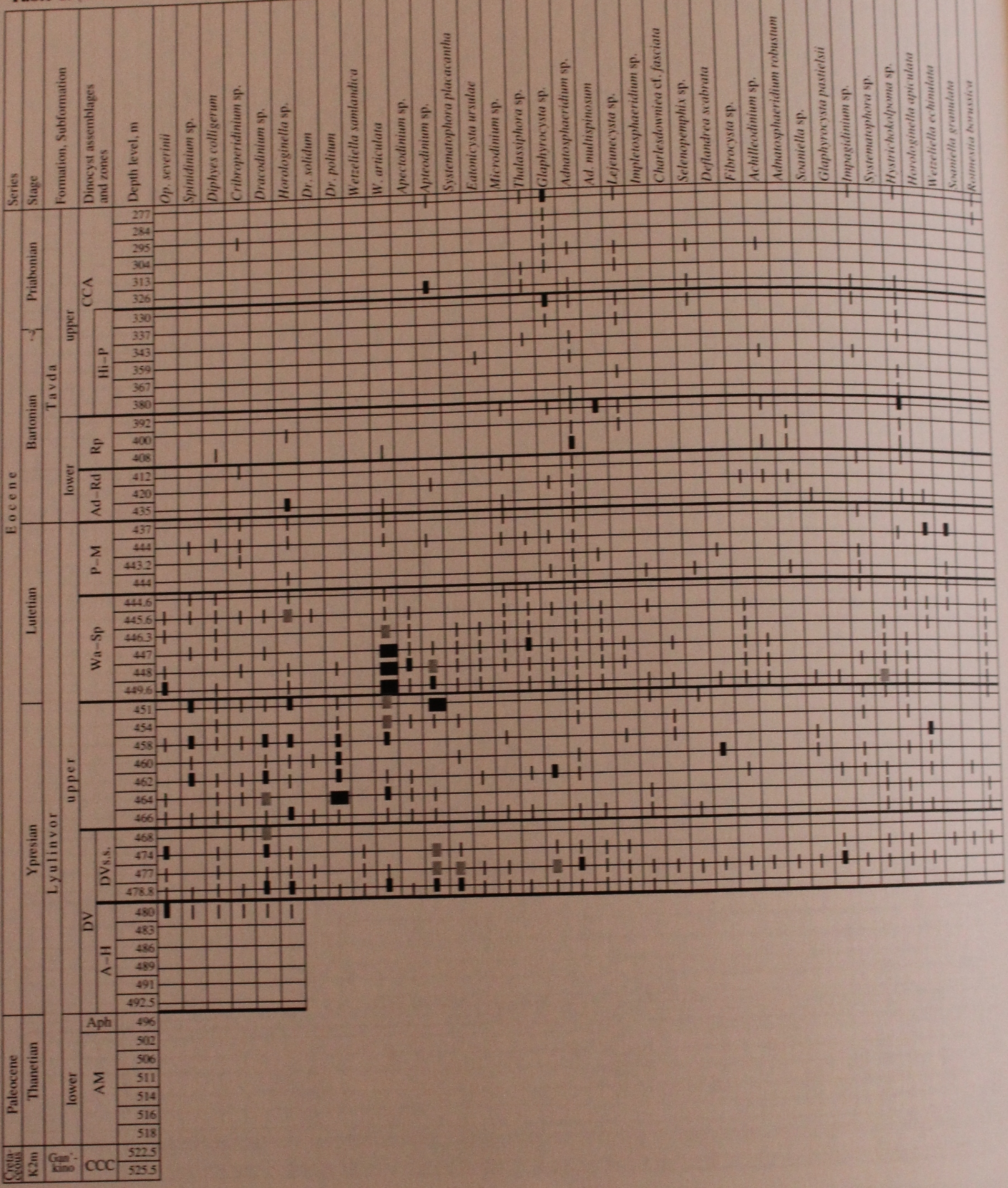
depth interval from 518 to 496 m (*A. margarita* Zone of the lower Thanetian). Distribution of phytoplankton forms is outlined in Table 1. Taxa dominating among dinocysts are *Alisocysta margarita, Alterbidinium rugulum, Cer(r)dinium speciosum, C. striatum, C. depressum, Deflandrea denticulata, D. oebisfeldensis, Areoligera senonensis, Areoligera coronata*, and species of *Cordosphaeridium, Spiniferites*, and *Achomosphaera* genera, while *Noremia* sp. and *Fromea* forms dominate among prasinophytes and acritarchs. *Apectodinium*



homomorphum and associated *Kallosphaeridium brevibarbatum, Kallosphaeridium* cf. *capulatum, Glaphyrocysta ordinata, Areoligera coronata, A. senonensis, Hystrichosphaeridium tubiferum*, and some other forms appear in the depth interval of 496–494 m (*A. homomorphum* Zone of the upper Thanetian). *Noremia* sp. is dominant taxon in the group of prasinophytes and acritarchs.

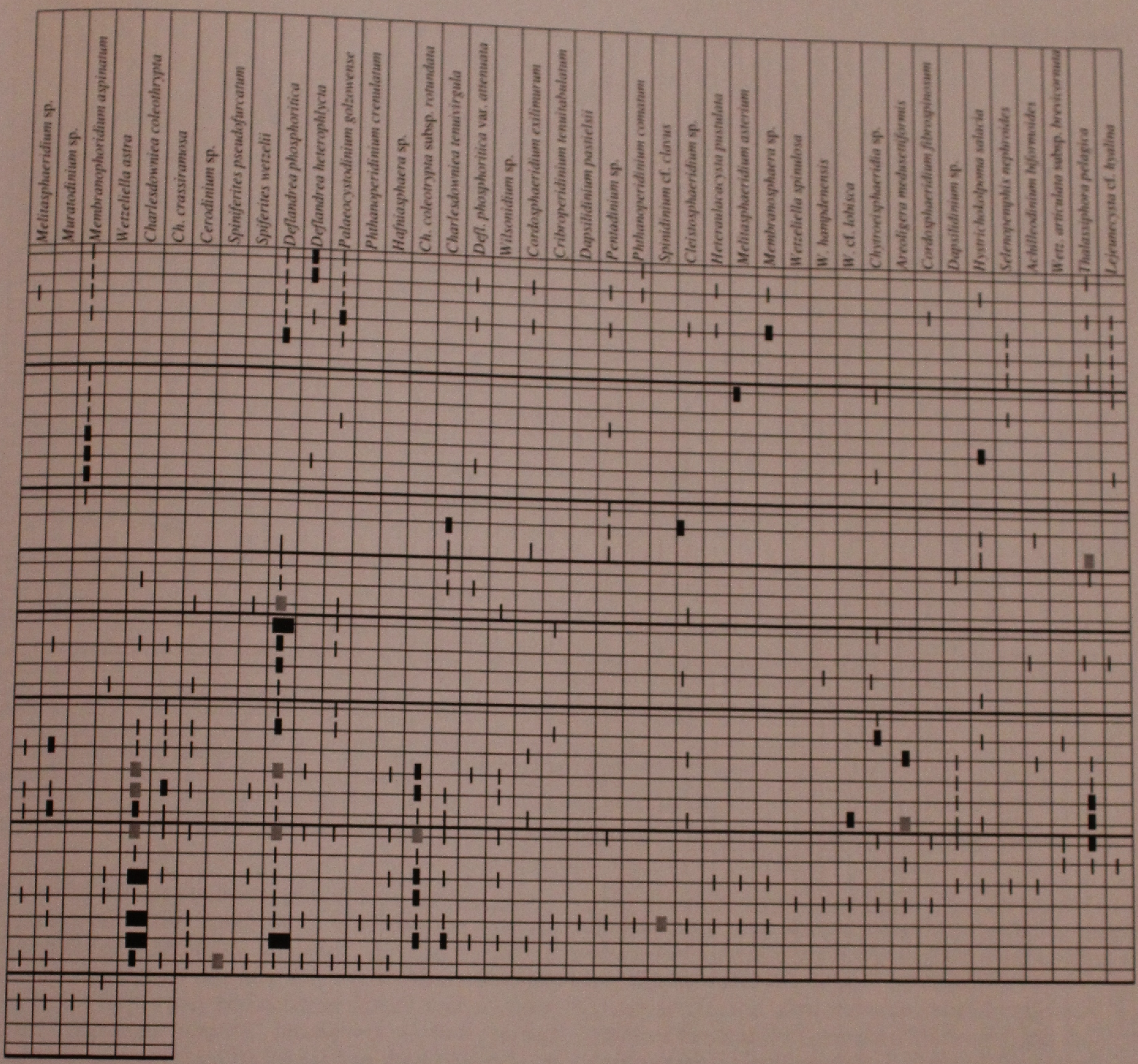
Foraminifers. Species *Glomospira* ex gr. *gaultina* and *G. gordialiformis* are identified in samples from the

Table 1. (Contd.)



depth levels of 519, 518, and 516 m (*G. gordialiformis* Beds). In the rank of zone, the beds were distinguished by Podobina [7] in the lower Lyulinvor Subhorizon of West Siberia.

Spores and pollen. Palynomorphs of higher plants (*Pinus* sp., *Protocedrus* sp., Taxodiaceae, *Trudopollis* sp., *Tricolporopollenites* sp., *Triporopollenites* sp., *Lygodium* sp.) occur as rare specimens.



Magnetostratigraphy. The lower Lyulinvor Subformation spans four zones N_1ll, R_1ll, N_2ll, and R_2ll of normal and reversed polarity, which are 9, 5, 4, and 9 m thick, respectively. The lower (N_1ll) and upper (R_1ll) ones are longest in duration (Fig. 5).

Electric logging. Records in electric logs for the lower Lyulinvor Subformation are poorly differentiated. The apparent resistivity values (AR) correspond to 4–5 ohm. Spontaneous polarization (SP) is also low (3 to 4 mV). In the basal sandstone bed, the AR and SP parameters increase up to 12–15 ohm and 7–12 mV, respectively (Fig. 6).

Upper Lyulinvor Subformation. The subformation penetrated by Borehole 9 in the depth interval of 493–435 m is 58 m thick. Its basal bed of fine-grained glauconite sandstone overlies the erosion surface of underlying deposits. Distinguishable in the rest of the sequence are two members. The lower Member "a" of light gray interlayering diatomaceous and opoka-like clays (depth interval of 493–451 m) encloses a bed of sandstone with cherty matrix, which is 1 m thick (depth interval of 470–469 m). The overlying Member "b" is composed of dark green clays (depth interval of 450–435 m), which bear scales and fine fish detritus and are intercalated with sandstone and siltstone interlayers up to 1 m thick (depth intervals of 451–450 and 448–447.5 m). Near the top, the clays are enriched in sandy and silty material. As is shown below, the upper half of Member "b" can be distinguished based on organic-walled phytoplankton as a separate biostratigraphic unit that is lacking, however, the distinctive lithologic features. In the core section 9, the subformation rocks yield the

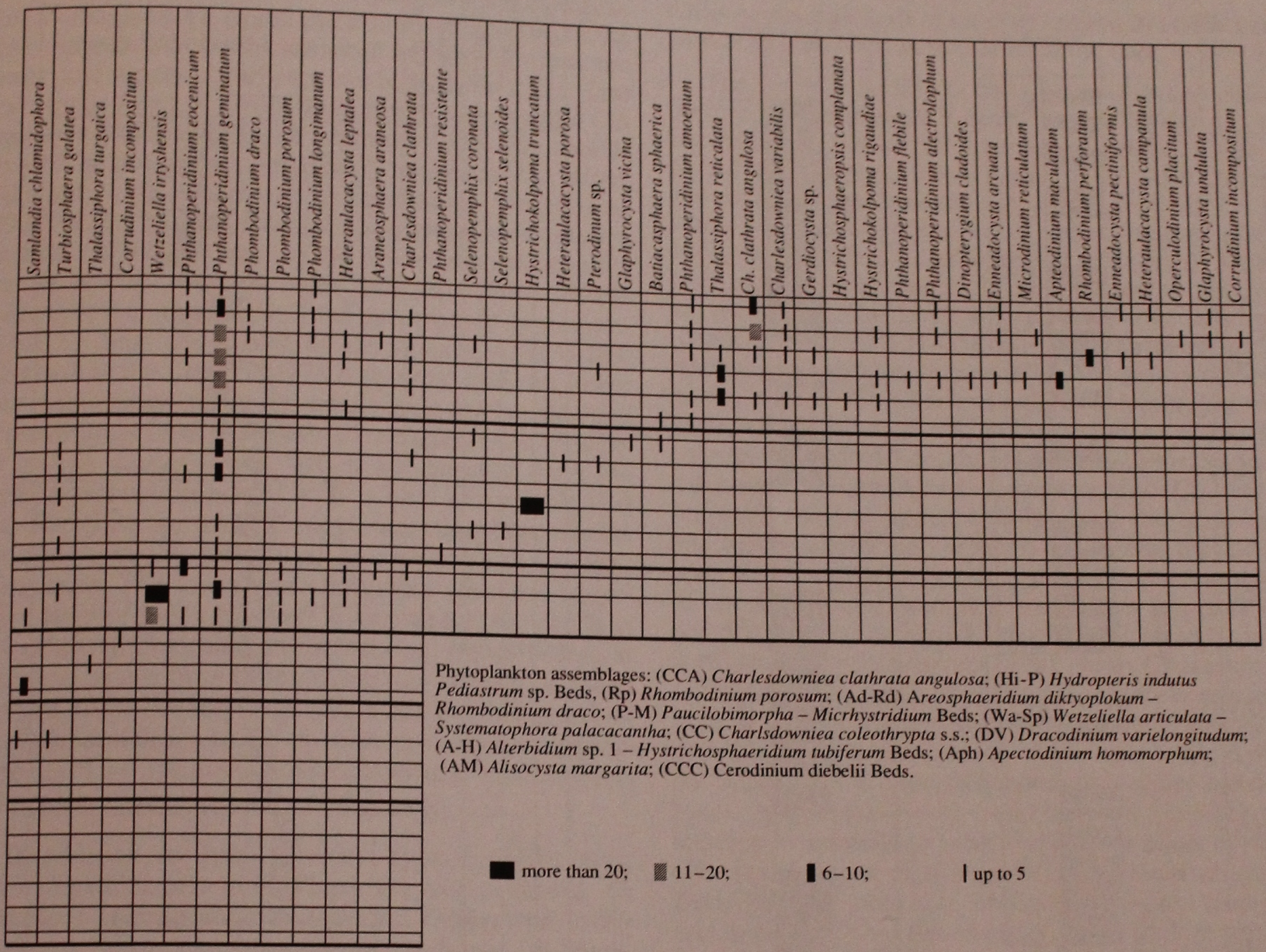
Table 1. (Contd.)

Series	Stage	Formation, Subformation	Dinocyst assemblages and zones	Depth level, m	*Deflandrea arcuata*	*Achilleodinium latispinosum*	*Spiniferites membranaceus*	*Hystrichosphaeropsis* sp.	*Samlandia* sp.	*Hystrichokolpoma granulata*	*Hystrichokolpoma cinctum*	*Fibrocysta vektensis*	*Lentinia serrata*	*Glaphyrocysta exuberans*	*Dapsilidinium pseudocolligerum*	*Paralecaniella indentata*	*Homotryblium abbreviatum*	*Lentinia wetzelii*	*Operculodinium microtrianum*	*Diphyes ficusoides*	*Deflandrea leptodermata*	*Thalassiphora patula*
Eocene	Priabonian	Tavda, upper	CCA	277				¦			+		+	■								
				284				¦					¦									
				295				¦														
				304	+				+				+									
				313				+						+								
				326																		
	-? Bartonian		Hi–P	330				+					+									
				337																		
				343																		
				359													+					
				367																		
				380																		
		Tavda, lower	Rp	392					+								¦					
				400				¦			+						¦					
				408				¦	+								¦					
			Ad–Rd	412	+								+									
				420				+														
				435												+						
	Lutetian	Lyulinvor, upper	P–M	437																		
				444														+				
				443.2	+																	
				444																		
			Wa–Sp	444.6					+												+	
				445.6																		
				446.3												+						
				447	+				+					¦								
				448										¦	+					+	+	+
				449.6					+					¦	+	+	+	+	+			
	Ypresian		Cc	451	+	+	+	+	+	+	+	+	+									
				454																		
				458																		
				460																		
				462																		
				464																		
				466																		
			DV: DVs.s.	468																		
				474																		
				477																		
				478.8																		
			DV: A–H	480																		
				483																		
				486																		
				489																		
				491																		
				492.5																		
Paleocene	Thanetian	Lyulinvor, lower	Aph	496																		
			AM	502																		
				506																		
				511																		
				514																		
				516																		
				518																		
Cretaceous	K2m	Gan'kino	CCC	522.5																		
				525.5																		

Depth level, m	*Homotryblium* sp.	*Heteraulacacysta pustulata*	*Charlesdowniea reticulata*	*Homotryblium tenuispinosum*	*Pentadinium laticinctum*	*Adnatosphaeridium robustum*	*Areosphaeridium diktyoplokum*	*Kisselovia* sp.	*Kisselovia ornata reticulata*	*Kisselovia ornata*	*Rhombodinium* sp.	*Thalassiphora elongata*	*Homotryblium oceanicum*	*Wilsonidium echinosuturatum*	*Glaphyrocysta semitecta*	*Deflandrea truncata*	*Deflandrea antarctica*	*Dapsilidinium simplex*
277							¦				¦							
284							¦				¦							
295				+	+		¦				¦	+			+			
304					¦		■				¦							
313											+							
326																		
330							+								+			
337																		
343																		
359																		
367			+															
380					+		+								+			
392	+						+						+					
400			¦	¦							¦	■	+		+			
408	+		+	+							¦							
412	+			+			+			+								
420												+			+			
435							+											
437							▒											
444						+	■											
443.2							¦											+
444							¦	▒	■	+	+	+	+	+	+	+	+	
444.6							+											
445.6		+			+	+												
446.3	+			■														
447			+	+														
448	+	+																
449.6																		
451																		

diverse assemblages of various microplankton groups (diatomaceous algae, radiolarians, benthic and planktonic foraminifers, organic-walled phytoplankton, spores and pollen).

Borehole 011BP penetrated only an upper portion of Member "a" with the hardground surface at the top. Drilling at this site was terminated at the depth of 498 m. The top of the upper Lyulinvor Subformation was



penetrated here at the depth of 456.2 m, and the recovered interval of this subdivision is as thick as 41.8 m. Like in the core section 9, Member “a” is composed of interlayering opoka-like and silty clays, which are light gray in the upper part and colored darker near the base of the recovered interval. Interlayers of fine-grained sandstone and siltstone (0.1 to 0.2 m thick) have been penetrated at the depth levels of 486.4 and 471 m. Like at the other site, the content of silty material, dispersed glauconite grains included, increases in the upper 4-m-thick interval of the sequence close to the contact with the overlying Tavda Formation. This interval correlative with Member “b” of the core section 9 is partially preserved after erosion. Rocks of the upper Lyulinvor Subformation, which have been recovered by Borehole 011BP, also yield abundant microplankton.

Organic-walled phytoplankton. Aleksandrova and Zaporozhets studied 26 samples: 15 from Member “a” and 11 from Member “b” of the core section 9 sampled at the depth levels of 492.5, 490, 489, 486, 480, 478.8, 477, 474, 468, 466, 464, 462, 460, 458, 454, 451, 449.6, 448, 447, 446.3, 445.6, 444.6, 444, 443.2, 440, and 437 m. In addition, Kul’kova studied 10 samples from the depth range of 490–440 m, where they were taken with the in-between intervals of 5 m. Dinocysts (10–12 to 70–75 species) were macerated from all the samples, some of which also yielded abundant prasinophytes and acritarchs. The distinguished dinocyst assemblages characterize the *Dracodinium varielongitudum* s. l. Zone of the middle Ypresian (492.5–466 m), the *Charlesdowniea coleothrypta* s. l. Zone of the upper Ypresian–lower Lutetian (466–451 m), and the *Wetzeliella articulata* (acme)–*Systematophora placacantha* Zone of the upper Lutetian (449.6–444 m). The former two zones are distinguished in Member “a,” and the third one spans the lower half of Member “b.” The interval between depth levels 444 and 435.5 m is ranked as the *Paucilobimorpha* (*Micrhystridium*) Beds according to their dominant taxa representing up to 70% of the organic-walled phytoplankton assemblage.

In the core section 011BP, Kul’kova studied 15 samples (depth interval of 497.7–454.8 m) from the upper Lyulinvor Subformation, and Zaporozhets additionally investigated 5 samples from the depth levels of 498, 490.5, 470.8, 459, and 456 m. They distinguished the uppermost part of *Dracodinium varielongitudum* Zone (samples from depth levels of 498 and 493.7 m) and the overlying *Charlesdowniea coleothrypta* Zone (493.2–

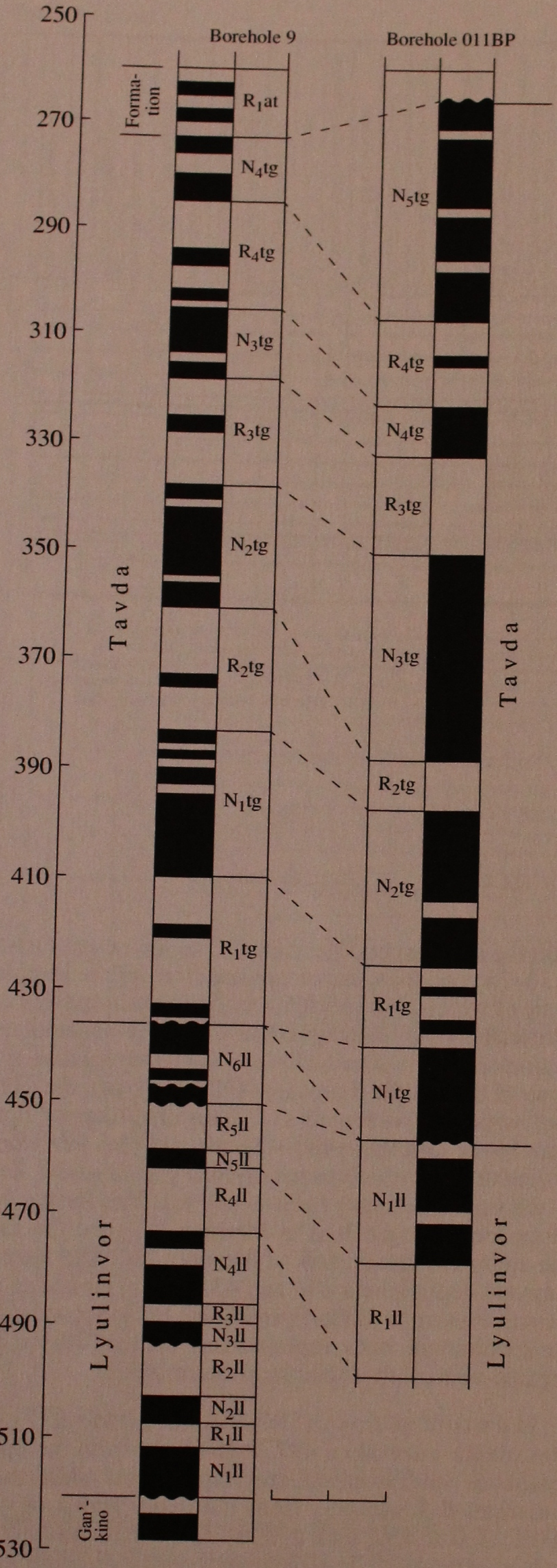


Fig. 5. Magnetostratigraphy of boreholes 9 and 011BP.

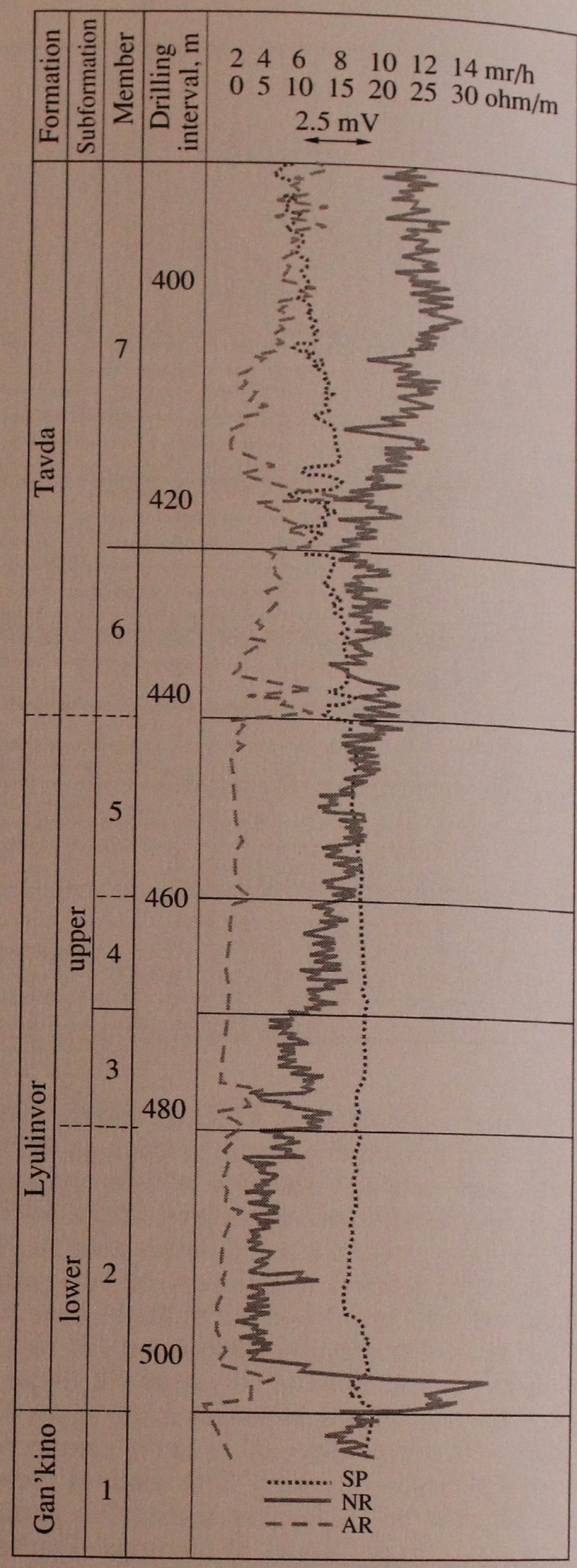


Fig. 6. Electric logs, Borehole 9, depth interval of 510–390 m: (SP) spontaneous polarization; (NR) natural radioactivity; (AR) apparent resistivity.

?460 m). In opinion of Zaporozhets, two samples from depth levels of 459 and 456 m belong to the *Wetzeliella articulata* (acme)–*Systematophora placacantha* assemblage, while Kul'kova believes that they still exemplify the preceding *Charlesdowniea coleothrypta* s. l. Zone.

In the core section 9, the *Dracodinium varielongitudum* Zone spans the depth interval of 492.5–466 m. Its base corresponds to the erosion surface between the lower and upper Lyulinvor subformations. The first occurrence level of *Dracodinium varielongitudum* (15 grains) is established at the depth of 491m. The zone is divided in two parts (subzones?) termed as the *Alterbidinium* sp.1–*Hystrichosphaeridium tubiferum* (492.5–478.8 m) and *Dracodinium varielongitudum* s. str. beds (478.8–466 m). In the lower beds, their index species is rare, whereas other indicative forms of the zone represent up to 50% of the spectrum in some samples. The mass abundance of the index species is first recorded at the depth of 478.8 m only, and the lower part of this biostratigraphic subdivision can be regarded as transitional from the lower *Wetzeliella meckelfeldensis* and *D. simile* zones, which are missing from the studied succession however. It is also remarkable that *Alterbidinium* sp. and *H. tubiferum* disappear almost completely in the interval of *D. varielongitudum* predominance. The lower zone boundary (the first occurrence level of index species) is recorded at the depth of 491 m above the hiatus in the section. Nevertheless, it is logical to attribute to this zone the interval of sands (sample from the depth of 492.5 m) occurring below this level and down to the erosion surface. The appearance level of frequent *Charlesdowniea coleothrypta* defines the upper boundary of the zone.

In addition to index species, typical of the zone under consideration are *Glaphyrocysta ordinata, G. pastielsii, Hafniasphaera septata, Deflandrea oebisfeldensis, Hystrichosphaeridium tubiferum, Achomosphaera crassipellis, Cordosphaeridium biarmatum, Horologinella inculta*, and some other forms. Species *Spiniferites granomembranaceus, Cerodinium depressum*, and *Operculodinium uncinispinosum* are characteristic of this zone only and do not occur above it. Taxa characteristic of older assemblages occur in the lower interval and may be partially redeposited. These are either *Areoligera senonensis, Alterbidinium* sp.1, *Kallosphaeridium brevibarbatum* and other *Kallosphaeridium* forms, or species limited in distribution by the upper zonal boundary and occurring as single specimens above it. The *Cordosphaeridium, Achomosphaera, Spiniferites*, and *Deflandrea* species mostly belong to transit taxa. *Noremia* and *Cometodinium* forms are characteristic representatives of prasinophytes and acritarchs from the lower part of the zone. Beginning from the depth of 478.5 m, there is recorded a mass abundance of *Dracodinium* species (*D. varielongitudum, D. condylos, D. politum*). Other encountered forms are *Wetzeliella articulata, Charlesdowniea edwardsii, Eatonecysta ursulae, Adnatosphaeridium multispinosum, Apteodinium* spp., *Rottnestia borrusica, Soanella granulata, Thalassiphora delicata*, and single specimens of *Tectatodinium* sp., *Lingulodinium* sp., *Impagidinium* sp., *Spinidinium* sp., and *Selenopemphix* sp. The dinocyst assemblage from *Dracodinium varielongitudum* Beds of the core section 011BP is very similar in composition to that from the core section 9.

The lower boundary of the *Charlesdowniea coleothrypta* Zone (Borehole 9, depth interval of 466–451 m; Borehole 011BP, depth interval of 493–459 m) is placed at the first occurrence level of its index species, and the upper one is established at the depth of 451 m, where the index species is still rather frequent (especially subspecies *Ch. coleothrypta rotundata*). Nevertheless, noticeable changes in composition of dinocysts are recorded at this level, where a sandstone interlayer (depth interval of 451–450 m) has been deposited in response to a sudden change in sedimentation environment. Within the *Charlesdowniea coleothrypta* s. l. Zone, distribution of *Ch. coleothrypta* s. s. and *Ch. coleothrypta rotundata*, the index taxa of synonymous subzones, is established conventionally. *Ch. coleothrypta rotundata* appears 10 m above the zone base, and its abundance rate is much lower than that of *Ch. coleothrypta* up to the depth of 454 m. In the upper beds of zonal sequence (samples from depth levels of 458 and 451 m), the indicated subspecies is already dominant among representatives of the genus *Charlesdowniea*, although it coexists with *Ch. coleothrypta* even here. The appearance level of abundant *Wetzeliella articulata*, the index species of the next zone, defines the upper limit of biostratigraphic unit under consideration. Above the lower boundary, *Ch. coleothrypta* appears in association with *Deflandrea phosphoritica, Ch. tenuivirgula, Cribroperidinium tenuitabulatum, Dapsilidinium pastielsii, Melitasphaeridium asterium*, and *Achilleodinium biformoides*. In the middle part, the associated newcomers are *Thalassiphora pelagica, Lejeunecysta hyalina*, and *Areoligera medusettiformis*. Dominant in the zone are representatives of genera *Deflandrea, Cordosphaeridium, Spiniferites, Glaphyrocysta*, and *Wetzeliella*. Species of genera *Systematophora, Spinidinium*, and *Horologinella* are also abundant in some samples. The abundance rate of acritarchs and prasinophytes is insignificant.

The stratigraphic range of *Ch. coleothrypta* dinocyst assemblage is easily recognizable owing to the mass abundance of its index species and subspecies *Ch. coleothrypta rotundata*, which occur in association with diverse representatives of genera *Deflandrea, Spiniferites, Cordosphaeridium*, and *Operculodinium*. *Wetzeliella articulata* is not infrequent as well, but *Alterbidinium* sp. 1, *Areoligera senonensis*, and *Kallosphaeridium* forms characteristic of older assemblages do not cross the lower boundary of *Charlesdowniea coleothrypta* Zone. The occurring single specimens of *Dracodinium varielongitudum*, the index species of underlying zone, disappears near the upper boundary of the zone.

In the core section 011BP, Kul'kova identified at the depth of 492,5 m the following taxa: *Areoligera* cf. *senonensis, Cerodinium sibiricum, Gonyaulacysta* sp., *Deflandrea dissoluta, D. oebisfeldensis, Deflandrea* sp., *Dracodinium varielongitudum, Deflandrea phosphoritica, Wetzeliella* cf. *articulata, Wetzeliella* sp., *Cordosphaeridium funiculatum, Homotryblium abbreviatum, Homotryblium* sp., *Spiniferites* spp., *Hystrichosphaeridium* sp., *Enneadocysta arcuata, Thalassiphora pelagica, Wilsonidium* sp., *Apectodinium* sp., *Phthanoperidinium stockmansii, Rhombodinium coronatum, Hystrichosphaeridium tubiferum, Samlandia chlamidophora, Hystrichokolpoma* sp., *Achomosphaera* sp., *Spiniferites ramosus, Soaniella granulata*, and *Charlesdowniea tenuivirgula*.

In opinion of Zaporozhets, the upper part of the upper Lyulinvor Subformation in the core section 011BP is already beyond the *Wetzeliella articulata* (acme)–*Systematophora placacantha* Zone of the lower Lutetian. Her opinion is substantiated by absence of index species *Ch. coleothrypta* in samples from the depth levels of 459 and 456 m, while *Wetzeliella articulata* is a common component in the former and dominant taxon in the latter.

The lower boundary of *Wetzeliella articulata* (acme)–*Systematophora placacantha* Zone (Borehole 9, depth interval of 449–444 m; Borehole 011BP, depth interval of 459–456 m) marks the mass appearance level of the first species. This taxon represents up to 15% and over 25 and 10% of dinocyst assemblages from the depth levels of 449.6, 448.5, and 447 m, respectively. Since the greater amount of *Wetziella* forms have not been identified at the species level because of a poor preservation state, the total abundance rate of specimens representing this genus is not less than 50% and more. The second species *Systematophora placacantha* is less abundant and represents 3 to 5% of the assemblages. Its last occurrence is recorded in the green clay member, above which the species does not occur. Nevertheless, the mass development of prasinophytes and acritarchs, but not the disappearance of *Systematophora placacantha* and appearance of single *Areosphaeridium diktyoplokum* species, is the most significant biotic event that has been probably related to a quick shoaling and partial freshening of the basin. As we believe, the upper boundary of the zone should be exactly at this level to be significant in both the stratigraphic (in core section 9) and ecologic aspects. In the core section 011BP, an upper part of the zone corresponds to a break in sedimentation.

The *Wetzeliella articulata–Systematophora placacantha* assemblage is very diverse (70–80 taxa), with well represented chorate cysts (genera *Cordosphaeridium, Operculodinium*, and others). It includes many new taxa (*Glaphyrocysta exuberans, Diphyes ficusoides, Dapsilidinium pseudocolligerum, Homotryblium oceanicum, H. tenuispinosum, Deflandrea arcuata*, and others) in addition to species widespread in older assemblages, such as *Charlesdowniea* forms, the index species of preceding zone included, *Eatonicysta ursulae, Wetzeliella meckelfeldensis, Heteraulacacysta pustulata, Glaphyrocysta ordinata, Apteodinium* sp., *Areoligera* sp., and *Apectodinium* sp. Also characteristic of the zone are very diverse species of genera *Homotryblium, Deflandrea, Cordosphaeridium, Glaphyrocysta, Operculodinium, Spiniferites, Achomosphaera, Apteodinium, Wetzeliella, Thalassiphora*, and *Spinidinium*.

In the core section 9, the uppermost part of the green clay member (depth interval of 444–435 m), which bears fish remains, is attributed to the *Paucilobimorpha–Micrhystridium* Beds of the terminal Lutetian–?basal Bartonian. In the core section 011BP, this interval corresponds to a hiatus. As is noted above, the assemblage with prasinophytes and acritarchs indicative of progressive basin shoaling is primarily of ecologic rather than of age significance, and we withhold comments here about its correlation with the dinocyst zonation.[1] When abundance and diversity of prasinophytes and acritarchs grew, the dinocyst species simultaneously decreased in number to 30–40 euryhaline forms (reduced to a half at least), while siliceous plankton became extinct. *Paucilobimorpha triradiata* and to a lesser extent *P. granuligera* are dominants of the prasinophytes–acritarch assemblage. Both taxa appear at this level for the first time. They coexist with single specimens of *Cymatiosphaera* forms, *Paucilobimorpha tripus*, and *Schizocysta* sp. *Deflandrea* species are as abundant and diverse as in the previous assemblage, but *Wetzeliella* forms are replaced by representatives of the genus *Kisselovia*. Many forms, especially the Paleocene taxa *Cerodinium markovae, C. diebelii, Kallosphaeridium*, and *Deflandrea oebisfeldensis*, are redeposited. Remarkable among species occurring in the beds under consideration are *Wetzeliella echinulata, Lejeunecysta globosa, Glaphyrocysta semitecta, Lentinia wetzelii*, and *Samlandia chlamidophora*. Many other taxa, e.g., *Tectatodinium, Cordosphaeridium, Deflandrea, Apteodinium, Cribroperidinium, Microdinium, Thalassiphora, Phelodinium, Spinidinium, Achilleodinium, Impagidinium, Hystrichokolpoma*, and *Hystrichosphaeropsis*, are of wide stratigraphic ranges.

Planktonic foraminifers. Species *Pseudohastigerina wilcoxoensis* and *Subbotina eoc enica* are identified in two samples from depth levels of 477 and 451 m of the core section 9, i.e., in Member "a" of light gray opoka-like clays. In the core section 011BP, a sample from the borehole bottom (depth 498 m) yielded *Subbotina eocaenica, Pseudohastigerina wilcoxensis, Subbotina pseudoeocena*, and *Acarinina* sp. (determinations by Krasheninnikov and Beniamovskii). In opinion of the latter, representatives of the genus *Acarinina* may be classed with *A. convexa*.

Planktonic foraminifers have been also macerated from two samples (depth levels of 449 and 445 m) characterizing Member "b." At the former level, Beniam-

[1] The terminal beds of the upper Lyulinvor Subformation in the depth range of 440–435 m seem to be corresponding, like the basal Tavda beds, to the *Areosphaeridium diktyoplokum–Rhombodinium draco* Zone, because both index species have been found in a sample from the depth of 440 m.

ovskii identified *Subbotina subtriloculinoides, S. ratusa, S. boweri, Acarinina rotundimarginata* (Krasheninnikov approved identification of the last taxon), *Acarinina* spp., and *Pseudohastigerina micra*, and this assemblage can be attributed to the *Acarinina rotundimarginata* Zone. At the next level, he identified *Hantkenina australis, Acarinina rotundimarginata, A. rugosoaculeata, Subbotina inaequispira, S. pseudoeocaena*, and a fragment of test resembling *S. turcmenica*. In the same sample, Krasheninnikov established presence of *Hantkenina alabamensis* and *Acarinina rotundimarginata*. The entire assemblage can be regarded as characteristic of the *Hantkenina alabamensis* Zone (the upper *H. australis* Subzone) of the upper Lutetian–lower Bartonian.

Benthic foraminifers. Agglutinated benthic foraminifers, among which *Bolivinopsis spectabilis* is leading taxon, have been encountered at the depth of 491 m in Borehole 9. Within the depth interval of 479–443 m, their assemblage is represented by *Ammomarginulina deflexa, A. spectata, Bathysiphon eocenicus, Bolivinopsis spectabilis, Gaudryinopsis subbotinae, Hyperammina friabilis, Hypperamminoides crumena, Rhabdammina cylindrica, Rhizammina indivasa, Labrospira granulosa, L. honesta, Proteonina* spp., *Psammosphaera laevigata, Reophax ampulacea, R. difflugiformis, R. subfusiformis, R. scorpirus, Saccammina sphaerica, Textularia carinatiformis, Trochammina gracilis, T. infirma*, and *Verneulinoides paleogenicus*. The index species of *Textularia carinatiformis* Zone defines biostratigraphic range of this assemblage. Within that zone (depth range from 454 to 446.5 m), there are the *Gaudryinopsis subbotinae* Beds. An assemblage of secretory foraminifers characteristic of the *Uvigerina costellata* Zone was found at the depth of 449 m. This assemblage includes *Bolivina microplancetiformis, U. castellata, Cibicides westi, Nodosaria ewaldi, N. longiscata*, and *Robulis inornata*. Secretory foraminifers from a higher level of the green clay member (depth 445 m) are represented by *Clavulinoides szaboi, Vaginulinopsis fragaria, Heterolepa eocaenica*, and *Planulina costate*, which belong to the upper part of the same *Uvigerina costellata* Zone distinguished in the Lutetian Kuberle and Kresty sequences of European Russia. In the core section 011BP, the entire upper Lyulinvor Subformation corresponds to the *Textularia carinatiformis* Zone characterizing the Lyulinvor sediments according to conclusions of É.N. Kisel'man.

Radiolarians. Kozlova who studied radiolarians from the upper Lyulinvor Subformation of both core sections discriminated three biostratigraphic subdivisions.

(1) The *Heliodiscus inca* Zone is established in the lower part of the upper Lyulinvor Subformation: Borehole 9, depth interval of 478,8–491m, and Borehole 011BP, depth interval of 493–498 m. A typical early Eocene (Ypresian) assemblage of the West Siberian type is confined to the indicated intervals. In addition to the index species, the assemblage includes *Acropyramis magnifica* (Clark et Campbell), *Spongocyclia composita* (Kozlova), *Stylosphaerella irinae*, (Lipman), *Heliodiscus hexasteriscus* Clark et Campbell, and new species *Apoxprunum curganica* Kozlova, which prevail over somewhat less abundant *Conoactinomma stilliformis* (Lipman) and *Lophosphaena sibirica* Gorbovetz. This assemblage of the middle Ypresian age is correlative with the nannoplankton Zone NP12 of the Paleogene standard and with the lower part of the *Morozovella aragonensis* Zone discriminated in succession of planktonic foraminifers of the Crimea–Caucasus region [8].

(2) The *Thecosphaerella turcmenica–Phacodiscinus testatus testatus* Beds span the middle and upper intervals of the upper Lyulinvor Subformation: Borehole 9, depth interval of 458–468.5 m, and Borehole 011BP, depth interval of 481–496 m. The beds reveal a considerable change in taxonomic composition of radiolarians whose assemblage includes a group of transit early Eocene and even late Paleocene taxa, such as *Amphicarydiscus biconstrictus* (Lipman), *Axoprunum inclarum* (Krasheninnikov), *Clathrocyclas multiplicatus* (Lipman), *Eucyrtidium striata exquisite* (Kozlova), and some others. These forms and associated fragments of the Late Cretaceous taxa point to erosion of older sediments, fossil fauna of which is redeposited. At the same time, the beds yield radiolarians, which are characteristic of younger *B. clinata–B. longa* and higher zones known in other regions (areas northward of the Caspian Sea, Ul'yanovsk region of the Volga River basin, and oceanic bottom sediments). These are *Albatrossidinium litos* (Clark et Campbell), *Amphymenium splendiarmatum* Haeckel, and *Periphaena splendida* (Lipman). The other species, *Axoprunum chabakovi* (Lipman), *Phacodiscinus testatus testatus* (Kozlova) and *Thecosphaerella turcmenica* (Lipman) included, which may occur sporadically in underlying horizons, show their mass abundance exactly in the *Buryella clinata–Buryella longa* and *Lychnocanium separatum* zones. Accordingly, the above radiolarian assemblage suggests that the stratigraphic interval under consideration may correspond to the *B. clinata–B. longa* Zone. Nevertheless, the index species and some other taxa characteristic of the zone have not been found in the assemblage, and the interval is attributed therefore to the *Thecosphaerella turcmenica–Phacodiscinus testatus testatus* Beds. The *B. clinata–B. longa* Zone of the terminal Ypresian is correlative with the nannoplankton Zone NP13 and with the upper part of *Morozovella aragonensis* Zone [8].

(3) The *Conocaryomma aralensis–Phacodiscinus testatus subsphaericus* Beds are recognized in the upper and terminal parts of the upper Lyulinvor Subformation: Borehole 9, depth interval of 445–458 m, and Borehole 011BP, depth interval of 459–473,5 m. Their lower boundary is defined at the appearance level of *Acanthosphaera formosa* Krasheninnikov. *Conocaryomma aralensis* Lipman and *Phacodiscinus testatus sub-*

sphaericus (Lipman) appear above this level, and mass accumulations of the latter are very characteristic of the *Lychnocanium separatum* Zone. Nearly at the top of the beds, there have been found *Phacodiscinus fragilis* (Totschilina) and *Stylosphaerella megaxyphos* (Clark et Campbell), the first appearance of which is usually confined to the *L. separatum* Zone. The *Lychnocanium separatum* Zone spans the lower part of the Lutetian Stage. It is correlative with the nannoplankton zones NP14 and NP15 and with *Acarinina bullbrooki* and *A. rotundimarginata* zones of planktonic foraminifers.

According to data of Vitukhin, radiolarians are abundant and diverse at the depth level of 462 m. Nevertheless, some nasselarian species represented by single specimens at the depth of 468.5 m have not been found at the level in question that marks the first appearance of *Siphocampe minuta, Lithostrobus picus, Dictyopora urceolus, Theocyrtis* sp., *Heliodiscus inca*, and *Phacodiscinus* aff. *testatus*. Species *Spongodiscus americanus* and *Spongotrochus radiatus* dominate here among spumellarians, and *Siphocampe minuta* is a dominant taxon of nasselarians.

Radiolarians from the depth range of 458.5–454 m belong most likely to the *Buriella clinata–B. longa* Zone. As the index species is absent in the assemblage, the zone can be discriminated conventionally based on present characteristic taxa *Acanthosphaera formosa* and *Phacodiscinus testatus subsphaericus*. In general, radiolarians are noticeably less diverse in the above interval that yields, in addition to the aforementioned taxa, only *Heliodiscus hexasteriscus, Spongodiscus americanus, Spongotrochus alveatus, S. radiatus, Amphisphaera coronata, Haliomma triglobulata, Eusiringium striata striata, Clathocyclas elegans, Lychnocanium* sp., and *Siphonocampe minuta*.

The assemblage from the depth range of 451–445 m (Member "b") is of a different composition. Species *Cenocaryomma aralensis* and *Calocyclas asperum* found here are characteristic of the *Lychnocanium separatum–Heterestrum schabalkinii* Zone, the index species of which have not been found however. Besides the fragmented Sphaeroidea tests and single nasselarians, the other associated taxa are *Patagospyris* sp., *Petalospyris* sp., and *Lithomelissa* sp.

Diatomaceous algae. In Borehole 9, diatoms are present in the middle and upper intervals of the lower member of the upper Lyulinvor Subformation (depth range of 483–458.5 m), which is composed of light gray opoka-like clays (samples from the depth levels of 483, 478.9, 477, 476, 474, 468.5, 466, 464, 462, 460, and 458.5 m). Diatoms occur as well in the upper member of green clays bearing fish remains (samples from the depth levels of 446, 445.7, and 445.1 m). An impoverished assemblage of neritic diatom genera *Paralia* and *Arachnoidiscus* is characteristic of the depth levels 483 and 478.9 m. Species *Pyxilla gracilis, Grunowiella gemmata*, and *Coscinodiscus payeri* are found at the depth of 477 m. Beginning from the depth of 474 m, diatoms are more diverse. Taxa appearing here are *Coscinodiscus decrescens, C. decrescenoides, Hemiaulus elegans, H. polymorphus* var. *Pseudopodosira westi*, and silicoflagellates *Dyctiocha transitoria* and *Naviculopsis minor.* Newcomers *Coscinodiscus polyactis, C. bulliensis, C. heteroporus, Brightwellia hyperborea*, and *Pseudotriceratium* forms are recorded in the depth range of 462.5(458.5 m, where silicoflagellates *Dyctiocha rotundata* and *D. transistoria* (=*Naviculopsis minor)* are more abundant than below and representatives of the genus *Ebriopsis* appear as well. According to composition of diatoms, the depth interval of 478.5–458.5 m corresponds to the *Pyxilla gracilis* Zone, and its upper part (460–458.5 m) can be regarded as the *Coscinodiscus polyactis* Beds transitional to the *Pyxilla oligocaenica* Zone. Based on her own zonal scale, Glezer distinguished in the depth range of 466–458.5 m (samples from the depth levels of 466, 462, 460, and 458.5 m) the *Brightwellia hyperborea* assemblage and silicoflagellates of the *Dictyocha secta* Zone, considering them as corresponding to the upper part of the *Pyxilla gracilis* s. l. Zone.

Diatoms and silicoflagellates have not been found in the depth range of 457–446 m, but higher in the section Radionova who studied three samples from depth levels of 446, 445.7, and 445.1 m identified abundant *Pyxilla gracilis* Jouse var. *tenuis* and *Pyxilla oligocaenica* var. *oligocaenica*, which associate with single specimens of *Coscinodiscus decrescens* and *C. payeri.* In the same samples, she found neritic (*Paralia, Pseudopodosira westii, Pyxidicula crenata*) and benthic (*Arachnoidiscus ehrenbergii, Istmia enermis*, and others) diatoms, resting spores, and sponge spicules. The encountered silicoflagellate species are *Mesocena oamaruensis* and *M. eodentalis.* The diversity of diatoms decreases upward, and above the depth level of 445 m, they do not occur. As Radionova concluded, the studied interval of green clays, which accumulated during regression under conditions of the progressing shoaling, corresponds to the upper part of *Pyxilla oligocaenica* Zone. Strelinikova who also studied microfossils from the last depth level arrived at the same conclusion. In opinion of Glezer, samples from the level under consideration characterize the terminal part of *Pyxilla oligocaenica* var. *tenuis* Zone. Until the recent time, Glezer attributed this part to the *Stephanopyxis crenata* Subzone, but now she thinks that it may be regarded as an individual zone. The diatom assemblage from the depth of 443.6 m is unusual, containing species of the genus *Cosmiodiscus*, which are characteristic of stratigraphic levels above the *Pyxilla oligocaenica* var. *tenuis* Zone.

Strel'nikova also investigated diatoms in nine samples from the depth range of 492–458 m of Borehole 011BP. At the depth levels of 492, 490.8, 487.5, and 479 m, she encountered the half-decomposed diatom frustules of unclear taxonomic affinity. Macerates from the depth levels of 475.3, 469.3, 463.3, and 458 m turned out to be most rich in diatoms. An assemblage from the depth of 475.3 m undoubtedly belongs to the

Pyxilla gracilis Zone, and that from the depth interval of 469.3–458 m to the *Pyxilla oligocaenica–P. oligocaenica* var. *tenuis* Zone. Besides the index species, taxa characteristic of the *Pyxilla gracilis* Zone are *Hyalodiscus radiatus, Hyalodiscus* sp., *Pseudoposira westii, Paralia sulcata*, less frequent *Coscinodiscus* sp. aff. *argus, Stephanopyxis megapora*, and single specimens of *Stephanopyxis arctica, Odontotropis carinata, Gyrodiscus vortex, Epithelion rossicum*, and *Hemiaulus* sp. The silicoflagellate group includes dominant *Naviculopsis constricta* and *Dictyocha fibula* occurring in association with less abundant *Dictyocha rotundata* and *D. transitoria.* Ebriids are represented by *Pseudoammodochium dictyoides* and *Ebriopsis exigua.* Three other samples characterize the representative assemblage of the younger zone. At the depth of 469.3 m, the assemblage includes abundant *Pyxilla gracilis, P. oligocaenica, Hyalodiscus* sp., *Pseudopodosira corolla, P. westii*, and *Paralia sulcata*, which coexist with less abundant *Paralia crenulata, Stephanopyxis turris* var. *intermedia, St. turris* var. *cylindrus, St. megapora, Coscinodiscus decrescens, Coscinodiscus* sp. (with sections), and *C. heteroporus.* Ebriids *Ammodochium speciosum, Pseudoammodochium dictyoides*, and *Ebriopsis exigua* are also abundant here. The encountered silicoflagellate species are *Mesocena elliptica, Naviculopsis constricta*, and *Dictyocha rotundata.* Most abundant at the depth of 463.3 m are *Pyxilla oligocaenica, P. oligocaenica* var. *tenius* (slightly less frequent than the type form), *P. gracilis*, and *Hyalodiscus* sp. The associated taxa are represented by less abundant *Pseudoposira westii, P. wittii, P. aspera, Paralia clavigera*, and by single *Anaulus weiprechtii* and *Aulacodiscus* sp. Prevailing among ebriids are *Ebriopsis exigua, E. mesnili, E. aplanata*, and *Pseudoammodochium dictyoides*, whereas silicoflagellates are represented by *Dictyocha elata, D. rotundata, D. obliqua, Mesocena elliptica*, and *Naviculopsis constricta.* Sponge spicules are the main organic remains at the depth of 458 m. Diatom frustules are not rock-forming here. They mostly represent *Pyxilla oligocaenica* var. *tenuis, Paralia sulcata, Hyalodiscus* sp., and rare or single specimens of *Pyxilla gracilis, Coscinodiscus decrescens, Paralia clavigera*, and *Pseudoposira westii.* Among ebriids, only *Pseudoammodiscus dictyoides* is identified.

Spores and pollen. Palynomorphs are insignificant components of organic remains from the upper Lyulinvor Subformation, especially from its lower interval. Consequently, they may be of a corrective significance only by the age determination of particular levels. Aleksandrova who studied palynomorphs from the core section 9 found only scarce pollen grains of conifers (*Pinus, Protocedrus*) and tricolporate form taxa in the depth range of 492.5–483 m. At the depth of 480 m, occasional pollen grains of ancient Pinaceae occur in association with sporadic pollen of Myricaceae, *Plicapollis* ex gr. *pseudoexcelsus*, and *Triporopollenites robustus.* Kul'kova identified *Platycaryapollis pseudocyclus, Plicapollis pseudoexcelsus, Triporopollenites robustus, Castanea crenataeformis, Interpollis supplingensis, Myrica* sp., *Podocarpus* sp., *Taxodium* sp., *Pinus* sp., and spores Polypodiaceae and *Cyathea* sp. in the same section. She correlated this assemblage with the *Triporopollenites robustus–Plicapollis pseudoexcelsus* assemblage [9]. Zaporozhets who studied samples from the depth range of 478–460 m also established here a low content of pollen representing Pinaceae, *Castanopsis pseudocingulum, Pompeckjoidaepollenites* sp., *Tricolporopollenites cingulum*, åyricaceae, *Triporopollenites* sp., and *Trudopollis* sp. With a certain reservation, she correlated them with the assemblage of *Araliaceaepollenites euphorii, Sapotaceoidaepollenites manifestus, Pompeckjoidaepollenites subhercinicus*, and *Castanopsis pseudocingulum.* Presumably attributable to the same assemblage is the diverse pollen of the form taxa *Anacolosidites* sp., *Rhoipites* sp., *Tricolporopollenites* sp. (dominant), *Triporopollenites* sp., *Triatriopollenites* sp., *Trudopollis pompekjii*, and *Plicapollis* sp., which coexist with accessory Pinaceae, Taxodiaceae, and Fagaceae, such as *Castanopsis* sp. (dominant), *Castanea* sp., *Quercus graciliformis*, and *Q. gracilis.* Scarce pollen grains represent in this assemblage the thermophilic plants, such as Palmae, *Platycarya* sp., *Rhus* sp., Hamamelidaceae, *Liquidambar* sp. and others. In the light-colored opoka-like clays of both core sections, Kul'kova recognized a more complete pollen spectrum of the indicated zone. The spectrum includes *Castanea crenataeformis, Castanopsis pseudocingulum, Loranthus elegans, Engelhardtia quietus, Subtriporopollenites* sp., *Thiatriopollenites aroboratus, Tricolpopollenites* sp., *Tricolpopollenites liblarensis, Reevesia lubomirovae, Ulmodeipites tricostatus, Subtriporopollenites megagranifer, Hamamelis* sp., *Carya* sp., *Nyssapollenites* sp., *Myrtaceidites* sp., Palmae sp., and *Myrica* sp. An insignificant admixture of coniferous pollen represents *Podocarpus* sp., *Cedrus* sp., *Pinus* spp., and Taxodiaceae. The present spores are those of *Gleichenia* sp., *Osmunda* sp., Polypodiaceae, and *Lycopodium* sp. Some samples yielded pollen of the *Longaxones* type.

In samples from the depth interval of 454–446.3 m of Borehole 9, which have been studied by Zaporozhets, palynomorphs are of the same composition, and their content gradually increases from 10 to 30% upward in the section. Pollen of conifers is insignificantly abundant as before and represents a third of the spectrum at the depth of 447 m only. The form taxa identified in this interval are *Rhoipites* sp., *Tricolporopollenites* sp., *Triporopollenites* sp., *Plicapollis* sp. (possibly redeposited), *Trudopollis* sp., *Tricolporopollenites cingulum*, and *Triatriopollenites myricoides.* Dominant among natural taxa are Fagaceae (*Castanea, Castanopsis*, and evergreen *Quercus* species) in association with rather abundant Hamamelidaceae. This set of taxa may be correlated with the *Castanea crenataeformis–Castanopsis pseudocingulum* assemblage of West Siberia.

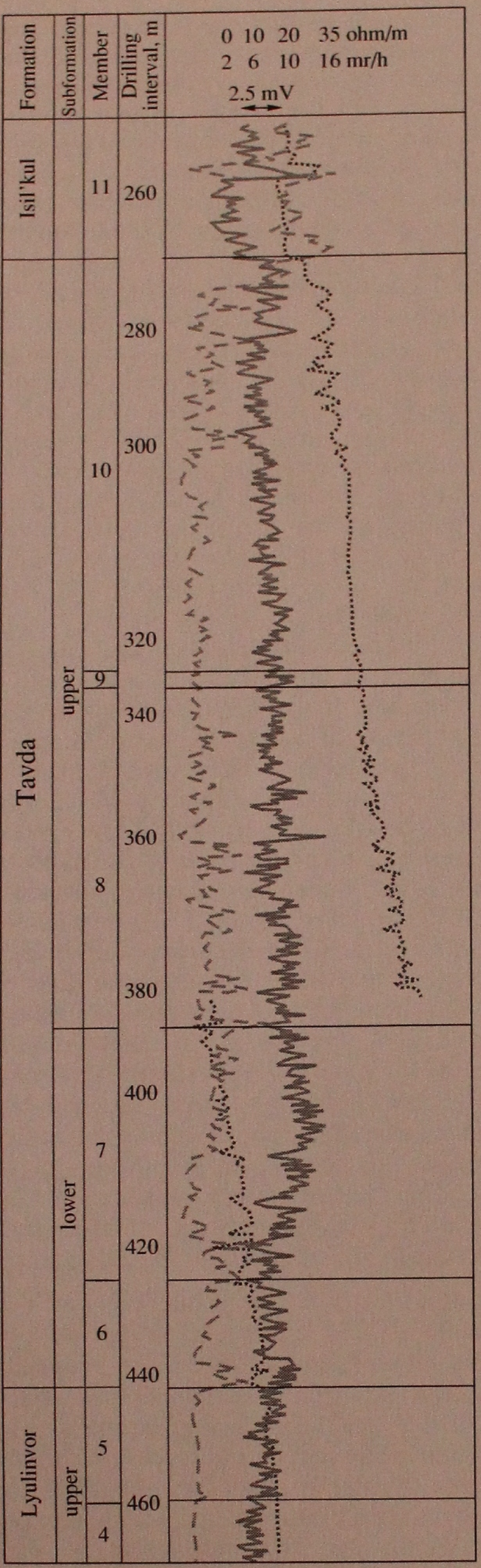


Fig. 7. Electric logs, Borehole 9, depth interval of 460–250 m (symbols as in Fig. 6).

The abundance and composition of palynomorphs sharply change in the section interval between 444 and 435 m, where the basin shoaling is recorded. Spores and pollen represent here 40 to 60% of the spectrum. They considerably prevail over dinocysts, percentage of which is equal to 10%. Pollen of flowering plants is somewhat more abundant than acritarchs and prasinophytes, which are more concentrated at this level as well. Conifers and Fagaceae constitute 25 and up to 50% of the spectrum, respectively. *Castanea* and *Castanopsis* (*C. pseudocingulum*) are still present among Fagaceae, but evergreen *Quercus gracilis* and *Q. graciliformis* are dominant in this family. Juglandaceae and Hamamelidaceae represent up to 8–9% of palynological spectra, while Betulaceae occur as occasional specimens. The identified Juglandaceae taxa are *Pterocarya* (up to 4%), *Juglans* (up to 3%), *Engelhardtia, Platycarya*, and *Carya* (scarce pollen grains). In the family Hamamelidaceae, percentages of *Corylopsis, Hamamelis, Liquidambar*, and *Fothergilla* (*F. gracile* included) are approximately equal (about 2%). The other taxa occurring in perceptible amounts are *Nyssa* (4%), *Rhus* (2%), *Acer* and *Comptonia* (1%). Pollen of *Myrica, Ulmus, Planera, Zelkova*, Moraceae, Ericaceae, *Tilia, Ilex, Eleagnus*, Oleaceae, *Cornus*, and *Nelumbo* is represented by single grains. Form species representing in sum not more than 5% are *Tricolporopollenites* sp. (4%), *Trudopollis pompeckjii, Plicapollis* sp., *Rhoipites* sp., and *Triporopollenites* sp. The described assemblage can be correlated with the regional *Quercus gracilis–Castanopsis pseudocingulum* assemblage.

Magnetostratigraphy. Seven magnetic polarity zones established in the upper Lyulinvor Subformation of the core section 9 are as follows: the normal polarity zones N_3ll, N_4ll, N_5ll, and N_6ll, and the reversed polarity zones R_3ll, R_4ll, and R_5ll with the normal polarity subzones inside two of them (Fig. 5). The zones range in thickness from 3 to 14 m. Two zones R_1ll and N_1ll, which are 20 and 22 m thick respectively, are established in this subformation recovered by Borehole 011BP.

The boundary between *Dracodinium varielongitudum* and *Charlesdowniea coleothrypta* is at the depth of 493.3 m inside the basal reversed-polarity zone R_1ll of the core section 011BP and at the depth of 466 m within the reversed polarity zone R_4ll in Borehole 9. As for the lower part of *D. varielongitudum* Zone penetrated by Borehole 9 only, it spans the interval of polarity zones N_3ll, R_3ll, N_4ll, and R_4ll (lower part). In the upper part of subformation recovered by Borehole 011BP, the *Charlesdowniea coleothrypta* and *Ch. coleothrypta rotundata* zones correspond to the interval spanning the greater part of the reversed polarity zone R_1ll and the normal polarity zone N_2ll with two reversed polarity intervals inside it. In the core section 9, the same stratigraphic interval corresponds to the reversed polarity zone R_4ll in its greater part, normal polarity zone N_5ll, and reversed polarity zone R_5ll. Frequent erosion

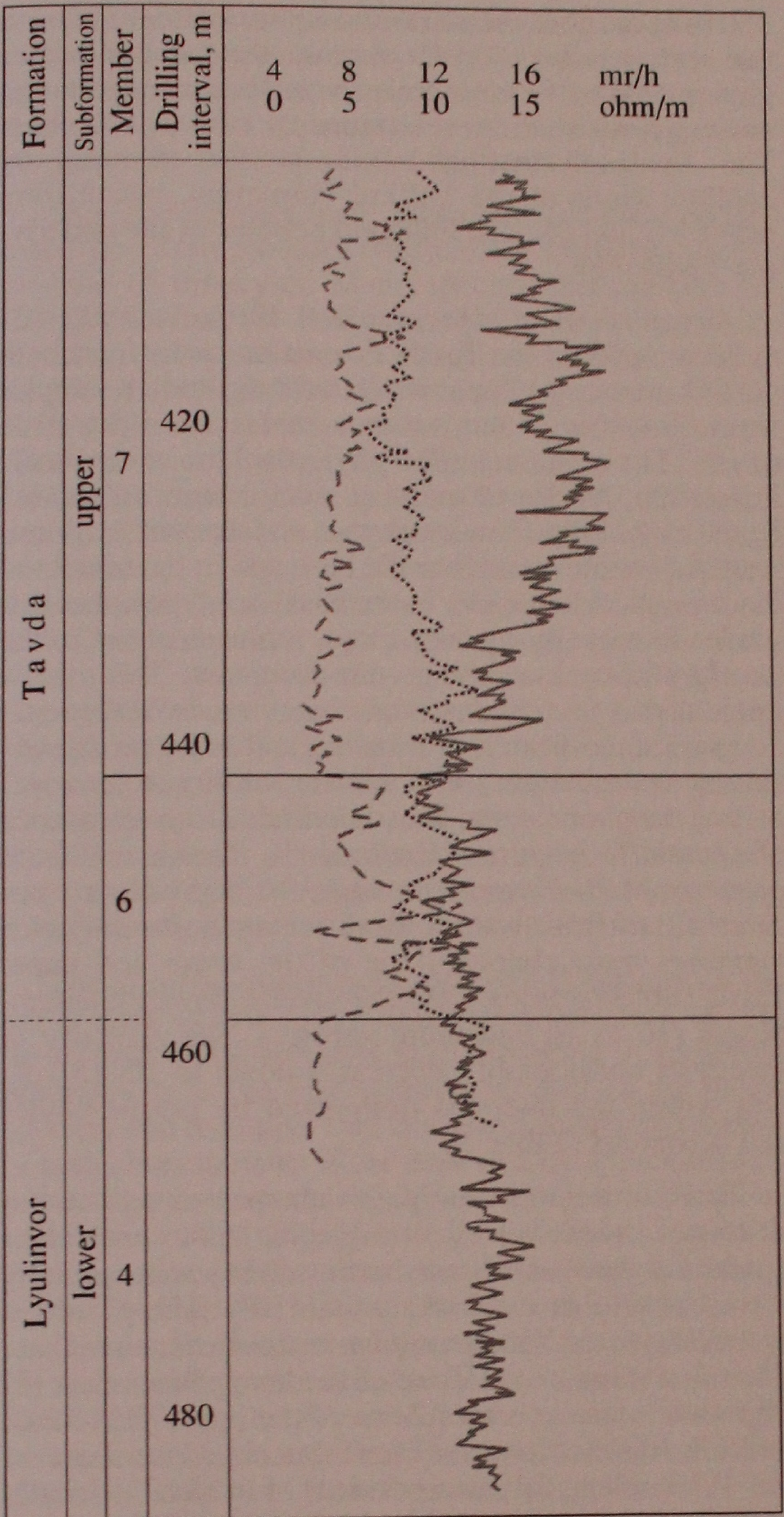


Fig. 8. Electric logs, Borehole 011BP, depth interval of 460–400 m (symbols as in Fig. 6).

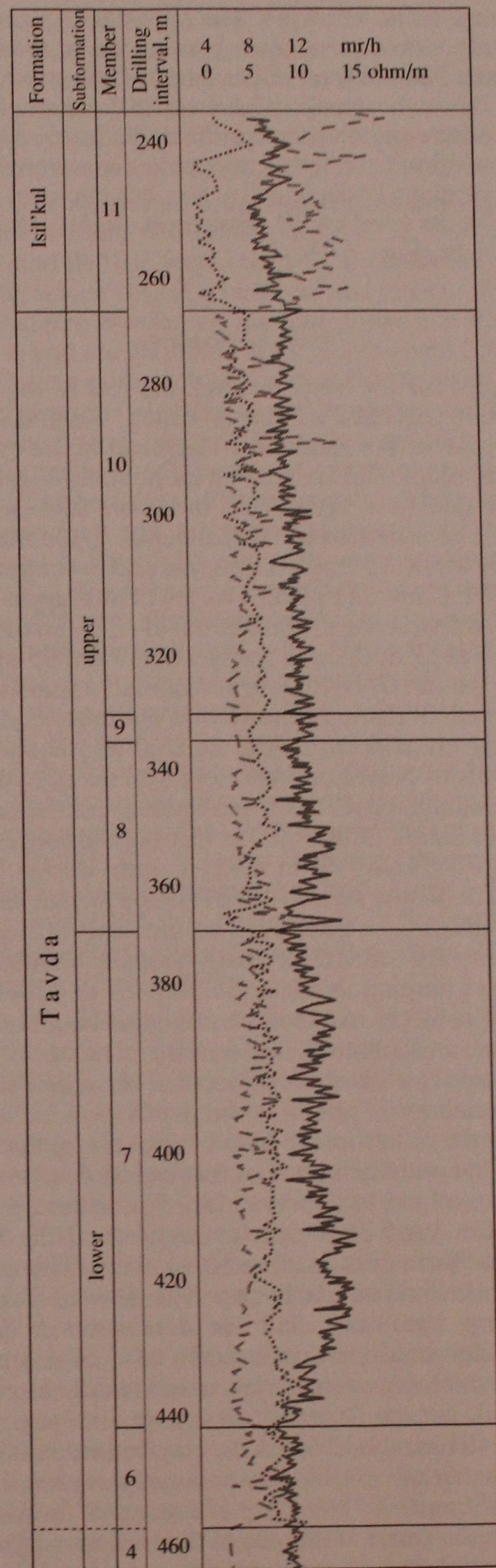


Fig. 9. Electric logs, Borehole 011BP, depth interval of 460–240 m (symbols as in Fig. 6).

events recorded in the upper Lyulinvor subformation and decreased thickness of magnetostratigraphic units are the main obstacles for the correct interpretation of paleomagnetic data. It is very likely that the upper Lyulinvor Subformation was partially eroded before the Tavda time as it follows from palynological and paleomagnetic data (decreased ranges and eliminated fragments of magnetic polarity zones).

Electric logging. Electric logs obtained for the upper Lyulinvor Subformation are differentiated even lesser than within the lower subformation. The AR values correspond in average to 3–4 ohm, and SP parameters range from 3 to 5 mV. The opposite displacements of both parameters are clearly recorded in the log for Borehole 9 at the level of basal bed of glauconite sandstone. The other peaks of AR and SP values are also confined to sandstone bed at the depth level of 470 m. The transition from light gray opoka-like to green nonsiliceous clays is depicted by a minor decrease of AR values at the level of SP parameters slightly displaced to the right (Figs. 6–9).

Tavda Formation

Except for the basal interval, the rest of the Tavda Formation sequence is of the so-called "Kulunda" type, since rocks of this kind are widespread in the synonymous lithologic–facies zone on the south of West Siberia. The thickness values (152 m in core section 9 and 178 m in core section 011BP) are close to the maximal ones known in the Omsk depression and in central areas of the West Siberian plate. The lower and upper intervals of the sequence are composed of clays. In the middle interval 50 m thick in core section 9 and 55 m thick in core section 011BP, there is recorded a transition in the eastward direction from coastal-marine to continental facies enriched in sandy material and hosting the interlayers of brown coal and segregations of hydrogoethite–limonite ores. The lower interval corresponds to the lower Tavda Subformation that is homogeneous in composition, being 47 m thick in core section 9 and 53 m thick in core section 011BP. In the former section, this subdivision is composed of greenish foliated fat clay with rare siderite or marly-siderite nodules and interlayers ranging in thickness from 0.1 to 0.5 m. The basal 10-m-thick member of fine-grained glauconite sandstone and siltstone has a sharp contact with the underlying Lyulinvor Formation. The subformation upper boundary is placed at the depth level of 388 m, which corresponds to the base of silty clays, the main rocks of the middle interval. A thin bed of siderite sandstone is confined to this boundary. In the core section 011BP, the basal clay–aleuritic member of the lower Tavda Subformation is also 10 m thick. Glauconite grains and abundant clasts or pellets derived from the underlying Lyulinvor clay are concentrated in the clayey–silty–sandy matrix near the base of this member. Transition between the lower and middle members is gradual. An interlayer of micaceous siltstone at the depth of 401 m, above which the clay beds are enriched in silty material, can be conventionally regarded as a marker of the lower boundary of the upper Tavda Subformation. In certain intervals of the section, silty clays enclose interlayers of sand, siderite, and pure clay. Leaf impressions of aquatic fern *Azolla vera* are found in both core sections at the depth of 330–331 (Borehole 011BP) and 337 m (Borehole 9). The upper interval predominantly composed of clay encloses frequent siltstone and sandstone interbeds and siderite lenses and interlayers. The boundary between this and middle interval is conventionally defined at the depth of 320 to 330 m in the core section 9 and at the depth of 300 m in the core section 011BP, because the organic-walled phytoplankton found above these levels suggests the more typical marine environments of sedimentation. The Tavda Formation top is eroded, overlain by kaolinic sands of the Isil'kul Formation, which form sole casts and enclose flattened pebbles of the underlying Tavda clay.

Organic-walled phytoplankton. Kul'kova studied 25 to 30 samples of the Tavda Formation rocks from both core sections, and Zaporozhets investigated 18 samples from Borehole 9 and seven samples from Borehole 011BP. The organic-walled phytoplankton of the Tavda Formation developed under a strict control of the sea basin hydrology. Prasinophytes and acritarchs dominate in two intervals: near the base and in the middle of the formation sequence. In the basal sandy member that grades into overlying silty clays, representatives of the late Lyulinvor assemblage are dominant. The middle interval rich in silty material characterizes sedimentation under conditions of shoaling and seawater stratification, as we believe, with a lower salinity in the upper part of the photic zone. This is evident from abundance of aquatic fern spores (*Hydropteris, Azolla*) and from presence of *Pediastrum* remains, the algal taxon characteristic of fresh waters. Both transgressive clay-rich members most characteristic of the lower and upper Tavda subformations yield the diverse dinocyst assemblages (30 to 40 and more species). The diversity of dinocysts considerably decreases down to 10–15 species within the intervals dominated by prasinophytes and acritarchs (Table 2).

Three dinocyst assemblages characterizing compositions of successive biostratigraphic zones are distinguished in the studied core sections (they are especially representative in core section 011BP). These are the assemblages of (1) *Areosphaeridium diktyoplokum–Rhombodinium draco* Zone of the lower Bartonian, (2) *Rhombodinium porosum* Zone of the upper Bartonian, and (3) *Charlesdowniea clathrata angulosa* Zone of the Priabonian, the composition of which is locally complicated by superimposed anomalous assemblages rich in prasinophytes, acritarchs, and spores of aquatic ferns. We also propose to discriminate the middle interval of the formation in the rank of *Hydropteris–Pediastrum* Beds (in the dinocyst zonation, this interval corresponds to the *Charlesdowniea clathrata angulosa* Zone, because single specimens of this index subspecies have been found in the indicated beds at the depth of 325 m in the core section 011BP).

In the core section 9, the *Areosphaeridium diktyoplokum–Rhombodinium draco* Zone spans the depth interval of 435–408 m, where the first index species has been found at all the sampling levels. Zaporozhets established the first occurrence level of the second species at the depth of 408 m near the zone upper boundary and detected its single specimens in the overlying zone. According to data obtained by Kul'kova, this taxon is present in all the samples from the lower Tavda Subformation beginning from its basal bed. In Borehole 9, the upper boundary of the zone is at the depth of 408 m corresponding to the appearance level of *Rhombodinium porosum*, the index species of the next zone.

The *Areosphaeridium diktyoplokum–Rhombodinium draco* Zone recorded considerable changes in composition of dinocysts. Many species characteristic of the first half of the Paleogene disappear at this level marking the appearance of many newcomers. Among the latter, there are *Thalassiphora elongata* and *Wetzeliella irtyschensis*, the endemics of West Siberia, and *Thalassiphora pelagica, Samlandia reticulifera, Homotryblim plectilum, Spiniferites wetzelii, Pterodinium* sp., *Corrudinium incompositum*, and others. Many newcomers, e.g., *Microdinium reticulatum, Adnatosphaeridium robustum, Wetzeliella articulata?*, and *Charlesdowniea tenuivirgula*, pass into the next zone. The transit species are *Samlandia chlamidophora, Palaeocystodinium golzowense, Deflandrea phosphoritica, Glaphyrocysta semitecta*, and *Spiniferites ramosus*. Redeposited forms (species of genera *Cerodinium, Alterbidinium*, and others) are characteristic of basal beds of the formation, which have been recovered by both boreholes. Species *Paucilobimorpha triradiata* are abundant in the basal sandstones.

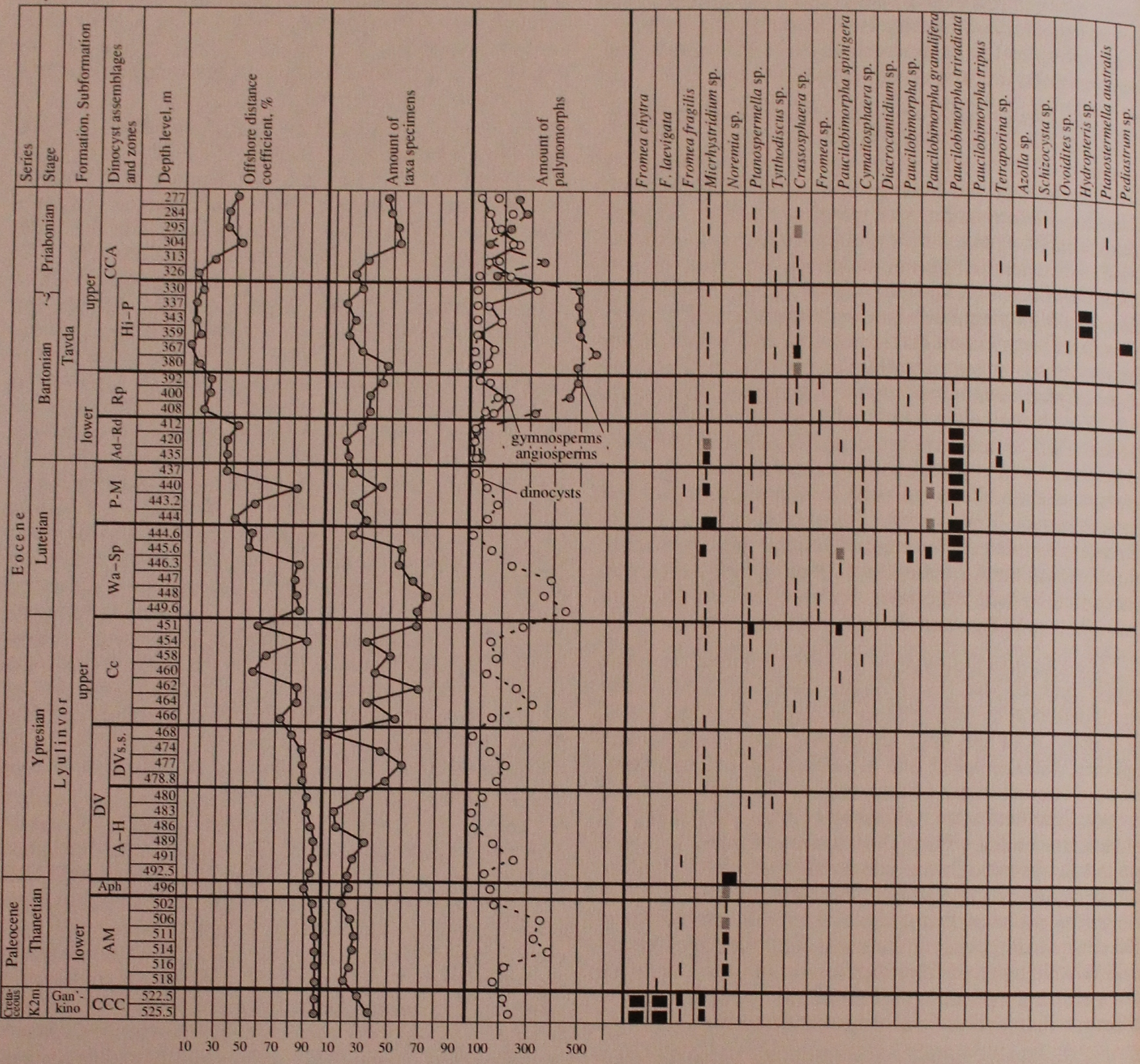
The *Rhombodinium porosum* Zone characterizes the upper part of the lower Tavda Subformation in the depth interval of 408–388 m of Borehole 9. Its lower boundary is at the first occurrence level of the index species, and the upper one is marked by disappearance of taxa characteristic of the zone and by appearance of rather abundant spores of aquatic ferns in association with thin-walled *Hystrichokolpoma* forms, prasinophytes, and acritarchs, which define the lower boundary of the *Hydropteris indutus (Pediastrum)* Beds. *Charlesdowniea clathrata angulosa*, the index subspecies of the next zone appears at the same level. In the core section 011BP, species *Rhombodinium porosum* have not been encountered, and it is difficult to discriminate here the zone in question from the underlying one.

Characteristic of the *Rhombodinium porosum* Zone are also some taxa, which do not occur in the overlying strata. These are *Wetzeliella irtyschensis, Kisselovia ornata, Homotryblium oceanicum, H. abbreviatum, Thalassiphora elongata, Achilleodinium biformoides, Glaphyrocysta undulata, Diphyes colligerum*, and *Charlesdowniea tenuivirgula*. The development of *Phthanoperidinium geminatum, Pht. eocenicum, Cordosphaeridium exilimurum, Chytroesphaeridia* sp., and some other forms commenced in the West Siberian basin in this zone only. About a half of taxa (*Charlesdowniea clathrata, Lentinia serrata, Selenopemphix nephroides, Diphyes colligerum, Palaeocystodinium golzowense, Membranophoridium aspinatum*, and species of genera *Phthanoperidinium, Deflandrea, Thalassiphora*, and *Cordosphaeridium*) are transit. Kul'kova [10] formerly considered *Kisselovia ornata* or *Wetzeliella irtyschesis* as the index species of the zone, but these two taxa are endemics occurring in West Siberian sections only. In distinction, *Rhombodinium porosum* is the index species of concurrent Eocene zones in European Russia and West Europe, thus being more appropriate for the nomenclature.

The *Hydropteris indutus–Pediastrum* Beds span the depth intervals of 380–330 and 361–322,7 m in boreholes 9 and 011BP, respectively. Dinocysts are rare in the beds, which reveal a fantastic abundance of spores of aquatic fern *Hyrdopteris indutus* (appear at the depth of 380 m and are abundant at the depth levels 359, 343, and 337 m in core section 9 and at the depth of 325 m in core section 011BP). Some samples yielded the *Azolla* spores and remains of fresh-water alga *Pediastrum*. Occasional specimens of green algae *Crassosphaera, Tytthodiscus, Pterospermella*, and acritarchs *Micrhystridium* spp. are present almost in all the samples studied. Dinocysts are commonly represented by thin-walled *Hystrichokolpoma* forms associated with species of genera *Phthanoperidinium, Cordosphaeridium*, and *Deflandrea* and with *Membranophoridium aspinatum, Selenopemphix nephroides*, and some other species. As is noted above, *Charlesdowniea clathrata angulosa*, the type subspecies of the youngest dinocyst zone of the Eocene succession, appears in the upper Tavda Subformation penetrated by Borehole 9 above the *Hydropteris indutus–Pediastrum* Beds. In the core section 011BP, this taxon is dispersed throughout the beds, being dominant near their top (sample from the depth level of 325 m). Accordingly, it is reasonable to consider the *Hydropteris indutus–Pediastrum* Beds as a subdivision of the indicated zone.

The *Charlesdowniea clathrata angulosa* Zone is over 100 m thick in the core section 9 (depth interval of 380–273 m) and even thicker in the core section 011BP (?361–265 m). Recognition of its lower boundary is complicated by the reduced diversity of dinocyst species in the *Hydropteris indutus–Pediastrum* Beds. In the core section 9, this boundary is conventionally placed at the disappearance level of *Wetzeliella irtyshensis* and *Kisselovia ornata* characteristic of the *Rhombodinium porosum* Zone, while in the core section 011BP it is defined at the first occurrence level of the index species. The taxonomic characterization of the zone is clear despite the broad sampling intervals. The index species coexists here with characteristic *Phthanoperidinium* species, such as *Phth. stockmansii* and *Phth. geminatum*, and with *Membranophoridium aspinatum, Rottnestia borrusica, Thalassiphora delicata, Enneadocysta arcuata*, and *Deflandrea phosphoritica* f. *attenuata*. Species *Araneosphaera araneosa, Phthanoperedinium resistente, Selenopemphix selenoides, S. coronata*, and others appear beginning from the basal level of *Hydropteris indutus–Pediastrum* Beds. Taxa successively appearing in the middle and upper intervals of the zone are *Heteraulacacysta porosa, Glaphyrocysta vicina, Lejeunecysta cinctoria, Batiacasphaera sphaerica, Phthanoperidinium amoe-*

Table 2. Distribution ranges of acritarchs, prasinophytes, and spores *Azolla vera, Hydropteris indutus* in the section penetrated by Borehole 9



num, Phth. flebile, Phth. alectrolophum, Trithyrodinium sp., *Charlesdowniea clathrata angulosa, Ch. variabilis, Hystrichosphaeropsis camplanata, Pentadinium gonoferum, Operculodinium placitum*, and some others (core section 9). The upper transgressive member of clayey beds (depth range of 295–277 m) recorded the recurrent appearance of species characteristic of lower beds of the lower Tavda Subformation (*Rhombodinium longimanum, Lentinia serrata*, and some others). Dinocysts from this depth range are especially diverse, represented by 50 species. Species *Phthanoperidinium amoenum* appears here earlier than in other regions of West Siberia.

Foraminifers. Beniamovskii analyzed 70 samples from different levels of the Tavda Formation and found foraminifers in 16 samples. The assemblage of planktonic foraminifers from Borehole 9 (depth range from 415 to 400 m) includes *Pseudohastigerina micra, Pseudogloboquadrina primitiva, Catapsydrax martini, C. echinatus, C. dissimilis, Catapsydrax sp., Subbotina pseudobulloides, S. linaperta, Acarinina* cf. *bullbrooki*, and *A. rotundimarginata*. The last taxon defines the Bartonian age of host deposits.

Species *Cyclammina crassa* of benthic foraminifers were found at the depth levels of 415.5, 415, 414.5, and 412 m. The *Cribroelphidium rischtanicum* assemblage with index species and *C. differensaperto* is established in the depth interval of 339–334 m (sampling levels at 339, 337.6, 337.3, and 334 m). These benthic taxa are characteristic of the Upper Eocene in Central Asia (Kisel'man, 1978).

Osracodes. Ostracode species found at different depth levels are *Clithrocytheridea* sp. juv. (413.5 m), *Loxoconcha* sp. (408 m), and *Cyamocytheridea* aff. *corrugata* (406.5 m). Species *Cytheridea probata, C. testate, Pontocypris sibirica, Loxoconca involuta, L. minsaensis, Loxoconca spp., Cytheromorpha barbantica, Cytheromorpha* sp., *Echinocythereis spongiosa, Clithrocytheredia innae, Bythoceratina* ex gr. *inpressa, Parascypris contracta,* and *Cytherura placida,* which are typical of the upper Eocene in the Aral–Turgai region, characterize the ostracode assemblage from the depth interval of 343–330 m. The transgressive clay member of the upper Tavda Subformation yielded ferruginate casts of *Loxoconcha* sp. and *Cytheridea* sp. (depth level of 291 m).

Spores and pollen. In opinion of Kul'kova, the Tavda Formation spans intervals of two regional palynological zones. These *Castanopsis pseudocingulum–Rhoipites* spp.–*Quercus gracilis* (or *Quercus graciliformis* in terminology of Zaporozhets) and *Quercus gracilis–Q. graciliformis* zones correspond respectively to the lower and upper Tavda subformations. Pollen of angiosperm plants, mostly of Fagaceae (up to 50%) and Hamamelidaceae (8 to 10%), is dominant in palynological spectra of the lower Tavda Subformation. A similar trend in distribution of palynomorphs is recorded in the lower half of the upper Tavda Subformation (*Hydropteris indutus Pediastrum* Beds). Several samples from the depth range of 330–313 m of Borehole 9 showed the anomalously high content (over 75%) of pollen produced by gymnosperm plants. In upper, clearly marine facies of the Tavda Formation, pollen of angiosperm plants is again dominant, though to a lesser extent than in the lower subformation. Palynomorphs of higher plants are usually as frequent as 500 to 600 specimens per a preparation. In the upper clay member of the upper Tavda Subformation, where abundance and diversity of dinocysts are higher (30 to 40% of the entire palynomorph assemblage), pollen of higher plants is less abundant. Pollen of Pinaceae is dominant in the group of gymnosperms, being noticeably more abundant than pollen of Taxodiaceae. Dominant among angiosperms are Fagaceae, while Juglandaceae are less abundant and Betulaceae are accessory. Pollen of thermophilic flowering plants is diverse, but many taxa are represented in pollen spectra by occasional specimens only.

Magnetostratigraphy. Eight magnetic polarity zones, four of normal polarity (N_1tg, N_2tg, N_3tg, and N_4tg) and four of reversed polarity (R_1tg, R_2tg, R_3tg, and R_4tg), all with inner subzones of opposite polarity, are established in the Tavda Formation sequence penetrated by Borehole 9. In the core section 011BP, there are nine zones, five of normal polarity (N_1tg, N_2tg, N_3tg, N_4tg, and N_5tg) and four of reversed polarity (R_1tg, R_2tg, R_3tg, and R_4tg), some of which have inner intervals of opposite polarity. In general, the normal polarity zones prevail over others in both sections of the Tavda Formation (Fig. 5).

Electric logging. Clays of the Tavda Formation, which are enriched in silty material, are characterized in logs by the higher AR parameters (6–8 locally up to 10 ohm). At the levels of sand and sandstone interbeds, this parameter increases up to 20–30 ohm. The SP values can be as high as 15–20 mV, being at the maximum within the depth range of basal member composed of sand and silty clay in both sections. The opposite AR and SP peaks at this depth are especially well seen in the log for Borehole 9. Additional peaks are recorded in both logs at the levels of siderite interlayers and lenses (Figs. 6–9).

CONCLUSION

Two core sections of reference boreholes drilled in the south of West Siberia are studied using a complex of bio- and magnetostratigraphic methods. Paleontology of found organic remains characterizing various groups of microplankton is described in detail. Four discriminated lithostratigraphic subdivisions are the Gan'kino Formation, lower and upper Lyulinvor subformations, and Tavda Formation. The first and second subdivisions have been penetrated by Borehole 9 only.

The Gan'kino Formation is composed of marly clays, whereas the overlying strata of marine Paleogene are all less calcareous.

The lower Lyulinvor Subformation characterizes the main stage of organic silica accumulation. It is composed of opoka, opoka-like clay, sandstone, and siltstone beds. The basal glauconite sandstone of the unit encloses phosphatic nodules and overlies with a hiatus the underlying Gan'kino Formation. The formation corresponds to a separate sedimentation cycle that is incomplete, because its upper layers are eroded.

The upper Lyulinvor Subformation is composed, in distinction from the lower one, of fine-grained clayey–siliceous sediments, which yield the diverse assemblages of microplankton. It is of the two-member structure. The thicker lower member is composed of gray opoka-like clay with a basal bed of glauconite sandstone. The overlying member of green, slightly siliceous clays bears fish remains. A break in sedimentation between two members is inferable based on lithologic features and abrupt compositional changes in microplankton assemblages. Accordingly, it seems reasonable to return into stratigraphic nomenclature the Nyurol'ka Formation that has been originally discriminated by S.B. Shatskii and is abolished now.

The glauconite sandstone bed with phosphatic nodules at the lower subformation base signifies the commencement of new sedimentary cycle after erosion of underlying sediments. Borehole 9 drilled near the

Table 3. Correlated zonal scales for different groups of microfossils, the marine Paleogene sections of West Siberia

Stage	Formation	Subformation	Member	Dinocysts	Radiolarians	Silicoflagellates	Diatoms	Foraminifers: benthic	Foraminifers: planktonic	Spores and pollen	Nannoplankton	Ostracodes	Pelecypods
← Priabonian	Tavda	upper	10	*Charlesdowniea clatrata angulosa*						*Quercus gracilis, Q. graciliformis*			
Bartonian	Tavda	upper	9	*Hydropteris indutus – Pediastrum* sp. Beds				*Cribroelphidium rischtanicum*				*Cytheridea probata, Echinocythereis spongiosa, Paracypris contracta* Beds	*Musculus* cf. *samensis* Beds
Bartonian	Tavda	upper	8										
Bartonian	Tavda	lower	7	*Rhombodinium porosum*					*Subbotina praebulloides* Beds	*Quercus gracilis, Q. graciliformis, Castanopsis pseudocingulum*		*Cyamocytheridea aff. corrugata*	
Bartonian	Tavda	lower	7, 6	*Areosphaeridium diktyoplokum, Rhombodinium draco*				*Cyclammina crassa* Beds					
Lutetian	Lyulinvor	upper	2	*Paucilobimorpha – Mystricrhystridium* Beds						*Quercus gracilis, Rhoipites granulatus, Castanopsis pseudocingulum*			
Lutetian	Lyulinvor	upper	5, 1	*Wetzeliella articulata* (acme), *Systemathopora placacantha*	*Conocaryomma aralensis – Phacodiscinus testatus subsphaericus* Beds		*Cosmiodiscus* Beds; *Stepanopyxis crenata*; *Pyxilla oligocaenica tenis* (terminal)	*Textularia carinatiformis*; *Uvigerina costellata*	*Hantkenina alabamensis* (*H. australis* Subzone); *A. rotundimarginata*	*Castanea crenataeformis, Castanopsis pseudocingulum*			
Lutetian	Lyulinvor	upper		*Charlesdowniea coleothrypta* (s.l.): *Charlesdowniea coleothrypta rotundata*				*Textularia carinatiformis*; *Gaudryinopsis subbotinae*		*Araliaceoipollenites euphori, Sapotaceoidaepollenites manifestus, Pompeckjoidaepollenites subhercynicus, Castanopis pseudocingulum*			
Ypresian	Lyulinvor	upper	4	*Charlesdowniea coleothrypta* (s.l.): *Charlesdowniea coleothrypta coleothrypta* (s.s.)	*Thecosphaerella turcmenica – Phacodiscinus testatus testatus* Beds	*Dyctyocha secta*	*Brightwellia hyperborea*; *Pyxilla gracilis*; *Coscinodiscus polyactis*	*Textularia carinatiformis*					
Ypresian	Lyulinvor	upper	3	*Dracodinium varielongitudum* s.l.: *Dracodinium varielongitudum* s.s.						*Pompeckjoidaepollenites subhercynicus, Castanopsis pseudocingulum*			
Ypresian	Lyulinvor	upper	3	*Dracodinium varielongitudum* s.l.: *Alterbidinium* sp. 1 – *Hystrichosphaeridium tubiferum* Beds	*Heliodiscus inca*			*Bolivinopsis spectabilis*		*Triporopollenites robustus, T. excelsus, Plicapolis pseudoexcelsus, Myrica*; Occasional *Pinus* sp., *Protocedrus* sp.			
Thanetian	Lyulinvor	lower	2	*Apectodinium homomorphum*						*Trudopollis menneri, Tricolporopollenites* sp.			
Thanetian	Lyulinvor	lower	2	*Alisocysta margarita*				*Glomospira gordialiformis*					
Maastrichtian	Gan'kino		1	*Cerodinium diebelii* Beds				*Spiroplectammina kasanzevi, Bulimina rosenkrantzi*		Assemblage of *Pinus* sp., *P. aralica, Protocedrus* sp. and single *Trudopollis* sp.	CC26 *Nephrolithus freques*	Assemblage of *Confusina notabilis, Cythere*(?) *sibirica*	

southern flank of the West Siberian sedimentary basin recovered an incomplete sequence of the unit, because the sea transgression reached this site later than the northern and central areas of the West Siberian plate. This is evident from the fact that the upper Paleocene–lower Eocene strata known in the Central and Trans-Uralian structural–lithologic zones are absent in the subformation sequence.

The green clay member yielded two assemblages of planktonic foraminifers, which belong to *Acarinina rotundimarginata* and *Hantkenina alabamensis* zones different in age and have been correlated with concurrent assemblages of dinocysts and siliceous microfossils. The results obtained clarify the member age and suggest that beds bearing the above assemblages of planktonic foraminifers are separated by a hiatus.

Now we can also convincingly argue for a considerable basin shoaling at the accumulation time of terminal beds of the green clay member. The arguments in favor of this event are the increased content of silty material in the clay matrix, on the one hand, and changes in composition of diatom assemblages and the appearance of abundant acritarchs and prasinophytes, especially of *Paucilabimorpha* forms, among the organic-walled phytoplankton, on the other.

The three-member structure of the Tavda Formation, which is characteristic of its sections in the Barabinsk and Kulunda lithologic-facies regions, is confirmed in both core sections. That structure is a consequence of two separate transgressive–regressive cycles, the last of which is reduced and represented by the transgressive part only. These peculiarities of sedimentation influenced the dynamics of palynological spectra. They were responsible for predominance of diverse dinocyst species in the lower and upper clay members, the principal ones in the lower and upper Tavda subformations, and for abundance of aquatic fern spores, which occur in association with prasinophytes and acritarchs in the middle interval that is enriched in silty material and ranked as the *Hydropteris indutus–Pediastrum* Beds.

The lower clay member of the lower Tavda Subformation and its basal bed of glauconite sandstone with clay pellets derived from underlying rocks of the Lyulinvor Formation correspond in range to the *Areosphaeridium diktyoplokum–Rhombodinium draco* and *Rhombodinium porosum* dinocyst zones. The *Acarinina–Catapsydrax* assemblage of planktonic foraminifers is obtained from clay interlayers in the middle interval of the subformation sequence. The upper Tavda Subformation that is silty in the lower part (*Hydropteris indutus–Pediastrum* Beds) and clayey in the upper one is attributed to the *Charlesdowniea clathrata angulosa* Zone. In both core sections, a marker bed rich in remains of macro- and microfauna (mollusks, ostracodes, benthic foraminifers, massulae and megaspores of *Azolla*, mass accumulations of *Hydropteris indutus* spores) is confined to the upper part of the shallow-water silty member.

The regional biostratigraphic scales for various groups of biota are coordinated between each other based on different representatives of microplankton occurring jointly in sediments of the Gan'kino Formation and upper Lyulinvor Subformation (Table 3). The diverse assemblage of nannoplankton found for the first time in the Gan'kino Formation of West Siberia is correlated with the dinocyst zones recognized in the same subdivision. Four discrete levels are established in succession of planktonic foraminifers, and corresponding foraminiferal assemblages are correlated with distribution ranges of siliceous and organic-walled phytoplankton, ostracodes, spores, and pollen. Dinocysts present in all the samples studied are used to define levels of biotic events presumably connected with breaks in sedimentation. The beds with abundant prasinophytes, acritarchs, and aquatic fern spores are indicative of the past shoaling events and seawater stratification in the basin. All the results obtained and age substantiation of discriminated biostratigraphic units will be discussed in the next our publication.

ACKNOWLEDGMENTS

The work was supported by the Russian Foundation for Basic Research, project nos. 00-05-64917, 00-15-98480, 02-05-65170, 02-05-64787, and by the state program "Leading Scientific Schools," project no. NSh-1615.2003.5.

Reviewers S.V. Popov and I.A. Basov

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