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# The Paleocene and Eocene in the Russian Part of West Eurasia

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**Abstract**—Biostratigraphic charts of marine Paleocene and Eocene in the European and West Siberian parts of Russia include the unified zonations of nannoplankton, planktonic and benthic foraminifers, dinocysts, radiolarians, diatoms, and palynomorphs of higher plants. These regional zonations summarize comprehensive data on the Lower Paleogene, which have been obtained by paleontologists and biostratigraphers in the last century. In the content and resolution degree, they represent a solid basis for geological and paleogeographic consideration and characterize the time succession of diverse biotic and abiotic events. On the other hand, the depicted biotic events have been controlled by successive tectonic, paleogeographic, and paleoclimatic events, because organisms determining contents of biostratigraphic zones changed not only in the course of evolution, but also in response to transformation of surroundings. As elements of general communication systems, epicontinental seas of the Paleogene have been interconnected via straits and seaways, which promoted interchange of water masses and biotas belonging to the Tethys, Atlantic or Arctic oceans, and inner seas. Size and configuration of the seas and seaways changed under influence of tectonic processes and eustatic events of epeirogenic or regional origin. Widening, narrowing, and cessation of communication ways have been responsible for different-scale changes in sedimentation and biotic environments. New materials on the Paleogene in a vast territory of Russian sector of West Eurasia offer an opportunity to revise somewhat the dynamics of climatic changes in the Northern Hemisphere during the Early Cenozoic, which characterize the terminal phase of transition from the warm to cold biosphere of the Earth.

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*Key words*: Paleocene, Eocene, Russian sector of West Eurasia, zonal biostratigraphy, tectonics, sedimentology, paleogeography, paleoclimate.

## INTRODUCTION

Our objective in this work is to consider biostratigraphic zonations of Paleocene and Eocene sediments in western regions of Russia, which depict evolution of organic world and are appropriate for understanding the regional sedimentological, paleogeographic, and paleoclimatic events of the Early Paleogene.

The Early Paleogene (Paleocene–Eocene) seas covered considerable areas in West Eurasia. Besides the South European areas of Russia, they covered almost entirely the West Siberian plain. Three zones of sedimentation are distinguishable according to prevailing types of sediments (Fig. 1; Akhmet’ev and Beniamovski, 2003; Radionova *et al.*, 2003):

(1) Zone of siliceous–terrigenous sediments containing fossil assemblages, which are dominated by remains of siliceous and organic-walled microorganisms (radiolarians, diatoms, and dinocysts); these sediments are characteristic of the West Siberian plate, Voronezh anteclise, and Ul’yanovsk–Saratov depression. Nannoplankton, secretory benthic and planktonic foraminifers representing calcareous groups of microbiota are of a limited distribution in the zone.

(2) Zone of terrigenous–siliceous–carbonate sediments; it spanned the Turgai basin, southern areas of the Russian plate, and eastern fringe of the Donbass. During the Early Paleogene, siliceous and organic-walled plankton coexisted here with nannoplankton, secretory benthic and planktonic foraminifers.

(3) Zone of terrigenous–carbonate sediments; this one includes the Scythian plate and monocline of the northern Caucasus. Dominant groups of calcareous microbiota occasionally occur here in association with siliceous fossils and organic-walled phytoplankton that is characteristic consequently of all three zones.

In this work, we analyzed jointly the sedimentation environments and distribution of taxa representing different groups of organisms important in stratigraphic aspect. These were benthic and planktonic foraminifers, nannoplankton, dinocysts, diatoms, and palynomorphs from numerous (over 50) reference sections composed of different sedimentary facies. Correlation of zonal scales is based on characteristic associations of benthic and planktonic organisms distinguished in the course of analysis.

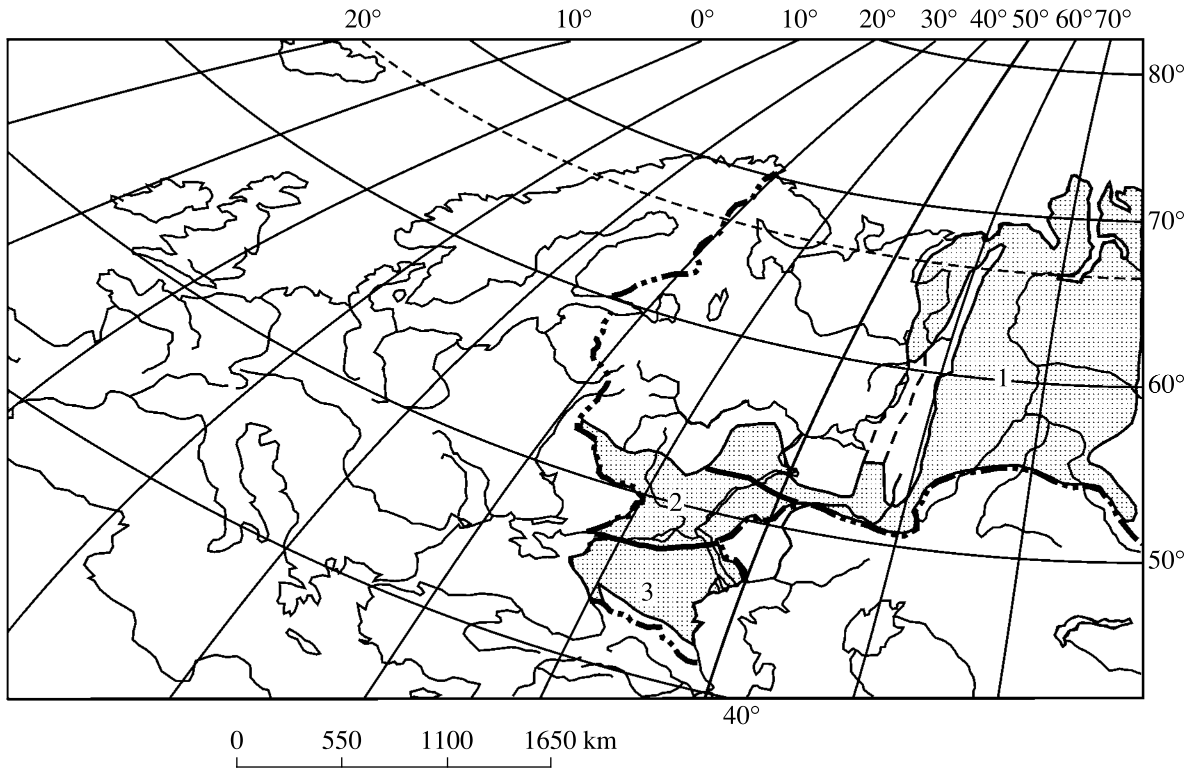


**Fig. 1.** Paleogene deposits in Russian sector of West Eurasia and zones of (1) siliceous–terrigenous, (2) siliceous–terrigenous–carbonate, and (3) terrigenous–carbonate sedimentation (dotted areas denote distribution areas of marine Paleogene).

## STRATIGRAPHIC BASIS FOR TECTONIC, SEDIMENTOLOGICAL, AND PALEOGEOGRAPHIC CONSIDERATIONS

### *Stratigraphic Chart of the Lower Paleogene in Southern Areas of European Russia*

The chart created for a vast territory of West Eurasia (from the Kara Sea in the north to southern Urals in the south and from the Caucasus in the southeast to Belarussian massif in the northwest) includes for the first time zonal scales of fossil benthic organisms and siliceous plankton, which are calibrated with reference to zonations of calcareous and organic-walled plankton (Akhmet'ev and Beniamovski, 2003). The reference standard used in the work is the combined (integrated) magnetobiochronological scale of the Cenozoic (Berggren *et al.*, 1995).

More than 10 years passed since the time, when previous stratigraphic chart (and zonations) for Paleogene deposits of the southern USSR was published (*Resolutions of the ISC…*, 1989; *Zonal Stratigraphy…*, 1991). Naturally, the additional materials collected since that time have been used to verify and substantiate better the biostratigraphic zones included in the chart (Figs. 2 and 3). Authors of zonations shown in columns of the chart are experts in paleontology and biostratigraphy: I.P. Tabachnikova, E.A. Shcherbinina (nannoplankton), E.M. Bugrova (benthic foraminifers), V.N. Beniamovski (benthic and planktonic foraminifers), G.E. Kozlova (radiolarians), Z.I. Glezer, N.I. Strel'nikova, T.V. Oreshkina, E.P. Radionova (diatoms), N.I. Zaporozhets, G.N. Aleksandrova, and A.I. Yakovleva (dinocysts).

Zones of different microplankton groups are designated by letter–number indices in the chart as follows: (NP) nannoplankton, (PF) planktonic foraminifers, (R) radiolarians, (Dt) diatoms, (Dn) dinocysts, (SP) spores and pollen.

In distinction from former charts, the nannoplankton zonation is of prime significance for the new one. According to Muzylev (1980) and subsequent data of Tabachnikova and Shcherbinina, the Paleogene successions of South European Russia are divisible into the standard zones of the reference nannoplankton scales (Martini, 1971; Bukry, 1973, 1975). Therefore, exactly the nannoplankton zonation playing leading part in coordination with the general scale is used to calibrate the other zonations.

Zonation of planktonic foraminifers has been established in reference sections of the Crimea–Caucasus province (Shutskaya, 1970; Krasheninnikov, 1982; Krasheninnikov and Muzylev, 1975; *Zonal Stratigraphy…*, 1991). The new sections studied and revision of earlier data showed that the former correlation of the *Nantkenina alabamensis* Zone with the NP16 Zone of nannoplankton scale should be revised. New data on nannoplankton imply that the Keresta Horizon (*Nantkenina alabamensis* Zone) corresponds everywhere,

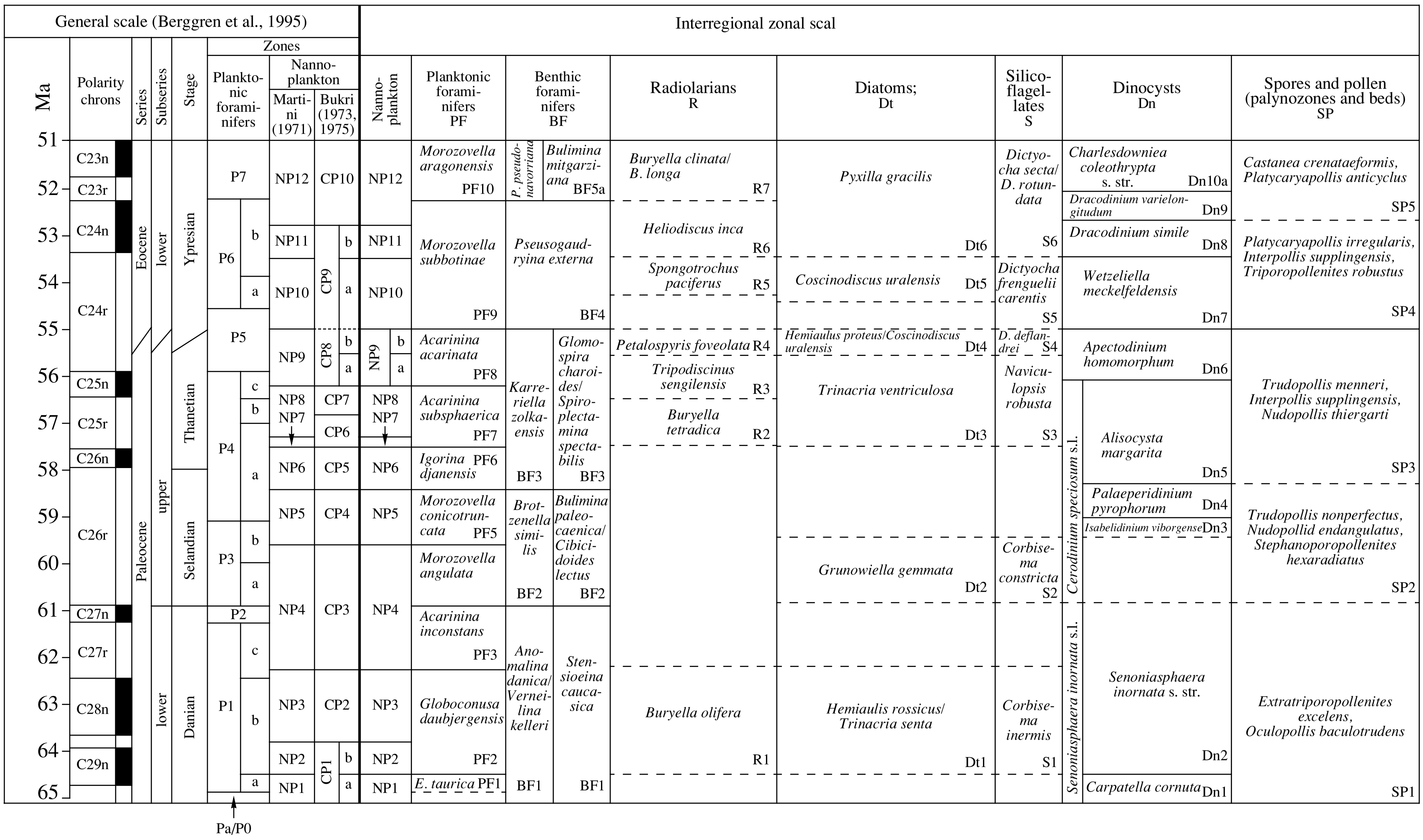


**Fig. 2.** Chart of biostratigraphic (zonal) division of the Paleocene and lower Eocene in South European Russia (after Akhmet’ev and Beniamovski, 2003).

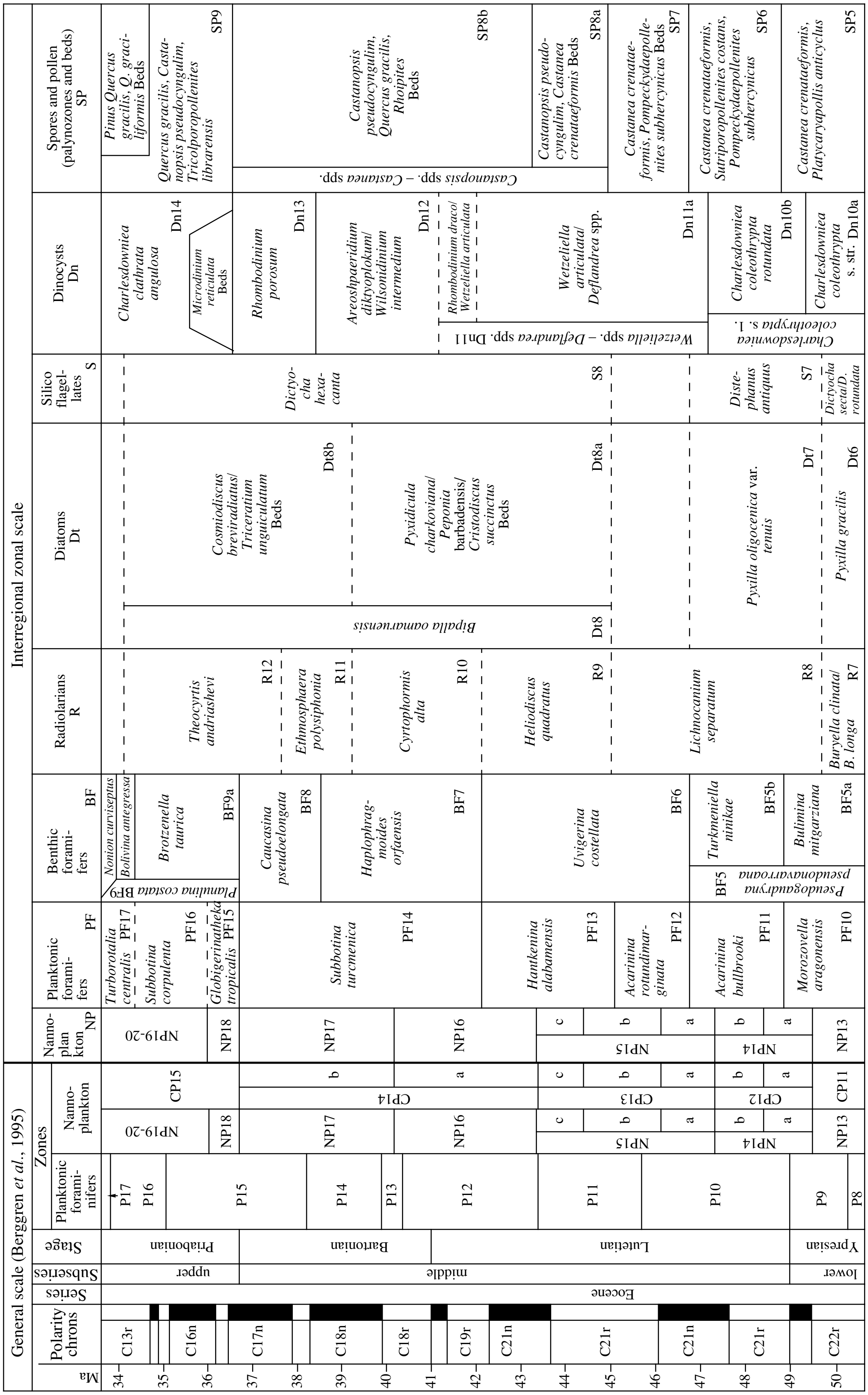


**Fig. 3.** Chart of biostratigraphic (zonal) division of the Eocene in South European Russia (after Akhmet'ev and Beniamovski, 2003).

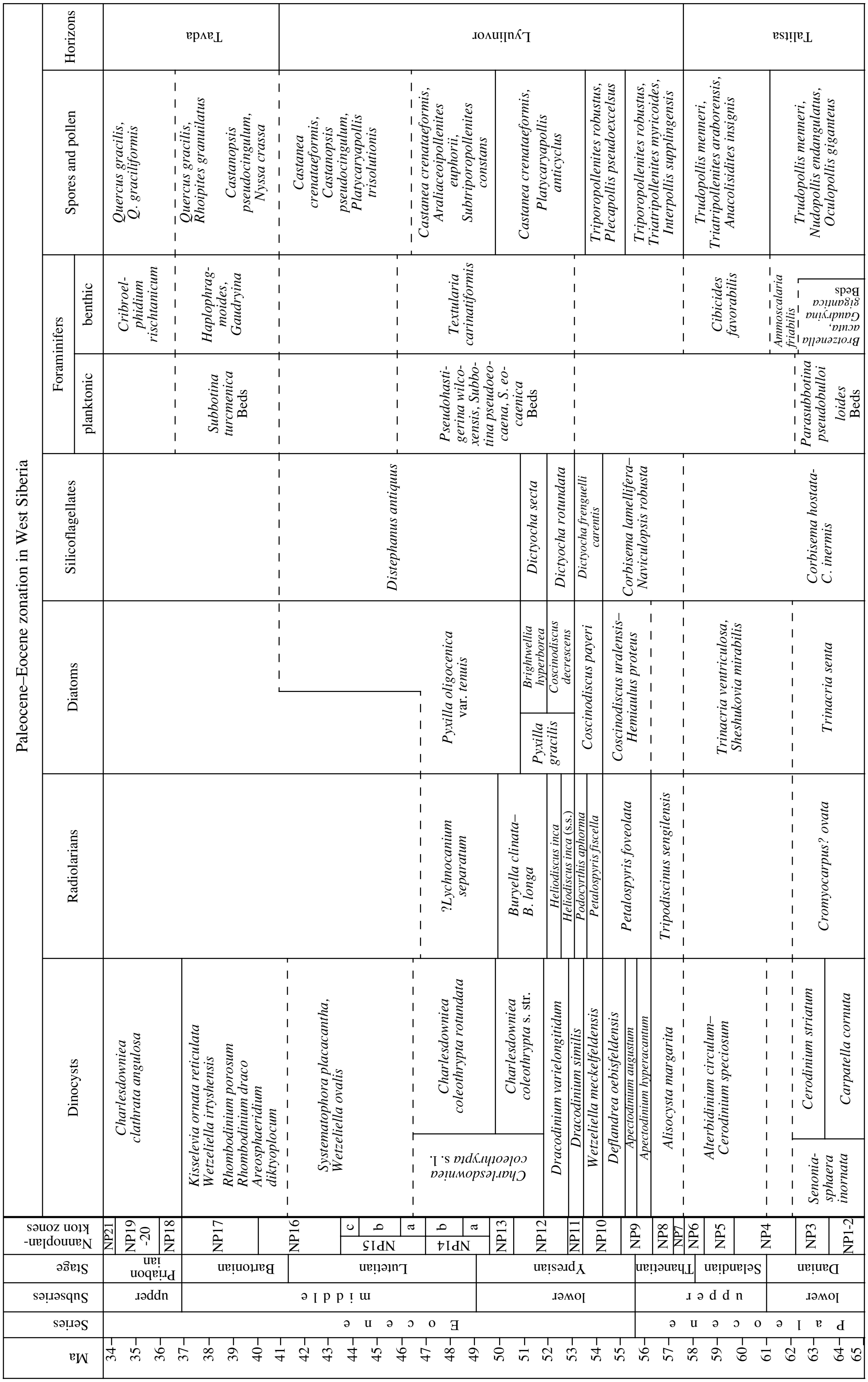


**Fig. 4.** Chart of biostratigraphic (zonal) division of the Paleocene and lower Eocene in West Siberia (after Akhmet'ev *et al.*, 2001, *Unified Schemes*..., 2001).

from the Bakhchisarai in Crimea to the Cape Aktumsuk in the western coast of the Aral Sea, to the middle–upper interval of the CP13 Zone or to the NP15 Zone (Shcherbinina, 2000; Beniamovski *et al.*, 2003).

The revised zonal divisions of *diatoms* have been correlated with *radiolarian* zones. The former zonal scales of both groups consisted of linked zones (Glezer, 1979; Strel'nikova, 1992; *Zonal Stratigraphy...,* 1991; Kozlova, 1999), but now it can be suggested that some zones of the scales are separated by hiatuses (Figs. 2, 3). It should be mentioned as well that boundaries between all zones of siliceous plankton are shown in the charts by dotted lines, because direct correlation between zonations of siliceous and calcareous plankton needs a more precise substantiation.

Recent data enhanced resolution of dinocyst zonation suggested by Andreeva-Grigorovich (1991). Aleksandrova (2001) who studied Paleogene assemblages of dinocysts from Borehole 28 drilled near Volgograd divided the former *Cerodinium speciosum* Zone into three biostratigraphic units: the lower *Isabeledinium viborgense*, middle *Palaeoperidinium pyrophorum*, and upper *Alisocysta margarita* zones. Zaporozhets was first to distinguish four successive dinocyst zones of the middle Eocene in Volgograd and Saratov areas near the Volga River (Fig. 3). The established succession consists of the *Wetzeliella articulata–Deflandrea* spp., *Rhombodinium draco–Wetzeliella articulata, Areosphaeridium diktyoplokum–Wilsodinium intermedium*, and *Rhombodinium porosum* zones.

### *Stratigraphic Chart of the Paleocene and Eocene in West Siberia*

A quarter of a century elapsed after authorization of the unified stratigraphic scheme of marine Paleogene in West Siberia (Shatsky, 1978). That scheme was constructed based on the stage scale of the Bakhchisarai stratotype in Crimea (*Stratigraphy of the USSR...*, 1975). As compared to it, the middle Eocene subseries is now of a greater stratigraphic range, and the main divisions are represented by international (West European) stages (Fig. 4). It is remarkable as well that dinocysts, a group of fossils very important in biostratigraphic aspect, is shown to be widespread in Paleogene deposits of the region. Their zonation established in the region has been coordinated with zonal scales of dinocysts studied comprehensively in southern areas of the former USSR and Western Europe (Kul'kova and Shatskii, 1990; Kul'kova, 1994). Since the terminal 1970s until present, biostratigraphic investigation of Paleogene deposits in West Siberia was aimed at perfection and enhancing the resolution of stratigraphic charts and at recognition of zonal assemblages in different groups of biota, which can be correlated with assemblages known in nearby and more distant regions.

In the chart under consideration (Fig. 4), *dinocysts* are considered, in distinction from the previous approach, as a leading biostratigraphic group. This is done, because the standard dinocyst zones established in Western Europe and southern Russia have been recognized in West Siberia and correlated with the nannoplankton zonation (Andreeva-Grigorovich, 1991; *Mesozoic and Cenozoic...*, 1998). In addition, the results obtained show that dinocysts commonly occurring in diverse sedimentary facies are appropriate for defining the stage boundaries. The dinocyst zonation is correlated with zonations of radiolarians, diatoms, silicoflagellates, and with zones and beds discriminated based on palynomorphs, ostracodes, planktonic and benthic foraminifers.

Elaborating zonal scales of foraminifers based on the reference Paleogene scales of West Siberia and the southern USSR (Kisel'man, 1978; Bugrova, 1988; Podobina, 1998), we took into account all the materials obtained recently (Akhmet'ev *et al.*, 2001a, 2004; Beniamovski *et al.*, 2002). The radiolarian zonation included into the chart was elaborated by Kozlova (1999) for Boreal regions of Russia. Glezer, Strel'nikova, Oreshkina, and Radionova, the well-known experts in planktonic algae, are authors of the accepted diatom zonation (Akhmet'ev *et al.*, 2001a).

The palynological scale is based on zonal divisions established in southern areas of the USSR (Panova *et al.*, 1990), southern trans-Urals (Vasil'eva, 1990), and West Siberia (Kul'kova, 1987; Akhmet'ev *et al.*, 2001a; *Unified Regional...*, 2001). Palynological zones are correlated with zonal scales established for different groups of marine phytoplankton, and the chart as a whole represents a solid basis for age evaluation and correlation of marine and continental sediments.

### *Perfection, Verification, and Details of Zonal Scales*

**Southern areas of European Russia.** Recently Beniamovski (2001) gained a higher resolution in some intervals of Paleocene and Eocene zonations of planktonic foraminifers studied in the Crimea–Caucasus province. In the new version, many of 17 zones established in that province are divided into subzones and beds, the units of a higher resolution, with due account for all the recommendations expressed earlier (Shutskaya, 1970; Korovina, 1970; Krasheninnikov and Muzylev, 1975; Bugrova, 1986, 1988) and new materials obtained by author. As a result, the new scale consists of 29 biostratigraphic divisions.

The *Eoglobigerina taurica* Zone (Fig. 5) is divided into the *Eoglobigerina eobulloides* and *Globanomalina planocompressa* subzones. The *Globoconusa daubjergensis* Zone is also divided in two units of the new scale: the *Parasubbotina pseudobulloides* and *Globanomalina compressa* subzones. The *Praemurica inconstans* Zone formerly undivided consists now of the *Praemurica inconstans* (s. s.) and *Praemurica uncinata* subzones. The *Acarinina acarinata* Zone corresponds to the lower *A. soldadoensis* and upper *Morozovella aequa* subzones. The latter, in turn, is divided into the lower *M. aequa–M. acuta* and upper *Subbotina patagonica* beds (Fig. 5). Three subdivisions established in the *Morozovella subbotinae Zone are M. subbotinae* (s. s.), *M. marginodentata*, and *M. lensiformis* subzones. The *Morozovella aragonensis* is similarly divided into three subunits: *M. aragonensis* (s. s.), *M. caucasica*, and *Globigerinatheka micra* subzones. The *Globigerinatheka subconglobata, G. index*, and *Hantkenina australis* subzones are distinguished in the *Hantkenina alabamensis* Zone. Finally, the *Subbotina turcmenica* Zone of the scale under consideration consists of the lower *S. azerbaidjanica* and upper *S. instabilis* subzones.

**West Siberia.** Data obtained from two reference boreholes, which have been drilled in the southeast of the West Siberian Lowland, are used to amend understanding of Paleogene biostratigraphy in the region and to verify correlation between zonal scales elaborated for different groups of fauna and flora (Beniamovski *et al.*, 2002; Akhmet'ev *et al.*, 2004). Borehole 9 drilled in the Barabinsk trough (Fig. 6) turned out to be more informative in biostratigraphic aspect than the other one. The results obtained by investigation of different micropaleontological groups are presented in brief below.

| Zones | Suggested subzones subzones (Beniamovski, 2001, with additions) | |
|---|---|---|
| | | |
| *Subbotina turcmenica* | *Subbotina praebulloides* | |
| | *Subbotina azerbaidjanica* | |
| *Hantkenina alabamensis* | *Hantkenina australis* | |
| | *Globigerinatheka index* | |
| | *Globigerinatheka subconglobata* | |
| | | |
| *Morozovella aragonensis* | *Globigerinatheka micra* | |
| | *Morozovella caucasica* | |
| | *Morozovella aragonensis* (s.s.) | |
| *Morozovella subbotinae* | *Morozovella lensiformis* | |
| | *Morozovella marginodentata* | |
| | *Morozovella subbotinae* (s. s.) | |
| *Acarinina acarinata* | *Morozovella aequa* | *Subbotina patagonica* |
| | | *Morozevella acuta*/*M. aequa* |
| | *Acarinina soldadoensis* | |
| | | |
| *Praemurica inconstans* | *Praemurica uncinata* | |
| | *Praemurica inconstans* (s. s.) | |
| *Globoconusa daubjergensis* | *Globanomalina compressa* | |
| | *Parasubbotina pseudobulloides* | |
| *Praemurica taurica* | *Globanomalina planocompressa* | |
| | *Eoglobigerina eobulloides* | |

**Fig. 5.** Units of higher resolution in planktonic foraminifer zonation of the Crimea–Caucasus region (after Beniamovski, 2001).

**Dinocysts.** The *Dracodinium varielongitudum* Zone is divided for the first time in two parts: the *Alterbidinium* sp. 1–*Hystrichosphaeridium tubiferum* and *Dracodinium varielongitudum* (s. s.) beds. The succession of zones and beds is verified within the Lutetian–early Bartonian interval, where two biostratigraphic subdivisions are distinguished: the *Wetzeliella articulata* (akme)–*Systematophora placacantha* Zone and *Paucilobimorpha–Micrhystridium* Beds. The first subdivision represents a chronostratigraphic zone of a broad geographic range, which has been discriminated earlier in the Lutetian of West Eurasia. The second one distinguished for the first time is of a rather wide geographic range as well. The *Paucilobimorpha–Micrhystridium* Beds accumulated in anaerobic environments during shoaling and partial freshening of sea basins in the terminal Lutetian–early Bartonian all along the northern periphery of the Peri-Tethys. A sharply increased abundance of *Paucilobimorpha* is recorded in the Vemmel sand and clay of the Asse Formation in Belgium and the Netherlands. Acritarchs of genera *Paucilobimorpha* and *Micrhystridium* are common fossils in the Kiev Formation of the Dnieper–Donets depression and in the Kuma Formation of the northern Ergeni area, where their presence is also indicative of anaerobic and somewhat freshened environments (Zaporozhets, 1998, 2001). A dinocyst assemblage of similar composition is characteristic of the Belinskii sequence in sections of the Turgai trough western flank, the quarries Belinskii and Kachar, Borehole 154 in the Ayat–Tobol interfluve (Beniamovski *et al.*, 1995). Two dinocysts zones (*Areosphaeridium diktyoplokum* and *Rhombodinium draco*) are established as well in the lower Tavda Subformation of the Bartonian. In the Bartonian–Priabonian transitional

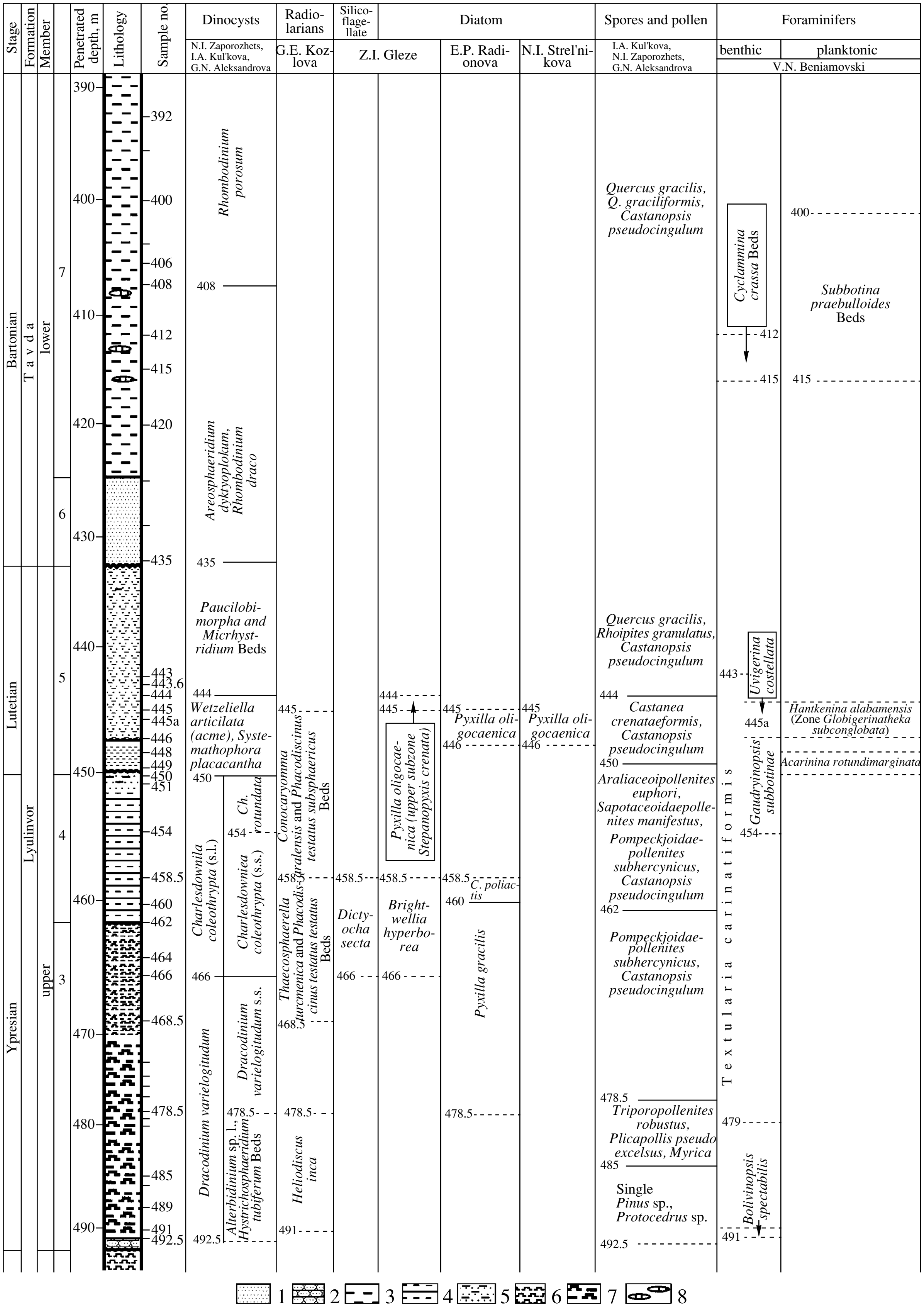


**Fig. 6.** Section of Borehole 9 (Barabinsk zone, the southeastern West Siberian plate) and data used to refine biostratigraphic zonation of the Paleocene and Eocene in West Siberia (after Beniamovski *et al.*, 2002; Akhmet'ev *et al.*, 2004): (1) sand; (2) sandstone; (3) clay; (4) siliceous clay; (5) silty–sandy–clayey rocks; (6) diatomite, opoka; (7) opoka-like and diatomaceous clay; (8) siderite septaria.

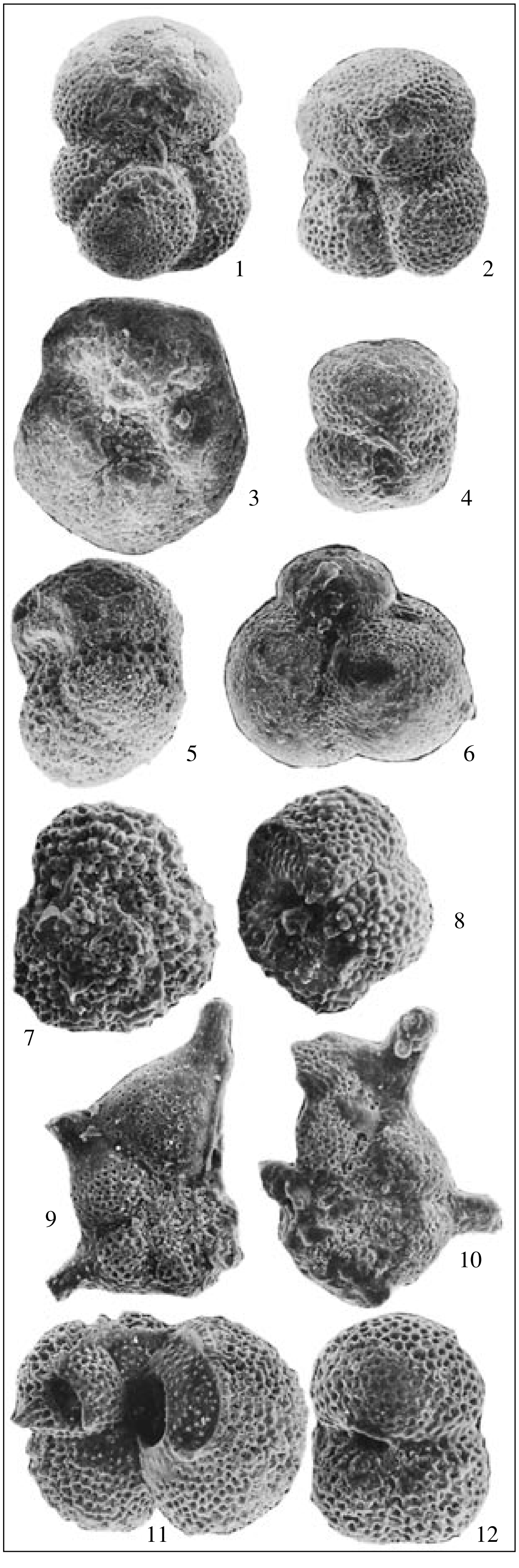
interval (basal part of the upper Tavda Subformation), there are discriminated the *Hydropteris indutus* and *Pediastrum* beds. Thus, the dinocyst zonation characterizing now the Paleogene of West Siberia consists of alternating biostratigraphic zones and beds, which accumulated in diverse environments, including settings with anomalous hydrological conditions. The new scale reflects progressing evolution of dinocysts in the Northern Hemisphere, on the one hand, and changes in composition of their assemblages under impact of ecologic factors, on the other.

**Radiolarians.** Unfortunately, radiolarian zones of the Boreal standard established in European Russia (Kozlova, 1999) cannot be discriminated in the upper Ypresian–lower Lutetian sections of the West Siberian basin periphery. Their analogues established here are the *Thaecosphaera turcmenica–Phacodiscinus testatus testatus* Beds of the upper Ypresian (equivalent of the *Buryella clinata–B. longa* Zone) and the *Conocaryomma aralensis–Phacodiscinus testatus subsphaericus* Beds of the Ypresian–Lutetian transition (equivalents of the *Lychnocanium separatum* Zone).

**Diatomaceous algae.** The *Brightwellia hyperborea* Zone known formerly in the eastern circum-Caspian syneclise only (Glezer, 1996) is discriminated in the terminal part of the *Pyxilla gracilis* Zone corresponding to the first half of the Eocene. Radionova suggested the other diatom zonation for this stratigraphic interval (Fig. 6), and discriminated the *Coscinodiscus polyactis* Beds, which can be regarded as a biostratigraphic subdivision transitional between the *P. gracilis* and *P. oligocaenica* zones.

The upper part of the *Pyxilla oligocaenica* Zone is proved to be of the Lutetian age. Diatoms coexist at this level with the Lutetian dinocysts of the *Wetzeliella articulata* (acme)–*Systematophora placacantha* Zone and with concurrent planktonic foraminifers of the upper *Hantkenina alabamensis* Zone.

The *Stepanopyxis crenata* Subzone is discriminated in the upper part of the *P. oligocaenica* for the first time in West Siberia. This subzone was known before only



Characteristic zonal species of planktonic foraminifers from Borehole 9

(1–6) *Subbotina praebulloides* Beds, Bartonian Stage, lower Tavda Subformation, samples from the depth of 404 and 400 m: (1) *Subbotina praebulloides* (Blow), (2) *S. linaperta* (Finlay), (3) *Acarinina rotundimarginata* Subbotina, (4–5) *Pseudogloboquadrina primitiva* (Finlay), (6) *Catapsydrax martini* (Blow et Banner); (7–10) lower *Globigerinatheka subconglobata* Subzone of the *Hantkenina alabamensis* Zone, upper Lutetian–basal Bartonian interval, terminal member of the upper Lyulinvor Subformation, sample 445a from the depth 445 m: (7–8) *Acarinina rugosoaculeata* Subbotina, (9–10) *Hantkenina liebusi* Shokina; (11, 12) *Acarinina rotundimarginata* Zone, middle Lutetian Substage, upper member of the upper Lyulinvor Subformation, sample from the depth 449 m: (11) *Turborotalia frontosa* (Subbotina), (12) *T. boweri* (Bolli).

in the circum-Caspian depression at the level of the NP15 Zone (Glezer, 1996).

**Foraminifers.** Three biostratigraphic units are added to the Lutetian–Bartonian interval of planktonic foraminifer zonation characterizing the Paleogene succession of West Siberia (Fig. 6 and the Plate). Illustrated in the Plate are characteristic species of planktonic foraminifers from the new subdivisions. The Lutetian interval of zonation is divided into units of the Crimea–Caucasus scale: the *Acarinina rotundimarginata* and *Hantkenina alabamensis* zones, whereas the local *Subbotina praebulloides* Beds are attributed to the Bartonian part. Zonation of benthic foraminifers includes the additional *Uvigerina costellata* Zone that has been distinguished in Lutetian sediments of the Kuberla and Keresta horizons of European Russia and the Crimea–Caucasus region (Bugrova, 1988; Akhmet’ev and Beniamovski, 2003).

### *High-Resolution Stratigraphic Subdivision Used to Evaluate Hiatuses, Tectonic Events, and Sedimentation Trends*

**South European Russia.** The high-resolution zonation of planktonic foraminifers in the Crimea–Caucasus region (Beniamovski, 2001), in which zones are numbered for convenience (PP1, PP2, PP3, etc.) and subzones or beds are designated by letters (a, b, c), has been tested in a series of sections. These are the Kheu, Kurkuzhin, Nal’chik, Zhentola, Urukh and Gubs sections of the northern Caucasus, the Bakhchisarai section of Crimea, the Keresta section of the Ergeni hill range, and the Aktumsuk section in the Aral region (Beniamovski, 2003a).

Hiatuses and their age ranges, which have been determined using that scale in the Paleocene–Eocene sections of the northern Caucasus, are shown in Fig. 7. The hiatuses coincide as a rule with boundaries between sequences. They have not been recognized in the Kheu section, where all zones of the scale are established. The less complete sections reveal hiatuses. The first of them is confined to the basal Danian and spans the *Euglobigerina taurica* Zone (PP1) and *Parasubbotina pseudobulloides* Subzone (PPa), as is established in the Kurkuzhin and Urukh sections, where the Cretaceous–Paleogene transition is exposed. The second hiatus recognized in the Gubs section spans the upper Ypresian and corresponds in range to the *Globigerinatheka micra* Subzone (PP10c). Next hiatuses are confined in the Nal’chik, Gubs, and Keresta sections to the boundary between the Keresta (middle–upper Lutetian) and Kuma (upper Lutetian–lower Priabonian) formations,

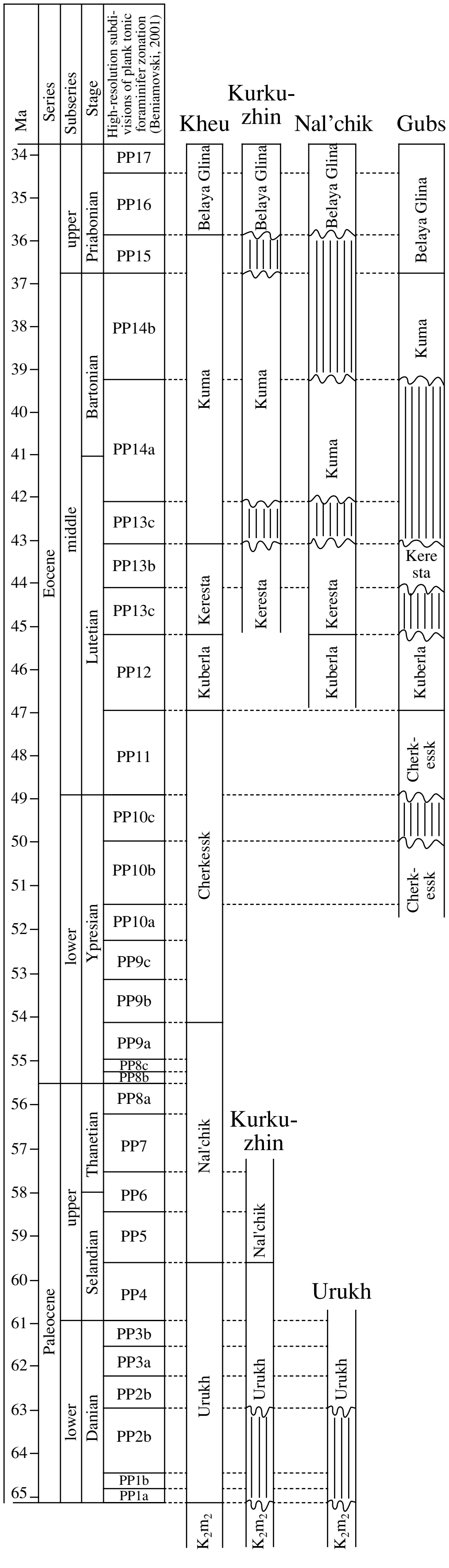


**Fig. 7.** High-resolution zonation of planktonic foraminifers from the Crimea–Caucasus region used as time scale to determine the hiatus spans in the Paleogene reference sections of the North Caucasian monocline.

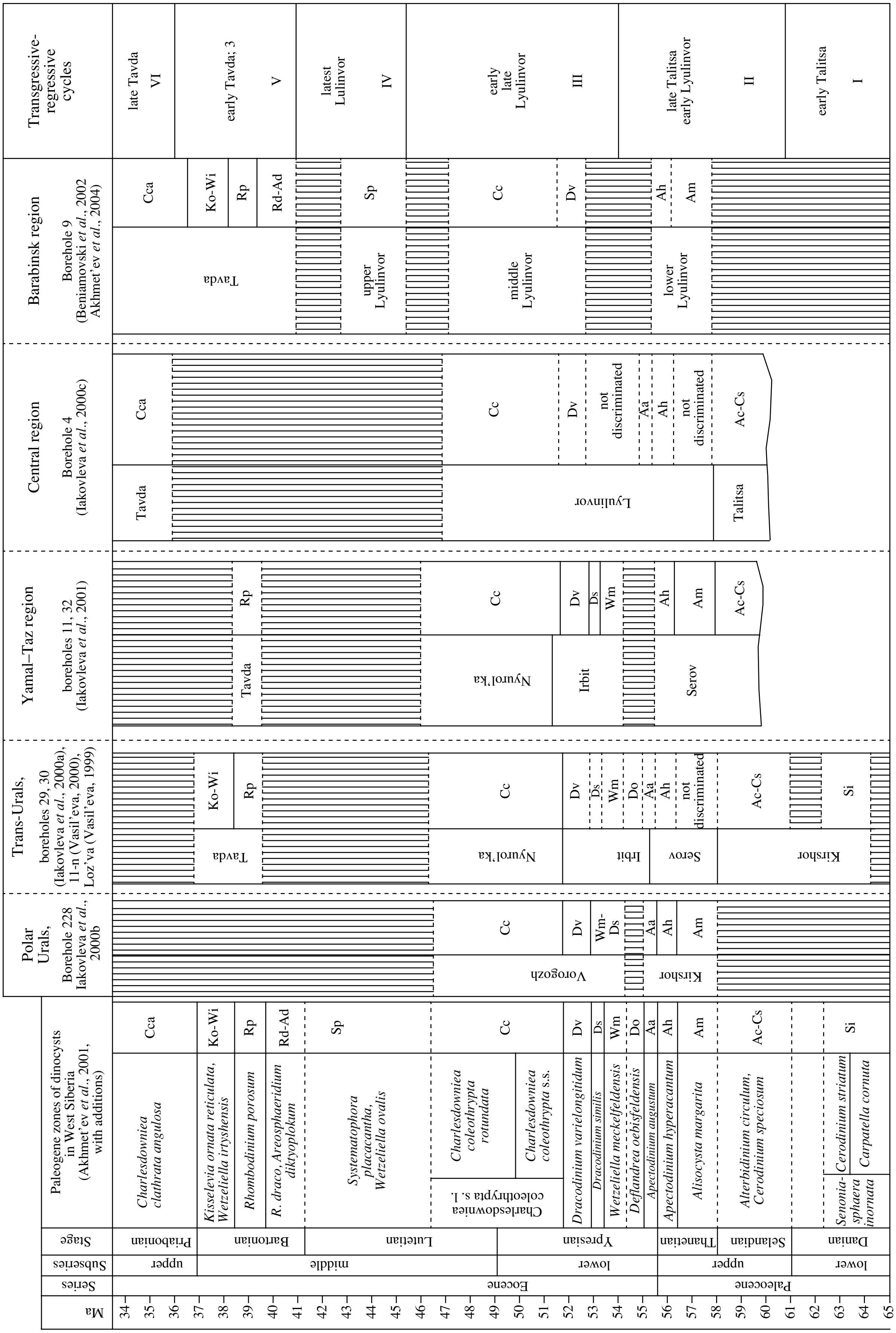


**Fig. 8.** Dinocyst zonation used as time scale to determine the hiatus spans and transgressive–regressive cycles in different lithologic–facies regions of West Siberia and Polar Urals.

where the *Hantkenina australis* Zone (PP13c) coupled with the *Subbotina azerbaidjanica* Subzone (PP14a) in the Gubs section are missed from the succession. The hiatus at the boundary between the Kuma and Belaya Glina formations is equivalent in its maximum range to the *Subbotina instabilis* Subzone (PP14b) coupled with the *Subbotina corpulenta* Zone (PP15).

Subdivision of the *Acarinina acarinata* Zone (PP8) into the lower *A. soldadoensis* (PP8a) and upper *Morozovella aequa* subzones with *M. aequa–M. acuta* (PP8b) and *S. patagonica* beds discriminated in the latter is suitable first to define the Paleocene–Eocene boundary in its current understanding (base of *M. aequa–M. acuta* Beds) and then to date the most important global and regional events. The principal events are the extinction of many benthic foraminifer species, disappearance and origin of some planktonic foraminifers, and commenced evolution of Eocene genera in communities of nannoplankton, diatoms and radiolarians. The global temperature optimum, $C_{org}$ excursion, and transition from carbonate to siliceous sedimentation are the remarkable events of the initial Eocene epoch (Beniamovski *et al.*, 1999; Aubry, 2000; Gavrilov and Shcherbinina, 2002; Radionova *et al.*, 2001; 2004).

It is necessary to mention also that in southern sections of the Crimea–Caucasus province the *Hantkenina australis* Subzone (PP13c) is represented by brown to dark brown marls of the Kuma Formation, which accumulated in anaerobic environments of a deep-water back-arc basin (Beniamovski *et al.*, 2003). In the northerly succession of the Scythian plate (Keresta site), the interval of this subzone is composed of white chalky marls of the Keresta Formation, which were deposited in anaerobic environments of a shelf sea. Here, indications of anoxic conditions similar to those of the Kuma time are recorded higher, in the *Subbotina azerbaidjanica* Subzone (PP14a). Consequently, they appeared approximately 0.5 m.y. later, when deep anoxic waters of the basin reached the Scythian plate at the time of considerable sea-level rise in the early Bartonian epoch. Anoxia spread throughout the water mass that explains the complete absence of benthic foraminifers in the Kuma Formation of the Keresta section and insignificant abundance of nannoplankton and calcareous planktonic foraminifers. As is suggested, the formation of anoxic basin at the time of the early Bartonian eustatic transgression has been caused by either the upwelling as in the model by Heckel (1977) adopted by Beniamovski and Shcherba (1997), or the intense influx of humus from proximal land (Azov arch) according to hypothesis of Gavrilov (Gavrilov and Kopaevich, 1996).

**West Siberia.** The dinocyst zonation is used in this case to assess ranges of hiatuses in reference sections of different structural-facies zones of West Siberia and the Polar Urals (Fig. 8). The upper Thanetian (*Apectodinium hyperacanthum* Zone) and upper Ypresian–basal Lutetian (*Dracodinium varielongitudum* and *Charlsdowniea coleothrypta* s. l. zones) sediments are present in all the sections of both regions. The indicated stratigraphic intervals characterize the most intense development of marine environments in the Uralian foredeep and West Siberian plate.

The regional hiatuses are recorded in the pre-Danian and pre-Thanetian intervals. The middle Danian and Selandian sediments are established only in the structural-facies zone of the trans-Urals. The next regional hiatus is confined to the Thanetian level predating the Ypresian Stage. It is most distinct in section of the Borehole 9 drilled in the Barabinsk structural-facies zone, where sediments of the *Dracodinium varielongitudum* Zone rest directly on the *A. hyperacanthum* Zone of the upper Thanetian. An intense regional erosion is recorded below the upper Bartonian (beneath the *Rhombodinium porosum* Zone), because the middle–upper Lutetian and lower Bartonian strata (interval of the *S. placacantha–W. ovalis* and *R. draco–A. dictyoplokum* zones) are missed in all the sections except for those of the Barabinsk structural-facies zone. The *Charlsdowniea clathrata angulosa* Zone of the upper Eocene is widespread in central and southern areas of West Siberia, being unknown in other areas, where continental coal-bearing deposits of the Yurkovo Formation are widespread instead. Deposits of the lower Oligocene (the Kurgan Beds corresponding to the *Phthanoperidinium amoenum* Zone) overlie with angular unconformity the uneven eroded surface of upper Eocene deposits filling in the pre-Oligocene incisions (Akhmet'ev *et al.*, 2001b).

The distinguished hiatuses coincide with regressive phases of transgressive–regressive cycles (Figs. 8 and 9). Six of these cycles distinguished in the Paleocene–Eocene succession of West Siberia correspond to the Danian (early Talitsa), late Selandian–Thanetian (late Talitsa–early Lyulinvor), Ypresian–early Lutetian (middle–late Lyulinvor), middle–late Lutetian (late Lyulinvor), Bartonian (early Tavda), and Priabonian (late Tavda) intervals. Each cycle is antedated by erosion of underlying sediments. Sedimentation rates have not been equal in different structural-facies zones. Vectors of sedimentation rates and thickness of sediments accumulated in the Polar Urals (Borehole 228) and Barabinsk structural-facies zone (Borehole 9) are compared in Fig. 10. As one can see, sediments 99 m thick accumulated during the Thanetian cycle in the first region, while in the second one they are only 30 m thick. On the other hand, the first region is lacking marine sediments of the Bartonian and Priabonian stages, whereas concurrent marine facies are 157 m thick in the Barabinsk zone (Fig. 10).

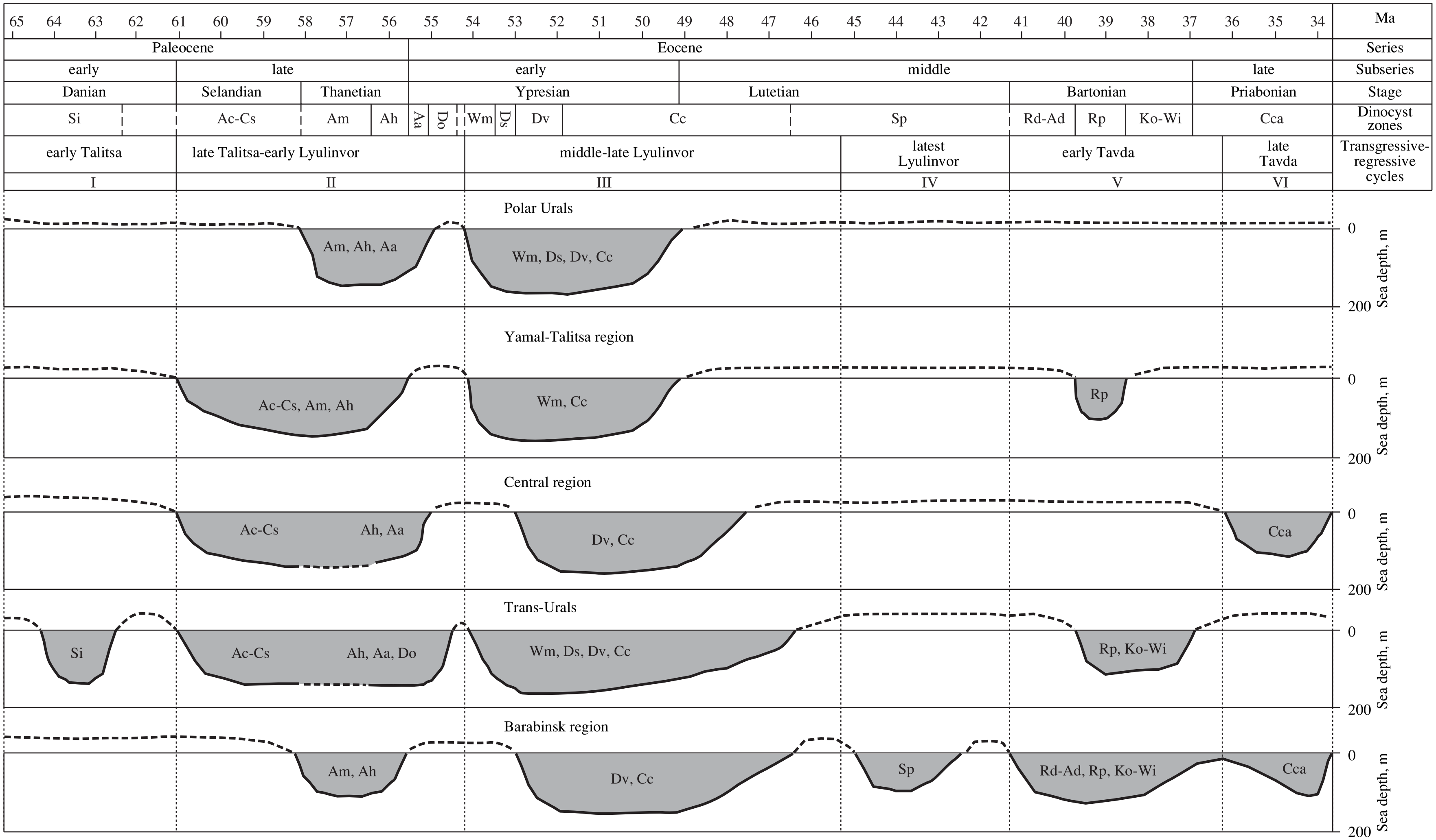


**Fig. 9.** Succession of tectonic movements and dynamics of sea basins evolution in the Polar Urals and West Siberia as inferred from dinocyst zonation in regional reference sections (shaded areas denote marine deposits, abbreviated indices of dinocyst zones as in Fig. 8).

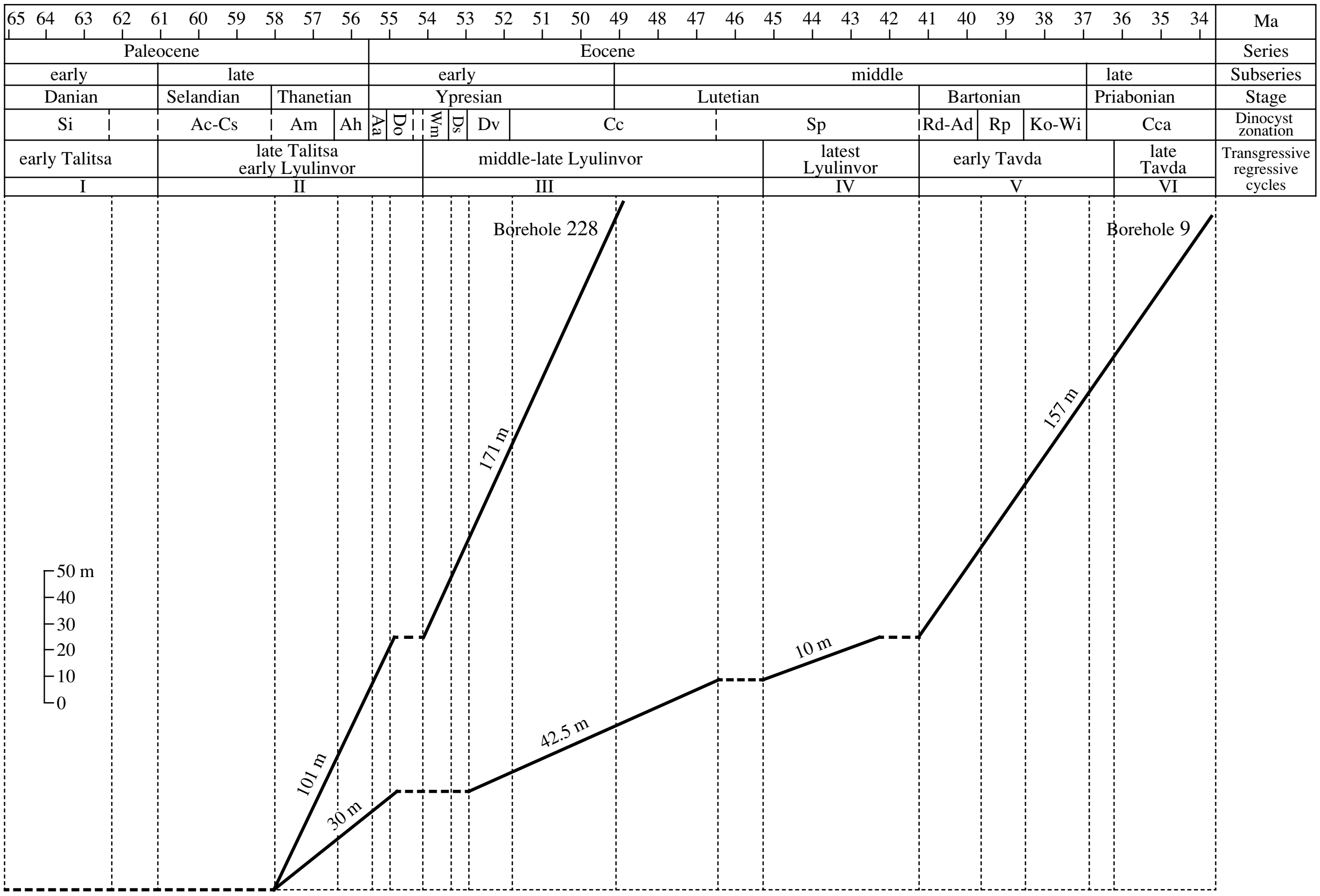


**Fig. 10.** Stratigraphic intervals and rates of sedimentation in two reference sections of boreholes 28 (Polar Urals) and 9 (Barabinsk region, southeastern West Siberia) as evaluated based on dinocyst zonation.

## *Paleogeographic and Paleoclimatic Substantiation of Biostratigraphic and Geological Reconstructions*

### Paleogeographic factors

Epicontinental seas and surrounding land areas of Central Eurasia were situated between the Arctic Ocean, Tethys, and North Atlantic.

The meridional and latitudinal sea-communication systems, which originated by the end of the Cretaceous and consisted of straits and seaways (Naidin, 2001), existed during the Paleogene as well (Fig. 11). The systems with relevant surficial and bottom currents of the same orientation controlled the water exchange and paleobiogeographic connections between the above oceans and epicontinental seas. Deepening, shallowing, and exsiccation of seaways and straits depended directly on tectonic movements of opposite signs and interrelated transformation of paleogeography. Opening and closing elements of communication systems modified directions of currents and influenced the water exchange patterns (Fig. 11) and thus the endemism degree of biota.

**The meridional communication system** included the West Siberian sea that was connected via the Turgai and Orsk straits in the south with seas of the Turan and Russian plates. In the north, the sea was open to waters of the Arctic Ocean. This meridional chain of seawater bodies separated paleophytochores termed by Zaklinskaya (1977) based on palynological data as the *Normapolles* and *Aquilapollenites* kingdoms.

The meridional West Siberian–Turgai seaway promoted influx of warm waters into the Polar latitudes and represented thus a kind of "heater" for Arctic regions. The influx cessation inserted immediate impact on climatic conditions in the Arctic and West Eurasia as a whole (Akhmet'ev, 1995, 2004).

During the Paleogene, the meridional communication system went through different phases of development, which are recorded in biotic and sedimentological changes.

The first early Danian phase corresponds to hiatus that is established everywhere in platform sections and spans the terminal Maastrichtian and lowermost Danian (Beniamovski, 2003b). Our analysis supports the assumption that the break in sedimentation was caused by immense regression of the terminal Mesozoic–initial Cenozoic time, which was triggered by the eustatic sea-level lowering over the globe (Naidin, 1976).

**Fig. 11.** Meridional (West Siberian sea, Turgai strait, Orsk channel) and latitudinal (Dnieper–Donets sea, Pripyat strait) communication systems and evolution of sea basins and straits in West Eurasia during the Early Paleogene (after Beniamovski, 2003, with modifications): (1) land; (2) sea.

As it follows from data on planktonic foraminifers, the Cenozoic marine sedimentation commenced in the middle Danian (interval of the *Globoconusa daubjergensis* Zone) nearly in all epicontinental seas of West Eurasia, the West Siberian sea included (Amon, 1987, 1990; Beniamovski, 2003b). During the early Danian continental phase, the *Trochodendroides* flora of the Siberian–Canadian province has penetrated into the central Urals (flora-bearing beds of the Loz'va River section described by A.N. Krishtofovich) and further into the Atlantic–European province (Akhmet'ev, 1995).

The second phase spans the early and initial late Paleocene (middle Danian–Selandian). It was the accumulation time of dark-colored carbonate-free clays of the lower Talitsa Subhorizon. Boreal diatom and radiolarian assemblages coexist in these deposits with foraminiferal assemblages containing Danian and Selandian forms of European origin (Podobina, 1990, 1998). A series of Selandian taxa is described from deposits recovered by four boreholes in the southwestern Yamal Peninsula (the Kharasavei area). Bugrova (oral communication) discovered here an assemblage of foraminifers characteristic of the *Ceratolamarckina tuberculata* Beds. The assemblage includes many species described by Brotzen (1948) from Selandian deposits of southern Sweden. These are *Ceratolamarckina tuberculata* (Brotzen), *C. perplexa* (Plummer), *Pseudopolymorphina geijeri angusta* Brotzen, *Sigmomorphina soluta* Brotzen, *Citharina plummoides* Plummer, *Pyramidina crassa* Brotzen, *Bolivina oedumi* Brotzen, and zonal species *Cibicides incognitus* Vassilenko. The last species is extremely abundant in the Paleocene deposits of Sumy Horizon near the Romny town, the Dnieper–Donets depression (Vasilenko, 1950).

A system of currents was in action. The southern current along southern and eastern coasts of the East European sea took origin in the Aral region deviating eastward, while the northern current run from the Arctic southward along the Uralian eastern coast (Akhmet'ev *et al.*, 2001a). These currents have been depicted earlier in the Mesozoic and Paleogene paleogeographic maps (Gol'bert *et al.*, 1968; Gol'bert, 1987; Umova *et al.*, 1968). In addition, there was one more current that circulated around the North European land favoring dispersal of foraminifers and mollusks in nearby sea zone (Beniamovski, 2003b).

The third phase of the communication system evolution commenced after break in sedimentation recorded across the Selandian–Thanetian boundary. It culminated in widening of the West Siberian sea with concurrent formation of semi-isolated Timan–Pechora gulf (Fig. 11). The oldest Cenozoic strata penetrated by Borehole 228 in the Polar Urals western flank (left bank of the Usa River, a right tributary of the Pechora River) correspond to transition from the upper Selandian to Thanetian (the *Trinacria ventriculosa* Zone of diatom zonation or the *Alisocysta margarita* Zone of dinocyst scale). These strata overlap the deeply eroded top of the Campanian sediments (Oreshkina *et al.*, 1998; Iakovleva *et al.*, 2000b).

The siliceous sedimentation in the Timan–Pechora sea gulf (opokas and diatomites with subordinate opoka-like clays of the lower Lyulinvor Subhorizon) was in progress since the late Selandian, especially in the Thanetian time. Siliceous plankton (diatoms, silicoflagellates, and radiolarians) became widespread during this period.

The fourth phase (middle–late Ypresian) characterizes the peak intensity of Arctic–Tethyan meridional communication, the maximum area extension of the West Siberian sea, and continuation of siliceous sedimentation (the middle and basal upper Lyulinvor subhorizons). The Ust-Yenisei gulf originated in the same time (*Atlas of Paleogeographic…*, 1968). The impact of southern water masses was perceptible only in the southeastern sector of the West Siberian sea. *Subbotina eocaenica* (Terquem), *S. pseudoeocaenica* (Subbotina), and *Pseudohastigerina wilcoxensis* (Cushman et Ponton) known from relevant sections represent rare Ypresian species of planktonic foraminifers of European origin, which appeared in the West Siberian sea owing to the southern current along southern and eastern coasts of the sea (Akhmet'ev *et al.*, 2001a; Beniamovski *et al.*, 2002).

The final cessation of Arctic communication in the second half of the middle Eocene influenced cardinally the composition of sediments and biota. The Lyulinvor complex of siliceous sediments gave way to the Tavda clay deposits. Radiolarians and diatoms disappeared, and diversity of foraminifers considerably decreased. Dinocyst assemblages of that time are indicative of salinity fluctuation in sea basin (Akhmet'ev *et al.*, 2004) with associated elimination of stenohaline species and simultaneous appearance of certain endemic taxa. Many ostracode species migrated from the Aral–Ustyurt basin into West Siberia. The sea basin, which considerably decreased in area during the terminal Bartonian and Priabonian, finally left the West Siberian plate by the end of the Eocene.

**The latitudinal communication system** included the Pripyat strait, Dnieper–Donets seaway, and Polish channel. Four phases are distinguishable in the Paleogene history of the system.

The first Sumy phase (middle Danian–initial Ypresian) commenced after regression of the terminal Maastrichtian–early Danian time. Western and eastern seas intensively communicated during this phase, as it evident from facies and biotic complexes in common on both sides of the above chain of channels (Kaplan *et al.*, 1977; Khokhlova and Oreshkina, 1999; Beniamovski, 2003b; Oreshkina and Oberhänsli, 2003). The circulating currents were of latitudinal orientation.

In the second Kanev phase (middle–late Ypresian), exsiccation of the Pripyat strait interrupted the communication (Balukhovsky *et al.*, 1998; Meulenkamp *et al.*, 2000; Beniamovski, 2003b). The Dnieper–Donets seaway turned at that time into a semiclosed sea gulf (Fig. 11). Assemblages of benthic foraminifers from West and East European provinces are almost deprived of species in common (Kaasschieter, 1961; Bugrova, 1988; Vinken, 1988; Naidin *et al.*, 1994).

The third Buchak–early Kiev phase corresponded to the early Lutetian downwarping of the Brest and Pripyat troughs and Polessk saddle that happened at the time of global eustatic sea-level rise (Haq *et al.*, 1987). As a result, western and eastern sea basins of the northern Peri-Tethys became connected again. The communication way was most broad in the late Lutetian (Keresta) time (Fig. 11). Similar assemblages of benthic foraminifers existed at that time everywhere in the northern Per-Tethys (Kaasschieter, 1961; Fursenko and Fursenko, 1961; Kaplan *et al.*, 1977; Grigyalis *et al.*, 1988; Bugrova, 1988; Naidin *et al.*, 1994; Radionova *et al.*, 1994).

Remarkable events of the fourth late Kiev–Khar'kov (Bartonian–Rupelian) phase are the contraction of seaways, their periodical exsiccation, and interruption of communication. Compositions of sediments and benthic foraminiferal assemblages in western and eastern seas of the northern Peri-Tethys were distinctly different (Bugrova, 2001).

### Paleoclimatic factors

The Paleogene climatic events in West and North Eurasia have been accompanied by changes in sedimentation, marine biota, and terrestrial vegetation (Figs. 12, 13). During the regression of the Maastrichtian–Danian boundary time, the mesophilic *Ginkgo–Taxodium–Trochodendroides–Platanus* flora, which developed under conditions of humid climate with a uniform distribution of annual precipitates, spread over the greater part of extratropical Eurasia. In inner regions of the continent, it reached the Zaisan depression, Dzhungar Alatau, and Mongolia occupying simultaneously northeastern China up to the latitude of Beijing (Akhmet'ev, 2004). In the west of circum-polar zone, flora of this kind existed in Spitsbergen and Greenland. Exsiccation of the West Siberian–Turgai seaway favored migration of mesophilic flora to the central and northern Urals. In the Tethyan province of West Eurasia, there was formed in the earliest Paleocene an ecotone zone, where *Ushia, Macclintockia*, and *Dewalquea* coexisted with plants of the *Trochodendroides–Platanus* flora. During the subsequent climatic warming of the Paleocene time, the indicated plant taxa represented remarkable components of the Gelinden "paratropical" flora. In northern Europe, they participated in vegetation of Boreal areas. The exsiccation of coastal zones in the Maastrichtian–Danian boundary period promoted the *Ushia* migration to the east, where relevant plants turned, like in Europe, into index forms of paratropical flora. In the Saratov and Ul'yanovsk areas near the Volga River, remains of *Ushia, Dewalquea*, Cupressaceae, and *Macclintockia* occur in sand strata of the so-called Sosnovka facies of the Syzran Horizon, i.e., much lower than the beds with Kamyshin flora containing remains of the originally described genus *Ushia.* Coasts of latitudinal seaways represented the main migration tracts for flora.

The Danian–Selandian boundary is indicative of transition from warm temperate climate with floras of the Tsagayan type (*Trochodendroides, Platanus*) to paratropical climate with the Gelinden-type floras (*Nypha, Ushia*). Simultaneously it was a time of initial development of thermophilic genera *Morozovella* and *Igorina*, which migrated northward up to the latitude of 50° N. In many regions, this event coincides with transition from the carbonate to carbonate–terrigenous–siliceous cyclothem.

The well-known crisis in the biosphere, which is recorded across the Paleocene–Eocene boundary and resulted in global extinction of Paleocene benthic foraminifers and in accelerated evolution of siliceous and organic-walled groups of plankton, was likely caused by subsequent greater warming and anoxic conditions in sea basins below the euphotic zone (from 500 m downward). The crisis changed composition of paratropical flora that survived the culmination phase in the terminal Paleogene. The broad-leaved flora of the terminal Thanetian from the Romankol site in the southern Urals and concurrent Cézan and Ria floras from periphery of the Parisian basin reveal a high abundance of tropical taxa, the maximum one in the middle latitudes. This is readily evident from the following list of families and genera present in the Romankol flora: Moraceae (*Artocarpus*, *Ficus*), Proteaceae (*Dryandra*), Magnoliaceae, Lauraceae (6 genera), Eophorbiaceae, Eleocarpaceae, Sterculiaceae, Combretaceae, Myrtaceae, Theaceae, Melastomataceae, Araliaceae, Sapotaceae (*Sideroxylon*), Symplocaceae, Apocynaceae, Rubiaceae (Makulbekov, 1977; Baikovskaya, 1984).

The flora composition changed as well in the Ypresian time, when paratropical climate gave way to subtropical climate of the monsoon type with humid summer seasons. This climatic transformation was presumably related to reduction of the seaway open-ended before, which connected seas of the eastern Peri-Tethys with the North Sea basin via northern Ukraine, Belarus, and southern Baltic region. Retention of southern and cessation of latitudinal transport of heat and humidity caused redistribution of seasonal precipitates. The most important indicators of newly formed monsoon climate are *Castanopsis* and associated evergreen Fagaceae and Lauraceae, as their recent analogues are concentrated now in the monsoon zone of Southeast Asia. Sections of Ypresian marine deposits (especially the second half of the stage) reveal appearance of black shale interlayers and extension of siliceous sedimentation areas.

In the second half of the Lutetian, warm-water foraminifers of genera *Globigerinatheka, Clavigerinella, Turborotalia,* and *Subbotina* migrated from the Tethyan

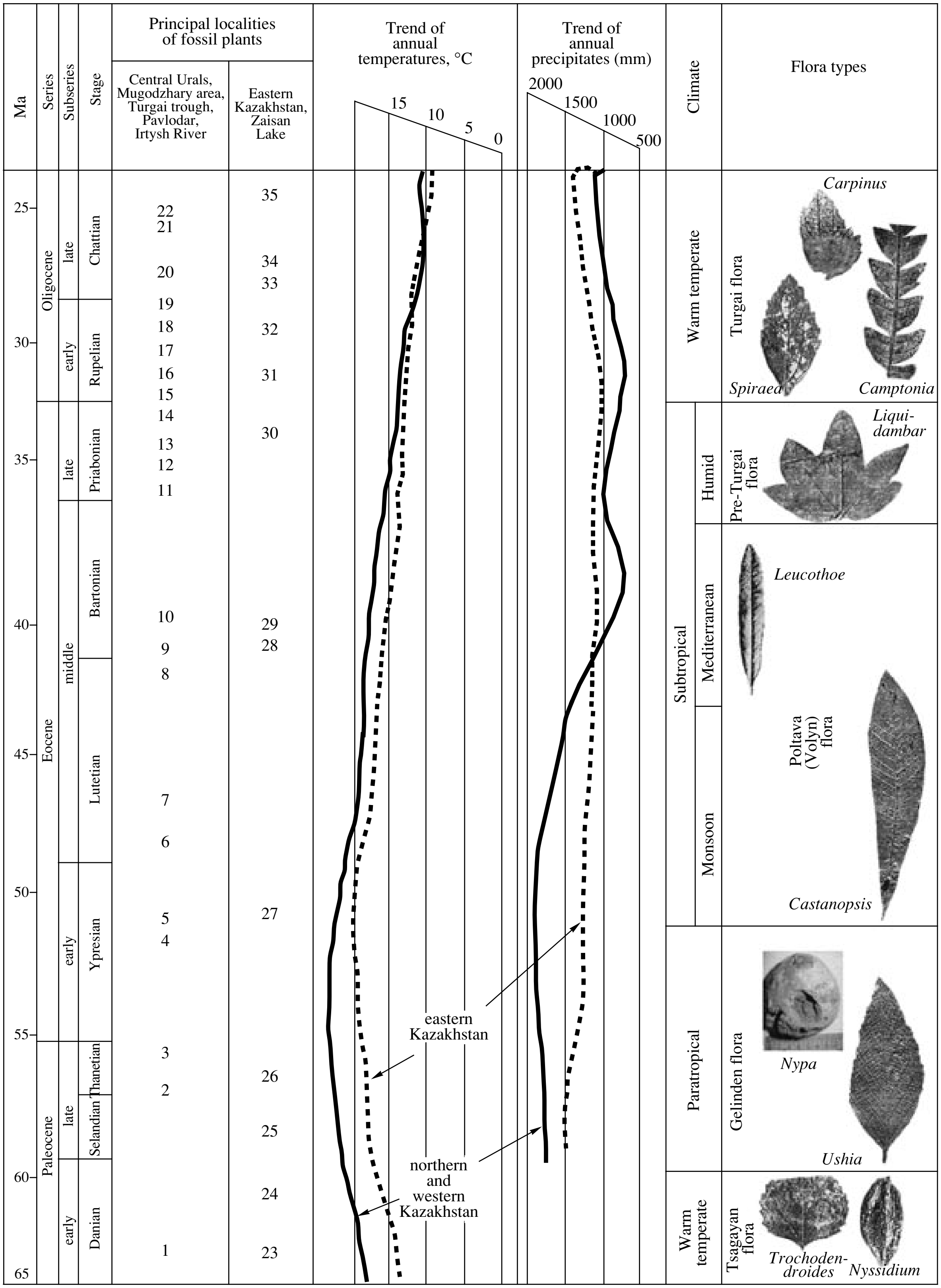


**Fig. 12.** Evolution of climate in Central Eurasia during the Paleogene (after Makulbekov, 1977; Akhmet'ev, 1995, 1996, 2004; *Geological and Biotic...*, 1998) and principal localities of fossil plants: (1) Loz'va; (2) Romankol; (3) Tykbutak; (4) Karakol; (5) Sorkol; (6) Or; (7) Katasor; (8) Zhamantuz; (9) Baky; (10) Shaida (base); 11. Shaida (top); 12. Irtysh–Karaganda Channel; 13. Akzhar; 14. Romanovskoe; 15. Kyzyl Tobe; 16. Shintuzsai; 17. Manyske-Suk; 18. Zhaman-Kaundy; 19. Tortmolla; 20. Altyn-Shokosai; 21. Azhylansai; 22. Altyn-Shokosai II; 23. Taizhuzgen; 24. Kara-Biryuk; 25. Chakulmes I; 26. Kiin-Kerish I; 27. Kershi; 28. Kiin-Kerish II; 29. Tuzabak; 30. Kiin-Kerish III; 31. Kiin-Kerish IV; 32. Ashutas I; 33. Kusto; 34. Ashutas II; 35. Ashutas III.

province into seas of the Crimea–Caucasus region. Their single representatives advanced to the north and reached the southern periphery of the West Siberian sea. In the terminal Lutetian–Bartonian time, assemblages of warm-water planktonic foraminifers gave way to cosmopolitan and more cold-resistant taxa (Fig. 13). This was likely a reaction to global cooling, because the first stage of glaciation in Antarctica took place at that time (Barron *et al.*, 1991a, 1991b).

After reorganization of sea communication systems of the Lutetian–Bartonian boundary time, subtropical climate in the middle latitudes of West Eurasia was most close to the present-day Mediterranean climate with humid winters and hot dry summers. The vegetation cover in these latitudes was dominated by angustifoliate to sclerophyllous *Quercus–Lauraceae* forests with Myricaceae, Ericaceae (*Leucothoe*), and Palmae (*Trachycarpus, Sabal*). Arboreal vegetation of the middle–initial late Eocene was rather uniform over the entire belt extending from central Europe (Czech Republic, Hungary) to the Pavolodar area at the Irtysh River. Interchange of floras was realized through northern coasts and archipelagoes of seas of the northern Peri-Tethys.

In the initial late Eocene, warm-water *Globigerinatheka* and *Turborotalia* forms appeared again in assemblages of planktonic foraminifers of the Crimea–Caucasus region (Fig. 13). Assemblages of benthic foraminifers became close in composition to the Mediterranean ones (Bugrova, 2001). Marine biota of the upper Tavda Subhorizon was under influence of faunas of the southern sea basin situated in the Aral–Central Asia region (Akhmet'ev *et al.*, 2001a; Beniamovski *et al.*, 2002).

In the late Eocene, when epicontinental sea recessed from the Turgai and West Siberia, climate was more humid, with relatively uniform seasonal distribution of atmospheric precipitates. The sclerophyllous *Quercus–Lauraceae* forests gave way in vegetation cover to communities of summer-green broad-leaved mesophilic plants with participation of Taxodiaceae, Juglandaceae, Hamamelidaceae, and Fagaceae. Compositional changes affected first the azonal riparian vegetation and then floras of higher landscape zones.

Finally, the Eocene–Oligocene boundary time corresponded to global climatic cooling responsible for synchronous changes in terrestrial vegetation (wide development of broad-leaved deciduous forests of the Turgai type) and marine biota (extinction of nannoplankton and planktonic foraminifers and origin of benthic foraminiferal assemblages of low diversity, which consisted of smaller thin-walled forms). The carbonate–terrigenous sedimentation gave way to the terrigenous one (*Geological and Biotic Events…*, 1998).

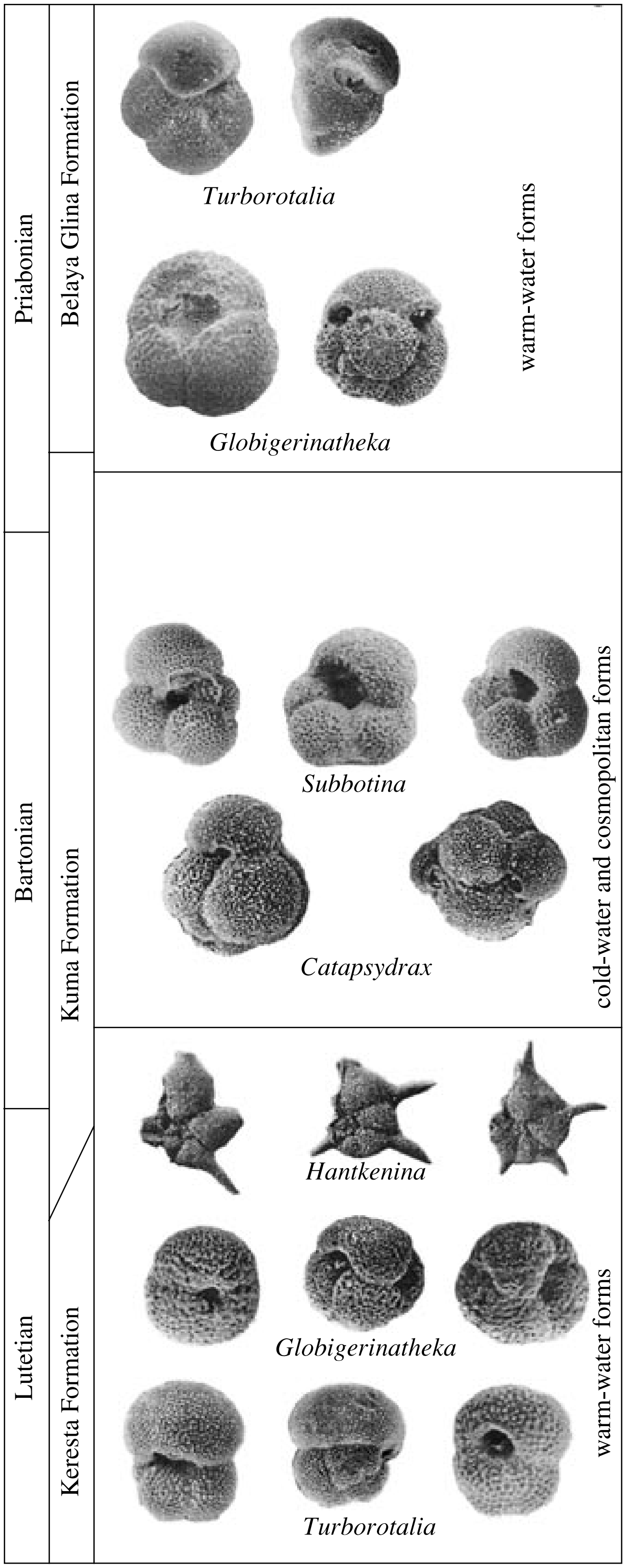


**Fig. 13.** Planktonic foraminifers indicative of seawater temperature from the middle–upper Eocene deposits in the Crimea–Caucasus region (after Beniamovski *et al.*, 2003).

## CONCLUSIONS

1. Zonations of different fossil groups, which are accepted for subdivision of Paleocene and Eocene sediments in the southern East European platform and West Siberia, are dissimilar in their ranks. (a) The nannoplankton zonation in use corresponds to the International global scale (Martini, 1971; Bukry, 1973, 1975). (b) Zonal scale of planktonic foraminifers includes regional zones of the middle Eocene (Beniamovski, 2001) in addition to analogues of the Paleocene, Ypresian, and Priabonian standard zones (Berggren and Norris, 1997; Berggren *et al.*, 1998). (c) The dinocyst scale considered as standard for South European Russia and West Siberia represents an integration of earlier dinocyst zonations established in northwestern Europe, southern areas of the USSR, and West Siberia. As a whole, it can be ranked as the modern standard of Paleogene dinocyst zonation in the north of Central Eurasia. (d) The radiolarian and diatom zonations, which are based on the Paleocene–Eocene reference sections of the Dnieper–Donets depression, Voronezh anteclise, Ul'yanovsk–Saratov trough, circum-Caspian depression, Turgai trough, and West Siberian plate, characterize stages in development of both fossil groups in middle and high latitudes of West Eurasia. (e) Palynozones are established in continental and marine sediments, being coordinated in the last case with dinocyst zones. They represent the reference standard to synchronize biotic events in seas of the northern Peri-Tethys and surrounding land areas of Eurasia.

2. The above zonal scales are used to distinguish hiatuses separating main transgressive–regressive cycles and to evaluate their stratigraphic ranges.

3. Three zones of siliceous–terrigenous, siliceous–carbonate–terrigenous, and carbonate–terrigenous sedimentation corresponded in the past to sea basins with different water masses and microplankton groups. Dinocysts, radiolarians, and diatoms were widespread in the first zone of the Boreal water mass. The second zone of sub-Tethyan water mass was inhabited by calcareous, siliceous, and organic-walled plankton. Distinct predominance of calcareous plankton was characteristic of the third zone of Tethyan to sub-Tethyan water masses.

4. The meridional and latitudinal communication systems, which originated in the Late Cretaceous, functioned as well during the Paleocene and Eocene facilitating interchange of waters and biota between oceans and inner seas. The longitudinal system of the West Siberian seaway and Turgai strait facilitated the Arctic–Tethyan communication. Western and eastern seas of the northern Peri-Tethys were interconnected via the latitudinal system of the Dnieper–Donets sea basin, Pripyat strait, and Polish channel. Sea currents of meridional and latitudinal orientation favored dispersal of marine organisms.

5. Deepening, shallowing or exsiccation of seaways, channels, and marginal seas of the northern Peri-Tethys depended on combined influence of eustatic sea-level changes, epeirogeny, and regional tectonic events. This controlled "work of sea-valves," which regulated transformation and diversification of biota.

The first and most significant transformation of biota happened at the Maastrichtian–Danian boundary time in response to concurrent global regression and associated climatic cooling, when inner seas disappeared in all the platforms of West Eurasia. Biotic events of the earliest Ypresian coincided in time with disturbance of latitudinal seaways that caused isolation of western and eastern seas of the northern Peri-Tethys and changed connections with the Atlantic Ocean. To a considerable extent, this transformation was reinforced by the well-known global event in biosphere, i.e., by destruction of hydrocarbon reservoirs in the World Ocean that triggered deposition of black shale and sapropel $C_{org}$-enriched sequences in sea basins (Naidin *et al.*, 1984). In southern Russia, sequences of this kind are known in the northern monocline of the Greater Caucasus and in the circum-Caspian depression (Shutskaya, 1970; Naidin *et al.*, 1994). In the Lutetian–Bartonian boundary period, after reduction and subsequent closure of the longitudinal communication system between the Tethys and Arctic Ocean, the latitudinal system was transformed as well that probably was a decisive factor responsible for formation of the Kuma anoxic basin.

6. Reorganization of sea communication systems created barriers or passageways for migration of terrestrial fauna and flora. It considerably influenced as well climatic conditions in West Eurasia. The paratropical humid climate that was settled in middle latitudes by the end of the early Paleocene gave way in the Ypresian time to the monsoon subtropical climate with humid summer seasons. After paleogeographic transformations and climatic inversion of the Lutetian–Bartonian boundary time, climate in middle latitudes of West Eurasia was still subtropical but with humid winters and dry hot summers like in the Mediterranean region at present. Finally, the progressing cooling of the terminal Eocene changed climatic conditions again, and climate still subtropical in the south turned in northerly areas into warm temperate and humid with relatively uniform distribution of annual precipitates. This favored development of the early Oligocene mesophilic coniferous–broad-leaved flora of the Turgai type.

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