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MIOCENE MARINE DIATOM BIOSTRATIGRAPHY OF THE EASTERN PARATETHYS (UKRAINE)

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Abstract: The diatom flora from the Miocene deposits of Ukraine was studied. Diatom zonation for the Early Miocene to Late Miocene is proposed. The first and last occurrences of diatoms, mass development of taxa, and level of reconstruction of the diatom association have been useful. The following diatom zones and beds with diatoms are defined: Craspedodiscus elegans-Cavitatus jouseanus in deposits of Batisiphonova Formation; Delphineis subtilissima in Korolevsky Beds; Lancineis parilis in the upper part of Balichska Formation; Actinocyclus ingens in Kartvel Beds and in the deposits of Tereblianska Formation; Anaulus mediterraneus in Kosovska Formation; Navicula pinnata in Buglovski and in Baskhevska deposits; Mastogloia szonthaghii-Cymatosira biharensis, Achnanthes baldjikii var. podolica and Navicula zichii in Sarmatian deposits; Thalassiosira delicatissima, Lyrella pigmea, Amphitetras sp., Actinoptychus senarius var. tamanica, Cymatosira savtchenkoi and Rhizosolenia bezrukovii in Meotian deposits; Stephanodiscus proprius-Stephanodiscus multifarius in Pontian. The stratigraphic position of the diatom zones and correlation with calcareous nannofossil zone are considered.

Key words: Miocene, Ukraine, biostratigraphy, marine sediments, zones, diatoms.

Introduction

The diatom zonation of the Neogene sediments of Ukraine is based on consecutive change of diatom assemblages. It includes the zone, mainly the cenozone, as the basic biostratigraphic unit, and layers with flora as an auxiliary unit. Each of them is characterized by specific taxonomic structure of a diatom assemblage, differing from those of above — and underlying levels. The diatom zonation of the Neogene of Ukraine unites both the first diatom zones defined by us and those known in other regions and found in Ukraine (Fig. 1).

Material and methods

The areas of marine and nonmarine sedimentary development of the Euxin part of the Eastern Paratethys, of some regions of Central Paratethys and modern Black Sea region were investigated. The diatoms from Neogene deposits of different geological regions of Ukraine were studied. Samples with Neogene diatoms from neighbouring areas of Russia, North-Eastern Bulgaria and the Bulgarian shelf of the Black Sea, as well as published materials were also used. Early Miocene diatoms in Ukraine are known in the Crimean region, on the southern slope of the Ukrainian Shield and in the Black Sea side. Marine Middle Miocene diatoms are known in the Volhyno-Podolia, Zakarpatie and in Crimean regions, nonmarine are known in the Donbass. Late Miocene diatoms are distributed in South-Eastern and Central Ukraine, in the Crimean region and in the sediments of the Black Sea (Fig. 2).

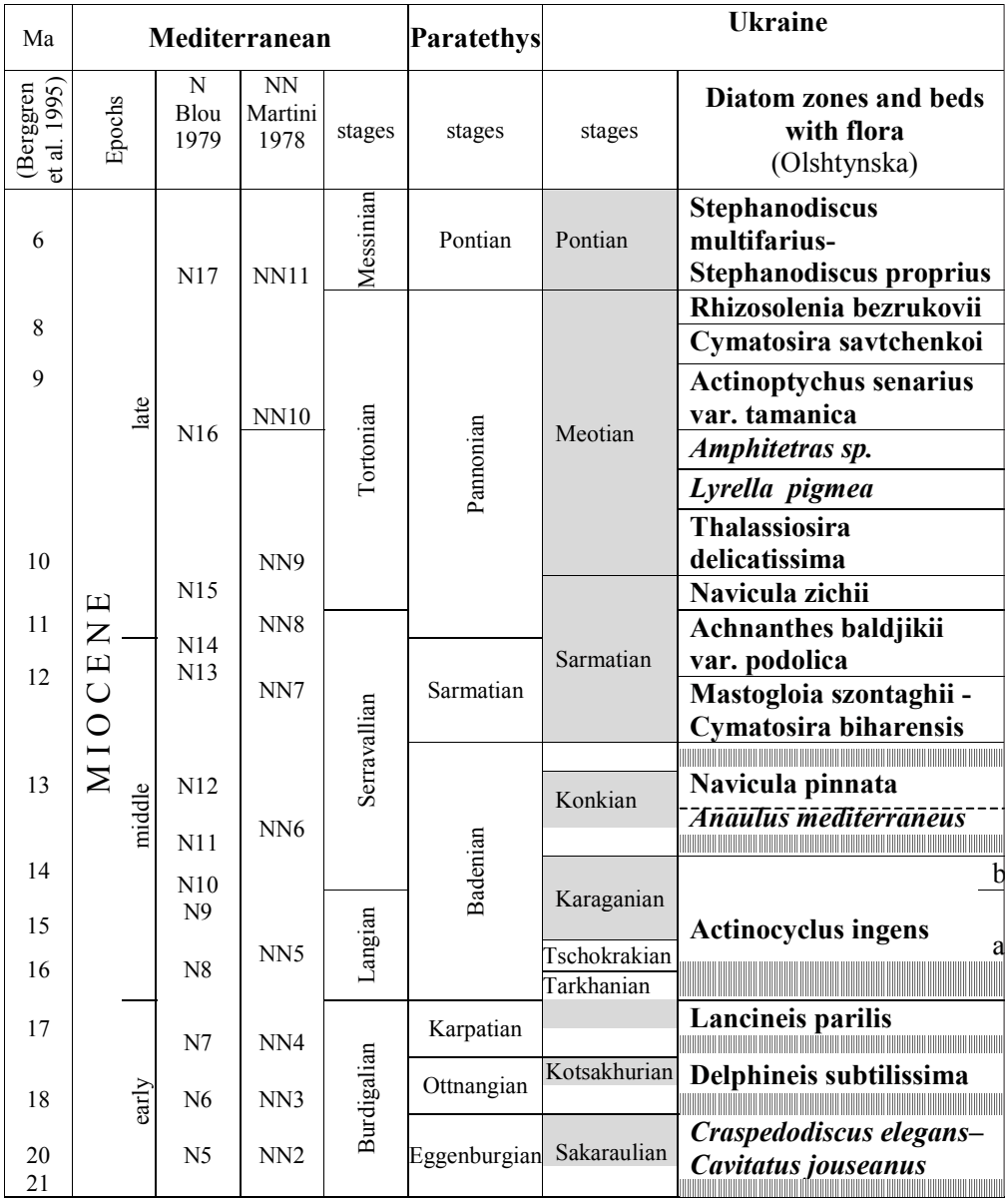
The frustules of diatoms were studied under light and scanning electron microscopes. The obtained results have served as the basis for diatom zonation of Ukraine.

Diatom zonation

The following diatom biostratigraphic levels can be distinguished in Miocene sediments of Ukraine.

The bed with *Craspedodiscus elegans–Cavitatus jouseanus* is defined in laminate clay of Batisiphonova Formation near mount Karagach of the Kerch Peninsula. The genera of *Chaetoceros* Ehr., *Coscinodiscus* Ehr., *Xanthiopyxis* Ehr. and *Actinocyclus* Ehr. are the most diverse. The species of *Craspedodiscus elegans* Ehr., *Cr. coscinodiscus* Ehr. and spores of *Xanthiopyxis* predominate and *Thalassionema nitzschioides* Grun. var. *obtusa*, *Cavitatus jouseanus* f. *linearis* Sheshuk. are also abundant. Moreover, *Coscinodiscus grossheimii* Gles., *Actinocyclus kisselevii* Makar., *Actinoptychus undulatus* var. *tamanica* Jouse are present in this layer. The assemblage of the Cr. elegans-C. jouseanus Bed is similar to the Eggenburgian Melosira hispanica Zone in the Central Paratethys, which was correlated (Řeháková 1975, 1977; Hajós 1986) with the calcareous nannofossil zone NN2 and planktonic foraminiferal zone N5 (Fig. 3). Diatoms from Ukraine differ with their high endemism and by the absence of many characteristic species of the M. hispanica Zone.

The presence of *Craspedodiscus elegans* here and *Cr. coscinodiscus* allows us to define the stratigraphic position of the diatoms. Barron (1985, 1992) has defined the datum levels of *Cr. elegans* s. lato in the Early Miocene as the interval 22.2 to 18.7 Ma and of *Cr. coscinodiscus* as the interval 23.5–12.5 Ma. The Cr. elegans Zone of the North Atlantic correlates with the top part of the planktonic foraminiferal zone N5 and undifferentiated NN2–NN3 calcareous nannofossil zone (Baldauf 1986). *Cavitatus jouseanus* is known from Late Oligocene and it is typical for the Early Miocene flora (Fig. 4). The bed with *Cr. elegans–C. jouseanus* can be correlated with a part of the



1 — Stephanodiscus multifarius — diatom zones
2 — *Amphitetras* sp. — beds with flora

— distribution of diatoms in Ukraine
— diatom data are barren

Fig. 1. Miocene diatom zonation of Ukraine.

Rocella vigilans-Synedra jouseana and Nitzschia maleinterpretata zones (Schrader & Fenner 1976), with the first half of the Rhizosolenia norvegica Zone (Dzhinoridze et al. 1979) and can be compared with a part of the Rossiella paleaceae and Cr. elegans zones (Barron 1985, 1992).

The Delphineis subtilissima Zone is defined in the Korolevsky Beds of core 23591, height 93.3 m near Lubimovka village in the southern part of the Ukrainian Shield and spread in the northern part of the Black Sea side. Diatoms are characterized by monotonous genera composition, high endemism and the appearance of *Delphineis subtilissima* (Pant.) Loss. The assemblage contains 10 species of the genus *Actinocyclus* and solitary species of *Aulacoseira* Thw., *Ellerbeckia* Craw., *Istmia* Ehr., *Rhaphoneis* Ehr., *Delphineis* Andrews, *Sceptroneis* Ehr., *Diploneis* Ehr., *Navicula* Bory. The species *Actinocyclus* aff. *gorbunovii* (Shesh.) Moiss. et Shesh., *A. kozyrenkoi* Olsht., *Aulacoseira praegranulata* (Jouse) Sim. dominate and *Ellerbeckia arenaria* (Moore et Rolphs) Crawford, *Istmia szaboi* Pant. are most characteristic (Fig. 5.1–4) (Olshtynska 1993, 1996, 1997).

The Delphineis subtilissima Zone of Ukraine is correlated with both the Rhaphoneis subtilissima Zone from the bottom

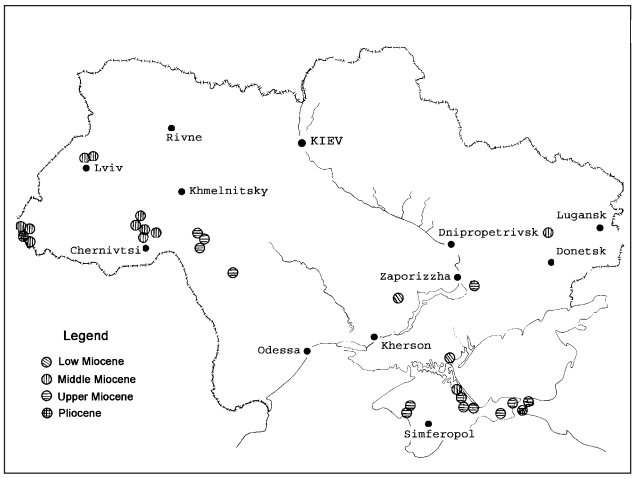


Fig. 2. Localities of Miocene diatoms in Ukraine.

of the upper part of Ottnangian of the Central Paratethys (Hajós 1986) (Fig. 3) and the upper part of the Coscinodiscus moronensis Zone of the Central Paratethys also with the calcareous nannofossil zone NN3, the planktonic foraminiferal zone N6 and the lower part of the silicoflagellata Corbisema triacantha var. flexuosa Zone (Hajós 1986; Řeháková 1977). In contrast to the R. subtilissima Zone of Central Paratethys the diatom assemblages from Ukraine are more monotonous, however they show similarity in their dominant group of species and also the presence of *D. subtilissima* having a narrow stratigraphic range.

The Lancineis parilis Zone is defined in clay of upper part of Balichska Formation in core 119-D, height 230 m near Ustechko village, Volhyno-Podolia. It is characterized by the appearance of *Lancineis parilis* (Fig. 5.5–6), diversity of genera *Rhaphoneis* Ehr., *Mastogloia* Thw., *Diploneis*, plenty of *Lancineis* sp., *Rhaphoneis scalaris* Ehr., *Rh. obesula* Hanna, *Hyalodiscus planus* Kozyr., *Thalassionema obesula* (Grun.) Andrews, *Delphineis penneliptica* Andrews, by the presence of *Diploneis szontaghii* Pant., *Cocconeis vetusta* A.S., *Denticulopsis* aff. *lauta* Bail., *Macrora stella* (Azp.) Hanna. The Badenian species *Eunotogramma variabile* Grun., *Triceratium laetum* f. *quadrata* Hajós, *Cymatosira biharensis* Pant., *Mastogloia splendida* (Greg.) Cl., *Nitzschia vermicularis* (Ktz.) Grun. and *Navicula jarrensis* Grun. occur at the top of the L. parilis Zone.

Diatoms are found together with planktonic foraminifers of the Quinqueloculina distrata Zone, calcareous nannofossils of the NN4 Zone and palynomorpha. It gave the possibility to prove the stratigraphical ranges of the diatoms and dating of the late Karpatian (Prisyazhnjuk et al. 1997).

The Lancineis parilis Zone of Ukraine can be correlated with the Rhaphoneis parilis Zone of the Karpatian formation of the Central Paratethys which is defined by the appearance of *Rh. parilis* Hanna (Hajós 1986). It was compared with the mostly Rhaphidodiscus marilandicus-Actinocyclus grunovii Zone sensu Řehaková (1977) and correlated with the nannofossil zone NN4, planktonic foraminiferal zone N7 (Fig. 3). The assemblage of the L. parilis Zone is similar to that of the Rh. parilis Zone in its diversity of *Rhaphoneis*, *Lancineis*, *Sceptroneis*. In contrast to the Central Paratethys species *Cymatogonia amblioceras* (Ehr.) A.S., *Actinoptychus stella* A.S., *Rhaphidodiscus marilandica* (Christ.) Christ. are absent in Ukraine.

The genus *Denticulopsis* Simonsen is an important biostratigraphic marker of the Miocene sediments and the occurrence of *D.* aff. *lauta* is a marker of Middle Miocene age of the L. parilis Zone (Fig. 4). *Delphineis penneliptica* also has a short range and wide geographical distribution and can be used for correlation. According to Abbott & Andrews (1979), Andrews (1990) and Yanagisava (1998) the first occurrence of *D. penneliptica* is noticed in the first half of Middle Miocene. It is present at approximately the same level in the Eastern Paratethys. Its last occurrence in the Northern Pacific is fixed at 14 Ma (Barron 1985).

The Actinocyclus ingens Zone was found in Kartvel Beds of the Karagan Formation of the Crimea and in deposits of the Tereblianska Formation of Zakarpatie. The A. ingens Zone of Ukraine is divided into subzones "a" and "b". It is characterized by an abundance of *Actinocyclus ingens* Rattr., mass of *Paralia crenulata* (Grun.) Gles. and *Pseudopodosira modesta* (Grun.) Gles., the presence of *Triceratium condecorum* Ehr., *Macrora stella*, *Psammodiscus nitidus* (Greg.) Round et Mann, *Actinoptychus thumii* A.S., *Thalassionema nitzschioides* Grun. The top part contains *Denticulopsis hustedtii* (Sim. et Kanaya).

The Actinocyclus ingens-Denticula lauta Zone was defined in the lower part of the Badenian formation of Czechia (Řeháková 1977) and correlated with the planktonic foraminiferal zones N8 -9 -10 and the calcareous nannofossil NN5 -6 zones of the Badenian. Its bottom part corresponds to the top Coscinodiscus pannonicus Zone of the Early Badenian of Hungary. The top part corresponds to the first half of Actinocyclus ingens Zone of the Middle Badenian of Hungary, which is correlated with the N9 -10 -11 zones and NN6 Zone (Fig. 3).

The Actinocyclus ingens Zone (subzone "a") is defined in the sandy clays of the Tereblianska Formation near Lipcha village, of the Solotvino depression of Zakarpatie and spread in Volhyno-Podolia. The assemblage is characterized by the variety of genus *Actinoptychus*, *Rhaphoneis*, *Coscinodiscus*, *Diploneis* (Vodopjan 1981). *A. ingens* is the dominant species; *Paralia sulcata* (Ehr.) Cl., *Actinocyclus octonarius* Ehr., *Rhaphoneis amphiceros* Ehr., *Rh. hungarica*, *Psammodiscus nitidus*, *Thalassionema nitzschioides* are subdominant; while *T. hirosakiensis* (Kanaya) Schrader, *Diploneis szontaghii* Pant., *Azpeitia vetustissima* (Pant.) Sims, *Coscinodiscus lewisianus* Grev., *Denticulopsis lauta* are also present. The A. ingens Subzone "a" corresponding to the part of the A. ingens-D. lauta Zone (Řeháková 1975, 1977) is also correlated with the Early Badenian Coscinodiscus pannonicus Zone and NN5 Zone (Hajós 1986).

The same species are characteristic for the D. lauta Zone of the Middle Miocene of the Norwegian Sea (Dzhinoridze et al. 1979), where the occurrence of *D. lauta* coincides with numerous *A. ingens*. The D. lauta Zone in Middle Miocene deposits of the oceans is also characterized by numerous *A. ingens* and the presence of *C. lewisianus* (Koizumi 1973).

The Actinocyclus ingens Zone (subzone "b") is defined in calcareous clay of the Kartvel Beds of the Karagan Forma-

CENTRAL PARATETHYS (M.Hajós 1986)				
Regional age classification		Řeháková 1975 (in 1977)	Hajós 1986	
		Central Paratethys **Diatom zones**	**Diatom zones**	**Silicoflagellata zones**
MIOCENE	Sarmatian	Coscinodiscus doljensis Anaulus simplex	Anaulus simplex	Distephanus slavnicii
	Badenian	?	Navicula pinnata	?
		Denticula lauta Actinocyclus ingens	Actinocyclus ingens	Dictiocha fibula Distephanus crux f. longispina
			Coscinodiscus pannonicus	?
	Karpatian	Rhaphidodiscus marilandicus	Rhaphoneis parilis	Mesocena elliptica
	Ottnangian	A. truanii - Coscinodiscus moronensis	Rhaphoneis subtilissima	Corbisema triacantha var. flexuosa f. IV
	Eggen-burgian	?	Melosira hispanica	Corbisema triacantha var. flexuosa f. III

NORTH-EASTERN BULGARIA	
Regional substages	Temniskova-Topalova 1994 **Diatom zones and subzones**
Chersonian	Navicula zichii
Bessarabian	Achnanthes baldjikii var. podolica
Volhynian	Mastogloia szontaghii-Cymatosira biharensis
Konkian	Stictodiscus californicus
Karaganian	Dimerogramma tortonicum, Rossiella mediopunctata v. matrensis
Tschokrakian	Pontodiscus baldjikianus

UKRAINE	
Regional substages	Olshtynska 1996 **Diatom zones and beds with flora**
Chersonian	Navicula zichii
Bessarabian	Achnanthes baldjikii var. podolica
Volhynian	Mastogloia szontaghii-Cymatosira biharensis
Konkian	Navicula pinnata
	Anaulus mediterraneus
Karaganian	Actinocyclus ingens b / a
Tschokrakian	
Tarkhanian	Lancineis parilis
Kotsakhurian	Delphineis subtilissima
Sakaraulian	Craspedodiscus elegans - Cavitatus jouseanus

Fig. 3. Correlation of Central Paratethys, North-eastern Bulgaria and Ukraine Miocene diatom zonation.

tion in core 23, height 258.0–265.0 m, near Sovetskiy village in the Crimea. Diatom assemblage is characterized by the abundance of *A. ingens* and the presence of *A. octonarius*, *Denticulopsis hustedtii*, *Coscinodiscus* cf. *tabularis* Grun. and *Azpeitia* sp. The assemblage of A. ingens Zone (subzone "b") can be correlated with the top part of the A. ingens Zone of the Middle Badenian sensu Hajós (1986) (Fig. 3).

The samples of the subzone "b" contain diatoms together with typical Kartvelian foraminifers *Quinqueloculina* ex. gr. *consobrina.*, *Q. indet.*, *Cassidulina* (?) *bogdanowiczi*, *Discorbis* sp., *D. kartvelicus*. The cover deposits contain foraminifers of the Bulimina-Bolivina Zone of the Konka Formation (Konenkova & Olshtynska 1996) and probably correspond to the NN6 calcareous nannofossil zone.

The characteristic feature of the subzone "b" is the presence of *D. hustedtii* and *Actinocyclus* with concentric valves. The first occurrence of *D. hustedtii* in the North Pacific (14.3 Ma) is reported at the base of the D. hustedtii-D. lauta Zone. It corresponds (Barron 1992) to the NN6 calcareous nannofossil zone and to the lower N11 foraminiferal zone. The A. ingens Zone (subzone "b") can be compared with part of the D. hustedtii-D. lauta Zone (Fig. 4).

The bed with *Anaulus mediterraneus* is defined in clays of the Kosovska Formation near Podgortsy village in the Volhyno-Podolia. The assemblage is characterized by the dominance of *Sheshukovia spinosa* (Ehr.), *Hyalodiscus subtilis* Bail., *Pseudopodosira westii*, *Cerataulus turgidus* Ehr. The subdominants are *Anaulus mediterraneus* Grun., *Asterolampra marilandica* Ehr., *Cocconeis scutellum* Ehr.

The species of *A. mediterraneus* is characteristic for the Middle Miocene of the Mediterranean area and also for upper part of Middle Miocene sediments of South Carolina and Georgia states (Abbott & Andrews 1979). The A. mediterraneus Bed can be compared with part of the D. hustedtii-D. lauta Zone and the NN6 calcareous nannofossil zone (Fig. 4). Its stratigraphic position can be determined as the late Upper Badenian.

The Navicula pinnata Zone is defined in the carbonaceous clay of the Buglovski deposits near Rudkovtsy village in the Volhyno-Podolia and spread in the Baskhevska Formation of the Zakarpatie. The assemblage is characterized by the abundance of *N. pinnata* Pant. Species of genera *Actinocyclus*, *Pseudoauliscus* Leud., *Paralia* Heib., *Navicula* and *Stauroneis* Ehr. are the most diversified. The diatoms in the Buglovski Beds are found together with Late Badenian molluscs of *Potamides schaueri*, *P. nodosoplicatum, Bittium deforme*, *Cerastoderma praeplicatum*, *Congeria sandbergeri*, poor calcareous nannofossils and foraminifers (Olshtynska & Prisyazhniuk 1994).

The N. pinnata Zone of the Volhyno-Podolia region corresponds to the N. pinnata Zone of the Late Badenian in the Central Paratethys which is correlated with NN7 Zone (Hajós 1986).

Sarmatian. The Sarmatian diatoms are characterized by great taxonomic diversity and considerable distinctions in systematic structure of assemblages from various localities.

The Mastogloia szonthaghii-Cymatosira biharensis Zone is defined in dark and clear marls of the Volhyn deposits near Kremenno village in Volhyno-Podolia and is wide spread within the South-Eastern, Central Ukraine and in the Crimea. This zone is distinguished by a great species diversity of the genera *Navicula*, *Amphora* Ehr., *Diploneis* and *Mastogloia*

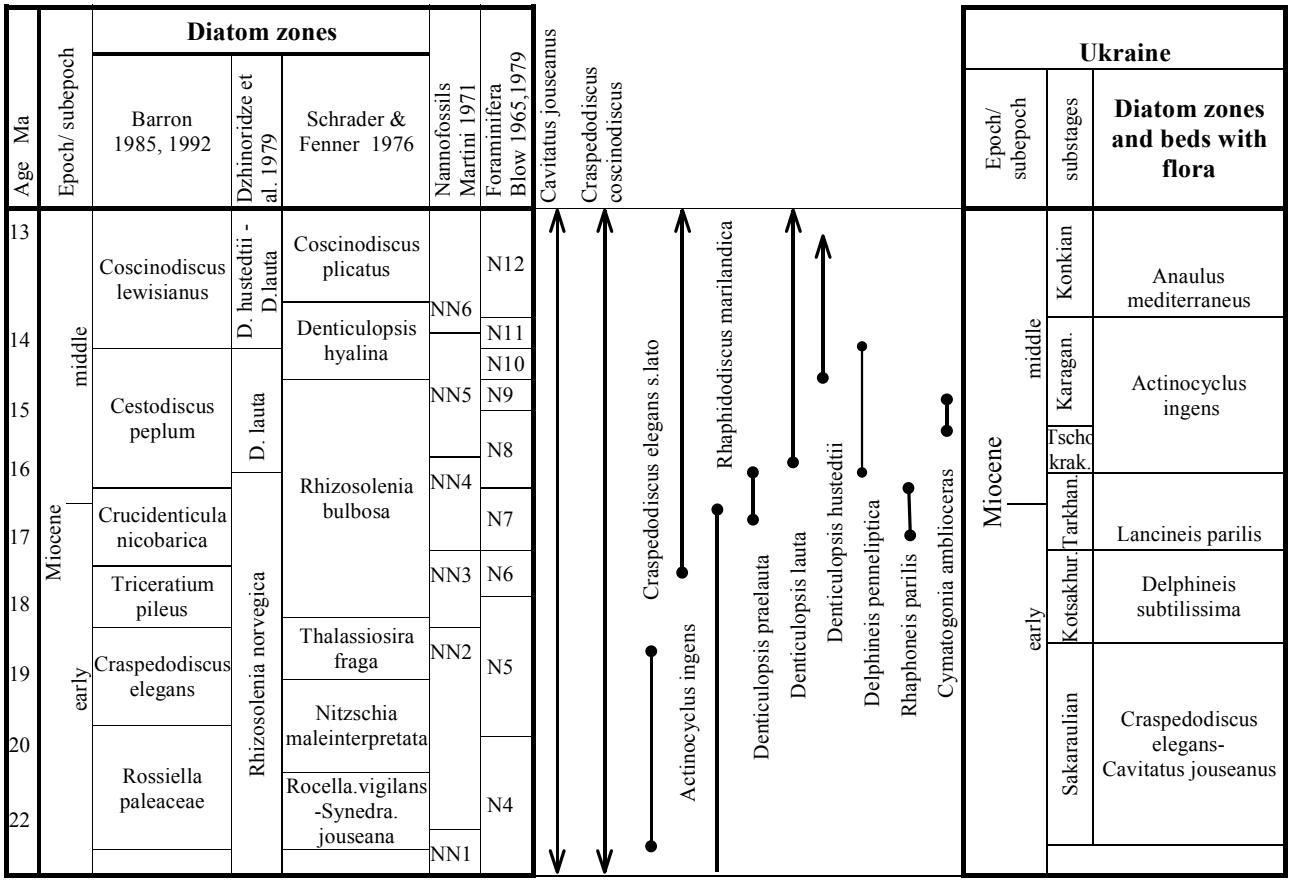


Fig. 4. Stratigraphic ranges of the important Early and Middle Miocene diatoms.

and appearance of *M. szonthaghii* Pant., *Anaulus simplex* Brun., *Dimidiata saccula* Hajós and *Dictyoneis mastogloidea* Pant. The characteristic species are *C. biharensis* (Fig. 5.7), *Coscinodiscus doljensis* Pant., *Achnanthes baldjikiani* (Bright.) Grun., *Caloneis liber* (W.Sm.) Cl., *Camphylodiscus fastuosus* f. *baldjikii* (Grun.) van Land., *Grammatophora insignis* Grun.

M. szonthaghii-C. biharensis Subzone was established in North-Eastern Bulgaria by Temniskova-Topalova (1994) and was correlated with the Early Sarmatian Coscinodiscus doljensis-Anaulus simplex Zone of Czechia and the Anaulus simplex Zone of Hungary. The latter is correlated with the nannofossil NN8 Zone (Fig. 3). M. szonthaghii-C. biharensis Zone of Ukraine is also correlated with the Early Sarmatian diatom zone of Moldova (Kozyrenko 1982), of the Crimea (Makarova & Kozyrenko 1966) and of Kazakhstan (Kozyrenko et al. 1985).

The Achnanthes baldjikii var. podolica Zone is defined in Bessarabian deposits near Molokish village in the Volhyno-Podolia and spread in the Zaporozhye area, the Crimea and the Zakarpatie. It is characterized by the great species diversity of the genera *Grammatophora* Ehr., *Cocconeis*, *Achnanthes* Bory, *Rhopalodia* O. Mull., *Navicula*, *Diploneis* and the appearance of *Achnanthes baldjikii* var. *podolica* Miss., *Actinocyclus(?) podolicus* Miss. and *Cocconeis scutellum* var. *inequalepunctata* Miss. The characteristic species are *Rhopalodia gibberula* (Ehr.) var. *gibberula* et var. *protracta* (Grun.) O. Mull., *Caloneis liber*.

Bessarabian diatom assemblages from various localities of Ukraine are appreciably different. There is a common group of species that makes it possible to correlate them with the A. baldjikii var. podolica Subzone of Bulgaria by Temniskova-Topalova (1994) (Fig. 3). The A. baldjikii var. podolica Zone probably corresponds to the nannofossil NN9 Zone.

The Navicula zichii Zone is defined in Cherson deposits in core 6 of the Kirov area in the Crimea region and spread in the Crimean region and in the bottom sediments of the Black Sea. It is characterized by a great species diversity of genera *Navicula, Amphora, Nitzschia, Achnanthes, Rhopalodia, Cocconeis*, appearance of *Navicula zichii* Pant., *N. andrusovii* Pant., *Nitzschia romanoviana* Pant., *Entomoneis gigantea* Grun. The key species of the assemblage are *Licmophora ehrenbergii* (Kutz.) Grun. var. *ehrenbergii* et var. *ovata* (W. Sm.) Perag., *Surirella maeotica* Pant.

The Navicula zichii Zone of Ukraine corresponds to the N. zichii Zone of North-Eastern Bulgaria which was defined on occurrence of the *Navicula zichii* (Temniskova-Topalova 1994) (Fig. 3) and can be correlated with the calcareous nannofossil NN9 Zone.

Meotian. The diatom zones and diatom beds in the Meotian deposits are defined in Janysh-Takyl section near both Zavetnoe and Kyz-Aul villages of East Crimea. One of the Meotian diatom zone is correlated with the calcareous nannofossil zone of the North Atlantic.

The Thalassiosira delicatissima Zone is defined in the bottom part of the Lower Meotian deposits as the interval con-

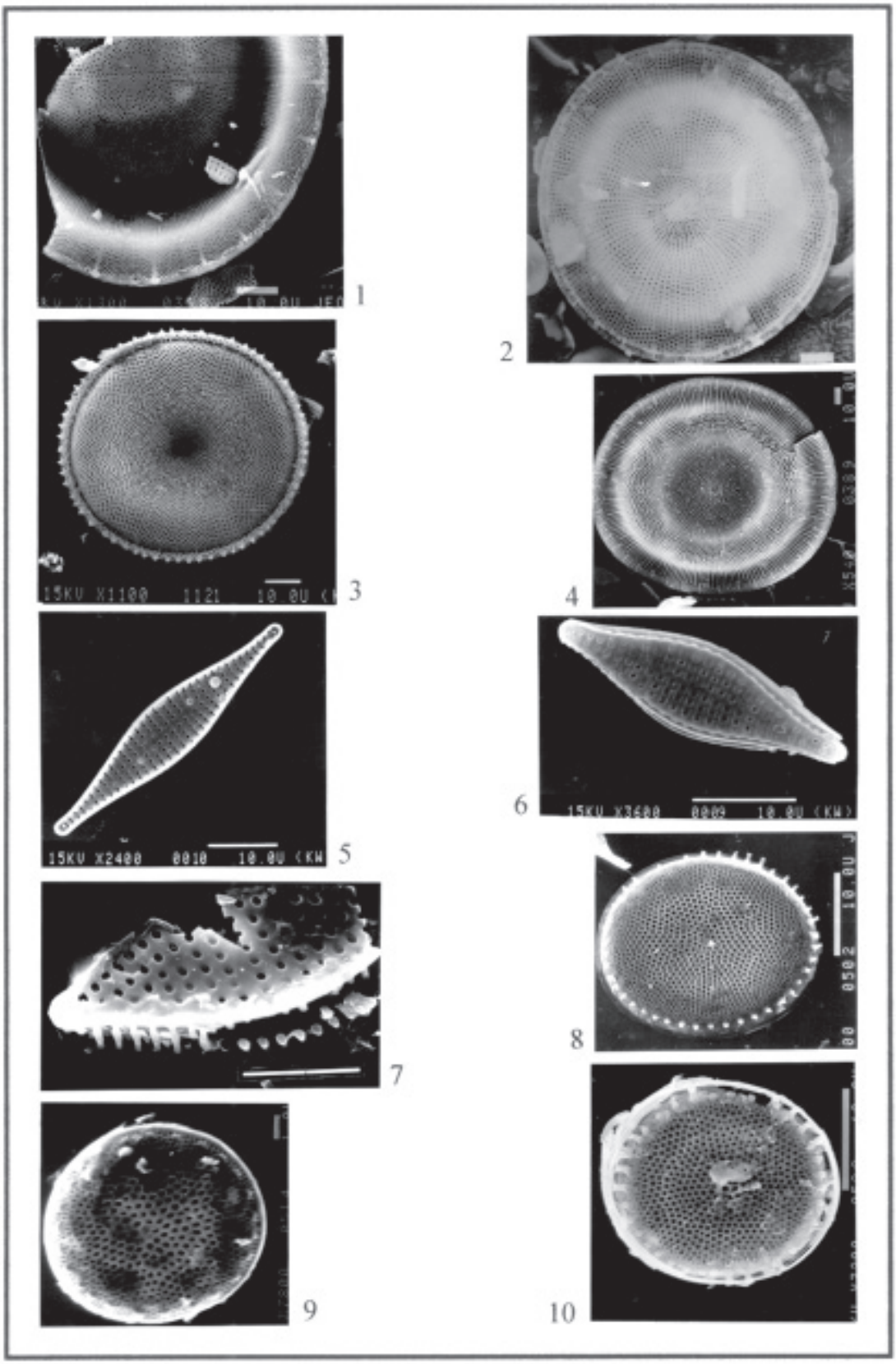


Fig. 5. 1 — *Actinocyclus kozyrenkoi* Olsht. 2 — *Actinocyclus fistulus* Olsht. 3 — *Actinocyclus coronatus* Olsht. 4 — *Actinocyclus gorbunovii* (Sheshuk.) Moiss. et Sheshuk. 5 — *Lancineis* sp. 6 — *Lancineis parilis* (Hanna) Andrews. 7 — *Cymatosira biharensis* Pant. 8 — *Thalassiosira maeotica* Pr.-Lavr. 9 — *Thalassiosira delicatissima* Pr.-Lavr. 10 — *Thalassiosira tenera* Pr.-Lavr. Scale bars: figs. 1–9, 10 =10 μm, fig. 9 =1 μm.

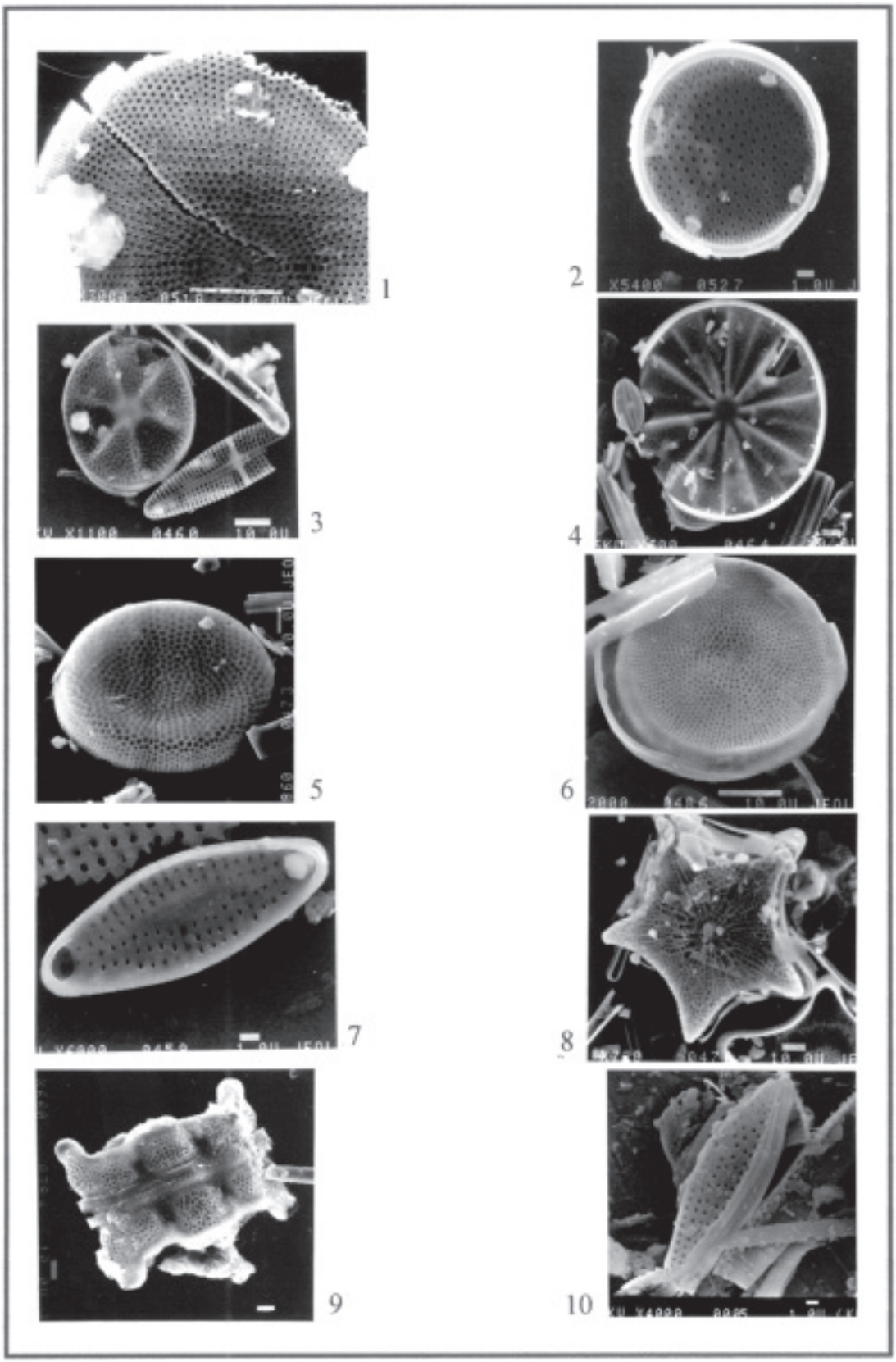


Fig. 6. 1 — *Actinocyclus curvatulus* var. *odontodiscus* (Grun.) Hust. 2 — *Actinocyclus variabilis* Freng. 3 — *Actinoptychus senarius* var. *tamanica* (Jouse) Hajós. 4 — *Actinoptychus vulgaris* Schum. 5 — *Coscinodiscus* aff. *convexus* A.S. 6 — *Coscinodiscus* sp. 7 — *Dimerogramma minor* (Greg.) Ralfs. 8 — *Amphitetras antediluvianum* Ehr. 9 — *Biddulphia tuomeyi* (Bail.) Roper. 10 — *Cymatosira savtchenkoi* Pr.-Lavr. Scale bars: figs. 1, 2, 4–6, 8, 9 =10 μm; figs. 3, 7, 10 =1 μm.

taining *Thalassiosira delicatissima* Pr.-Lavr. Its characteristic species are *Thalassiosira maeotica* Pr.-Lavr., *T. tenera* Pr.-Lavr., *T. coronifera* Pr.-Lavr., *Actinocyclus variabilis* Freng. and *A. curvatulus* Grun. (Fig. 5.8–10, Fig. 6.1–2). The Th. delicatissima Zone spreads on Kerch and Taman peninsulas and corresponds to the assemblage with *Th. delicatissima* and *Th. tenera* of the Meotian of Eastern Crimea (Makarova & Kozyrenko 1966) and corresponds to the nannofossil NN10 Zone.

The bed with *Lyrella pigmea* is defined in the bottom part of the Lower Meotian deposits. Key species of the assemblage are *Lyrella (Fallacia) pygmaea* (Kutz.) Stick et Mann, *Actinocyclus* cf. *octonarius* (sp.1), *A. miocenicus*, *Coscinodiscus obscurus* A.S. The bed has a local spreading.

The bed with *Amphitetras* sp. is defined in the middle part of the Lower Meotian deposits. The key species of the assemblage are *Amphitetras* sp., *Navicula reinhardtii* Grun., *Actinocyclus* sp., *Dimerogramma minor* (Greg.) Ralfs. The bed has a local distribution.

The Actinoptychus senarius var. tamanica Zone is defined in the bottom part of the Upper Meotian deposits. It is characterized by the appearance of abundant *A. senarius* var. *tamanica* (Jouse) Hajós. Characteristic species are *Hyalodiscus frenquelli* Hanna, *Endictia oceanica* Ehr., *Amphitetras antediluvianum* Ehr., *Nitzschia panduriformis* Grev. et al. (Fig. 6.3–9). The A. senarius var. tamanica Zone spread on Kerch Peninsula and corresponds to the assemblage with *Hyalodiscus frenguellii* and *Amphitetras antediluvianum* revealed from the Meotian sediments of Crimea (Makarova & Kozyrenko 1966). It is similar to the Pannonian diatom assemblage of Hungary (Hajós 1971).

The Cymatosira savtchenkoi Zone is defined in the bottom part of the Upper Meotian deposits as the interval containing *Cymatosira savtchenkoi* Pr.-Lavr. The characteristic feature of this zone is the appearance numerous *C. savtchenkoi* (Fig. 6.10) and *Lithodesmium* cf. *undulatum* Ehr. The species *Rhabdonema adriatica* Ktz*., Endictia oceanica* Ehr. are dominating, *Psammodiscus nitidus*, *Nitzschia separanda* Grun. are numerous so *Pseudotriceratium cinnamomeum* (Grev.) Grun. and *Denticulopsis lauta* are present in the assemblage.

The C. savtchenkoi Zone corresponds to the C. "biharensis" Zone of the Late Miocene of the North Atlantic (Schrader & Fenner 1976). The latter corresponds to the middle part of the D. hustedtii Zone (Koizumi 1973) and to the Nitzschia miocenica–bottom Thalassiosira convexa zones (Schrader 1976). The C. "biharensis" Zone in the North Atlantic is correlated with part of the nannofossil NN11 Zone, part of the foraminiferal N17 Zone and the end of 7–6 paleomagnetic epochs (Schrader & Fenner 1976). This zone is known in the Norwegian Sea too (Dzhinoridze et al. 1979).

The C. savtchenkoi Zone of Ukraine corresponds to the Upper Meotian C. "biharensis" Zone (Kulichenko & Olshtynska 1980; Olshtynska & Kozyrenko 1995) on the Kerch and Taman peninsulas and is correlated with the nannofossil NN10 Zone in Ukraine.

The Rhizosolenia bezrukovii Zone is defined in the top part of the Upper Meotian sediments of the Zhelezny Rog section of the Kerch Peninsula. The occurrence of *Rhizosolenia bezrukovii* Jouse marks the base of this zone, the dominant association with numerous *Actinocyclus octonarius* is in the top of it. The characteristic species are *Thalassiosira maeotica*, *Cyclotella castracane* Brun., *C. praekutzingiana* Mukhina, *Actinocyclus octonarius*, *Grammatophora marina* (Ling.) Kutz, *Rhaphoneis maeoitica* (Milov.) Shesh. et Gles., *Chaetoceros danicus* Cl.

The Rh. bezrukovii Zone corresponds to layer XIII of the Deep See Drilling Project Leg. 42-a, sample 381, 38c-34,6 and sample 380, 56cc-55,3 in the Black Sea (Jouse & Mukhina 1980).

Pontian. Diatoms are rare in the Pontian deposits of Ukraine, but are distributed on the Kerch and Taman peninsulas and in the bottom deposits of the Black Sea.

The Stephanodiscus proprius-Stephanodiscus multifarius Zone is defined in the Pontian deposits in bottom deposits of the Black Sea and corresponds to layer XII of the Deep See Drilling Project Leg 42-a, Hole 380 and 381 (Jouse & Mukhina 1980; Khursevich & Mukhina 1995). The base of the S. proprius-S. multifarius Zone is determined by the occurrence of *S. proprius* Churs. et Mukhina and *S. multifarius* Churs. et Mukhina, in the top the number of these species is sharply reduced. The appearance of *Cyclostephanos ponticus* (Jouse) Churs., *C. stelliformis* Churs. et Mukhina, *C. pliocenicus* Churs. et Mukhina, *Aulacoseira bellicosa* (Herib), *A. elegans* Mukhina, *A. papilio* Mukhina and the disappearance of *A. stockesianus* (Grev.) and *Coscinodiscus granii* Gough take place within the zone. The dominant species are *A. stockesianus*, *Coscinodiscus granii*, *Cyclotella proshkina* Jouse et Mukhina and *C. praekutzingiana*.

The bottom of the S. proprius-S. multifarius Zone is found in the top part of the Pontian deposits of Kerch and Taman and correlated with the calcareous nannofossil NN11 Zone.

Conclusion

The diatom biostratigraphic zonation for the Miocene deposits of Ukraine is proposed. 12 diatom zones and 4 beds with diatom flora have been revealed in the Miocene sediments. Most of the diatom levels have been correlated with the Central Paratethys, North-Eastern Bulgaria and ocean diatom zonation. Optimum correlation is proper to diatom events of the Early and Middle Miocene with the diatom zonation of the Central Paratethys, Sarmatian — with diatom zonation of North-Eastern Bulgaria, Meotian Cymatosira savtchenkoi Zone with C. "biharensis" Zone of the North Atlantic. The taxonomical and ecological composition of the diatom assemblages point to the existence of a connection of the east Paratethys with the Tethys in Sakaraulian, with Mediterranean in the Kartvelian and with the North Atlantic in the Late Meotian.

This is a first attempt to correlate the diatom levels with the calcareous nannofossil zones. Biostratigraphic control and correlation of the same diatom events is complicated because of the absence of planktonic foraminifers and calcareous nannofossils together with diatoms and as a result of the great provincialism of the Miocene diatoms of Ukraine.

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