Eocene stratigraphy of key sections of the Dnieper-Donets Depression based on calcareous and siliceous microplankton

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ABSTRACT
Radiolarian, diatom, nannoplankton, and foraminifer assemblages were studied in detail in four key sections (Kantemirovka, Sergeevka, and 9540 Rudaevka, 5-93 Boguchar boreholes) of the south and central parts of the Voronezh anticline area. The widespread middle Eocene sediments lie uncorformably on marls and limestones of Upper Cretaceous age. They are mainly composed by a transgressive-regressive succession of phosphoritic sands, marls, and siliceous clays of the Kiev Formation in the Ukraine (or Sergeevka and Tishki formations in Russia) and by sandy clays and siliceous clays of the lower part of the Khar'kov Formation in the Ukraine (or Kas'anovka Formation in Russia). Lithologically, the coeval formations range from terrigenous-carbonate to siliceous-carbonate. The age of the formations has long remained a point of discussion. Recent studies based on calcareous and, especially, siliceous microplankton allowed a direct correlation of these sections with standard zonal scales.

KEY WORDS
Dnieper-Donets Depression, radiolaria, diatoms, silicoflagellates, foraminifera, Eocene, stratigraphy.

RÉSUMÉ

Stratigraphie des coupes clés de l'Éocène dans la dépression du Dniepr-Donets fondée sur le microplancton calcaire et siliceux.

Les assemblages de radiolaires, diatomées, nannoplancton et foraminifères ont été étudiés en détail dans quatre séries clés (les coupes de Kantemirovka et Sergeevka et les forages 9540 Rudaevka et 5-93 Boguchar) des parties méridionale et centrale de la région de l'anticlinal de Voronezh. Les sédiments, largement répandus, de l'Éocène moyen reposent en discontinuité sur des marnes et calcaires du Crétacé supérieur. Ils sont principalement composés d'une succession transgression-régression de sables phosphatés, de marnes et d'argiles siliceuses de la formation de Kiev en Ukraine (ou les formations de Sergeevka et Tishki en Russie) et par des argiles sableuses et des argiles siliceuses dans la partie inférieure de la formation de Khar'kov en Ukraine (ou de Kas'anovka en Russie). Lithologiquement, les formations équivalentes vont des carbonates terrigènes aux carbonates siliceux. L'âge des formations est resté longtemps très discuté. Les études récentes, fondées sur le microplancton calcaire et surtout siliceux permettent des corrélations directes avec les zones des échelles standart.

MOTS CLÉS
Dépression du Dniepr-Donets, radiolaires, diatomées, silicoflagellés, foraminifères, Éocène, stratigraphie.

INTRODUCTION

The Palaeogene sediments of the south-eastern slope of the Voronezh anticline, which also represents the north-east flank of the Dnieper-Donets Depression (see Radionova *et al.*, this volume, fig. 1), have been studied stratigraphically since the 1960s, when the lithostratigraphic scheme was proposed and used to subdivide these deposits (Semenov 1965). The Palaeogene deposits of the region represent a gradual transition from typical facies of the Dnieper-Donets Basin (Ukrainian type of succession) to facies of the Volga-Don Region. In the western part of the area, a Ukrainian lithostratigraphic scheme (Makarenko *et al.* 1987) is used. The Palaeogene of the marginal east-northern areas of Dnieper-Donets Basin is subdivided according to Semenov (1965). In Volga-Don Region, the scheme of Kurlaev (1968) is used (Fig. 1). This facies transition can be observed in sections studied in the present paper. The presence of both calcareous and siliceous microplankton in all studied sections allowed us to correlate the Eocene part of all the sections.

The Palaeogene succession of the western Kantemirovka and Sergeevka sections (Fig. 2) is very similar to that of the central part of Dnieper-Donets Depression and begins with dark green and greyish green mica-glauconite sands of Buchack Formation containing no macro- or microfossils. Up to the section lies the Sergeevka Formation represented by marls with sandy and clayey interlayers at the base. The superposing Tishki Formation is composed by sandy noncarbonate clays. Both Sergeevka and Tishki formations represent distinct transgressive-regressive cycle and are believed to correspond to the Kiev Formation of the Ukraine. The overlapping Kas'yan Formation, as a rule, begins with sandy layer grading up to the section into siliceous clays. The uppermost Kantemirovka Formation is exposed in the Kantemirovka Section only and is composed of sandy deposits. The Kas'yan and Kantemirovka formations represent the second transgressive-regressive cycle and are coeval to the Khar'kov Formation of the Ukraine.

In the Boguchar Section, the Eocene formations are composed of facies different from that of the three western sections (Sergeevka, Kantemirovka and Rudaevka). The lowermost sedimentary cycle includes lowermost Osinovo and Tchir beds, represented by more terrigenous sediments

Epoch		Stages	Dnieper-Donets Depression (Makarenko *et al.* 1987)	South-eastern border of Voronezh antecline (Semionov 1965)	Lower reaches of Volga and Don rivers (Kurlaev & Akhlestina 1988)	This paper	
Oligocene			Kharkov Formation: Mezhigorka Fm.	Kantemirovka Fm.		Kante-mirovka Fm.	Kharkov Fm.
Eocene	Upper	Priabonian	Kharkov Formation: Obukhovka Fm.	Kasyan Fm.		Kante-mirovka Fm.	Kharkov Fm.
Eocene	Middle	Bartonian	Kiev Fm.	Tishki Fm.	Kuma Fm.	Kasyan Fm.	Kharkov Fm.
Eocene	Middle	Bartonian	Kiev Fm.	Tishki Fm.	Kuma Fm.	Tishki Fm.	Kiev Fm.
Eocene	Middle	Lutetian	Kiev Fm.	Sergeevska Fm.	Tchir beds	Sergeevka Fm.	Kiev Fm.
Eocene	Middle	Lutetian		Osinovo Fm.	Osinovo Fm.	Sergeevka Fm.	Kiev Fm.

FIG. 1. — The Eocene lithostratigraphic scheme of the studied region.

than those of Sergeevka Formation, and brownish clays named Kuma Formation. The last formation corresponds in its sedimentary composition and stratigraphic position to the Kuma Formation of the Northern Cis-Caucasia.

Lithostratigraphical units of south-western Russia (Voronezh anticline) can be considered as a reflection of the transgressive-regressive succession in the North Peri-Tethys Region. A number of problems arise when the issues concerning the Palaeogene palaeogeography and detailed age correlation are to be approached.

The first problem is the age span of the Kiev "marl" and its correlation with eastern sections. The second problem lies in determining the age of the siliceous units, i.e., the upper part of the Kiev Formation and the lower part of Khar'kov Formation, and in correlating them with coeval stratigraphic units further east.

SAMPLES

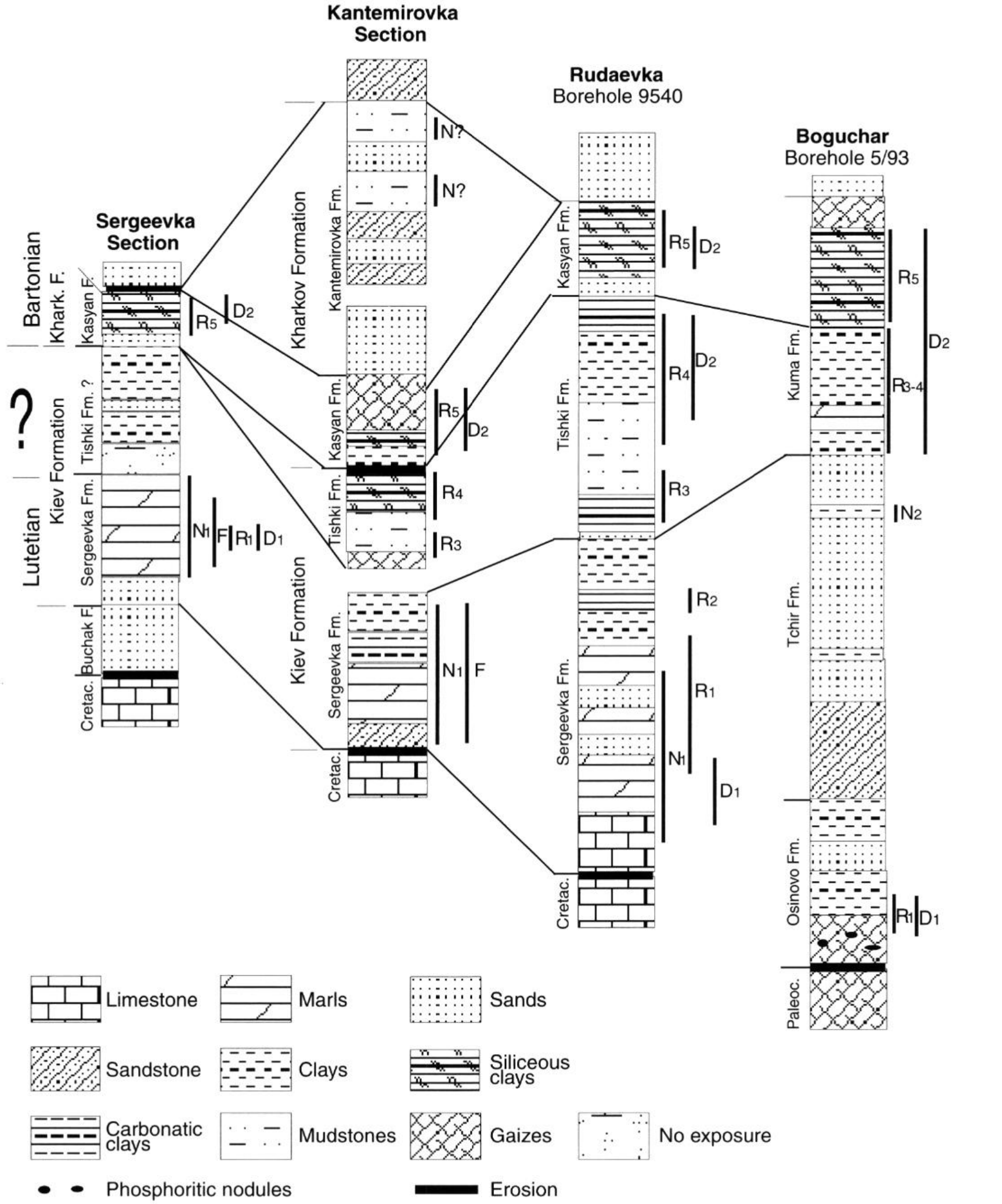
Two sections – Kantemirovka and Sergeevka – and two boreholes – 5-93 Boguchar and 9540 Rudaevka – were sampled carefully during the field trip to the Voronezh anticline area in July 1994. More than 100 samples were processed, and in 79 of them microfossils were found (Fig. 2A).

METHODS

To study siliceous micro-organisms, each sample was placed into a 400 ml glass, desegregated mechanically, and then boiled for 15 minutes with addition of about 50 ml of 30% hydrogen peroxide (H_2O_2). Each sample was soaked for one hour with distilled water, rinsed, and the procedure was repeated until the settling time became about 5 minutes for radiolarians. Slides for radiolarian study were prepared on 24 × 24 mm cover glasses and mounted in Canada balm on 24 × 80 mm glass slides. Samples for diatom study were mounted on 18 × 18 glass slides. Radiolarians were examined at × 400, and diatoms, at × 1000.

For nannoplankton study, smear slides from liquid alcohol suspension were made with Canada balm and examined at × 1000 with the use of immersion oil.

A


Kantemirovka
Section
Rudaevka
Borehole 9540
Boguchar
Borehole 5/93
Sergeevka
Section
Bartonian
Khark. F.
Kasyan F.
?
Tishki Fm. ?
Kiev Formation
Lutetian
Sergeevka Fm.
Buchak F.
Cretac.
R5
D2
N1
F
R1
D1
Kharkov Formation
Kantemirovka Fm.
N?
N?
Kasyan Fm.
Tishki Fm.
R5
D2
R4
R3
Kiev Formation
Sergeevka Fm.
N1
F
Cretac.
Kasyan Fm.
R5
D2
Tishki Fm.
R4
D2
R3
R2
Sergeevka Fm.
R1
N1
D1
Cretac.
Kuma Fm.
R5
R3-4
D2
N2
Tchir Fm.
Osinovo Fm.
R1
D1
Paleoc.
Limestone
Marls
Sands
Sandstone
Clays
Siliceous clays
Carbonatic clays
Mudstones
Gaizes
No exposure
Phosphoritic nodules
Erosion

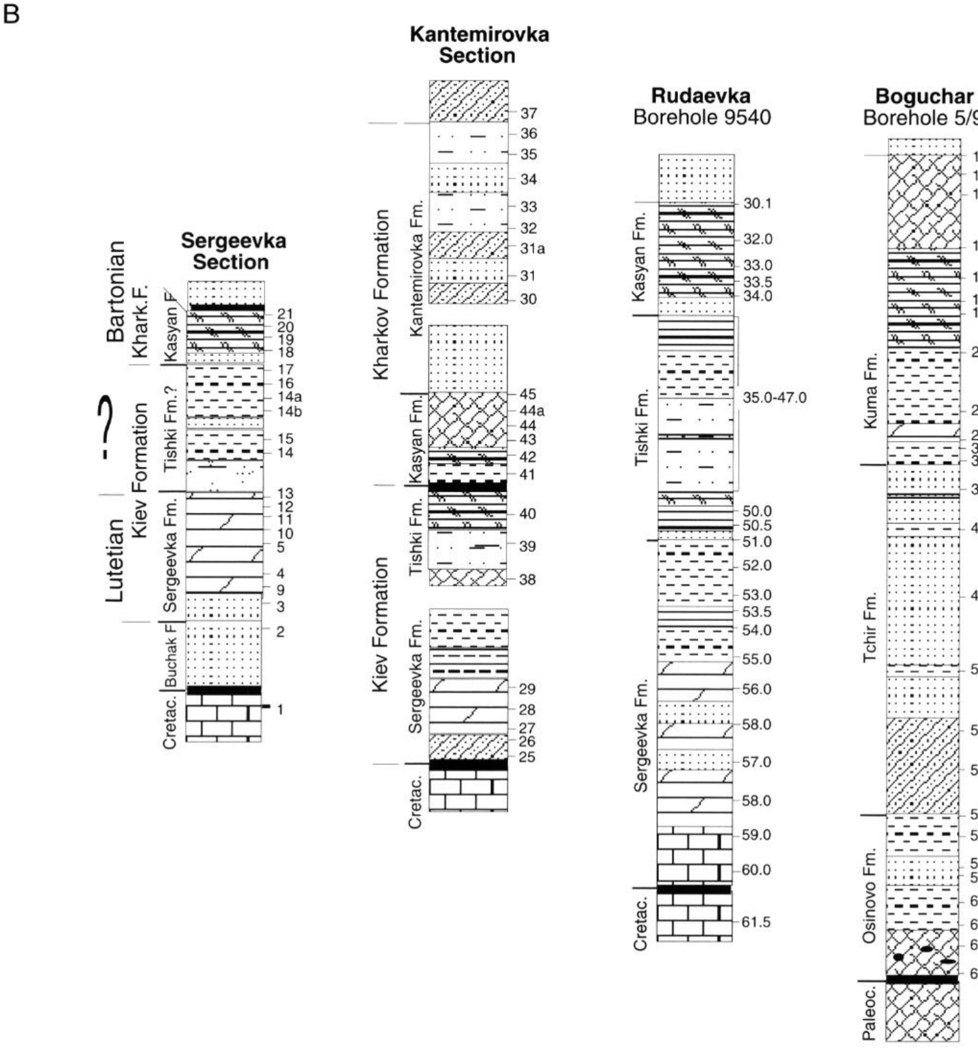


FIG. 2. — **A**, correlation of studied sections of the eastern slope of the Dnieper-Donets Depression. N_{1-2}, nannofossil assemblage; **F**, foraminifera assemblage; R_{1-5}, radiolaria assemblage; D_{1-2}, diatoms assemblage. **B**, samples number from the sections.

Foraminifers were washed with the use of sieves and examined at × 25-30.

MICROPALEONTOLOGICAL ANALYSIS

The correlation of the foraminifera, nannofossil, silicoflagellate, radiolaria, and diatom zonal scales used in this paper are shown in Figure 3. Results of micropalaeontological study of sections are shown in Figures 2, 3 and Tables 1 to 13. Species were recorded as abundant (A) if more than 15 specimens were present in the slide, as frequent (F) if 10-15 species were present, as common (C) if 3-9 specimens occurred in the slide, and as rare (R) if 1-2 specimens were found.

SERGEEVKA SECTION

Sergeevka Section, occupying the north-western-most position among the studied sections, is very similar in lithological composition to the succession of the Dnieper-Donets Depression. It begins with dark green and greyish green mica-glauconite sands of the Buchack Formation, which are barren of macro- and microfossils. Up to the section, the Kiev Formation represented by marls with sandy and clayey beds 7 m in thickness lies. These are overlain by the Kiev Formation: marls with sandy and clay beds 7 m thick. The upper part of the Kiev Formation is composed of sandy non-carbonate clays, 5 m in thickness. The lower part of the formation is the same as the Sergeevka Formation of Semenov (1965) scheme, and the upper part of the Kiev Formation is equivalent to Semenov (1965) Tishki Formation. The lower part of the Khar'kov Formation [Kas'yan Formation of Semenov (1965) scheme] begins with sandy layer passing upsection into siliceous clays. The exposed thickness of these sediments is about 5 m. They are unconformably overlapped by sands of Neogene (?) age.

Nannofossils
At the base of the Sergeevka Formation in a sandy unit, a poor nannofossil assemblage (N: range of nannofossil assemblage in Figs 2, 3) of the middle Eocene age is present.
A rather abundant nannofossil association (N1) including *Cyclicargolithus floridanus* (Roth & Hay *in* Hay *et al.* 1967) Bukry, *Discoaster barbadiensis* Tan, *D. nodifer* (Bramlete & Riedel) Bukry, *D. strictus* Stradner, *D. wemmelensis* Achuthan & Stradner, *Reticulofenestra dictyoda* (Deflandre *in* Deflandre & Fert), Stradner *in* Strander & Edwards, etc, was found in marls of the Sergeevka Formation (Table 1). Nevertheless, the absence of any boundary zonal markers does not allow us to judge whether it belongs to the uppermost CP13 *Nannotetrina quadrata* or lowermost CP14 *Reticulofenestra umbilica* zones.

Foraminifera
In the marls of the Sergeevka Formation, an abundant and well-preserved benthic foraminifera association (F: range of foraminifera assemblage in Figs 2, 3) contains *Spiroplectammina pishvanovae* A. V. Furssenko & K. B. Furssenko, *Clavulinoides sczaboi* (Hantken), *Vaginulinopsis decorata* (Reuss), *Cibicidoides biumbonatus* (A. V. Furssenko & K. B. Furssenko), *Uvigerina spinocostata* Cushman & Jarvis (= *Hopkinsia bykovae ukrainica* Kraeva), *U. costellata* Morozova, *Bulimina macilenta* Cushman & Parker, *B. cooki* Cushman (Table 2). This assemblage can be related to the middle-upper Lutetian *Pseudoclavulina subbotinae-Uvigerina spinocostata-Bolivina cookei* regional zone (Naidin *et al.* 1994; Radionova *et al.* 1994).

Radiolaria
The most ancient radiolarian assemblage (R: range of radiolarian assemblage in Figs 2, 3) was found in the middle part of the marls of the Sergeevka Formation (Table 3) and is represented by *Clathrocyclas minima* Clark & Campbell, *Heliodiscus heliasteriscus* Clark & Campbell, *H. dupla* Kozlova, *Spongomelissa* sp. A, *Lithomelissa* sp. A, *Calocyclas semipolita* Clark & Campbell, *Thecosphaera minor* Campbell & Clark, *Stylotrochus radiatus* Lipman, *Theocyrtis lithos* Clark & Campbell. Taxonomical composition of the association cannot constrain the age of sediments more precisely than middle Eocene. Upsection, radiolaria are found only in siliceous clays of Kas'yanovka Formation assemblage (R5) is taxonomically diversified and abundant, containing *Stylodictya irregularis* Vinassa, *Heliodiscus heliasteriscus* Clark & Campbell, *Heterosestrum formosum* Tochilina, *H. tschuenkoi* Lipman, *Lithomelissa* sp. B, *Melittosphaera magnoporulosa* Nakaseko, *Heliodiscus fragilis* Tochilina, *H. testatus* Kozlova, *"Lophocyrtis" sinitzini* Lipman, *Clathrocyclas extensa multiplicata* (Clark & Campbell), *Tripodiscinus kaptarenkoi* Gorbunov, *T.* aff. *tribrachiatus* Gorbunov, *Theocyrtis lithos* Clark & Campbell, and *Theocyrtis andriashevi* Petrushevskaya. It belongs to the *Theocyrtis andriashevi* regional zone.

Diatoms
In the lower part of the Sergeevka Formation (Table 4), a typical Kiev diatom assemblage with *Peponia barbadensis* Greville (D1) (D: range of diatom assemblage in Figs 2, 3) was found. Common taxa include *Paralia oamaruensis* (Grove & Stuart) Gleser – index-species of the zone of the same name of the local scheme of

Epoch		Stage	Planktonic foraminifera zonation (Boli & Saunders 1985)	Crimea-Caucasus planktonic foraminifera zonal scale (Anonymous 1989)	Nannofossil zonal scale (Okada & Bukry 1980)	Silicoflagellate zonal scale (Bukry 1981)	Regional zonal scales: radiolarians (Kozlova 1990)	Regional zonal scales: diatoms Glezer 1989	Regional zonal scales: diatoms this paper
EOCENE	upper		P15	*Globigerapsis tropicalis*	CP15 *Chiasmolithus oamaruensis*	*Corbisema apiculata*	*Theocyrtis andriasheva* R5	*Paralia oamaruensis*	
	middle	BARTONIAN	P14	*Globigerina turkmenica*	CP14b *Discoaster saipanensis*	*Dictyocha hexacantha*	*Ethmosphara polysiphonia* R4		layers with *Brightwellia imperfecta* D2-D2A
			P13	*Hantkenina alabamensis*	CP14a *Discoaster bifax*		*Cytophormis alta* R3		
		LUTETIAN	P12	*Acarinina rotundimarginata*	CP13 *Nannotetrina quadrata*	*Naviculopsis foliaceae*	*Heliodiscus quadratus* R2	*Pyxilla oligocenica* var. *tenue*	layers with *Peponia barbadensis* D1

FIG. 3. — The correlation of the foraminifera, nannofossil, silicoflagellate, radiolaria and diatom zonal scales.

Glezer (1979) – and *Cristodiscus* (*Coscinodiscus*) *succinctus* (Sheshukova & Gleser) Gleser & Olshtinskaya, date index-species of the boreal zonal scheme of Strelnikova (1992). *Peponia barbadensis* Greville, index-species of the proposed regional scheme (Radionova 1996) occurs rarely. According to Glezer's (1979) local diatom scheme, the *Paralia oamaruensis* zone is related to the Upper Eocene, and according to Strelnikova (1992) boreal scheme, the *Coscinodiscus succinctus* zone belongs to uppermost Lutetian-lower Bartonian. Layers with *Peponia barbadense* Greville are considered as upper Lutetian. The association includes pelagic species *Pyxidicula joynsonii* (A. Schmidt) Strelnikova & Nikolaev, *P. charkoviana* (Jousé) Strelnikova & Nikolaev, *Craspedodiscus moelleri* A. Schmidt, and a number of neritic species. In Khar'kov (Kas'yanovka) Formation, a diatom assemblage with *Brigthwellia imperfecta* Jousé (D2) becomes more abundant. Besides, *Melosira architecturalis* Brun (Schmidt *et al.*) and *Pyxilla prolongata* Brun are common. The *Coscinodiscus* group becomes more diversified (*C. decrescenoides* Jousé, *C. bulliens* Schmidt, *C. oculusiridis* Ehrenberg), as well as the *Hemiaulus* group (*H. polymorphus* var. *charkovianus* Jousé, *H. tschestnovii* Pantoäek). In the upper part of the Brighwellia imperfecta (?) unit, *Cosmiodiscus breviradiatus* Gleser & Olshtinskaya and *Pseudotriceratium chenevieri* (Meistner) Gleser, appear. Index-species *Brightwellia imperfecta* Jousé, covering a part of the Bartonian stratigraphic interval of distribution, allows determining the stratigraphic range of the Kas'yanovka Formation.

KANTEMIROVKA SECTION

The lower part of Sergeevka Formation (Fig. 2), a sandstone layer 1.5 m thick with phosphorite nodules, lies on the Upper Cretaceous limestones. Up to the section is a unit of grey marls and carbonate clays 3-4 m thick. The upper part of the Sergeevka Formation is represented by non-carbonate clays of undetermined thickness. The Tishki Formation lies unconformably on the Sergeevka Formation and is composed of non-carbonate clays 4-5 m thick, with glauconite at the base and siliceous in the upper part. The Kas'yanovka Formation is represented by intercalations of reddish-yellowish gaize, breccia-like argilites, and glauconite sandstones 4 m thick. Sands and sandstones of the Kantemirovka Formation overlap these sediments unconformably.

Nannofossils

An abundant and diversified nannofossil assemblage was obtained from the marls of the Sergeevka Formation (N1) (Fig. 2). This assemblage includes, among others, the typical species of the CP13 *Nannotetrina quadrata* zone: *Nannotetrina cristata* (Martini) Perch-Nielsen, *Discoaster strictus* Stradner, *Dictyococcites onustus* Perch-Nielsen (Table 5).

In the uppermost part of the section, i.e. in carbonate beds within the sandy Kantemirovka Formation, a very poor and possibly reworked nannofossil assemblage of Bartonian age was found.

Foraminifera

In the lower part of the Sergeevka Formation marls, the abundant and diversified planktonic foraminifera assemblage (F) was found (Table 6). The most abundant are: *Subbotina turcmenica* (Khalilov), *S. boweri* (Bolli), *Globigerinatheka index* (Finlay), *Acarinina* aff. *rugosoaculeata* Subbotina. The assemblage can be related to the upper part of the *Acarinina rotundimarginata* (s.l.) zone of the Crimea-Caucasus scheme (beds with *Globigerinatheka index*, Beniamovskii 1995). Benthic foraminifera are represented by *Pseudoclavulina subbotinae* Nikitina, *Vaginulinopsis decorata* (Reuss), *Gyroidina soldani* (d'Orbigny), *Bulimina sculptilis* Cushman, *B. cooki* Cushman, *Uvigerina spinocostata* Cushman & Jarvis, *U. pygmea* d'Orbigny, *U. costellata* Morozova. They are related to the middle-late Lutetian *Pseudoclavulina subbotinae-Uvigerina spinocostata-Bolivina cookei* regional zone. Most of the species of the assemblages can be traced in the European palaeobiogeographical area from Belgium to the west part of Kazakhstan.

Radiolaria

In the lower part of the Tishki Formation, the radiolarian assemblage (R3) is taxonomically poor, represented by *Cyrtophormis alta* Moksyakova, *Clathrocyclas talwanii* Bjorklund & Kellogg, and *Lithomelissa* sp. A. (Table 7) and most likely belongs to the *Cyrtophormis alta* regional zone (Kozlova 1990).

Upsection in uppermost part of the Tishki Formation and lowermost part of the Kas'yanovka Formation (the boundary between them is not determined precisely in the section), radiolaria become more diversified (R4): *Lithomelissa* sp. A., *Heliodiscus heliasteriscus* Clark & Campbell, *H. zonatum* (Lipman), *H. fragilis* Tochilina, *Melittosphaera magnoporulosa* Nakaseko, *Calocyclas semipolita* Clark & Campbell, *Tripodiscinus kaptarenkoe* Gorbunov, *Clathrocyclas extensa multiplicata* (Clark & Campbell), *"Lophocyrtis" sinitzini* Lipman, *Bathropyramis aneotos* (Clark & Cambell), *Calocyclas asperum* Ehrenberg, *Hexacontium* aff. *pachydermum* Jorgensen, *Stylodyctya hastata* Ehrenberg, *S. irregularis* (Vinassa), *Tripilidium clavipes* Bjorklund, *Theocyrtis lithos* Clark & Campbell, etc. Lastly, in siliceous clayey marls of the Kas'yanovka Formation, the assemblage of *Theocyrtis andriashevi* regional zone (R5) is seen and includes besides a number of species known from R4 assemblage, *Lithelius foremanae* Sanfilippo & Riedel, *Stylosphaera balbis* (Sanfilippo & Riedel), *Lithomelissa* sp. B, *Heterosestrum formosum* Tochilina, *H. tschuenkoi* Lipman, and *Theocyrtis andriashevi* Petrushevskaya.

Diatoms and Silicoflagellates

The diatom assemblage obtained from the upper part of the Tishki and Kas'yanovka formations is similar to the D2 association from the Sergeevka Section, although it is not so diversified (Table 8). Important is the presence of *Cosmiodiscusm breviradiatus* Gleser & Olshtinskaya, and *Brightwellia coronata* (Brightwell) Ralfs *in* Pritchard, in the lower Kas'yanovka Formation and the appearance of *Triceratium unguiculatum* Greville, in the upper part of the same formation.

9540 RUDAEVKA BOREHOLE

White chalk unit 3 m in thickness is correlated to the Sergeevka Formation (Fig. 2). It is superseded by alternating marls and carbonate clays 6 m thick. The upper part of the Sergeevka Formation is composed of alternating carbonate and non-carbonate clays. The total thickness of the Sergeevka Formation is 13 m. At the base of the Tishki Formation, a layer of glauconite sand up to 0.5 m thick can be traced. The overlying unit is represented by intercalations of clayey mudstones, opoka sandstones and clays, sometimes with thin beds of carbonate clays. The thickness of this formation is 14 m. At the base of the Kas'yanovka Formation, a 0.5 m-thick glauconite sandy layer is present, overlapped by clayey diatomites 4 m in thickness. The uppermost 8 m of the section are represented by sands of the Poltava Formation.

Nannofossils

A nannofossil assemblage related to CP13-CP14 nannoplankton zones boundary interval (N) was found at the base of the marly section of the Sergeevka Formation. The assemblage is not so rich as in Kantemirovka Section, but seems to be of the same age because of the presence of *Rhabdosphaera gladius* Locker, which is zonal marker of the CP13 *Nannotetrina quadrata* zone top boundary (Table 9).

Foraminifera

Foraminifera in borehole 9540 occur rarely. For this reason, siliceous microfossils are the primary basis for stratigraphic subdivision of the section.

Radiolaria

A radiolarian assemblage (Table 10) represented by *Stylodyctya hastata* Ehrenberg, *Thecosphaera minor* (Clark & Campbell), *Heliodiscus heliasteriscus* Clark & Campbell, *Clathrocyclas principi principi* Clark & Campbell, *Stylotrochus* sp., and *Lithomelissa* sp. A was found in the lower part of the Sergeevka Formation marls. The assemblage is not taxonomically diversified. All the species are known from the Keresta and Kuma formations of southern Cis-Caucasia and Central Asia (Moksyakova 1972). The age cannot be constrained more precisely than upper Luthetian-Bartonian. The upper part of the same formation contains a more diversified assemblage (R2), represented by *Heliodiscus hexasteriscus* Clark & Campbell, *Hexacontium pachydermum* Jorgensen, *Petalospyris* aff. *dubia* Clark & Campbell, *Clathrocyclas extensa* Clark & Campbell, *Theocorys reticula* Kozlova, *Heterosestrum formosum* Tochilina, *H. tschuenkoi* Lipman, *Stylosphaera coronata laevis* Ehrenberg, *Tripodiscinus tumulosus* (Kozlova), *Xiphospira ocellata* (Ehrenberg), *Thecosphaera californica* Clark & Campbell and *Lithomelissa* aff. *haeckeli* Butschli. The composition of the association is close to the Kuma Formation, the assemblage not including only species of the genera *Tripodiscinus* and *Heterosestrum*.

Up to the section in clayey marls of the Tishki Formation, an assemblage containing abundant *Cenosphaera mitgarzi* Lipman and rare *Heterosestrum tschuenkoi* Lipman, *Peripyramis circumtexta* Haeckel, and *Cyrtophormis alta* Moksyakova was found. The presence of the latter species together with *Heterosestrum tschuenkoi* Lipman, in spite of the poor taxonomical composition allows correlating this association to the *Cyrtophormis alta* (R3) regional radiolarian zone. Higher up to the section in clays of the same formation, the following radiolarian assemblage (R4) is present: *Cenosphaera mitgarzi* Lipman, *Stylodyctya irregularis* (Vinassa), *S. hastata* Ehrenberg, *Heterosestrum formosum* Tochilina and *Theocorys reticula* Kozlova. These taxa are not indicative but the stratigraphical position of the assemblage in the section suggests that it can be related approximately to the *Ethmosphaera polysiphonia* regional zone.

Up to the section in siliceous clays of the Kas'yanovka Formation, the radiolarian assemblage (R5) becomes more diversified and abundant: *Cenosphaera micropora*, *Stylodyctya irregularis* (Vinassa), *S. hastata* (Ehrenberg), *Heliodiscus zonatus* Tochilina, *Heterosestrum formosum* Tochilina, *Lithelius* sp., *Theocyrtis andriashevi* Petrushevskaya, *Calocyclas semipolita* Clark & Campbell and *Lithomelissa* sp. B. This assemblage most probably belongs to the *Theocyrtis andriashevi* regional zone.

Diatoms and Silicoflagellates

Diatoms were found at the base of the marl unit of the Sergeevka Formation and in noncarbonate clays in the upper part of the same Formation. The assemblage is rather poor (D1) (Table 11). Besides, species known from the Kantemirovka and Sergeevka sections: *Cristodiscus duplex* Gleser & Olshtinskaya and *Coscinodiscus* aff. *tenerrimus* Jousé, and silicoflagellates *Dictyocha pentagona* (Schulz) Bukry & Foster, and *Naviculopsis foliaceae* Deflandre can be noted. In the lower part of Tishki Formation, a poor diatom assemblage containing neritic *Paralia sulcata* (Ehrenberg) Cleve, *Pseudopodosira hyalina* Jousé and *Aulacodiscus excavatus* A. Schmidt was found. Among pelagic species, *Coscinodiscus obscurus* var. *cancavus* Gleser *in* Diatomovye vodorosly SSSR, dominates. In the upper part of the Tishki Formation, the diatom flora becomes more diversified. More representatives of the *Pyxidicula* genus [*P. moelleri* (A. Schmidt)

Strelnikova & Nikolaev, *P. grunowii* (Grove & Stuart) Strelnikova & Nikolaev, *P. joynsonii* (A. Schmidt) Strelnikova & Nikolaev, *P. charkoviana* (Jousé), Strelnikova & Nikolaev), *Craspedodiscus oblongus* (Greville) Hanna and *Coscinodiscus* aff. *marginatus* Ehrenberg] appear. Large diatom cells dominate along with unusually looking specimens of *Melosira architecturalis* Brun (Schmidt *et al.*) which are up to 60-70 mm in diameter. The disappearance of *Craspedodiscus oblongus* (Greville) Hanna takes place in the upper part of the Bartonian. The presence of this typical species determines the age of the upper part of the Tishki Formation as the Bartonian.

The assemblage of the Kas'yanovka Formation includes common species of D2 assemblage. In the uppermost part of the formation (depth 32 m), the abundance and diversity of silicoflagellates increases. Common are typical Bartonian taxa such as *Naviculopsis foliaceae* Deflandre, *N. nordica* Bukry, *Distephanus crus* (Ehrenberg) Haeckel, *Dictyocha spinosa* (Deflandre) Glezer, *D. deflandrei* Franguelli, *Corbisema hastata globulata* Bukry, *C. inermis* Lemm.

5-93 Boguchar borehole

The lithostratigraphic subdivision of this section is made according to the scheme of Kurlaev & Akhlestina (1988) for the Khoper monocline. The Veshenka Formation (Fig. 2), composed by sandy opokas 5 m thick, lies on the Upper Cretaceous sediments. The Osinovo beds overlie them unconformably. They are represented by light grey opokas with phosphorite nodules at the base, intercalated with sandstones. Their thickness is 6 m. The Tchirsky beds consist of strong quartzites 5.2 m thick, and upsection of fine-grained glauconite sands with rare beds of calcareous clays. Their thickness is 18 m. The Kuma Formation lies on sands and is represented by greenish low-carbonate opokas 2 m thick, turning up to the section into brownish non-calcareous clays. The upper part of the formation is composed by light opokas passing into opoka sandstones. The total thickness of the formation is 20 m.

Nannofossils

The rather poor nannofossil assemblage with rare *Chiasmolithus grandis* (Bramlette & Riedel) Radomski, *C. modestus* Perch-Nielsen, *C. solitus* (Bramlette & Sullivan) Locker, *Discoaster barbadiensis* Tan, *D. nodifer* (Bramletter & Riedel) Bukry, *Neococcolithus dubius* (Deflandre) Black, *Reticulofenestra dictyoda* (Deflandre *in* Deflandre & Fert) Stradner *in* Stradner & Edwards, *R. umbilicus* (Levin) Martini & Ritzkovski, *Coccolithus formosus* (Kamptner) Wise found in siliceous marls within a sandy unit formerly considered as a part of Buchack (?) Formation, but this association can be considered as the uppermost part of the Lutetian CP13 *Nannotetrina quadrata* zone or the lowermost Bartonian CP14a *Discoaster bifax* subzone.

Radiolaria

A radiolarian assemblage (Table 12) obtained from the base of Osinovo beds contains *Clathrocyclas minima* Lipman, *Heliodiscus heliasteriscus* Clark & Campbell, *H. dupla* Kozlova, *Spongomelissa* sp. A, *Lithomelissa* sp. A, *Thecosphaera minor* Campbell & Clark, *Spongotrochus radiatus* Lipman, *Stylodyctya irregularis* (Vinassa), and *Theocyrtis lithos* Campbell & Clark. The age of the assemblage is tentatively thought to be the middle Eocene, and not younger than upper Lutetian.

Up to the section in siliceous clays and marls of Kuma Formation, the abundant radiolarian assemblages of the *Cyrtophormis alta-Ethmosphaera polysiphonia* (R3-R4) regional zones were found. The association contains *Hexacontium pachydermum* Jorgensen, *Stylosphaera coronata coronata* Ehrenberg, *Lithelius spiralis* Lipman, *Bathropyramis anoetus* (Clark & Campbell), *Clathrocyclas talwanii* Bjorklund & Kellogg, *Cenosphaera mitgarzi* Lipman, *Theocyrtis lithos* Clark & Campbell, *Cyrtophormis alta* Moksyakova, *Artobotrys norvegiensis* Bjorklund & Kellogg, *Theocorys reticula* Kozlova, *Lithomelissa stigi* Butschli, *Tripodiscinus tribrachiatus* Kozlova, *T. kaptarenkoi* Gorbunov, and several other taxa.

The youngest radiolarian assemblage of the *Theocyrtis andriashevi* regional zone (R5) was obtained from siliceous clays of Kuma Formation. It is abundant, well-preserved, and contains *Hexacontium pachydermum* Kozlova, *Heterosestrum shabalkini* Lipman, *Thecosphaera minor* Campbell & Clark, *Tripodiscinus tribra-*

chiatus Kozlova, *Theocyrtis andriashevi* Petrushevskaya, *Haliomma immensa* Kozlova, *Calocyclas asperum* Ehrenberg and *Rhodospyris donensis* Zagorodnuk.

Diatoms and silicoflagellates

At the base of the Osinovo beds the following diatom association was found: *Paralia oamaruensis* (Grove & Stuart) Gleser, *Cristodiscus* (*Coscinidiscus*) *succinctus* (Sheshukova & Gleser) Gleser & Olshtinskaya, *Hemiaulus polymorphus* var. *charkovianus* (Sheshukova & Gleser) Gleser & Olshtinskaya, plus *Coscinodiscus obsurcus* var. *concavus* Gleser *in* Diatomovye vodorosly SSSR, *C. asteroides* Truan & Witt, *C. bulliens* A. Schmidt, *C. decrescenoides* Jousé, *C. oculusiridis* Ehrenberg, *Brightwellia* sp., *Hemiaulus polycystinorum* Ehrenberg, *Melosira* Brun (Schmidt *et al.*), *Pyxidicula* aff. *moelleri* A. Schmidt and *P. charkoviana* (Jousé). Silicoflagellates are represented by *Naviculopsis nordica hyalina* Bukry, *Mesocena concava* Perch-Nielsen, *M. apiculata* Schuiz and *Dictyocha venzoi* Morlotti & Rio. Key species of this assemblage are the same as those of the D1 association of the three other sections. The association belongs to the upper Lutetian.

In the lower part of Kuma Formation the diatom association (Table 13) is similar to the D2 assemblage from 9540 Rudaevka borehole, and in the middle part of the Kuma Formation the same silicoflagellate assemblage was found. The trend of changes in diatom and silicoflagellate composition is similar both in the 9540 Rudaevka borehole and in the 5-93 Boguchar borehole. At the 17.8 m level silicoflagellates dominate, but upsection they are replaced by siliceous sponges.

Discussion

In the eastern part of Dnieper-Donets Depression (the area of transition to Volga-Don Region) the facies change of Eocene sediments is so dramatic that one needs to use three different lithostratigraphic schemes (Fig. 1) from north-west to south-east to subdivide the Eocene deposits. These schemes (for Ukraine, Voronezh antecline, and the Volga-Don Region) are not sufficiently correlated yet. In the eastern part of study region, some lithostratigraphic subdivisions of the northern Caucasus scheme are used. That gives us a reason to suggest a lithostratigraphic and microplanktonic correlation for the Crimea-Caucasus area and the Dnieper-Donets Depression, because all the studied sections showed similar sedimentary cyclicities, and their formations can be dated and correlated on the basis of calcareous microfossils in the lower part of sections and on siliceous microfossils in the upper part.

In the Crimea-Caucasus area, the lower middle Eocene (Lutetian) sediments are represented by marls and limestones of Keresta Formation. Up to the section, Kuma Formation composed by carbonatic clays rich in organic matter lies with erosion in a number of localities. The following changes in calcareous microplankton assemblages occur through the Keresta-Kuma boundary. The nannofossil assemblages of Keresta Formation are very rich all over the area, and the CP13 *Nannotetrina quadrata* zone (Fig. 3) and all three subzones (CP13a, CP13b, and CP13c) of nannofossil standard zonal scale (Okada & Bukry 1980) can be established. The top of Keresta Formation is marked by disappearance of *Nannotetrina quadrata* (Bramlette & Sullivan) Bukry, *N. cristata* (Martini) Perch-Nielen (1971), *Discoaster gemmifer* Stradner, *D. martinii* Stradner. No new species appear at the base of Kuma Formation. The CP14 *Reticulofenestra umbilica* zone stands out among the deep ocean sediments owing to the *Discoaster bifax* Bukry appearance. In all studied sections of the South of the Former USSR, this species appears within CP13b *Chiasmolithus gigas* subzone, i.e., much earlier than in DSDP sites, where the zonal scale of Okada & Bukry (1980) was established. Recently, its appearance was recorded within Lutetian deposits of Parisian Basin and Hampshire (Aubri 1983). Hence, this species cannot be used as a zonal marker in epicontinental basins. A few meters above the Kuma Formation's bottom, characteristic species of CP14 zone gradually appear. These changes in nannofossil assemblages led us to place the CP13/CP14 zone boundary along the Keresta-Kuma boundary because in spite of the absence of the traditional zonal marker, these zones are distinguished by the full spectrum of the assemblage.

The changes in planktonic foraminifera assemblages proceed in a similar way. At the top of

Keresta Formation, such peculiar species as *Subbotina frontosa* Subbotina, *S. subtriloculinoides* (Khalilov), *Acarinina bullbrooki* Bolli, *Globigerinatheka subconglobata* (Khalilov *in* Shutzkaya), *G. index* (Finlay) (*Acarinina rotundimarginata* zone of the Crimea-Caucasus zonal scale are present – beds with *G. subconglobata-G. index*). The foraminiferal assemblage of Kuma Formation is composed by *Hantkenina alabamensis* Cushman, *Subbotina aserbaidjanica* (Khalilov) and other species. Then, the *Acarinina rotundimarginata-Hantkenina alabamensis* zone boundary is established mostly by the disappearance of the characteristic species of the first zone and corresponds with Keresta-Kuma formations boundary.

Far to the north, the Kuma Formation sediments onlap the sediments corresponding to the Keresta Formation with pronounced erosion. The siliceous plankton comes into play along with the calcareous microfossils. The correlation of radiolarian and diatom zonal scales with that of foraminifera and nannofossils were made in the sections of the northern Peri-Caspian (Khokhlova 1996; Radionova 1996). The correspondence of the radiolarian *Heliodiscus quadratus* zone (R2) to the foraminiferal *Acarinina rotundimarginata* zone, and *Cytophormis alta* (R3), *Ethmosphaera polysiphonia* (R4) to the foraminiferal *Hantkenina alabamensis* and *Globorotalia turcmenica* zones is shown.

In all studied sections of Dnieper-Donets Depression the same zonal succession was traced. The *Heliodiscus quadratus* (R2) zone assemblage is recorded within the lowermost part of all four sections, i.e., within Sergeevka Formation and Tchir beds. The following three zones (R3-R5) are established within the uppermost part of Tishki and Kas'yan formations. This suggests a correlation of these formations with Kuma Formation of the South of the Former USSR.

It is common knowledge that diatom assemblage of the Kiev and Khar'kov formations of Ukraine was proposed as *Paralia oamaruensis* zone (Glezer *et al.* 1965), but boundary markers were not represented, so that even nowadays under closer examination it is hard to establish the boundaries of this zone. In all studied sections two intervals with abundant diatoms separated by sediment interval of variable thickness without diatoms were found. Hence, we record not zones, but layers with *Peponia barbadensis* Greville (D1) and layers with *Brightwellia imperfecta* Jousé (or *Cosmodiscus breviradiatus* Gleser & Olshtinskaya) (D2).

Beds with *Peponia barbadense* Greville, corresponding to the "Kiev" Formation or its correlates, correlate with the upper Luthetian, and beds with *Brightwellia imperfecta* Jousé, corresponding to the lower part of the "Khar'kov" Formation, with the Bartonian. Of the diatoms, *Peponia barbadensis* Greville is restricted to the Luthetian, *Craspedodiscus oblongus* (Greville) Hanna disappears in the upper part of the Bartonian (Fenner 1985), and *Brightwellia imperfecta* is restricted to the second half of the middle Eocene (Fenner 1985). Silicoflagellates manifest the disappearance of *Dictyocha spinosa* (Deflandre) Gleser (in the Sergeevka Formation) and appearance of *Dictyocha hexacantha* Schulz (in the Kas'yanovka Formation), or else, *Naviculopsis foliaceae*/*Dictyocha hexacantha* zone boundary correlates with the CP13/CP14 (Bukry 1981) nannoplankton zone boundary.

PALAEOGEOGRAPHY

The benthic forams *Pseudoclavulina subbotinae* Nikitina, *Uvigerina spinocostata* Cushman & Jarvis, *Vaginulopsis decorata* (Reuss), *Clavulinoides szaboi* (Hantken), *Bulimina macilenta* Cushman & Parker, *Bolivina cooki* Cushman, *Spiroplectamina pishvanovae* A. V. Furssenko & K. B. Furssenko in the Sergeevka Section are widespread in Lutetian deposits of various Peri-Tethys localities from Belgium to West Turkmenia (Kaasschniter 1961; Furssenko & Furssenko 1961; Shutzkaya 1970; Bugrova 1988; Grigaylis *et al.* 1988; Naidin *et al.* 1994). The fact that the same foraminifera assemblage is spread over an enormous area in the northern Peri-Tethys suggests the existence of a continuous basin with ubiquitous palaeobiologic links. Moving along the line of sections studied in the present paper from north-west to south-east, i.e., from Sergeevka Section to the Boguchar borehole, it can be seen that radiolarian assemblages are more taxonomically diversified and well-preserved in Boguchar borehole located in the south-eastern part of the region. By the way, taxonomical composition of the earliest complex at the base of section is close to coeval associations of Kuma Formation of southern regions, and that of younger R3-R5 assemblages is similar to coeval complexes of Norway Basin and Peri-Caspian Basin (Kozlova & Petrushevskaya 1979; Khokhlova 1996). Nevertheless, radiolarians in this section represent an association of an open marine basin with normal salinity. Conversely, radiolarian composition in borehole 9540 seems to reflect alternating open marine and of shallow-water basin conditions, possibly with a restricted connection with the main basin. Sediments at the base of section (Sergeevka marls) and in the upper part of the section (Kas'yanovka siliceous clays, R5) contain diversified open-marine radiolarian associations, but in the middle part of the section in clays of the Tishki Formation, the radiolarian assemblage (R3-R4) is represented by abundant specimens of *Cenosphaera mitgarzi* Lipman and sparse specimens of *Cyrtophormis alta* Moksyakova and *Bathropyramis* sp. A strong predominance of one species is known to testify to the absence of open-oceanic conditions, probably to low salinity conditions.

The oldest radiolarian assemblage is most abundant and diversified in the marls of Sergeevka Formation in the section of the same name, and the youngest (R5) assemblage is most diversified in Kas'yanovka Formation of Kantemirovka Section.

CONCLUSION

The study of four sections of the eastern slope of the Dnieper-Donets Depression allowed us to correct age determination of the Eocene Formation.

The marls of Sergeevka Formation most likely belong to uppermost Lutetian. The benthic foraminiferal zone *Pseudoclavulina subbotinae-Uvigerina spinocostata-Bolivina cookei* distinguished here can be traced in the Keresta Formation through much of the south of European Russia, and in Vemmel and Ash formations of Belgium (Kaasschiter 1961; Radionova *et al.* 1994). The upper part of the planktonic foraminiferal *Acarinina rotundimarginata* zone (bed with *Globigerinatheka index*) found in the lower Sergeevka marls confirms this age determination. Data based on nannofossils (CP13 *Nannotetrina* zone) identify the boundary between their Lutetian age, too.

The age of the Tishki Formation is clearly Bartonian. This interpretation is confirmed by planktonic foraminifera of the *Globigerina turcmenica* zone. The diatom assemblages from the base of the Sergeevka Formation and the lower part of the Osinovo beds (D1), in the upper part of the Tishki, Kas'yanovka and Kuma Formations (D2) are related to *Paralia oamaruensis* diatom zone of (Glezer 1979) and to *Coscinodiscus succinctus* zone of Strelnikova (1992) scheme. In Sergeevka Section, in assemblage D1 the index species *Peponia barbadensis* Greville (Radionova 1996), and in D2, the index species *Brightwellia imperfecta* Jousé, which undoubtedly testify to middle Eocene age, were found.

Sediments of the Kas'yanovka Formation in all studied sections contain almost the same diatom assemblage. A notable feature of the assemblage is the presence of *Paralia oamaruensis* (Grove & Stuart) Gleser and *Coscinodiscus succinctus* (Sheshukova & Gleser) Gleser & Olshtinskaya, the index-species of zones in local diatom schemes of Glezer (1979) and Strelnikova (1992). This diatom assemblage is very close to the association obtained from the base of the Khar'kov Formation in the northern part of Dnieper-Donets Depression (see Radionova *et al.*, this volume, Fig. 1, boreholes 3 and 4; Radionova *et al.* 1994). No evidence of the upper Eocene age for the Kas'yan Formation has been found from radiolaria or diatoms, and we confidently suggest the upper Bartonian age for Kas'yan Formation.

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APPENDIX

TABLE 1. — Stratigraphic range chart of nannofossils in Sergeevka Section. **A**, abundant (more than 15 specimens); **F**, frequent (10-15 specimens); **C**, common (3-9 specimens); **R**, rare (1-2 specimens).

Species/sample number	8	11	12	14
Blackites spinosus	F	R		
Chiasmolithus solitus	R	A	C	
Coccolithus formosus	A	C	R	
Cyclicargolithus floridanus	A	A	A	R
Discoaster barbadiensis	F	F	F	
Discoaster binodosus	F	F	F	
Discoaster distinctus	F			
Discoaster nodifer	F	F		
Discoaster saipanensis		F		
Discoaster strictus	R	F		
Discoaster wemmelensis			F	
Helicosphaera bramlettei	F			
Helicosphaera lophata			F	
Holodiscolithus macroporus			F	
Neococcolithes dubius	F	F	F	
Pontosphaera multipora	F	F	F	
Reticulofenestra dictyoda	C	F		F
Reticulofenestra haqii	A	A	C	F
Reticulofenestra umbilicus	A	A	C	
Sphenolithus furcatolitoides	F			
Sphenolithus moriformis	F	F	F	
Sphenolithus spiniger	F	F		
Transversopontis pulcher	F	F	F	F

TABLE 2. — Stratigraphic range chart of foraminifera of Sergeevka Section. **b**, benthos; **p**, plankton. Legend: see Table 1.

Species/sample number		1	2	3	9	4	5	10	11	12	13
Acarinina bullbrooki	p		F								
Acarinina pentacamerata	p		A	R							
Acarinina cf. *rotundimarginata*	p		R								
Clavulina cylindrica	b		R		F	F	F	R	F	C	F
Clavulinoides szaboi	b			C		A	R	C	C	C	F
Pseudoclavulina subbotinae	b					R		R	R		F
Spiroplectammina pishvanovae	b				F	F					
Vaginulinopsis decorata	b			C			F	A		F	F
Uvigerina costulata	b						C		C		
Uvigerina macilenta	b			C		C			A		F
Uvigerina spinocostata	b			C						C	

TABLE 3. — Stratigraphic range chart of radiolaria in Sergeevka Section. Legend: see Table 1.

Species/sample number	**9**	**19**	**20**	**21**	**22**	**23**
Calocyclas semipolita	A	R	R		R	
Clathrocyclas minima	C					
Clathrocyclas extensa					A	
Heliodiscus dupla	R					
Heterosesrum formosum			R	F	F	F
Heliodiscus heliasteriscus			C		A	
Heliodiscus zonatus	C					
Heliodiscus fragilis					R	
Heterosestrum tschuenkoi		R			C	
Hexacontium pachydermum		R	R			
Larcospira minor	R					
Lithomelissa sp. B					A	
Lithomelissa sp. A	C	R				
Lophocyrtis sinitzini		C	R			
Melittosphaera magnoporulosa					C	
Phacodiscus testatus					C	
Porodiscus parvus					R	
Spongomelissa sp. A	C					
Stylodyctya irregularis	R		C		C	
Stylotrochus radiatus	R					
Theocyrtis lithos	C	F			R	
Thecosphaera californica			R			
Tripodiscinus aff. *clavipes*		F				
Tripodiscinus kaptarenkoe			C		R	
Tripodiscinus aff. *tribrachiatus*		F				

TABLE 4. — Stratigraphic range chart of diatoms and silicoflagellates in Sergeevka Section. Legend: see Table 1.

Species/sample number	9	19	20	22
Diatoms				
Arachnoidiscus ehrenbergii	F		F	
Arachnoidiscus asteromphalus			R	
Aulacodiscus excavatus	C	F	F	F
Azpeitia aff. *oligocenica*				R
Brightwellia imperfecta (?)				R
Corona retinervis			F	
Coscinodiscus bulliens				F
Coscinodiscus obscurus	C	C	C	C
Coscinodiscus obscurus var. *cancavus*		C	C	F
Cosmiodiscus breviradiatus				F
Coscinodiscus patera (?)				R
Craspedodiscus moelleri	F	R	F	R
Cristodiscus (*Coscinodiscus*) *succinctus*	R	F	F	A
Cristodiscus crux		F		
Cristodiscus decrescenoides		F	A	
Hemiaulus polymorphus var. *charkovianus*		F		F
Hyalodiscus radiatus		F	F	R
Hyalodiscus inflatus	C			
Hyalodiscus johnsonii	R	F		
Hyalodiscus kelleri var. *fasciculatus*	C	F	F	
Melosira architecturalis		F	C	
Melosira fausta	F	F		
Paralia oamaruensis	C	C	C	C
Paralia sulcata var. *sibirica*		C		
Peponia barbadensis	R			
Pseudopodosira hyalina	F	C		
Pseudopodosira bella		F	F	
Pseudopodosira westii	F	C		
Pseudotriceratium chenevieri				R
Pseudotriceratium pyleyformis		F		
Pyxidicula charkoviana	F	A	C	F
Pyxilla gracilis			F	
Pyxilla schenkii		R		
Pyxilla tchernovii		R		
Trinacria excavata			F	F
Triceratium aff. *kanaya* var. *trilobata*	R		F	
Triceratium ventricosa	C	C		
Silicoflagellates				
Dictyocha spinosa			F	
Distephanus pentadonus		F		
Distephanus grunowii		R		F
Naviculopsis constricta		F		
Naviculopsis oamaruensis	F			

TABLE 5. — Stratigraphic range chart of nannofossils in Kantemirovka Section. Legend: see Table 1.

Species/sample number	27	28	29	30	33
Blackites spinosus	F	F	F		
Chiasmolithus solitus	F	F	F	F	
Chiasmolithus tituf	F	F			
Coccolithus formosus	A	C	R	F	F
Cyclicargolithus floridanus	C	A	C	R	F
Discoaster barbadiensis	C	F			
Discoaster bifax	R	F			
Discoaster binodosus	R	F	F	F	
Discoaster deflandreis	R	F	F		
Discoaster saipanensis	F				
Discoaster strictus	F	F	F		
Discoaster onustus	R	F			
Helicosphaera bramlettei	F	F		F	
Helicosphaera seminulum	F				
Nannotetrina cristata	F	F			
Neococcolithes dubius	C	R	F		
Pontosphaera multipora	F	F	F		
Pontosphaera duocavus	F	F			
Reticulofenestra coenura	A	R	F	F	F
Reticulofenestra haqii	A	A	C	F	
Reticulofenestra umbilicus	C	R	F	F	
Sphenolithus moriformis	F	F			
Sphenolithus obtusus		F	F		
Sphenolithus radians		F			
Transversopontis pulcher		F	F	F	
Zygrhablithus bijugatus		R	F	F	F

TABLE 6. — Stratigraphic range chart of foraminifera in Kantemirovka Section. **b**, benthos; **p**, plankton. Legend: see Table 1.

Species/sample number		27	28	29
Acarinina rugosoaculeata	p	F		
Bolivina cookei	b	F	C	
Bulimina sculptilis	b		C	
Clavulina colomi	b	C	C	C
Clavulina cylindrica	b	C	C	C
Clavulinoides szaboi	b	A	A	C
Globigerinatheka index	p		R	
Pseudoclavulina subbotinae	b	F	F	C
Pseudohastigerina micra	p	F	C	
Spiroplectammina pishvanovae	b	F	C	
Subbotina turcmenica	p		C	A
Vaginulinopsis decorata	b	F	C	C
Uvigerina costellata	b	C	C	
Uvigerina macilenta	b	C	C	
Uvigerina spinocostata	b	C	C	

TABLE 7. — Stratigraphic range chart of radiolaria in Kantemirovka Section. Legend: see Table 1.

Species/sample number	39	40	41	42	43	44A
Bathropyramis aneotos			F			
Calocyclas asperum		R	R	R	R	
Calocyclas semipolita			R	R		
Ceratospyris sp. aff. *T. crassipes*		R				
Clatrocyclas extensa multiplicata		R		R		
Clathrocyclas talwanii	R	R	R	R		
Clathrocyclas sinitzini			F		F	F
Clathrocyclas sp. 1			R			
Conocaryomma sp.				C		
Cyrtophormis alta	C					
Heliodiscus heliasteriscus			A		A	
Heliodiscus zonatum			C			
Heliodiscus fragilis			C	F		
Heterosestrum formosum			A			A
Heterosestrum tschuenkoi						A
Hexacontium aff. *pachydermum*			A	C	C	C
Lithelius foremanae						C
Lithomelissa sp. A	C	A	A	A		C
Lithomelissa sp. B						C
Lithelius foremanae						C
Melittosphaera magnoporulosa			C	R		
Pseudodyctyophimus sp.				C		
Stylodyctya irregulare			C			
Stylosphaera coronata			F	F	F	F
Theocyrtis lithos						
Theocyrtis andriashevi						
Tripodiscinus kaptarenkoe			R	R	A	A
Velicucculus aff. *oddgurneri*		R				
Tripilidium clavipes						
Stylosphaera balbis						F
Tripodiscinus sp.						A

TABLE 8. — Stratigraphic ranges chart of diatoms and silicoflagellates in Kantemirovka Section. Legend: see Table 1.

Species/sample number	**39**	**40**	**42**	**43**	**44A**
Diatoms					
Aulacodiscus excavatus	F	F			F
Aulacodiscus kelleri var. *fasciculatus*				F	F
Arachnoidiscus ehrenbergii		F	F		F
Brightwellia coronata			R		
Cerataulus deflandrei		F			F
Corona retinervis			F	F	
Coscinodiscus obscurus	F	F	C	C	
Coscinodiscus obscurus var. *cancavus*	F	C	C	C	C
Coscinodiscus asteromphalus				F	
Coscinodiscus decrescenoides			C	F	C
Cristodiscus (*Coscinodiscus*) *succinctus*		F	C	C	
Hemiaulus polymorphus var. *charkovianus*	C			F	F
Hemiaulus tchernovii				F	F
Hemiaulus polycystinorum		F			F
Melosira architecturalis			C	C	F
Paralia sulcata var. *sibirica*		C	C	C	C
Paralia oamaruensis		C	C	C	F
Pseudopodosira hyalina		C	C	C	C
Pseudopodosira pyleiformis			C	C	F
Pyxilla gracilis		F			F
Pyxidicula charkoviana		F	C	F	F
Pyxidicula johnsonii				A	F
Pyxidicula aff. *moelleri*				F	F
Thalassiosiropsis wittiana				F	
Triceratium ventricosa		F		F	
Triceratium aff. *kanaya* var. *triloata*		R			R
Triceratium unguiculatum					R
Tricacria excavata var. *tetragona*				F	F
Silicoflagellates					
Dictyocha deflandrei				F	
Mesocena oamaruensis		F			
Naviculopsis constricta				F	
Naviculopsis foliaceae		F		F	

TABLE 9. — Stratigraphic range chart of nannofossils in Rudaevka (borehole 9540). Legend: see Table 1.

Species/sample number	**61-5**	**60-5**	**56**
Blackites spinosus	C		
Chiasmolithus grandis	F		
Chiasmolithus solitus	C	F	F
Chiasmolithus tituf	F	F	F
Clathrolithus spinosus	F		
Coccolithus formosus	R		F
Coccolithus pelagicus	R	R	R
Cyclicargolithus floridanus	A	A	C
Discoaster barbadiensis	F		F
Discoaster bifax	F		
Discoaster distinctus	R	F	F
Discoaster nodifer	R	F	F
Discoaster saipanensis	F		
Discoaster strictus	R		
Helicosphaera bramlettei	F		
Helicosphaera lophota	F		
Neococcolithes dubius	C	F	F
Pontosphaera duocavus	F		
Pontosphaera multipora	F	F	
Reticulofenestra umbilicus	C	F	F
Rhabdosphaera gladius	F		

TABLE 10. — Stratigraphic range chart of radiolaria in Rudaevka (borehole 9540). Legend: see Table 1.

Species/sample number	**60-5**	**59**	**53-5**	**51**	**50**	**49-5**	**47**	**45**	**43-5**	**39**	**35**	**33**
Stylodyctya hastata	F			F							F	R
Cenosphaera mitgarzi							A	A	C			
Thecosphaera minor	R											
Heliodiscus heliasteriscus	F		C	C							F	R
Clathrocyclas principi principi	R											
Lithomelissa sp. A	F											
Stylotrochus sp.	F			F								R
Hexacontium pachydermum			C	C								
Stylodyctya irregularis										A	C	A
Petalospyris aff. *dubia*			F									
Clathrocyclas extensa			F									
Theocorys reticula			F	F							F	
Heterosestrum formosum			F	C							C	F
Heterosestrum tschuenkoi			F	C	R							
Stylosphaera coronata laevis				F								
Tripodiscinus tumulosus				F								
Hiphospira ocellata				F								
Thecosphaera californica				F								
Lithomelissa aff. *haeckeli*				F								
Cenosphaera micropora												F
Cyrtophormis altus					R							
Perypyramis circumtexta							R					
Calocyclas semipolita												F
Lophophaena sp. B												A
Heliodiscus zonatus												C
Theocyrtis andriashevi												C

TABLE 11. — Stratigraphic range chart of diatoms and silicoflagellates in Rudaevka (borehole 5420). Legend: see Table 1.

Species/sample number	**60-5**	**53-5**	**50**	**47**	**38**	**37**	**35**	**34**	**33**	**32**
Diatoms										
Aulacodiscus excavatus	F									F
Aulacodiscus kelleri var. *fasciculatus*			F							
Cerataulus deflandrei		F								
Corona retinervis		F								
Coscinodiscus bulliens		F						F		
Coscinodiscus obscurus	F	F			C	C	C	C	C	R
Coscinodiscus obscurus var. *cancavus*		C	A		F		C	C	C	
Coscinodiscus asteromphalus									F	
Coscinodiscus decrescens									F	F
Coscinodiscus decrescenoides				F				F		F
Cosmiodiscus breviradiatus									F	
Cristodiscus succinctus		F								
Cristodiscus duplex	F									
Craspedodiscus moelleri						F				
Craspedodiscus oblongus						C				
Hemiaulus polymorphus var. *charkovianus*		F						F	F	C
Hemiaulus tchernovii			F							
Hyalodiscus radiatus				F						
Melosira architecturalis		C		F		F				
Paralia oamaruensis	C					C		F		C
Pseudopodosira hyalina		F	C			C	C			C
Pseudopodosira westii								F		
Pseudopodosira pyleyformis						C	F			F
Pseudopodosira bella		F								
Pyxilla gracilis		F								
Pyxidicula charkoviana	F	C	C				C			
Pyxidicula grunowii						F				
Pyxidicula aff. *moelleri*	F		C		F	F	F	F	F	F
Pyxidicula johnsonii				F						
Pyxidicula marginata							R			
Pyxidicula megapora										F
Triceratium kanaya var. *trilobata*							F	F		
Triceratium ventricosa										
Tricacria excavata										
Silicoflagellates										
Corbisema hastata globulosa										F
Corbisema triacantha		F								F
Dictyocha deflandrei										F
Dictyocha spinosa										
Distephanus pentadonus	F									
Naviculopsis foliaceae										C
Naviculopsis constricta										C
Naviculopsis nordica										C
Corbisema triacantha										F

TABLE 12. — Stratigraphic range chart of radiolaria in Boguchar (borehole 5-93). Legend: see Table 1.

Species/sample number	**63-4**	**62-1**	**60-1**	**31-5**	**31**	**30**	**23-4**	**17-4**	**16**	**12**	**11**
Thecosphaera californica	F										
Calocyclas semipolita	C										
Heliodiscus heliasteriscus	C										
Lychnocanium bellum	F										
Artostrobus aff. *annulatus*	F										
Stylodyctya irregularis	A										
Petalospyris dubia	C	F									
Lithomelissa haeckeli		F	F								
Hexacontium pachydermum		R	F	F	F	F			F		
Hexacontium sp.											
Spongomelissa sp. 1			C								
Lithomelissa sp. A											
Stylosphaera coronata coronata			C	F							
Heliodiscus dupla			F								
Tripodiscinus aff.*vanus*	F										
Heterosestrum formosum			C								
Stylotrochus radiatus	C	C	C								
Heterosestrum thcuenkoi			R								
Heterosestrum shabalkini								R			R
Clathrocyclas talwanii											
Cenosphaera mitgarzi							F	F			
Theocyrtis lithos				C							R
Theocorys reticula				A							
Artobotrys norvegiensis				F							
Lithomelissa stigi							C				
Peripyramis anoetum				R							
Lithelius spiralis				R		C	C	C			
Thecosphaera minor									R		
Cyrtophormis alta					C	R			F		
Tripodiscinus tribrachiatus							F	F	R		
Tripodisciunus kaptarenkoi							F	C			
Theocyrtis andriashevi							R	F	F		
Haliomma immensa							A				
Calocyclas asperum						R		C			
Rhodosphaera donensis					R	C					

TABLE 13. — Stratigraphic range chart of diatoms and silicoflagellates in Boguchar (borehole 5-93). Legend: see Table 1.

Species/sample number	**63-4**	**62-1**	**60-1**	**29-5**	**28-2**	**24-2**	**17-1**	**15-1**
Diatoms								
Actinoptychus intermedius		F			F			
Aulacodiscus excavatus	F							
Aulacodiscus kelleri var. *fasciculatus*	F							
Aulacodiscus inflatus		R						
Azpeitia aff. *oligocenica*			F					
Brightwellia sp.			R					
Cerataulus deflandrei	F					F		
Corona retinervis			F			F		
Coscinodiscus bulliens	F		F			F		
Coscinodiscus obscurus	C	C					F	F
Coscinodiscus obscurus var. *cancavus*	F	C	C					
Coscinodiscus asteromphalus			R					
Coscinodiscus decrescens	F							
Coscinodiscus marginatus					F			
Coscinodiscus decrescenoides	F		F					
Cosmiodiscus breviradiatus						F		F
Cristodiscus succinctus	F				F			
Cristodiscus duplex	F					F		
Craspedodiscus moelleri						F		
Craspedodiscus oblongus				F	C	C		
Hemialus polycystinorum	F			F		F		
H. polymorphus var. *charkovianus*	F					F	C	
Hyalodiscus radiatus	R		F			F		
Melosira architecturalis	F	F		F	C	C		
Paralia sulcata var. *sibirica*	C	C						
Paralia oamaruensis	F	C				R		
Pseudopodosira hyalina	C				F	C	C	F
Pseudopodosira pyleyformis	F		F		C		F	
Pseudopodosira bella					C			
Pyxilla gracilis	F				F	F		
P. oligocenica var. *oligocenica*					F	F		
Pyxidicula charkoviana	F	F	F	C		C		
Pyxidicula grunowii				F				
Pyxidicula aff. *moelleri*	F			F		F		
Pyxidicula johnsonii	F							
Pyxidicula crenata						F		
Pyxidicula megapora		F	F					
Pyxidicula spinodissima					R			
Stellarima mucrotrias	F		F					
Triceratium ventricosa			F	F		C		
Triceratium aff. *kanaya* var. *triloata*						F		
Tricacria excavata	F		F			F		
Tricacria exsculpta					F			
Silicoflagellates								
Corbisema hastata globulosa								F
Corbisema enermis								F
Dictyocha deflandrei	F							
Dictyocha spinosa								F
Dictyocha hexacantha						F		
Distephanus pentagonus			F					
Naviculopsis foliaceae								C
Naviculopsis constricta								F
Naviculopsis nordica								C