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On the Late Paleocene Stratigraphy of the Saratov Volga Region: Micropaleontological Characteristics of the Kamyshin Formation, Dyupa Gully Section

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Abstract—This paper presents the results of the integrated study of dinocysts and diatoms from the Kamyshin Formation, Dyupa Gully section. The Kamyshin Formation is shown to have been formed in the Late Thanetian–initial Eocene and to include the IETM interval. The Dyupa Gully section is comprised of the deposits of two transgressive-regressive cycles. The section is comprehensively characterized by micropaleontological finds (dinocysts, radiolarians, and diatoms) and proposed as a key section of the Middle Volga Region.

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Key words: Late Thanetian, Early Eocene, dinocysts, diatoms, stratigraphy, Volga River Region.

INTRODUCTION

The Paleogene stratigraphy of the Volga Region has developed since the end of the 19th century. The majority of Paleocene lithostratons (Syzran, Saratov, and Kamyshin formations), detailed by Pavlov (1896), Arkhangelsky (1928), Milanovskii (1940), and Leonov (1961), were established in the Saratov part of the Volga Region. Their age remains debatable to this day, because the Paleocene in the Saratov and Volgograd parts of the Volga Region is comprised chiefly of terrigenous deposits (silt, sand, and clay) containing rather sporadic malacofaunas and extremely poor microfaunas. Now that zonal scales based on carbonate, siliceous, and organic-walled plankton, that are included into the general Paleogene scale (*Resolutions* …, 1989; *Zonal* …, 1991), have been developed to subdivide the marine Paleogene deposits of southern Russia, reliable temporal limits on the age of the lithostratons on a zonal basis for the Paleocene of the Volga Region is rather hotly debated.

Currently, a reliable age attribution only exists for the Kamyshin Horizon, identified across the vast area of the Volga and Cis-Caspian regions (Akhmetiev and Beniamovskii, 2003). Thus, east of the Volga River Region, in Novouzen key well no. 1 (Fig. 1), the correlatives of the Kamyshin Formation contain nannoplankton Zone CP8 (Musatov, 1993), which is dated to the terminal Late Paleocene. The deposits of the Kamyshin and Proleika formations, uncovered by well no. 28 (town of Dubovka) in the lower Volga Region (Aleksandrova, 2001), have yielded dinocyst assemblages and palynological spectra correlative to NP8–NP9 nannoplankton zones, which correspond to the late Thanetian. In the Ulyanovsk part of the Volga Region, the Kamyshin Horizon, composed of diatomite, is also attributed to the Late Paleocene. The horizon is characterized by the *Buriella tetradica, Tripodiscinus sengilensis*, and *Petalospyrtis foveolata* radiolarian zones (Kozlova, 1999) and the *Trinacria ventriculosa* and *Hemiaulus proteus* diatom zones (Oreshkina and Oberhanslli, 2003). In all these cases, we are dealing exclusively with facies correlatives of the Kamyshin Formation.

In its stratotype, between the town of Kamyshin and the village of Balyklei, the Kamyshin Formation is subdivided into the Lower and Upper Kamyshin Subformations (Milanovskii, 1940; Fig. 1). The base of the Lower Kamyshin Subformation typically contains a horizon of coarse-grained cross-layered sand and sandstone with pebbles and small shark teeth, up to 3 m thick. Further upsection, this subformation consists of dark gray sand and clayey opokas up to 12–15 m thick. The Upper Kamyshin Subformation is formed by a complexly built sequence of quartz sand with subordinate intercalations of clay and sandstone 20–26 m thick. The transition between the subformations is gradual. The total thickness of the formation in the vicinity of the town of Kamyshin is up to 40 m.

Paleontologically, the formation is poorly characterized. Conchilofaunas are represented by a single species, *Teredina* sp. (Zubkovich, 1960). The Upper Kamyshin Subformation in the vicinity of the town of Kamyshin is known to contain a fossil flora locality. This flora was repeatedly studied and was found to be correlative to the type flora of Gelinden (Pavlov, 1896; Krasnov, 1910; Baranov, 1959; Makulbekov, 1977; etc.). Analysis of the lithological structure and palynological assemblages from the key sections (Kuznetsova, 1965, 1970, 1973; Distanov et al., 1970) makes it pos-

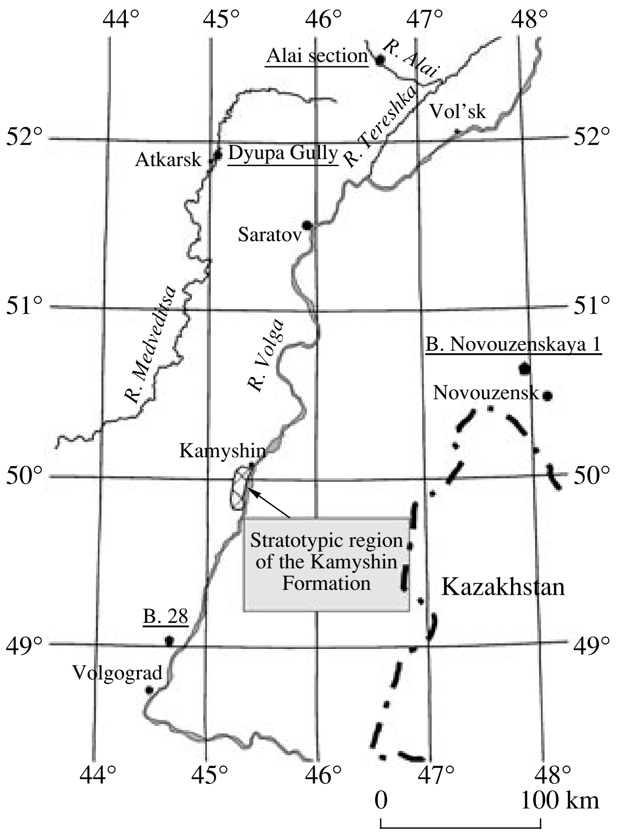


Fig. 1. Schematic map of the sections mentioned in the paper.

sible to attribute the Kamyshin Formation to a single sedimentological assemblage corresponding to the major Kamyshin stage of deposition. The age of this stage was determined by these workers as Late Paleocene.

In the Saratov Region, there are two sections of the Kamyshin Formation, lithologically similar to the type section, although containing some microfaunas which enable the stratigraphy of these deposits to be improved. One of these sections, Dyupa Gully, is located in the west of the region, near the town of Atkarsk (the results of its study are presented in this paper). The other is along the Alai River, in the northeastern part of the region, north of the town of Vol'sk. The microfauna of the Dyupa Gully section has previously been studied (Kozlova, 1999; etc.). The lower part of the sequence has yielded siliceous plankton, which provided the basis for establishing the Upper Paleocene *Tripodiscinus sengilensis* and *Petalospiris foveolata* Radiolarian Zones, and the assemblage of the *Trinacria ventriculosa* Diatom Zone (Strelnikova, pers comm). We have revisited the Dyupa Gully section in order to redocument and resample it on stations 0.6–1 m apart. For the Lower Kamyshin Subformation, we obtained biostratigraphic subdivisions based on diatoms and dinocysts and exclusively on dinocysts for most of the Upper Kamyshin Subformation.

MATERIALS AND METHODS

In 2004 we described the Dyupa Gully section based on natural outcrops along a creek, which is situated in the Medveditsa River Basin, near the village of Lomovka, Atkarsk district (Saratov Region). The section is shown from the bottom upwards in Fig. 2:

Layer 1. The exposed bottom of the Lower Kamyshin Subformation is olive-gray sandy silt, which has an apparent thickness of 0.5 m and gradually transforms into the overlying sediments.

Layer 2. Dense dark gray, nearly black clays with an apparent thickness of more than 4–5 m.

Layer 3. Consolidated sandstone about 1.5 m thick.

Layer 4. The exposed bottom of the Upper Kamyshin Subformation is composed of dense black clays that are bluish and sticky in wet conditions, and about 1.5 m thick. The upper boundary is sharp, showing no evidence of hiatus.

Layer 5. Olive-gray lumpy sandy clays 1.7 m thick. Lithologically, this layer is correlated with the sandy beds of station 1 (Fig. 1).

Layer 6. Loose lumpy sandy opokas, denser in the upper portion of the layer and gradually transforming into fractured sandstone. The total thickness is 2.1 m.

Layer 7. The sands are fine-grained, light yellow-gray, slightly clayey (opokas-like?), and 2 m thick. The boundary with the overlying sediments is apparently unconformable.

Layer 8. (A) at the base of this layer there is a bed that is 0.2–0.3 m thick and consists of flat "cakes" of variously silicified sandstone with tracks of deposit feeders separated by loose sandy material, in which a shark tooth was found; (B) upward the section a thin layer of sandy gritstone is overlain by fine-grained unconsolidated quartzose sandstone with an apparent thickness of 1.5 m. This layer apparently belongs to the Kalinino Formation.

Both microplankton groups (diatoms and dinocysts) were found only in Layers 1 and 2 of the Lower Kamyshin Subformation; in addition, dinocysts were found in Layers 4 and 5 of the Upper Kamyshin Subformation.

The palynological samples were processed according to the technique used in the Laboratory of Paleofloristics at the Geological Institute, Russian Academy of Sciences (GIN): (1) treatment with 10% HCl to dissolve carbonates; (2) treatment with hot 5% Na_2HPO_4OH to remove clay minerals during further decantation; (3) separation of the residue by centrifuging in heavy liquid (specific gravity of 2.25, KJ + CdJ solution) to extract palynomorphs; (4) treatment in a mixture of acetic anhydride and sulfuric acid at a ratio of 9 : 1; and (5) the material obtained is collected in test tubes and covered with glycerin for further study and storage.

The material was studied in glycerin-jelly slides. Palynomorphs were counted up to 250 specimens. The percentages of dinocysts, cyanobacteria, and acritarchs were calculated with respect to their sum total, disregarding spores and pollen grains. The proportions of spores and pollen grains were calculated with respect to the sum total of all palynomorphs.

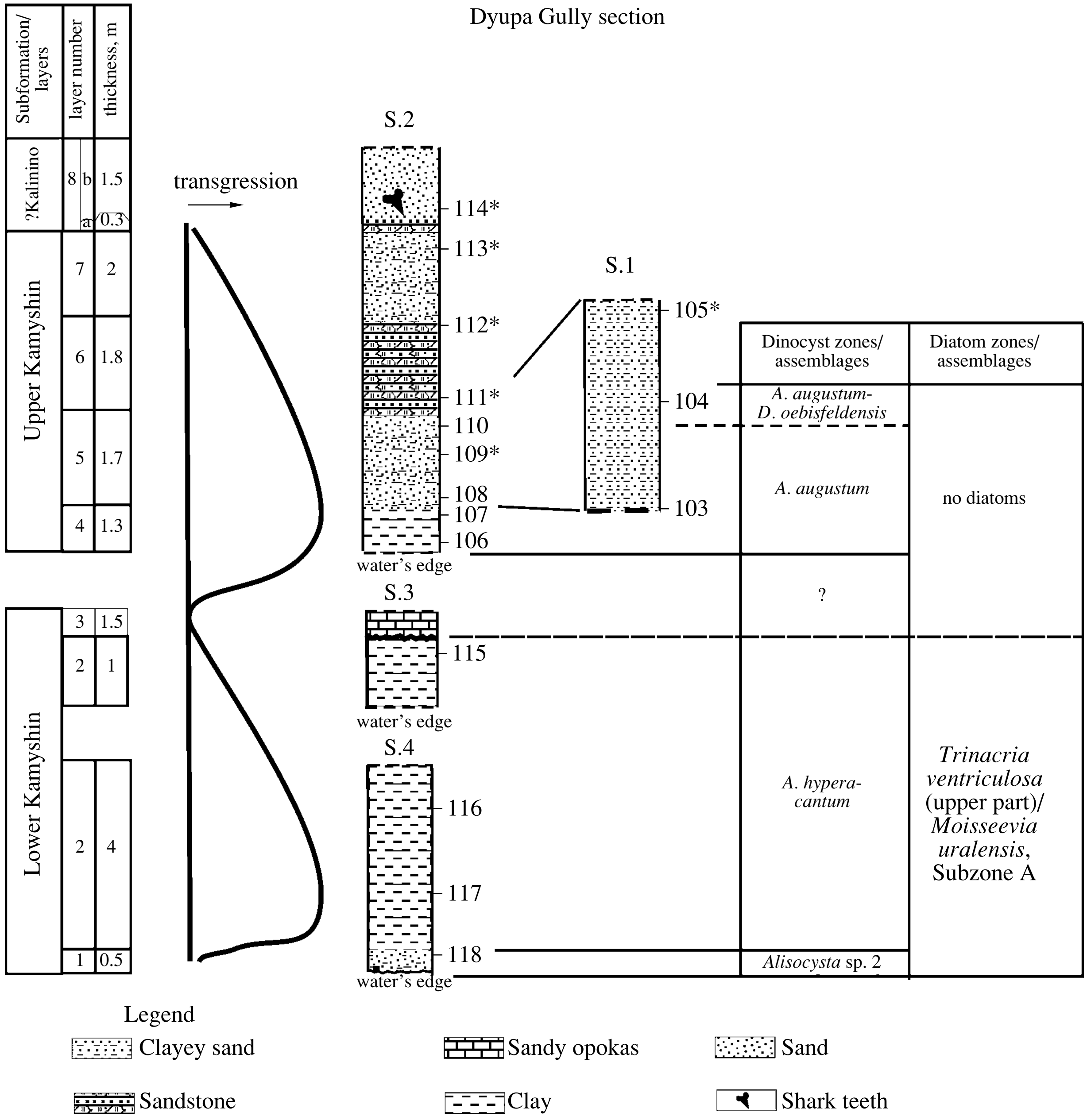


Fig. 2. The lithology, zonal subdivision, and transgressive-regressive cycles of the Kamyshin Formation in the Dyupa Gully section: (s.) stations; asterisked samples do not contain microplankton.

The diatoms were studied according to the standard method (*Diatom* …, 1974).

The material studied is kept at the Laboratories of Paleofloristics and Micropaleontology of Geological Institute, Russian Academy of Sciences (GIN).

RESULTS

Dinocysts

Fifteen samples have been studied. The occurrence and species composition of the dinocysts of the Dyupa Gully section are shown in Fig. 3. The qualitative characteristics of various dinocyst groups are given in Fig. 4. In the section, several dinocyst assemblages were revealed.

An assemblage with *Alisocysta* sp. 2 was revealed from Layer 1 (sample 118). The assemblage shows a low species diversity (15 species). The dominants are *Areoligera* (*A. senonensis, A. coronata*, and *A.* sp.) and *Glaphyrocysta* (*G. ordinata, G. pastielsii*, and *G. divaricata*). *Cordosphaeridium* spp., *Spiniferites* spp., *Achomosphaera* spp., *Cerodinium speciosum*, and *Rottnestia borussica* also occur. Single specimens of *Deflandrea oebisfeldensis* and *Alisocysta* sp. 2 sensu Heilmann-

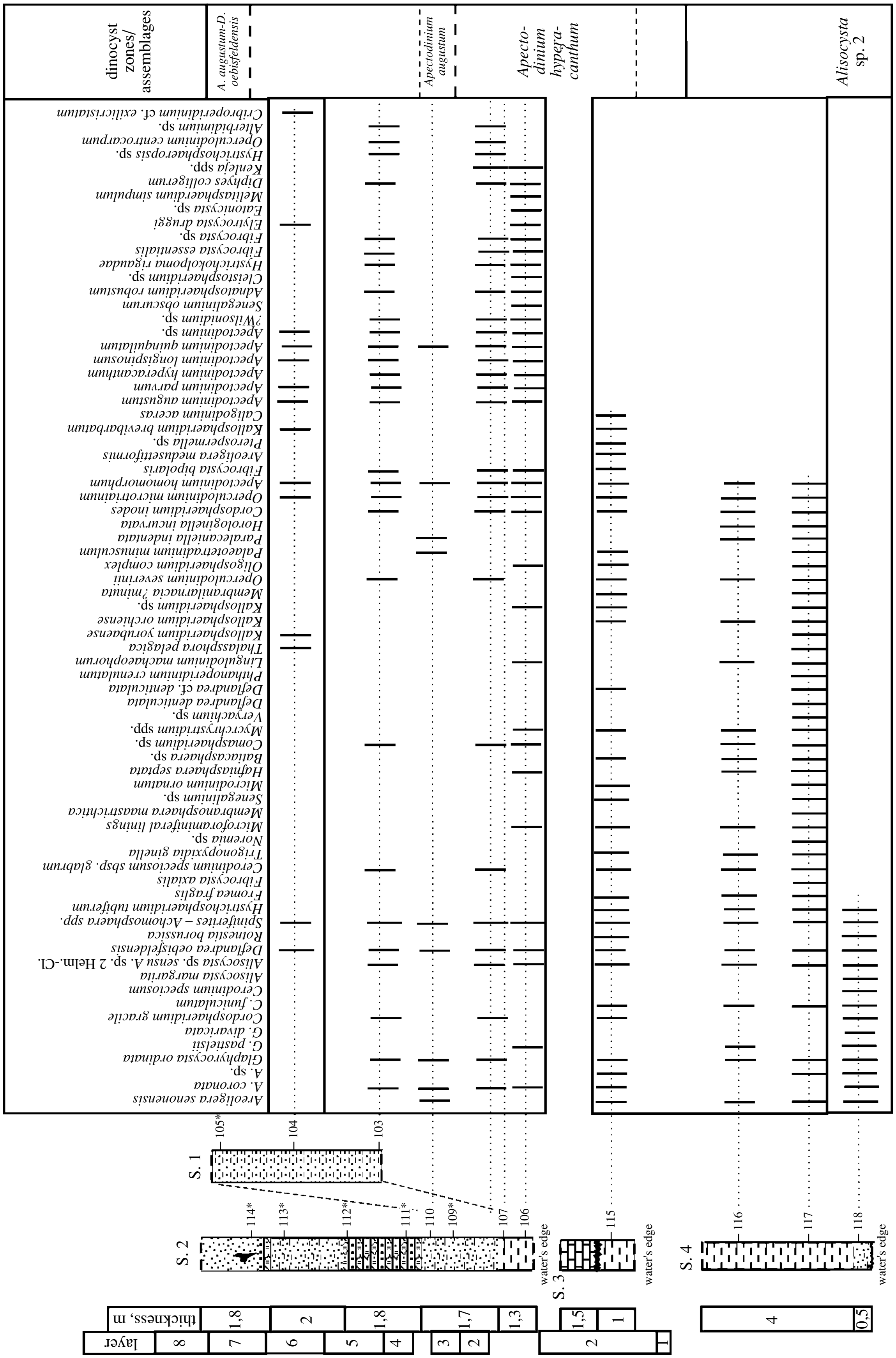


Fig. 3. The occurrence of palynomorphs in the Dyupa Gully section. See the legend in Fig. 2.

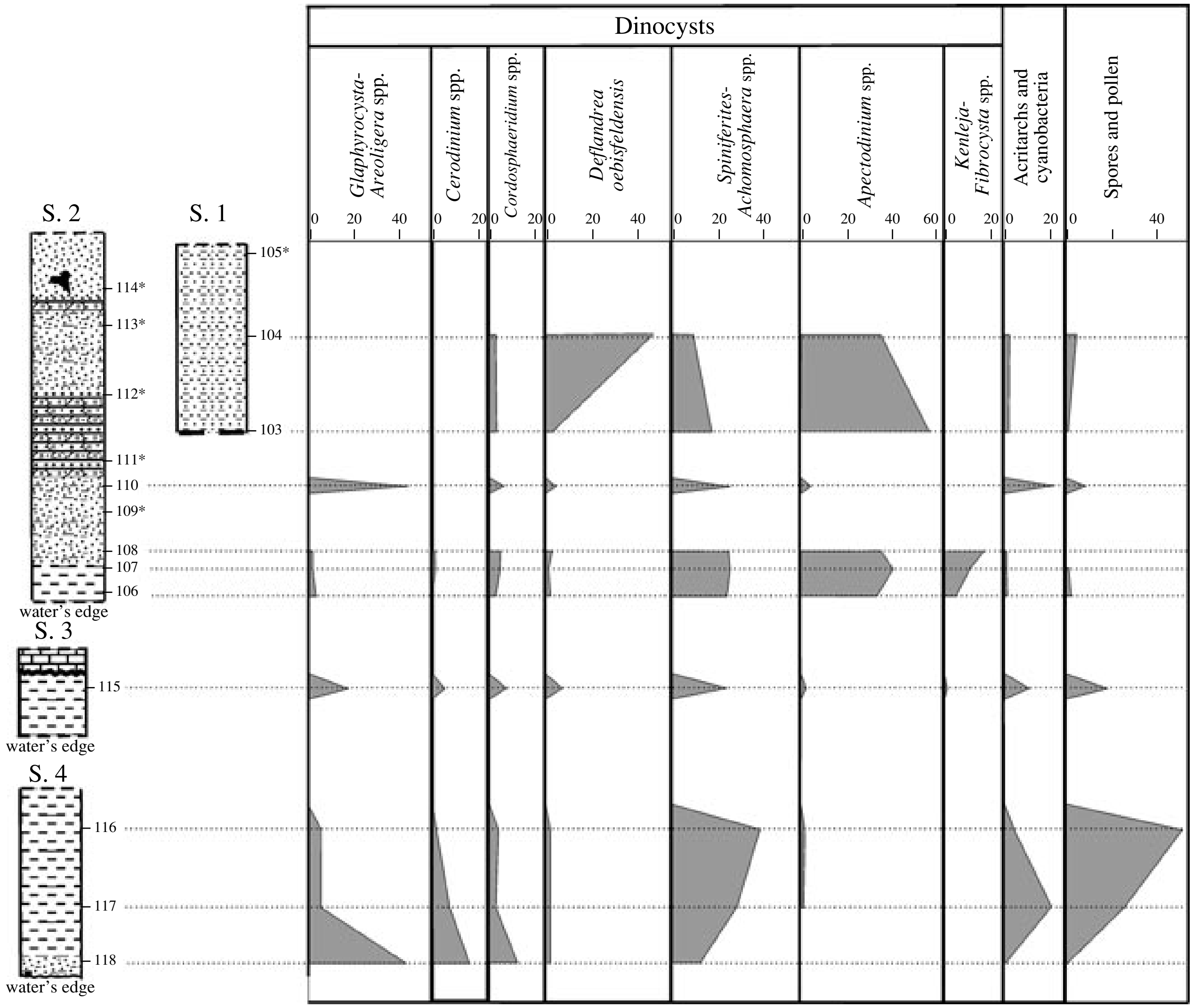


Fig. 4. The occurrence and percentage of main palynological groups in the Dyupa Gully section. See the legend in Fig. 2.

Clausen, 1985 were observed. Spores, pollen grains, acritarchs, and cyanobacteria are present in small amounts. The age of the assemblage is debatable.

Layer 2 (samples 117–115) contains **an assemblage with *Apectodinium hyperacanthum***, which is dominated by *Spiniferites* spp. and *Achomosphaera* spp. Species of *Areoligera* and *Glaphyrocysta* occur in small numbers. Several new species appear: *Apectodinium homomorphum, Operculodinium severinii*, and *Lingulodinium machaeophorum.*

The spores and pollen account for up to 50% of the assemblage total, and acritarchs and cyanobacteria account for up to 20%. Higher plant debris, coal particles, and microforaminiferal linings are abundant, indicating a shallow-water environment. The appearance of *Apectodinium homomorphum* allows a reliable correlation between this part of the Kamyshin Formation and the *Apectodinium hyperacanthum* Zone of western Europe (Powell, 1992).

An assemblage with *Apectodinium augustum* was revealed in Layers 4 and 5 (samples 106–108, 110, 103). Among the dinocysts, species of the genera *Apectodinium* (*A. augustum, A. parvum, A. homomorphum*, and others), *Spiniferites* spp., and *Achomosphaera* spp. prevail (55%). Taxa that can be assigned to *Wilsonidium* sp. are present (2%). Amorphous organic material is abundant. Spores and pollen grains are rare. In samples 106–108 *Kenleja* spp., *Fibrocysta* spp., and *Senegalinium* spp. constitute a significant part of the assemblage.

Sample 110 yielded a slightly different assemblage. The dominants are *Glaphyrocysta ordinata, Spiniferites* spp., *Achomosphaera* spp., and acritarchs (*Paralecaniella indentata*); the latter account for 20% of the assemblage.

These samples contain *Apectodinium augustum*, the index-species of the *Apectodinium augustum* Zone of western Europe (Powell, 1992).

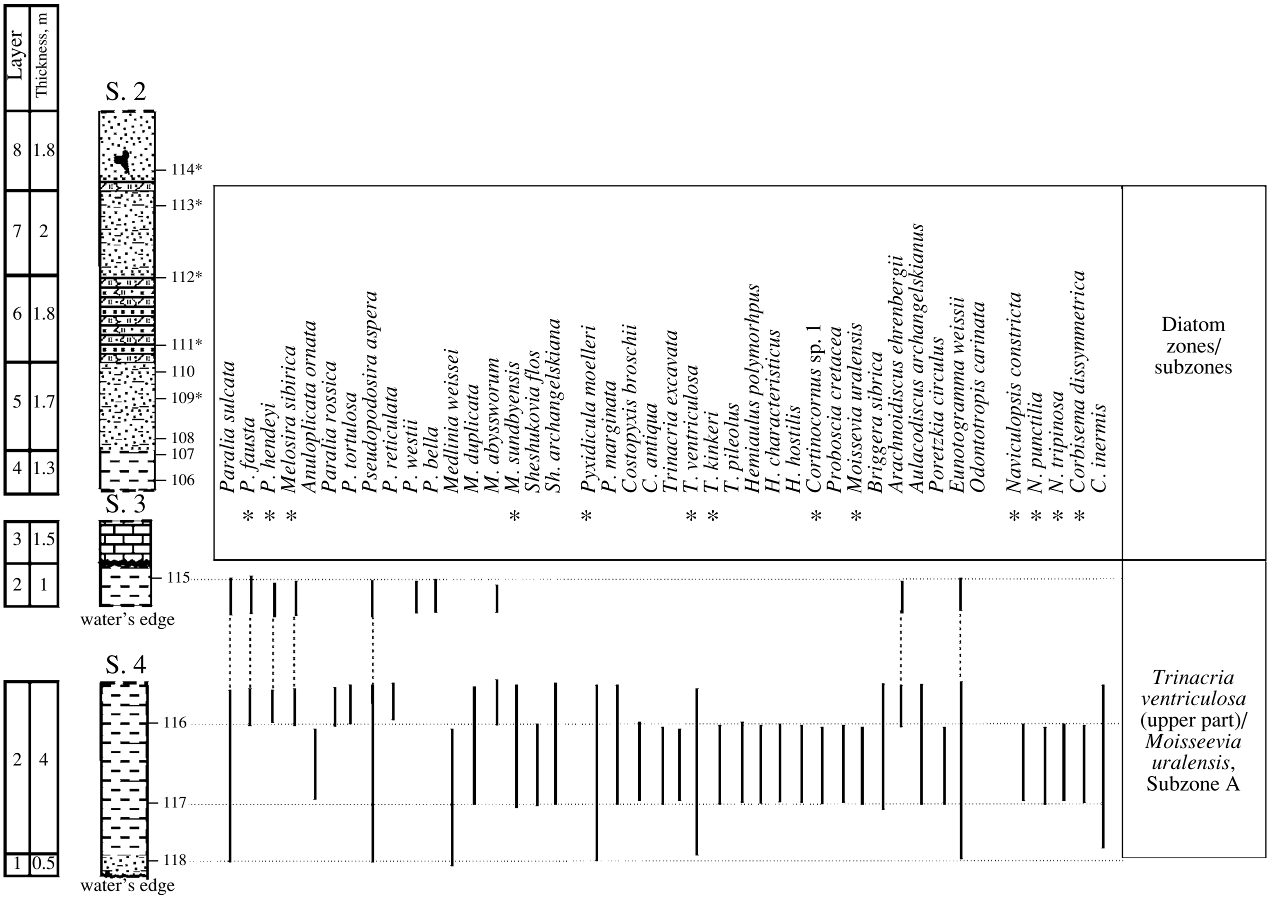


Fig. 5. The occurrence of diatoms in the Dyupa Gully section: (*) species that appear in the Late Paleocene. See the legend in Fig. 2.

An assemblage with *Apectodinium augustum–Deflandrea oebisfeldensis* was established in sample 104 from station 1. There, the dominants are different: *Apectodinium* (35%) is outnumbered by *Deflandrea* oebisfeldensis (50%). Species of *Spiniferites* and *Achomosphaera* are much less abundant than in samples from the underlying layers. Other dinocyst taxa are rare.

Diatoms and Silicoflagellates

Diatoms are only found in the two lower layers of the section and constitute a single assemblage (Fig. 5).

Sponge spicules prevail in Layer 1; the diatom assemblage is poor: species with hard frustules dominate: *Eunotogramma weissii, Stephanogonia danica*, and *Pterotheca kittoniana.* Only the girdles of the valves of *Medlinia weissii* remain. *Paralia selecta* and *P. sulcata* are occasionally present. Of stratigraphically significant species, this layer contains *Pyxidicula moelleri.*

In Layer 2 (sample 117), the number of diatoms increases dramatically. The assemblage includes 40 species, which constitute several ecological groups:

(1) The families Paraleaceae and Pseudopodosiraceae are represented by 12 species. Most of them were earlier assigned to the genus *Melosira*, many members of which are known to exist from the Cretaceous onward. The assemblage under study contains several unequivocally Cretaceous species: *Paralia selecta, P. rossica*, and *Pseudopodosira aspera.* Other members of these genera are known to originate in the Early Paleogene, with the exception of *Paralia hendey* and *P. fausta*, described from Late Paleocene sediments (Sims and Crawford, 2002), and *Paralia tortulosa* from the Eocene of Ukraine (*Diatom* …, 1992). All these taxa are tychopelagic semibenthic diatoms.

(2) Members of the genera *Medlinia* and *Shesheukovia* of the Shesheukoviaceae are the second most abundant in the assemblage. Five out of the six species are known from the Cretaceous, and only *Medlinia sundbyensis* was described from the Late Paleocene (Sims, 1998). This group consists of tychopelagic diatoms.

(3) Open-marine genera are *Pyxidicula, Trinacria, Hemiaulus, Proboscia*, and *Moisseevia.*

(4) The last group is formed by transient species belonging to genera of uncertain systematic and ecological position known from the Cretaceous: *Odontotropis, Poretzkia*, and *Eunotogramma.*

In the upper part of Layer 2 (sample 116), the marine plankton becomes less abundant, and benthic diatoms known from the Cretaceous strata appear: *Arachnoidiscus ehrenbergii, Briggera* sp., and *Aulacodiscus archangelskianus.* Members of the genus *Paralia* once again become dominants in the roof of the Layer (sample 115). Among them *P. hendeyi* and *P. fausta* are significant. *Pseudopodosira westii* is also prominent.

Pyxidicula moelleri, Trinacria ventriculosa, Hemiaulus characteristicus, and *Moisseevia uralensis* are stratigraphically important. The co-occurrence of these four species allows us to correlate the first and second layers with the upper part of the *Trinacria ventriculosa* Zone of the zonation proposed by Strelnikova (1992) or to Subzone A of the *Moisseevia uralensis* Zone (Radionova et al., 2004a; Oreshkina and Radionova, 2005).

Of interest is the presence in these layers of *Cortinocornus* sp. 1, which is close to *Cortinocornus rossicus.* The latter species is known from Cretaceous and Danian sediments (Strelnikova, 1974; Harwood, 1988; etc.). *Cortinocornus* sp. 1 may be considered as the latest member of the genus in the Late Paleocene. Its presence is recorded in the upper part of the *Trinacria ventriculosa* Zone in the Sengelei section and, approximately at the same level, in the upper part of Subzone A of the *Moisseevia uralensis* Zone in the Korkino quarry (Oreshkina and Radionova, 2005).

Silicoflagellates are found in single specimens in these sediments. Only *Corbisema inermis* occurs in all samples. They are more numerous in the middle part of the second layer, which yielded *Naviculopsis constricta, N. punctilia, N. trispinosa*, and *Corbisema disymmetrica*, typical of the Upper Paleocene.

DISCUSSION

(1) Compared to its stratotype near Kamyshin, the Kamyshin Formation in the Dyupa Gully section has a reduced thickness (12 m or more), and it is clearly divisible into two subformations, each beginning with a clay member and terminating in a member of sand or sandstone. Both subformations may be interpreted as transgressive-regressive cycles (of the 5th order, according to Haq et al., 1987), which is readily apparent from the lithological composition of the deposits and from how one ecological group of siliceous organisms is replaced by another.

The exposed base of the lower subformation consists of clayey silt. The siliceous remains are dominated by sponge spicules; diatoms are not numerous; apparently, only the species with the strongest tests, such as *Eunotogramma weissii*, are preserved. In the other, less silicified forms (e.g., *Medlinia weissei*), only girdles of valves and costae are preserved. The particulars of composition of siliceous organisms and their degree of preservation give indirect evidence that the deposits in question are from the base of a transgressive cycle.

In the lower and middle parts of the second layer, the diatom abundance sharply increases; here, we observe nearly the entire diversity of the assemblage, including open marine diatom species, as well as several silicoflagellate genera. This marks the maximum transgression.

In the upper part of the second layer, the diatom composition once again becomes impoverished due to the considerable reduction and eventual disappearance of open marine species and to the increasing proportion of benthos and sponge spicules. The assemblages are very well preserved. All these traits indicate a gradual regression. This transgressive-regressive cycle is crowned with a bed of strong sandstone containing no organic remains. This bed is a likely correlative of the well-known "Kamyshin plate," crowning the deposits of the Kamyshin Horizon in a number of sections of the Ulyanovsk part of the Volga Region.

Deposits of the upper cycle differ considerably in terms of the composition of microorganisms: the leading role in the assemblage belongs to organic-walled organisms, while siliceous organisms are represented by sporadic sponge spicules. Here, the regressive part of the cycle (Layers 6 and 7) contains no marine microplankton; it consists of loose sandy opoka, gradually passing into rubble sandstone, in turn giving way to sand. These deposits may correspond to the "layers with floras" in the stratotype.

Further upsection (Layer 8), there is the next transgressive cycle with washouts that contains an intercalation of loose conglomerate at the base, corresponding, apparently, to the Kalinino layers.

The stratigraphic range of the cycles identified from the Dyupa section is identical to the cycles we established in the Turgay (Torghay) Strait and western Siberia (Radionova et al., 2004b), thus suggesting that in the Late Paleocene there existed a continuous basin of the North Peri-Tethys.

(2) The stratigraphic range of the Kamyshin Formation in the Dyupa Gully section is best determined by dinocysts, because the established assemblages are quite precisely correlative to the North European scales (Heilmann-Clausen, 1985; Powell, 1992; Mudge and Bujak, 1996; Fig. 6).

The lowermost assemblage of *Alisocysta* sp. 2 may correspond to a part of the *Alisocysta margarita* Zone (Powell, 1992), judging from the mass occurrence of *Areoligera* and *Glaphyrocysta* and the lack of the index-species of the underlying *Palaeoperidinium pyrophorum* Zone. According to Powell (1992), the *Alisocysta margarita* Zone in the western European basins is correlative to nannoplankton NP8 Zone of the Late Thanetian (Martini, 1971). However, in the scale for the Danian Basin, Heilmann-Clausen (1985)

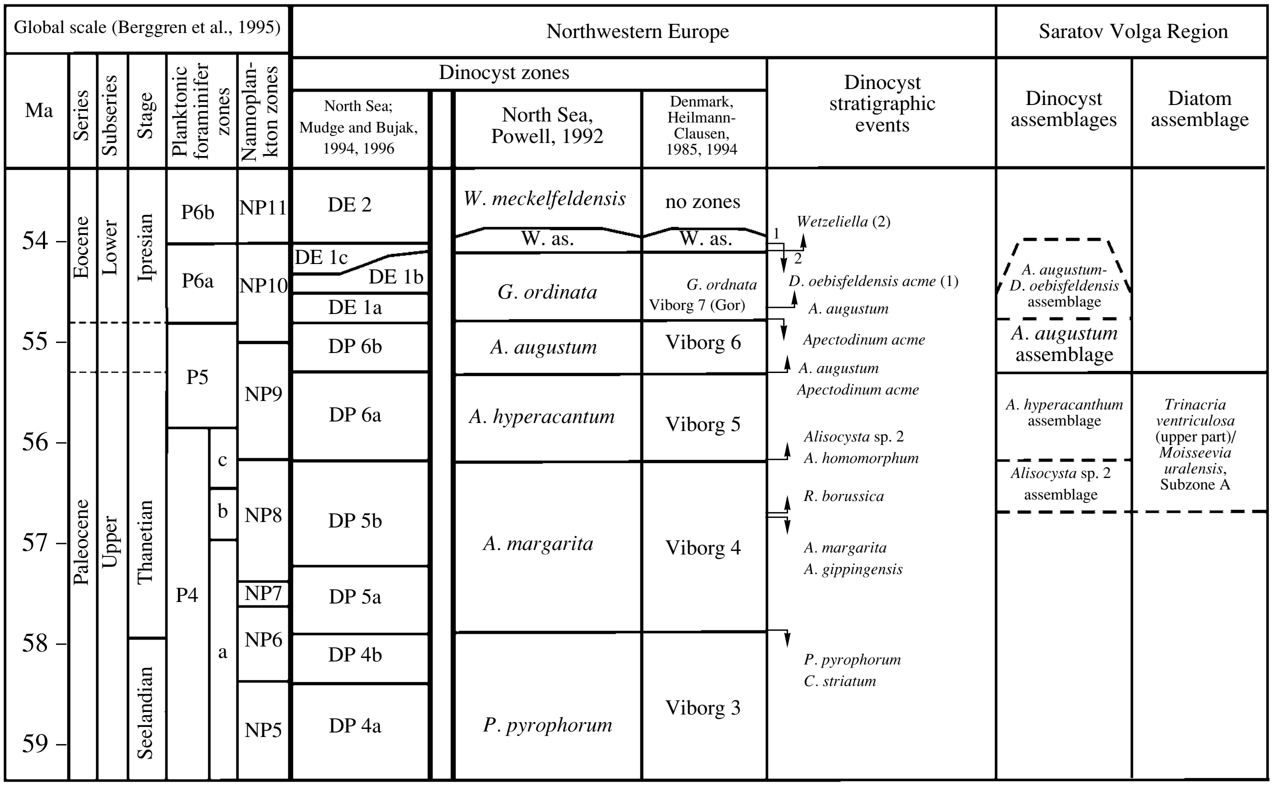


Fig. 6. The correlation between the dinocyst and diatom assemblages of the Saratov Volga Region and the Northwest European dinocyst zonation.

Explanation of Plate 1

Fig. 1. *Glaphyrocysta ordinata* (Williams et Downie) Stover et Evitt; GIN no. 118, Upper Paleocene, Thanetian, *Alisocysta* sp. 2 assemblages.

Fig. 2. *Cerodinium speciosum* subsp. *glabrum* (Gocht) Lentin et Williams; GIN no. 117, Upper Paleocene, Thanetian, *Apectodinium hyperacanthum* Zone.

Fig. 3. *Operculodinium severinii* (Cookson et Cranwell) Islam; GIN no. 116, Upper Paleocene, Thanetian, *Apectodinium hyperacanthum* Zone.

Fig. 4. *Alisocysta* sp. 2 sensu Heilmann-Clausen, 1985; GIN no. 115, Upper Paleocene, Thanetian, *Apectodinium hyperacanthum* Zone.

Fig. 5. *Areoligera senonensis* Lejeune-Carpentier; GIN no. 118, Upper Paleocene, Thanetian, *Alisocysta* sp. 2 Zone sensu Heilmann-Clausen.

Fig. 6. *Rottnestia borussica* (Eisenack) Cookson et Eisenack; GIN no. 115, Upper Paleocene, Thanetian, *Apectodinium hyperacanthum* Zone.

Fig. 7. *Fibrocysta* sp.; GIN no. 103, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 8. *Apectodinium homomorphum* (Deflandre et Cookson) Lentin et Williams; GIN no. 115, Upper Paleocene, Thanetian, *Apectodinium hyperacanthum* Zone.

Fig. 9. *Apectodinium augustum* (Harland) Lentin et Williams; GIN no. 103, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 10. *Achomosphaera ramulifera* (Deflandre) Evitt; GIN no. 106, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 11. *Apectodinium quinquilatum* (Williams et Downie) Costa et Downie; GIN no. 108, base of Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 12. *Wilsonidium* sp.; GIN no. 108, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 13. *Apectodinium* sp.; GIN no. 108, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 14. *Senegalinium obscurum* (Drugg) Stover et Evitt; GIN no. 106, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 15. *Diphyes colligerum* (Deflandre et Cookson) Cookson; GIN no. 106, base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Fig. 16. *Wilsonidium* sp.; GIN no. 106, the base of the Eocene, Ypresian (?), *Apectodinium augustum* Zone.

Scale bar 50 µm.

Plate 1

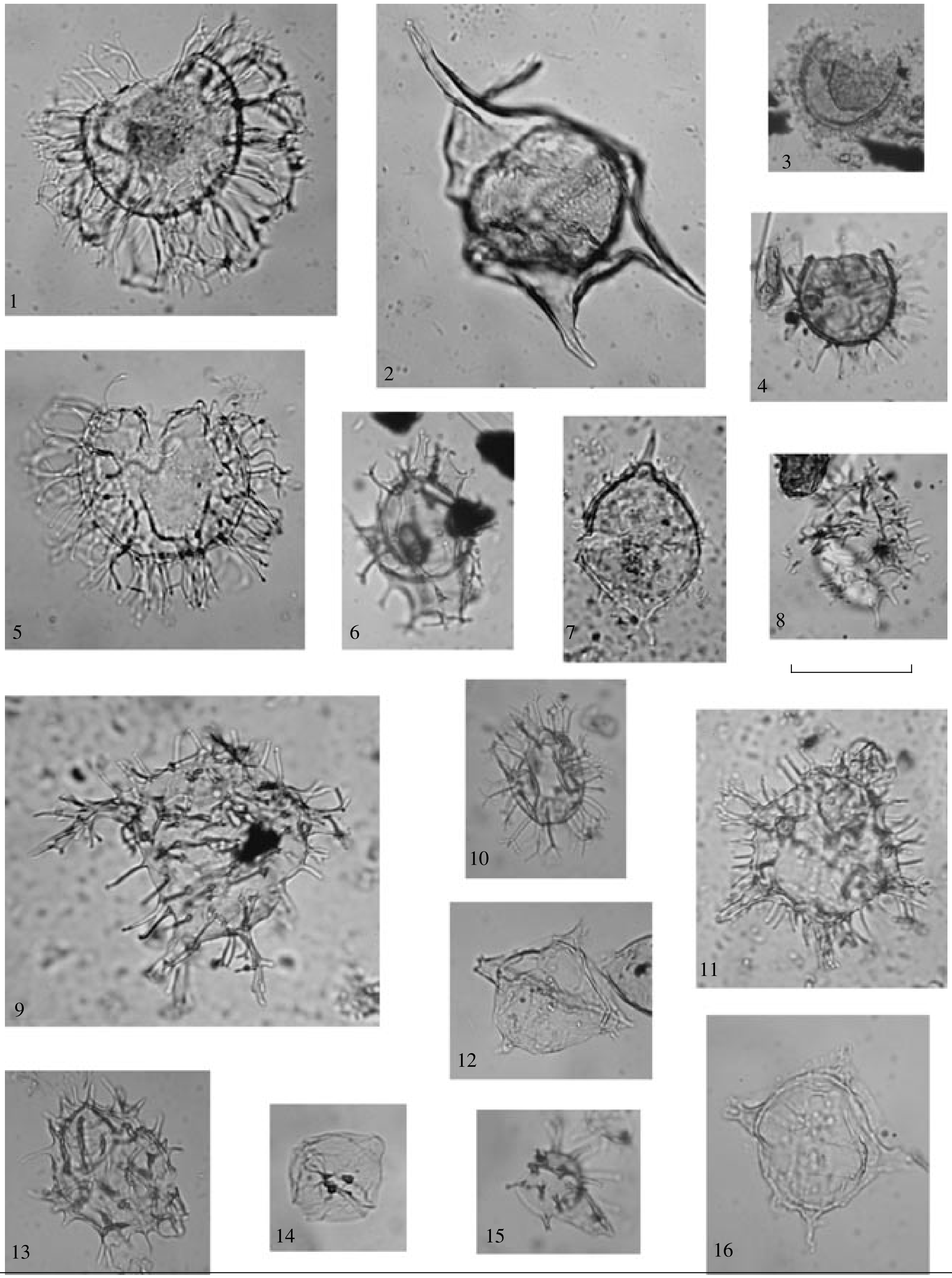
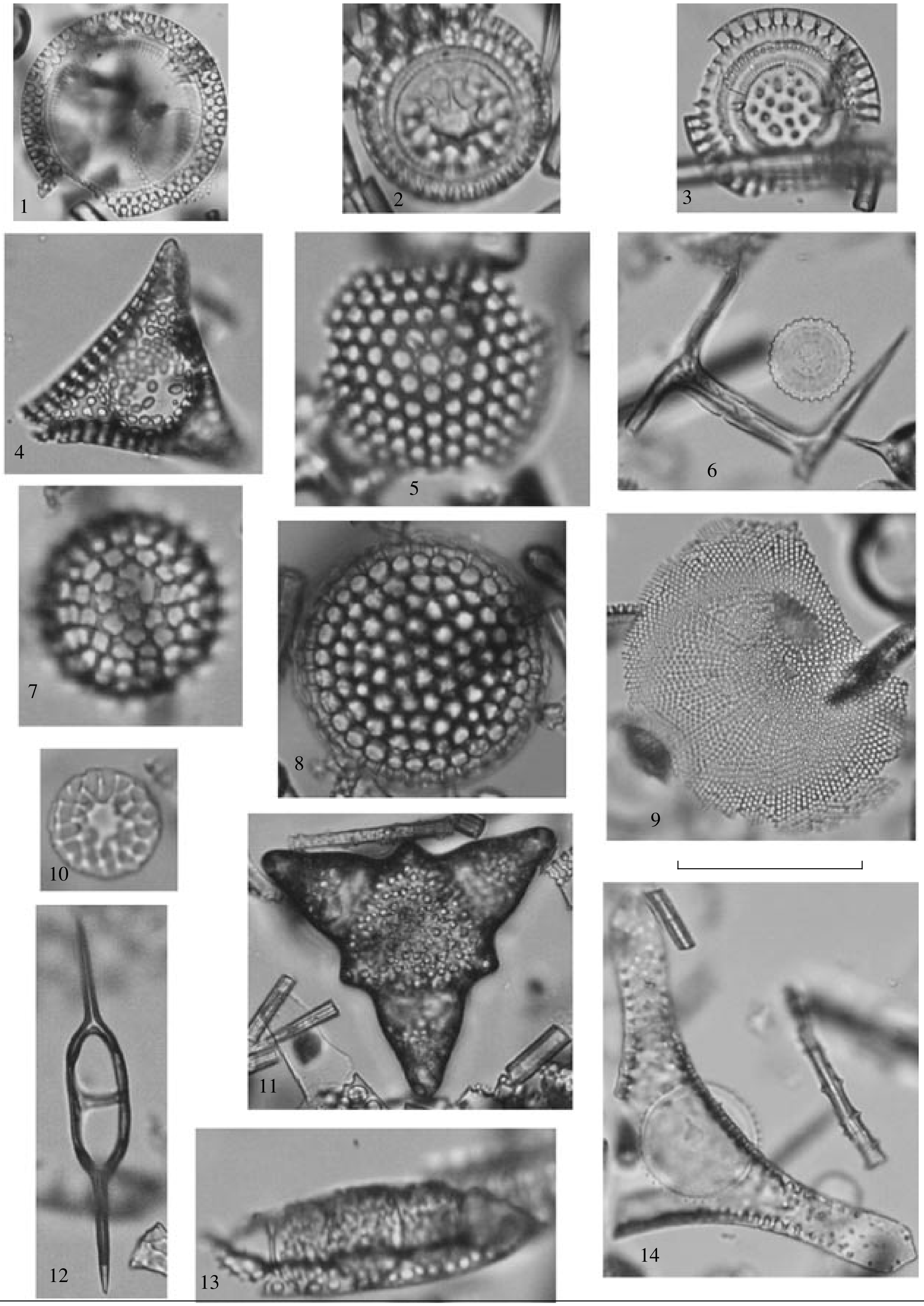


Plate 2



pointed to the co-occurrence of *Alisocysta* sp. 2 sensu Heilmann-Clausen, 1985 and *Deflandrea oebisfeldensis* within "Zone 5," which corresponds to a higher stratigraphic level than the *Alisocysta margarita* Zone (Fig. 6). On the other hand, Iakovleva and Kulkova (2003) recorded the first appearance of both these species within the *Alisocysta margarita* Zone. In addition, this assemblage may be correlated to Subzone P6a (Mudge and Bujak, 1996), which, in North Sea sections, lacks *Apectodinium augustum, Alisocysta margarita*, and *Areoligera gippingensis* and consists of an assemblage of transient taxa. According to data by Powell and Brinkhuis (Luterbacher et al., 2004, text-fig. 20.3), the appearance of *Rottnestia borussica* is indicated at the middle of the NP8 nannoplankton Zone, suggesting that the assemblage established from sample 118 may belong to the upper part of the *Alisocysta margarita* Zone.

Therefore, although the age of the assemblage remains open to discussion, it has a narrow interval of occurrence: its stratigraphic range may be indirectly constrained from the top of Zone NP8 to the bottom of NP9(?) based on nannoplankton.

The greater part of the Lower Kamyshin Subformation containing the dinocyst assemblage with *Apectodinium hyperacanthum* is correlative to the level of the *Apectodinium hyperacanthum* Zone of western Europe (Powell, 1992), to "Zone 5" of the Danian Basin, or Zone P6a of the North Sea Basin (Mudge and Bujak, 1996). According to Powell (1992), the *A. hyperacanthum* Zone corresponds to NP9a nannoplankton Zone of the terminal Thanetian (Martini, 1971).

Massive development of species of the genus *Apectodinium* is registered in the lower part of the Upper Kamyshin subformation, including *A. augustum*, the index-species of the homonymous zone of western Europe (Powell, 1992). Figure 5 shows that this zone corresponds to "Zone 6" of the Danian Basin and Zone P6b of the North Sea Basin and is correlative to NP9b–NP10 (lower part) nannoplankton zones. The appearance of *Apectodinium augustum* and mass development of species of this genus are confined to the Paleocene/Eocene boundary (Luterbacher et al., 2004) and to the IETM global event (Initial Eocene Thermal Maximum; Crouch et al., 2003).

An intriguing feature of the dinocyst assemblage with *Apectodinium augustum* is that it contains some taxa (such as *Wilsonidium* sp.) that are close in terms of evolution to the Eocene genera of the family Wetzelielloidaceae. Their presence was first established in the Late Paleocene–Early Eocene deposits of western Kazakhstan in the Torangly section (Akhmetiev and Zaporozhets, 1996). Further studies in the sections of the northeastern Peri-Tethys revealed their presence in the Late Paleocene–Early Eocene deposits (including the IETM interval) of the Turgay Strait (Iakovleva et al., 2001) and in Uzbekistan (Crouch et al., 2003). Therefore, we may conclude that these taxa were widespread in the northeastern Peri-Tethys basin throughout the Late Paleocene–initial Eocene.

The stratigraphic position of the *Apectodinium augustum-Deflandrea oebisfeldensis* assemblage can be interpreted in two ways. On the one hand, the fact that it includes *Apectodinium augustum* may suggest that it belongs to the homonymous zone. On the other hand, the considerable abundance of *Deflandrea oebisfeldensis* in the dinocyst association makes it attributable to "Zone 7" (Heilmann-Clausen, 1985) or to Subzone E1b (Bujak and Madge, 1994), which display massive occurrence of *Deflandrea oebisfeldensis.* In the North Sea Basin, these zones are correlated with the middle part of NP10 nannoplankton Zone. It is likely that in the Dyupa section we observe a transitional interval between the *Apectodinium augustum* and *Deflandrea oebisfeldensis* zones.

(3) The stratigraphic subdivision of the Dyupa section based on siliceous plankton, as mentioned above, has already been performed. From the base of the Lower Kamyshin Subformation, Kozlova (1999) established an assemblage of the radiolarian *Tripodiscinus sengilensis* Zone, and further upsection, an assemblage of the lower part of the *Petalospiris foveolata* Zone.

Explanation of Plate 2

Fig. 1. *Paralia fausta* (A. Schmidt) Sims et Crawford.

Figs. 2 and 3. *Paralia hendeyi* Sims et Crawford.

Fig. 4. *Trinacria ventriculosa* A. Schmidt.

Fig. 5. *Pyxidicula moelleri* (A. Schmidt) Strelnikova et Nikolaev.

Fig. 6. *Hemiaulus characteristicus* Hajos.

Fig. 7. *Costopyxis broschii* (Grunow) Strelnikova et Nikolaev.

Fig. 8. *Pseudopodosira reticulata* Strelnikova.

Fig. 9. *Moisseevia uralensis* (Jouse) Strelnikova.

Fig. 10. *Pseudopodosira aspera* (Jouse) Strelnikova.

Fig. 11. *Sheshukovia archangelskiana* (Witt) Gleser.

Fig. 12. *Naviculopsis constricta* (Schulz) Frenguelli.

Fig. 13. *Cortinocornis* sp. 1.

Fig. 14. *Trinacria kinkeri* A. Schmidt.

All the specimens come from sample GIN no. 117, Upper Paleocene, Thanetian, *Trinacria ventriculosa* Zone (upper part) or *Moisseevia uralensis*, Subzone A. Scale bar 50 µm.

Diatoms from the same interval were determined by Strelnikova (pers. comm.) as an assemblage of the *Trinacria ventriculosa* Zone, the diatom composition, in her opinion, being poor. The close spacing of samples in our own study enables us to collect sufficiently representative diatom material. As mentioned above, all samples of the Lower Kamyshin Subformation yielded the same diatom assemblage, which can be interpreted as nearshore with a considerable predominance of transient species (including Cretaceous taxa). It is only in the middle part of the sequence that the composition of the association becomes richer due to the appearance of open-marine species to comprise more than 40 species. In the upper part of the Lower Kamyshin Subformation, the diatom species diversity once again drops to ten species, and new, Paleocene species of stratigraphically significant genera such as *Paralia* and *Medlinia* become common. Therefore, considerable innovations that took place at the end of the Paleocene in the diatom assemblage involve the conservative littoral taxa as well (Oreshkina and Oberhansi, 2003; Radionova et al., 2004b).

The Lower Kamyshin Subformation in the Dyupa Gully section belongs to the upper part of the *Trinacria ventriculosa* Zone, which is identified, among other things, by the appearance of *Pyxidicula moelleri* (Oreshkina and Radionova, 2005), or to Subzone A of the *Moisseevia uralensis* Zone, which is in turn defined by the appearance of the zonal species (Radionova et al., 2004a). In the Dyupa section, the same samples yielded dinocyst assemblages with *Alisocysta* sp. 2 and *Apectodinium hyperacanthum*, which correspond to the top of the nannoplankton Zone NP8(?) and nannoplankton Subzone NP9a, i.e., to the late Thanetian (Fig. 5). Therefore, the stratigraphic range of the diatom zone, formerly considered to be coincident with the early Thanetian (Akhmetiev and Beniamovskii, 2003; and others), is hereby further refined.

CONCLUSIONS

Our micropaleontological studies enable us to refine the stratigraphic range of the Kamyshin Formation in its type locality to the terminal Paleocene through basal Eocene. The dinocyst associations identified in this section strongly resemble the dinocyst assemblages of western Europe, on the one hand, and the Turgay Valley and Middle Asia, on the other.

For the first time in the Volga Region, we have established a dinocyst assemblage containing *Apectodinium augustum* and corresponding to the *Apectodinium* acme interval. The appearance of *Apectodinium augustum* and massive development of species of this genus mark the Paleocene/Eocene boundary (Luterbacher et al., 2004) and the IETM global event (Crouch et al., 2003).

The Dyupa Gully section, which comprises deposits of two complete cycles of the Late Paleocene– initial Eocene, and is well-characterized micropaleontologically based on dinocysts, radiolarians, and diatoms, is pivotal to the correlation of the deposits of the Middle and Lower Volga Region, as well as coeval sections in Transuralia.

THE LIST OF MICROPLANKTON TAXA OF THE KAMYSHIN FORMATION

Dinocysts, acritarchs, and cyanobacteria. The nomenclature is after "Lentin and Williams Index of Fossil Dinoflagellates" (Williams et al., 1998).

Achomosphaera alcicornu (Eisenack) Davey et Williams, 1966

Achomosphaera crassipellis (Deflandre and Cookson) Stover et Evitt, 1978

Achomosphaera ramulifera (Deflandre) Evitt, 1963

Achomosphaera sagena Davey et Williams, 1966

Adnatosphaeridium robustum (Morgenroth) De Coninck, 1975

Alisocysta margarita Harland, 1979

Alisocysta sp. sensu *Alisocysta* sp. 2 in Heilmann-Clausen, 1985

Alterbidinium sp.

Apectodinium augustum (Harland) Lentin et Williams, 1981

Apectodinium homomorphum (Deflandre et Cookson) Lentin et Williams, 1977

Apectodinium hyperacanthum (Cookson et Eisenack) Lentin et Williams, 1977

Apectodinium longispinosum (Wilson) Bujak et Davies, 1983

Apectodinium parvum (Alberti) Lentin et Williams, 1977

Apectodinium quinquelatum (Williams et Downie) Costa et Downie, 1979

Apectodinium sp.

Areoligera coronata (O. Wetzel) Lejeune-Carpentier, 1938

Areoligera gippingensis Jolley, 1992

Areoligera medusettiformis O. Wetzel, 1933

Areoligera senonensis Lejeune-Carpentier, 1938

Areoligera sp.

Batiacasphaera sp.

Caligodinium aceras (Manum et Cookson) Lentin et Williams, 1973

Cerodinium speciosum (Alberti) Lentin et Williams, 1987

Cerodinium speciosum subsp. *glabrum* (Gocht) Lentin et Williams, 1987

Cerodinium striatum (Drugg) Lentin et Williams 1987

Cleistosphaeridium sp.

Comasphaeridium sp.

Cordosphaeridium gracile (Eisenack) Davey et Williams), 1966b

Cordosphaeridium funiculatum Morgenroth, 1966

Cordosphaeridium inodes (Klumpp) Eisenack, 1963

Cribroperidinium cf. exilicristatum (Davey) Stover et Evitt, 1978

Deflandrea denticulata Alberti, 1959

Deflandrea oebisfeldensis Alberti, 1959

Diphyes colligerum (Deflandre et Cookson) Cookson, 1965

Eatonicysta sp.

Elytrocysta druggii Stover et Evitt, 1978

Fibrocysta axialis (Eisenack) Stover et Evitt, 1978

Fibrocysta bipolaris (Cookson et Eisenack) Stover et Evitt, 1978

Fibrocysta essentialis (de Coninck) Brinkhuis et Zachariasse, 1988

Fibrocysta sp.

Fromea fragilis (Cookson et Eisenack) Stover et Evitt, 1978

Glaphyrocysta ordinata (Williams et Downie) Stover et Evitt, 1978

Glaphyrocysta divaricata (Williams et Downie) Stover et Evitt, 1978

Glaphyrocysta pastielsii (Deflandre et Cookson) Stover et Evitt, 1978

Hafniasphaera septata (Cookson et Eisenack) Hansen, 1977

Horologinella incurvata Cookson et Eisenack, 1962

Hystrichokolpoma rigaudae Deflandre et Cookson, 1955

Hystrichosphaeridium tubiferum (Ehrenberg) Deflandre, 1937

Hystrichosphaeropsis sp.

Kallosphaeridium brevibarbatum de Coninck, 1969

Kallosphaeridium orchiense de Coninck, 1975

Kallosphaeridium yorubaense Jan du Chene et Adediran, 1985

Kallosphaeridium sp.

Kenleja spp.

Lingulodinium machaeophorum (Deflandre et Cookson) Wall, 1967

Melitasphaeridium ?simpulum Islam, 1983

Membranilarnacia ?minuta de Coninck, 1969

Membranosphaera maastrichtica Samoilovich, 1961

Microdinium ornatum Cookson and Eisenack, 1960

Mycrhystridium spp.

Noremia sp.

Oligosphaeridium complex (White) Davey et Williams, 1966

Operculodinium centrocarpum (Deflandre et Cookson) Wall, 1967

Operculodinium microtriainum (Klumpp) Islam, 1983

Operculodinium severinii (Cookson et Cranwell) Islam, 1983

Palaeoperidinium pyrophorum (Ehrenberg ex O. Wetzel) Sarjeant, 1967

Palaeotetradinium minusculum (Alberti) Stover et Evitt, 1978

Paralecaniella indentata (Deflandre et Cookson) Cookson et Eisenack, 1970

Phthanoperidinium crenulatum (de Coninck) Lentin et Williams, 1977

Pterospermella sp.

Rottnestia borussica (Eisenack) Cookson et Eisenack, 1961

Senegalinium obscurum (Drugg) Stover et Evitt, 1978

Senegalinium sp.

Spiniferites membranaceus (Rossignol) Sarjeant, 1970

Spiniferites porosus (Manum et Cookson) Harland, 1973

Spiniferites pseudofurcatus (Klumpp) Sarjeant, 1981

Spiniferites ramosus (Ehrenberg) Loeblich et Loeblich, 1966

Spiniferites ramosus subsp. *granosus* (Davey et Williams) Lentin et Williams, 1973

Spiniferites scabrosus (Clark et Verdier) Lentin et Williams, 1975

Thalassiphora pelagica (Eisenack) Eisenack et Gocht, 1960

Trigonopyxidia ginella (Cookson et Eisenack) Downie et Sarjeant, 1965

Veryachium spp.

Wilsonidium sp.

Diatoms

Anuloplicata ornata (Grunow) Gleser, 1992

Arachnoidiscus ehrenbergii Bailey, 1849

Aulacodiscus archangelskianus Witt, 1886

Briggera sibirica (Grunow) R. Ross et P.A. Sims, 1985

Cortinocornus sp. 1

Costopyxis antiqua (Jouse) Gleser, 1988

Costopyxis broschii (Grunow) Strelnikova et Nikolaev, 1988

Eunotogramma weissii Ehrenberg, 1854

Hemiaulus characteristicus Hajos, 1976

Hemiaulus hostilis Heiberg, 1863

Hemiaulus polymorhpus Grunow, 1884

Medlinia abyssorum (Grunow) P.A. Sims, 1998

Medlinia sundbyensis (Simonsen) P.A. Sims, 1998

Medlinia weissei (Grunow) P.A. Sims, 1998

Medlinia duplicata (A. Schmidt) P.A. Sims, 1998

Melosira sibirica A. Schmidt, 1892

Moisseevia uralensis (Jouse) Strelnikova, 1998

Odontotropis carinata Grunow, 1884

Paralia fausta (A. Schmidt) Sims et Crawford, 2002

Paralia hendeyi Sims et Crawford, 2002

Paralia rossica (Pantochek) Gleser, 1992

Paralia selecta (A. Schmidt) Gleser, 1992

Paralia sulcata (Grunow) Gleser, 1992

Paralia tortulosa Gleser, 1992

Poretzkia circulus Jouse, 1949

Proboscia cretacea (Hajos et Stradner) Jordan et Priddle, 1991

Pseudopodosira aspera (Jouse) Strelnikova, 1974

Pseudopodosira bella Possnova et Gleser, 1964

Pseudopodosira westii (W. Smith) Sheshukova et Gleser, 1964

Pseudopodosira reticulata Strelnikova, 1974

Pterotheca kittoniana Grunow, 1883

Pyxidicula marginata (Grunow) Strelnikova et Nikolaev, 1988

Pyxidicula moelleri (A. Schmidt) Strelnikova et Nikolaev, 1988

Sheshukovia archangelskiana (Witt) Gleser, 1984

Sheshukovia flos (Ehrenberg) Gleser, 1984

Stephanogonia danica Fenner, 1991

Trinacria excavata Heiberg, 1863

Trinacria kinkeri A. Schmidt, 1884–1937

Trinacria pileolus (Ehrenberg ?) Grunow, 1884

Trinacria ventriculosa A. Schmidt, 1884–1937

Silicoflagellates

Corbisema disymmetrica (Dumitrica) Bukry, 1976

Corbisema inermis (Lemmermann) Bukry, 1976

Naviculopsis constricta (Schulz) Frenguelli, 1940

Naviculopsis punctilia Perch-Nielsen, 1976

Naviculopsis trispinosa (Schulz) Gleser, 1966

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