

The Mezino-Lapshinovka Reference Section of the Upper Cretaceous and Problems of Santonian–Campanian Boundary in Saratov Area near the Volga River

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Abstract—Results of multidisciplinary study in the Upper Cretaceous reference section and characteristics of the Mezino-Lapshinovka Formation stratotype are presented. The late Santonian age of the formation is substantiated based on the analyzed organic remains. The formation is considered to be a stratigraphic equivalent of the *Pteria* Beds, the age of which was animatedly discussed during over a century. The age of the Mozhzhevelovyi Ovrage Formation that underlies the Mezino-Lapshinovka Formation and yields foraminifers, radiolarians, and calcareous nannoplankton is also discussed. The ammonite assemblage of the lower upper Campanian first discovered in the basal part of the Ardym Formation of the Volga region is characterized.

Key words: Coniacian, Santonian, and Campanian stages, Mozhzhevelovyi Ovrage, Mezino-Lapshinovka, Rybushka, and Ardym formations, ammonite, belemnites, bivalves, foraminifers, radiolarians, calcareous nannoplankton, zonal subdivision.

Contributing to elaboration of the Upper Cretaceous stratigraphic scale for the East European platform, geologists from the Research Institute of Geology and geological faculty of the Saratov State University took active part in defining local stratigraphic units (formations) in lower and middle courses of the Volga River, where they were out of practical use until recently. Views of Saratov geologists on stratigraphic ranges, lithology, and nomenclature of defined formations are expounded in publications of the last decade (Ivanov, 1995; Popov and Ivanov, 1996, 1997; Ivanov and Popov, 1998; Ivanov and Pervushov, 1998; Pervushov *et al.*, 1998a, 1998b, 1998c). The last version of stratigraphic scheme elaborated for the Saratov region is included, as a main constituting part, into the Upper Cretaceous stratigraphic scheme of the East European platform, which was accepted at the Interdepartmental regional stratigraphic meeting and then approved by the Interdepartmental Stratigraphic Committee of Russia in February of 2001. The scheme includes 13 stratigraphic units: Melovatka, Bannovka, Vol'sk, Mozhzhevelovyi Ovrage, Mezino-Lapshinovka, synchronous Rybushka and Pudovkino, Ardym, synchronous Tereshka and Nalitovka, Lokh, Nikolaevka, and

Karamysh formations. All these units, except for the Tereshka Formation previously described by V.V. Butsura as Tereshka Beds and for the Nalitovka Formation first defined by G.A. Zhukova, were originally defined by E.M. Pervushov, A.V. Ivanov, and E.V. Popov. They are briefly characterized in "The abridged atlas of Late Cretaceous bivalves from the southeastern East European platform" (Yakushin and Ivanov, 2001), although the descriptions presented are very simplified and do not satisfy requirements of the Stratigraphic Code (1992, p. 39).

This work is dedicated to the multidisciplinary characterization of the Mezino-Lapshinovka Formation stratotype described by Ivanov, Olfer'ev, Pervushov, Sel'tser, and Kharitonov. Organic remains collected during field works were studied by Sel'tser (ammonoids), Ivanov, Pervushov, Kharitonov (bivalves), Beniamovskii (foraminifers), Vishnevskaya (radiolarians), and Shcherbinina (nannofossils). Alekseev who examined terrigenous fraction and composition of bioclasts in samples collected for micropaleontological studies was a coordinator of the work.

The study of the Mezino-Lapshinovka Formation stratotype and layers above and below it enabled a new interpretation of the debatable Santonian/Campanian boundary in the Volga River region and of the *Pteria* Beds age. The *Pteria* Beds correspond to sediments with abundant shells of bivalves *Oxytoma* (*Hypoxytoma*) *tenuicostata* (Roemer, 1841) first attributed to the genus *Avicula*. Subsequently, this species was referred to the subgenus *Pteria* (*Oxytoma*) (Woods, 1905) that was included afterward into the genus *Oxytoma* Meek, 1964 (Glazunova, 1960).

SECTION DESCRIPTION

The Upper Cretaceous section near the village of Mezino-Lapshinovka is examined in the wall of abandoned quarry in the eastern outskirts of the village. The site is in the Tatishchev district of the Saratov region approximately 40 km north-northwest of the regional center (Fig. 1). The following beds are exposed in the quarry wall from its base to the upper edge (Figs. 2, 3).

The Mozhzhevelovyi Ovrage Formation

(1) Interval 13.6–13.9 m. Marl, gray to yellowish gray, micaceous, glauconitic. Glauconite occurring as fine sand-sized grains is regularly scattered in the rock as a rule, although it is locally concentrated in separate lenses and powdery accumulations. The uppermost part encloses distinct inclined and subvertical fucoids 1.0 to 1.5 cm in diameter filled in with silty material enriched in glauconite. The apparent thickness is 0.3 m.

(2) Interval 12.4–13.6 m. Fine-grained quartz–glauconite sand, light and greenish gray near the top to dark gray and bright green at the base of the layer, with the glauconite content increasing downward. The sand is calcareous, silty near the top, bioturbated; fucoids are commonly colored yellow or red because of filling jarosite and Fe hydroxides. The middle and lower parts of the layer contain subautochthonous remains of fossil sponges *Sororistrips* sp. and *Plocoscyphia* sp. with associated silicification of surrounding sediments, as well as rare belemnite rostra and phosphorite nodules. The transition to overlying sediments is gradual. The thickness is 1.2 m.

(3) Interval 10.7–12.4 m. Siliceous marl, light gray, intensely silicified in the lower and upper parts, grading into dark gray, laterally sustained opoka. In the middle part, marl is sandy, fine-grained, bearing quartz, glauconite, and rounded lens-like inclusions of jarosite and Fe hydroxides. Psammitic material is concentrated in lenses determining bedding patterns of the rock. Large thin-walled shells of *Oxytoma tenuicostata* (Roem.) and *Liostrea wegmaniana* (d'Orb.) are scattered throughout the unit. The bed lower part yields rare small rostra of belemnite *Actinocamax* sp. and exhibits crustacean burrows with fish scale at the bottom and fucoids. The transition to overlying sediments is gradual. The thickness is 1.7 m.

(4) Interval 10.5–10.7 m. Calcareous clay, gray to light gray, siliceous, flaggy, containing shells of *Oxytoma tenuicostata* (Roem.) and *Liostrea wegmaniana* (d'Orb.). The transition to overlying sediments is gradual. The thickness is 0.2 m.

(5) Interval 10.0–10.5 m. Opoka, light gray with brown spots, ferruginous, bioturbated, enclosing shells of oysters *Liostrea wegmaniana* (d'Orb.) and *Gryphaeostrea lateralis* (Nilss.). The transition to overlying sediments is gradual. The thickness is 0.5 m.

(6) Interval 9.3–10.0 m. Clay, gray, with a greenish tint and rusty brown spots at the top, calcareous, irregularly silicified; the silicification degree increases upward. Sediments yield shells of *Oxytoma tenuicostata* (Roem.), *Liostrea wegmaniana* (d'Orb.), and *Acutostrea acutirostris* (Nills.). The thickness is 0.7 m.

The Mezino-Lapshinovka Formation

(7) Interval 8.8–9.3 m. Fine-grained glauconite sand, light gray with greenish tint and rusty brown ferruginous spots, calcareous, containing rare phosphorite nodules up to 5 cm across, rostra of belemnites *Belemnitella praecursor* Stoll., *Actinocamax verus fragilis* Arkh., and *Paractinocamax grossouvrei depressus* (Andreae), and small shark teeth. Both contacts are distinct. The thickness is 0.5 m.

(8) Interval 3.8–8.8 m. Alternating diatomaceous marls and opokas connected by gradual transitions. Marls are light gray, with abundant rusty brown spots of Fe-hydroxides, containing glauconite grains in the upper part of the layer, and yielding scarce rostra of belemnites *Actinocamax verus fragilis* Arkh. and *Belemnitella* sp. Opokas are gray to dark gray, mottled because of irregular silicification, compact, resonant, characterized by angular fracture, and enclosing *Oxytoma tenuicostata* (Roem.), *Sphenoceramus* cf. *pinniformis* (Willet), *S. patootensis* (Lor.), *Liostrea wegmaniana* (d'Orb.), *Gryphaeostrea lateralis* (Nills.), *Acutostrea acutirostris* (Nills.), and *Monoticulina hippopodia* (Nills.). The hardground indicating a hiatus at the top is represented by dark gray to black coarse-clastic opoka 0.3 m thick, enclosing numerous crustacean burrows with fish scale at their bottoms. Material filling fucoids contains quartz and glauconite grains derived from the overlying bed. The hardground opoka yields usually isolated and horizontally arranged valves of *Oxytoma tenuicostata* (Roem.) up to 3–4 cm across. The thickness is 0.5 m.

The Rybushka Formation

(9) Interval 2.5–3.8 m. Fine-grained sand, light gray with greenish tint, glauconitic, highly calcareous, sometimes grading into sandy marl, with thin lenticular bedding, phosphorite nodules up to 5 cm across and similarly sized rusty brown ferruginous concretions. The bed is intensely bioturbated, particularly in the lower part. Abundance of silty material increases

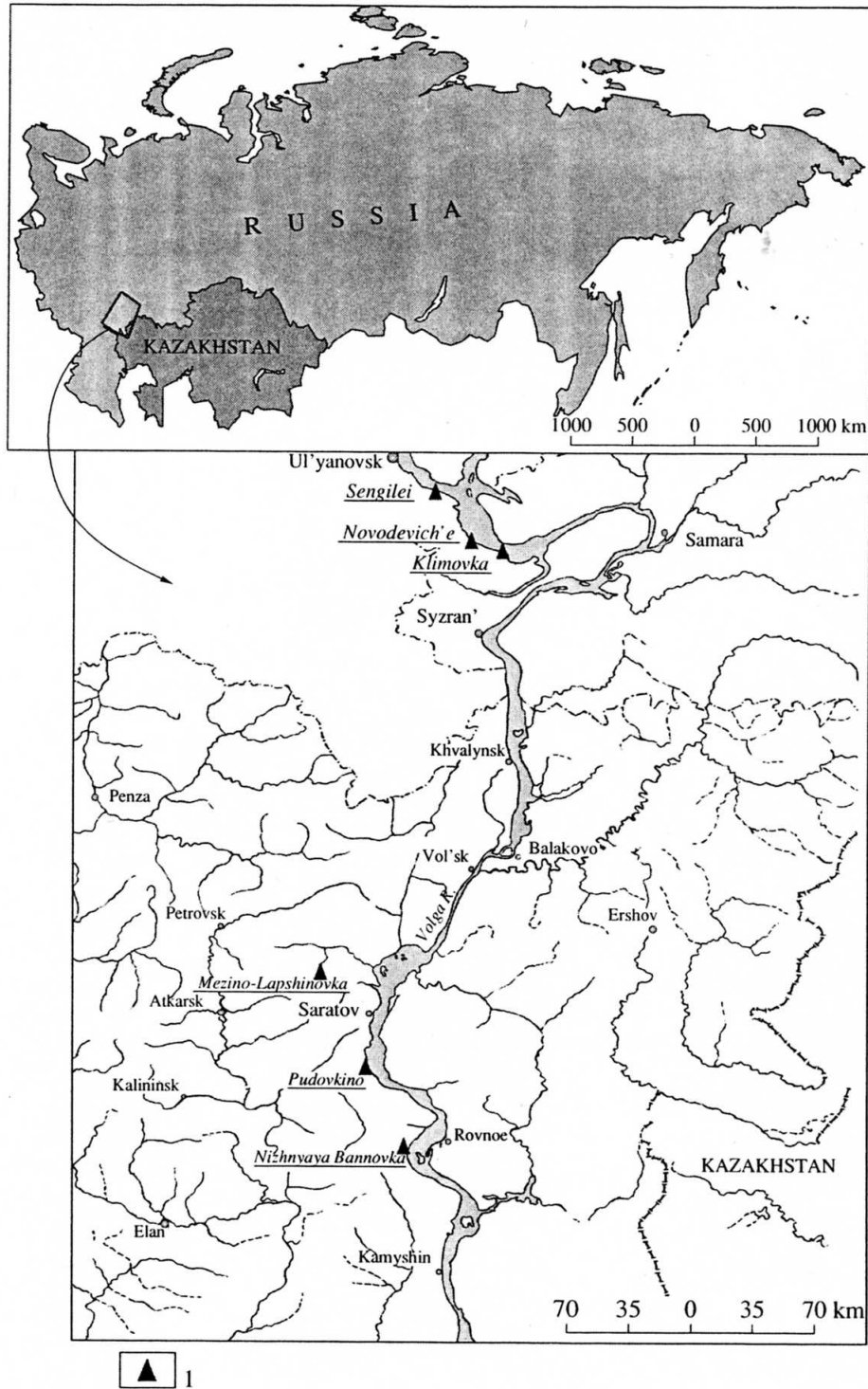


Fig. 1. Localities of the Mezino-Lapshinovka (1) and other reference sections of "Pteria Beds."

toward the base, where sand is colored pale to grayish brown. In the middle part of the bed, there are abundant subhorizontally arranged rostra of belemnites *Belemnellocamax mammillatus mammillatus* (Nills.) and *B. mammillatus volgensis* Najd., remains of siliceous sponges *Rhizopoterion cervicorne* (Goldf.), fragments

of cups belonging to other ventriculitids, and valves of oyster *Gryphaeostrea lateralis* (Nills.). The lower part of the bed yields abundant isolated valves of *Oxytoma tenuicostata* (Roem.), *O. intermedia* A. Ivanov, and *Microchlamys pulchella* (Nills.). The transition to overlying sediments is gradual. The thickness is 1.3 m.

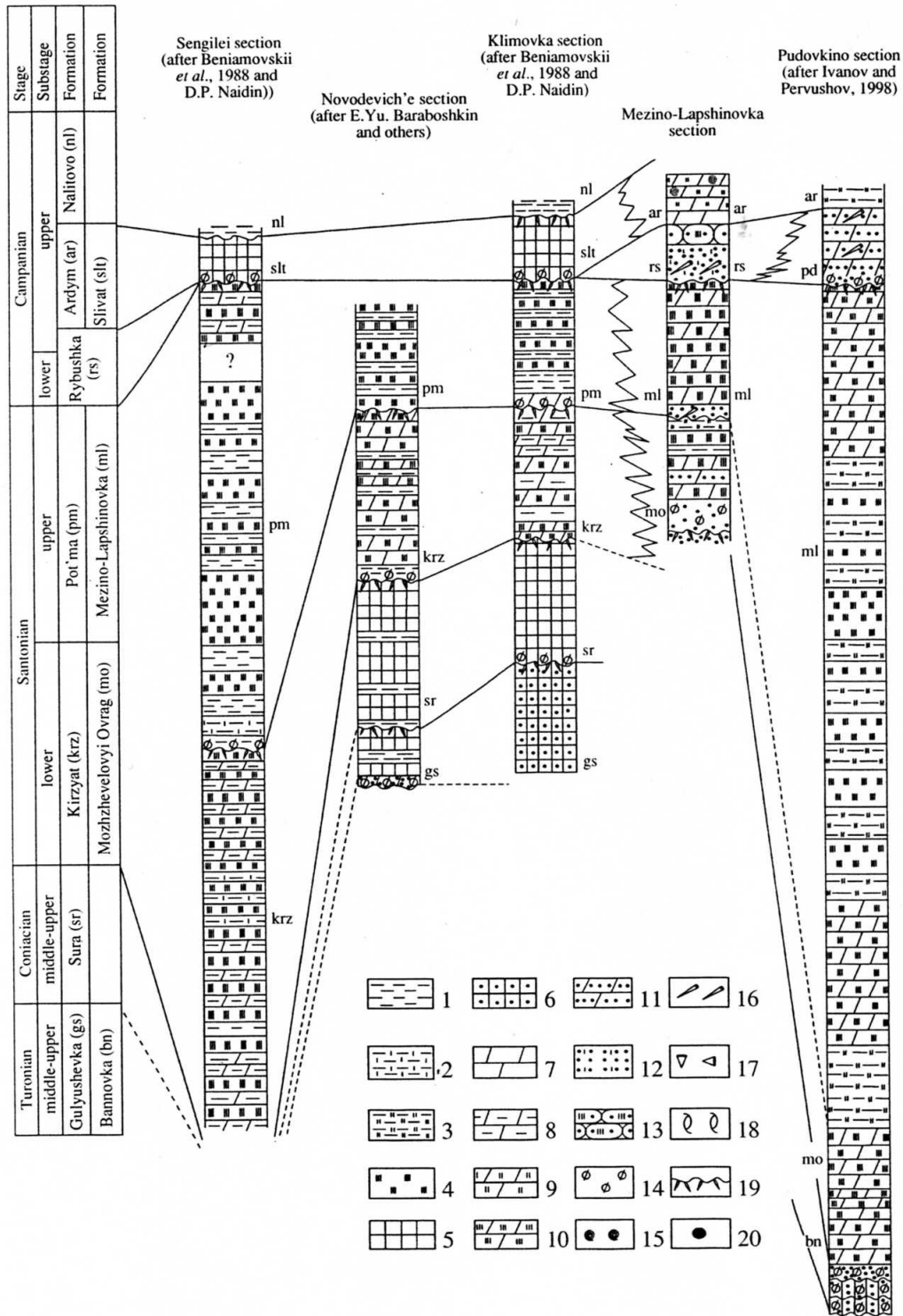


Fig. 2. Correlation of the Turonian–Campanian reference sections in the Ul'yanovsk–Saratov region, right side of the Volga River: (1) clay; (2) calcareous clay; (3) siliceous clay; (4) opoka; (5) chalk; (6) sandy chalk; (7) marl; (8) clayey marl; (9) tripoli marl; (10) siliceous marl; (11) sandy marl; (12) calcareous sand; (13) siliceous sandstone; (14) inclusions of phosphorite nodules. Fossils: (15) ammonites, (16) belemnite rostra, (17) sponges, (18) bivalves; (19) unconformities or hardgrounds; (20) levels with organic remains. Indices of local stratigraphic units (formations): (gs) Gulyushevka, (bn) Bannovka, (sr) Sura, (krz) Kirzyat, (mo) Mozhzhelovoyi Ovrage, (pm) Pot'ma, (ml) Mezino-Lapshinovka, (rs) Rybuschka, (pd) Pudovkino, (ar) Ardym, (slt) Slivat, (nl) Nalitovo.

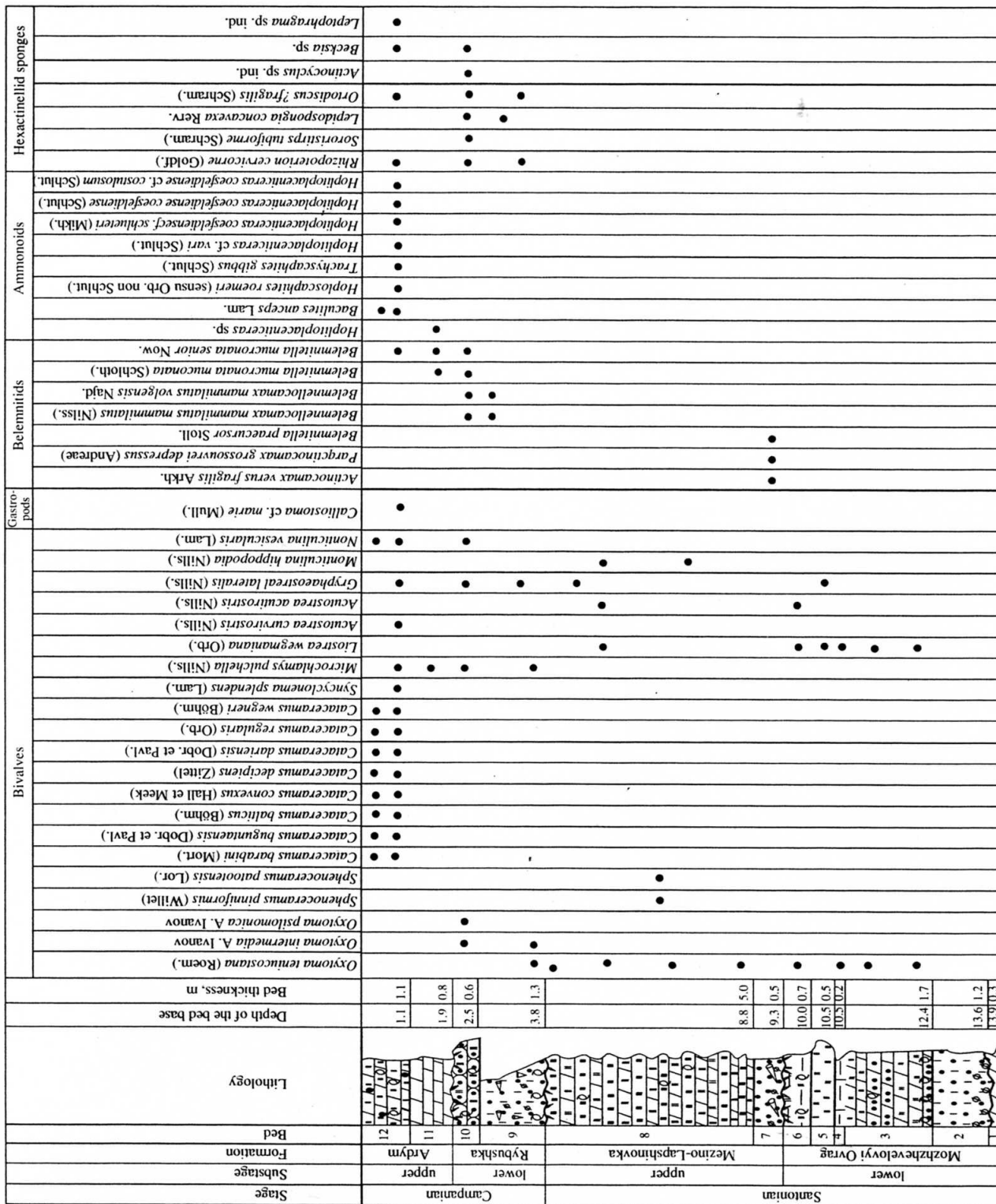


Fig. 3. Distribution of invertebrate remains in the Mezino-Lapshinovka section (legend as in Fig. 2).

(10) Interval 1.9–2.5 m. Fine- to medium-grained quartz–glauconite sand, greenish gray, irregularly silty, with siliceous cement of the basal type near the base and interstitial at the top of the bed. Near the base, there are ferruginous concretions 2–5 cm across, partly developed after flat fragments of siliceous sponges. The bed encloses accumulations of intact shells and separate valves of oyster species *Monticulina vesicularis* (Lam.), *Gryphaeostrea lateralis* (Nills.), pectinids *Oxytoma intermedia* A. Ivanov, *O. psilomonica* A. Ivanov, and *Microchlamys pulchella* (Nills.), rostra of belemnites *Belemnellocamax mammillatus mammillatus* (Nills.), *B. mammillatus volgenšis* Najd., *Belemnitella mucronata mucronata* (Schloth.), *B. mucronata senior* Now., and remains of sponges *Rhizopoterion cervicorne* (Goldf.), *Sororistirps tubiforme* (Schram), *Actinocyclus* sp., *Becksia* sp., *Ortodiscus* sp., and *Lepidospongia* sp. Being well resistant to erosion, the bed forms a distinct projection in the quarry wall. Sandstone is best cemented near the upper undulating and sharp contact with overlying sediments. The thickness is 0.6 m.

The Ardym Formation

(11) Interval 1.1–1.9 m. Chalky marl, light gray to almost white, vaguely flaggy, with nest-shaped glauconite accumulations at the base. The bed yielded a cast fragment of ammonite *Hoplitoplacenticerus* sp., and rostra of belemnites *Belemnitella mucronata mucronata* (Schloth.) and *B. mucronata senior* Now. The transition to overlying sediments is gradual. The thickness is 0.8 m.

(12) Interval 0–1.1 m. Light gray, irregularly silicified bioturbated flaggy marls showing angular fracture and alternating with whitish, slightly glauconitic flaggy calcareous clays locally grading into highly clayey marls. Marls yield abundant and diverse macrofossils: shells of ammonites *Baculites anceps* Lam., *Hopliplacenticerus coesfeldiense coesfeldiense* (Schlüt.), *H. coesfeldiense* cf. *costulosum* (Schlüt.), *H. coesfeldiense* cf. *schlueteri* Mikh., *H. cf. vari* (Schlüt.), *Trachyscaphites gibbus* (Schlüt.), and *Hoploscaphites roemeri* (d'Orb. non Schlüt.); nautilids *Eutrephoceras* sp.; rostra of belemnites *Belemnitella mucronata senior* Now.; shells of diverse inoceramids *Cataceramus barabini* (Mort.), *C. buguntaensis* (Dobr. et. Pavl.), *C. balticus* (Böhm.), *C. convexus* (Hall et Meek), *C. decipiens* (Zitt.), *C. dariensis* (Dobr. et. Pavl.), *C. regularis* (d'Orb.), and *C. wegneri* (Böhm.); pectinids *Synsyclonema splendens* (Lah.) and *Microchlamys pulchella* (Nills.); oyster species *Monticulina vesicularis* (Lam.), *Acutostrea curvirostris* (Nills.), and *Gryphaeostrea lateralis* (Nills.); gastropods *Callistoma marie* (Muller) and *Turritella* sp.; echinoids *Micraster* sp. and *Echinocorys* sp.; sponges *Rhizopoterion* sp. and *Ortodiscus* sp. The apparent thickness is 1.1 m.

MINERAL COMPOSITION AND BIOCLASTS

Macerated foraminiferal and radiolarian residues were used to examine the mineral composition of rocks and bioclasts. Small skeletal remains of organisms and fragments of their larger skeletons are considered here as bioclasts. The occurrence frequency of various components in residues is estimated in conditional categories as “scarce,” “rare,” “few,” “frequent,” and “abundant.” Being largely subjective, the categories defined by one researcher elucidate additional correlation levels undetectable during study of fossil assemblages.

In total, 14 mineral and organic components are established in the studied residues. Figure 4 demonstrates their distribution throughout the section under consideration.

The Mozhzhevelovyi Ovrage Formation

A single residue from Bed 1 (Sample 24) contains abundant fine-grained quartz and nodular glauconite grains, white mica (muscovite), and bioclasts representing abundant fish remains, scarce radiolarians, and rare spicules of siliceous sponges.

Sandstones of Bed 2 (samples 23 and 22) showed presence of fine-grained, poorly rounded quartz grains abundant in the lower and rare in the upper part. Another mineral component is glauconite colored dark green and nodular. Siliceous sponge spicules and well-rounded fish bone remains are scattered through the entire bed being accompanied by rare radiolarians and scarce phosphatic fecal pellets.

Siliceous marls of Bed 3 (samples 1–3, 1/1–1/4) contain abundant fine-grained angular quartz grains and glauconite, coarse-grained nodular in the lower and fine-grained rounded in the upper part. The lower part of the bed is enriched in flakes of white and greenish mica, which become scarce upward. The basal portion encloses small phosphate nodules (microphosphorite) up to 1.5 mm across. Permanently occurring fish remains and siliceous sponge spicules, frequent and diverse radiolarians, secretory and agglutinated benthic foraminifers represent organic components. Rare fragments of bivalve shells are confined to the bed upper part, while rare prisms of inoceramid shells occur throughout the bed.

Calcareous–siliceous clays of Bed 4 (Sample 4) bear light-green glauconite grains, usually small-sized detrital and less commonly large nodular, and fine poorly rounded quartz and rare phosphate grains. The coarse-grained fraction (>50 µm) constitutes only 1% of the rock. Abundant are flakes of white mica. Secretory foraminifers are rare and poorly preserved. Beginning from this level, radiolarians become abundant in the section. They are accompanied by abundant fish remains, few spicules of siliceous sponges, rare clasts of molluscan shells, inoceramid prisms, and scarce fecal pellets and shark teeth.

Bed 5 (Sample 5) marks a sharp decrease in proportion of terrigenous fine-grained quartz, glauconite, and mica (all few); abundance of coarse-grained fraction is negligible (0.2%). It is noteworthy that a single grain of black phosphorite 1 mm across was found precisely at this level. Among organic remains, there are rare tests of benthic foraminifers, abundant fish clasts, radiolarians, rare spicules of siliceous sponges, scarce echinoid needles, and inoceramid prisms.

Lithology of Bed 6 is similar to that of Bed 5: it is also impoverished in coarse terrigenous material and bioclasts (0.4%). The mineral fraction consists of few fine-grained quartz, mica, glauconite, and rare small brown phosphate grains (up to 1 mm across). Sediment contains frequent radiolarians, siliceous sponge spicules, fish remains, rather numerous benthic foraminifers, and rare inoceramid prisms. Based on their composition, sediments of beds 5 and 6 could be united into a single unit.

The Mezino-Lapshinovka Formation

The glauconitic sandstones of Bed 7 (Sample 7) contain abundant light green nodular and rod-shaped glauconite and rare angular fine-grained quartz grains. Organic components are represented by abundant short inoceramid prisms, few fish remains, rare fragments of bivalve shells, rare radiolarians, and scarce foraminifers. Noteworthy is the appearance of small planktonic foraminifers at this level.

The lower portion of Bed 8 of opoka and siliceous clay (samples 8–13 and 25–28) contains nodular and detrital glauconite, proportion of which gradually decreases upward. Sample 11 is barren of glauconite, which appears again higher in the section. In the uppermost part of the bed, glauconite is abundant (17% in Sample 13). The bed is marked by almost complete disappearance of mica and low content of fine-grained quartz. Sediments of the bed accumulated during the transgression peak at maximal distance from provenance. Organic components are represented by rare fish remains (mainly in the lower and partly in the upper part of the bed), rare radiolarians occurring discretely, abundant inoceramid prisms, and shell fragments of other bivalves. Being siliceous in composition and resistant to disintegration, Sample 10 is impoverished in bioclasts. Rare small-sized foraminifers are represented mainly by benthic forms. Planktonic species are registered only at some levels (samples 9 and 12). Rare echinoid needles occur in the upper part of the bed (samples 11–13). Sample 28 (1.5 m below the bed roof) contains rather abundant well-preserved ostracods.

The Rybushka Formation

Data on residue from Bed 9 composed of glauconitic sandstones are somewhat ambiguous. Samples 14 and 32 characterize in fact the hardground crowning Bed 8, which is developed after opokas with deep

fucoids. Therefore, both samples consist fifty–fifty of two components: greenish gray to beige–gray siliceous–marly matrix and green glauconite sand filling in fucoids. Since it was impossible to separate these components in the course of sample preparation, the composition of detrital fraction in Bed 9 could be characterized based on samples 15, 29, and 30 collected from higher layers. They contain abundant coarse-grained dark green nodular glauconite and a little of fine-grained quartz. Bioclastic fraction includes rare siliceous sponge spicules, inoceramid prisms, and few rounded bone fragments and scale of fishes. Foraminifers, planktonic forms included, are rare.

Siliceous sandstones of Bed 10 are resistant to disintegration. They bear abundant nodular glauconite, rare fine-grained quartz, tests of benthic foraminifers, and fragments of bivalve shells.

The Ardym Formation

Residues from Beds 11 and 12 (samples 17–21) are similar in composition of mineral and biogenic components. The lower samples 17–19 bear abundant coarse-grained nodular glauconite, while scarce mica flakes occur in Sample 18 only. Fine-grained quartz is rare (Sample 18). Characteristic of Bed 11 are frequent, relatively diverse ostracods, particularly abundant in Sample 18, small *Cyrtopedia* plates, and rare echinoid needles. Both beds contain relatively abundant, mainly benthic and rare planktonic foraminifers. There are also permanently occurring inoceramid prisms and occasional sponge spicules. We failed to disintegrate opokas of Sample 21, and its component composition remains unknown.

BIOSTRATIGRAPHIC ANALYSIS

Mollusks

As is seen from above characteristics of the section, bivalve mollusks are dominated by species *Oxytoma tenuicostata* (Roem.), which is abundant in the Mozhzhevelovyi Ovrage and Mezino-Lapshinovka formations and in the lower part of the Rybushka Formation (beds 1, 3, 4, 6, 8, and 9, Fig. 4). First appearance of *Oxytoma intermedia* A. Ivanov is recorded in the latter unit (Bed 9). In the terminal part of the section (Bed 10), the last species occurs in association with *Oxytoma psilomonica* A. Ivanov, whereas *O. tenuicostata* (Roem.) has not been found at this level. The oyster species *Liostrea wegmaniana* (d'Orb.) is registered in beds 3–8 of the Mozhzhevelovyi Ovrage and Mezino-Lapshinovka formations, while *Acutostrea acutirostris* (Nills.) occurs only in the Mezino-Lapshinovka Formation (beds 7 and 8). Bed 8 yields *Monticulina hippopodia* (Nills.) that is replaced by *Monticulina vesicularis* (Lam.) in the upper part of the Rybushka Formation (Bed 10) and in the Ardym Formation. Finally, *Gryphaeostrea lateralis* (Nills.) occurs sporadically beginning from Bed 5 and then higher in beds 9, 10, and 12.

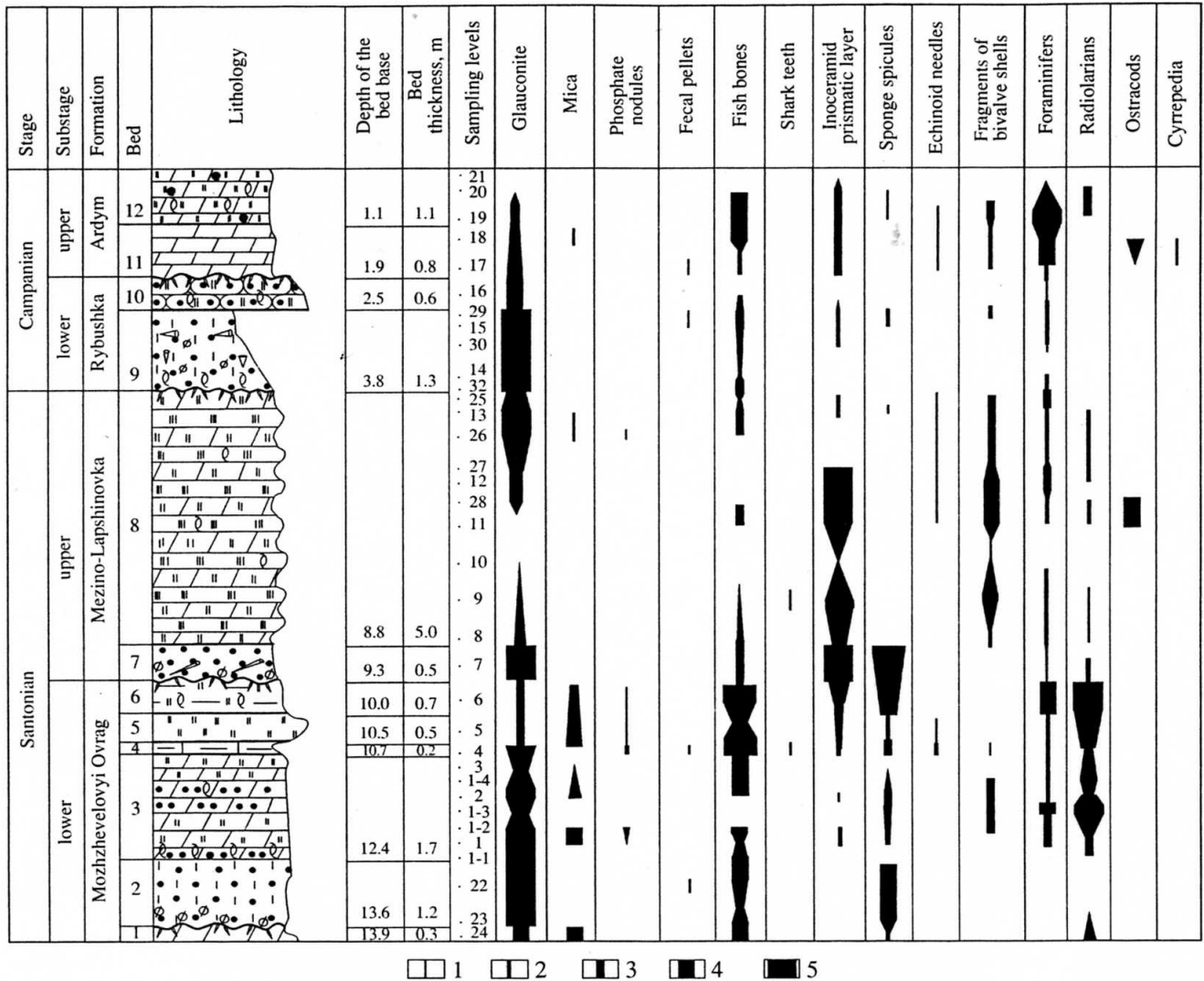


Fig. 4. Distribution of mineral and organic components in the Mezino-Lapshinovka section. The component content in residue: (1) scarce, (2) (rare), (3) few, (4) common, (5) abundant (other symbols as in Fig. 2).

Important among inoceramid forms found in Bed 8 of the Mezino-Lapshinovka Formation is species *Sphenoceras* cf. *pinniformis* (Willet) characteristic, according to Tröger (2000), of the terminal middle (Zone 27) and basal upper (Zone 28) Santonian in northwestern Germany. It was found in association with *Phenocermus patootensis* Lor., the typical upper Santonian species of West Europe.

The diverse inoceramid assemblage of the Ardym Formation (Bed 12) includes *Cataceramus balticus* (Böhm.), *C. barabini* (Mort.), *C. buguntaensis* (Dobr. et. Pavl.), *C. convexus* (Hall et Meek), *C. dariensis* (Dobr. et Pavl.), *C. decipiens* (Zitt.), *C. regularis* (d'Orb.), and *C. wegneri* (Böhm.). All the listed species occur in the Campanian and lower Maastrichtian, being most abundant in the upper Campanian. Simultaneously, *Cataceramus dariensis* (Dobr. et Pavl.) was known until recently only from lower Campanian sedi-

ments of the Donbas region and northern Caucasus (Kotsyubinskii and Savchinskaya, 1974). Pectinids *Subcyclonema splendens* (Lah.) and *Microchlamys pulchella* (Nills.) from the same bed are most characteristic of the terminal upper Campanian (*Belemnitella langei* Zone) and Maastrichtian in the Russian platform (Kotsyubinskii and Savchinskaya, 1974).

Of greatest interest are cephalopods found in the Ardym Formation (Bed 12) of the Mezino-Lapshinovka section. The ammonite assemblage from this bed includes *Hopliplacenticerus coesfeldiense coesfeldiense* (Schlüt.), *H. coesfeldiense* cf. *costulosum* (Schlüt.), *H. coesfeldiense* cf. *schlueteri* Mikh., *H. cf. vari* (Schlüt.), and *Trachyscaphites gibbus* (Schlüt.). Host sediments of these taxa are directly correlative with the upper Campanian *Hopliplacenticerus marroti* Zone of the standard scale. These sediments yielded also an ammonite form determined as *Hoplos-*

caphites roemeri (sensu d'Orbigny, 1850, non Schlüter, 1872), because it is barren of tubercles at the lateral side of whorls. Mikhailov (1951, pp. 19 and 98), who determined this form as *Acanthoscaphites* cf. *roemeri* (d.Orb.), reported on its association with various *Hoplilenticeras coesfeldiense* (Schlüt.) subspecies in cement marls of the Amvrosievka site in southern periphery of the Donbas region.

Belemnites occur in both the Mezino-Lapshinovka (beds 7 and 8) and Rybushka (beds 9 and 10) formations. Sands of Bed 2 yield *Actinocamax verus fragilis* Arkh., *Paractinocamax grossouvrei depressus* (Andreae), and *Belemnitella praecursor* Stoll. The first species is of a relatively wide stratigraphic range (Coniacian–Santonian), while the second one is characteristic of the upper Santonian in southern Sweden, western Germany, and England, and of the *Pteria* Beds in the Kazanskaya Village outskirts, the Don River basin (Naidin, 1964). The third taxon appears in the upper Santonian and occurs in the lower Campanian. *Belemnitella praecursor* Stoll. and *Paractinocamax* ex gr. *grossouvrei* (Janet) were found in the upper Santonian (*Placenticeras paraplanum* Subzone) of French Pyrenees (Cristensen *et al.*, 1993). Marls and opokas of Bed 8 contain *Actinocamax verus fragilis* Arkh. and undeterminable rostra of other belemnites.

A sharp change in composition of belemnite assemblages is established at the boundary between beds 8 and 9. Lower sands of the Rybushka Formation (Bed 9), which yield abundant rostra of *Belemnelloccamax mammillatus mammillatus* (Nills.) and *B. mammillatus volgensis* Najd., can be attributed to the terminal part of the lower Campanian (Naidin *et al.*, 1986; Olfer'ev and Alekseev, 2003). In Bed 10, these species are accompanied by *Belemnitella mucronata mucronata* (Schloth.) and *B. mucronata senior* Now., which are found in the overlying Ardym Formation as well (beds 11 and 12). The latter contains also shells of gastropod taxon *Callostoma* cf. *mariae* (Müller), which is typical of the *Mucronata* Chalk in Germany (Blank, 1974).

Foraminifers

The lowermost foraminiferal assemblage is established in Sample 1 from Bed 3 of the Mozhzhevelovyi Ovrage Formation (Fig. 5). It includes the following taxa: ataxophragmiids *Harena amanda* (Wolosch.) and *Novatrix obesa* (Reuss); nodosariids, in particular stratigraphically important neoflabellins with prevalent *Neoflabellina* cf. *gibbera* (Wedek.), *N.* cf. *santonica* Koch. and occasional *N.* cf. *suturalis* (Cushm.); discorbids *Valvulineria mariei* Vass., *Stensioeina exculpta exculpta* (Reuss), *S. granulata* cf. *perfecta* Koch, and *S. mursataiensis* Vass., which represents probably a senior synonym of the West European subspecies *Stensioeina granulata incondita* Koch; anomalinids *Cibicides beaumontianus* (d'Orb.); buliminids *Praebulimina ventricosa* (Brotz.). Almost identical assemblage occurs slightly higher, in Sample 1/2. Forms supplementing

the assemblage in the higher Bed 3 (Sample 2) are *Osangularia whitei* (Brotz.), *O. corderiana* (d'Orb.), *Gyroidinoides girardanus* (Reuss), *Stensioeina granulata granulata* Koch, and abundant *S. mursataiensis* Vass. Bed 4 (Sample 4) yields an impoverished assemblage consisting of *Harena amanda* (Wolosch.), *Novatrix obesa* (Reuss), *Praebulimina ventricosa* (Brotz.), and of a test fragment probably belonging to *Neoflabellina* cf. *deltoidea* Wedek. The single species *Novatrix obesa* (Reuss) is present in Bed 5. *Stensioeina mursataiensis* Vass., *S. granulata* cf. *perfecta* Koch, *Neoflabellina* cf. *gibbera* (Wedek.), *N.* cf. *santonica* Koch, *N.* cf. *suturalis* (Cushm.), *N.* cf. *deltoidea* (Wedek.), and *Valvulineria mariei* Vass. represent the assemblage from beds 3–5 of the Mozhzhevelovyi Ovrage Formation, which are correlative with the lower Santonian *Stensioeina granulata perfecta* Zone of western Kazakhstan or with the terminal part of the *Gavelinella infrasantonica* Zone of the East European platform (Akimets *et al.*, 1991). In West Europe, this zone spans the middle–upper Santonian boundary layers (Koch, 1977; Bailey *et al.*, 1984; Schönfeld, 1990), as the three-member subdivision of the stage is accepted here.

The assemblage from Bed 6 (Sample 6) is similar to that from underlying sediments of the Mozhzhevelovyi Ovrage Formation and also includes *Harena amanda* (Wolosch.), *Novatrix obesa* (Reuss), *N.* cf. *santonica* Koch, *Stensioeina exculpta exculpta* (Reuss), *S. granulata* cf. *perfecta* Koch, *S. mursataiensis* Vass., and *Praebulimina ventricosa* (Brotz.). Noteworthy is the first appearance of single small-sized *Gavelinella stelligera* (Marie) at this level. This taxon is an index species of the synonymous local zone corresponding to the Santonian in the regional Upper Cretaceous scheme of the East European platform (Olfer'ev and Alekseev, 2003).

The next assemblage characterizes the Mezino-Lapshinovka Formation. Appearing in the lower part of this formation (samples 9 and 11) are *Stensioeina* cf. *pommerana* Brotz., abundant typical *Gavelinella stelligera* (Marie) and *Eponides?* aff. *grodnoensis* Akim. The last form is very close to *Eponides moskvini* (Kell.). These species are accompanied by *Valvulineria mariei* Vass. and *Praebulimina ventricosa* Brotz. characteristic also of the Mozhzhevelovyi Ovrage Formation. In the terminal part of the Mezino-Lapshinovka Formation (samples 28, 12, 26, 13), the assemblage shows a decreased abundance of neoflabellins, newcomers among which are abundant typical *Neoflabellina deltoidea* (Wedek.) and *N. suturalis* (Cushm.) from samples 28 and 13. Additional renewals in the assemblage are recorded at the appearance levels of *Quadrimorphina minuta* (Cushm.) and of *Gavelinella dainae* (Mjatl.) in samples 26 and 13 respectively. Planktonic forms *Whiteinella* sp., *Archaeoglobigerina* sp., *Globotruncana globigerinoides* (Marie), *Rugoglobigerina rugosa* (Plumm.), and *Helvetiella* sp. also appear at these levels.

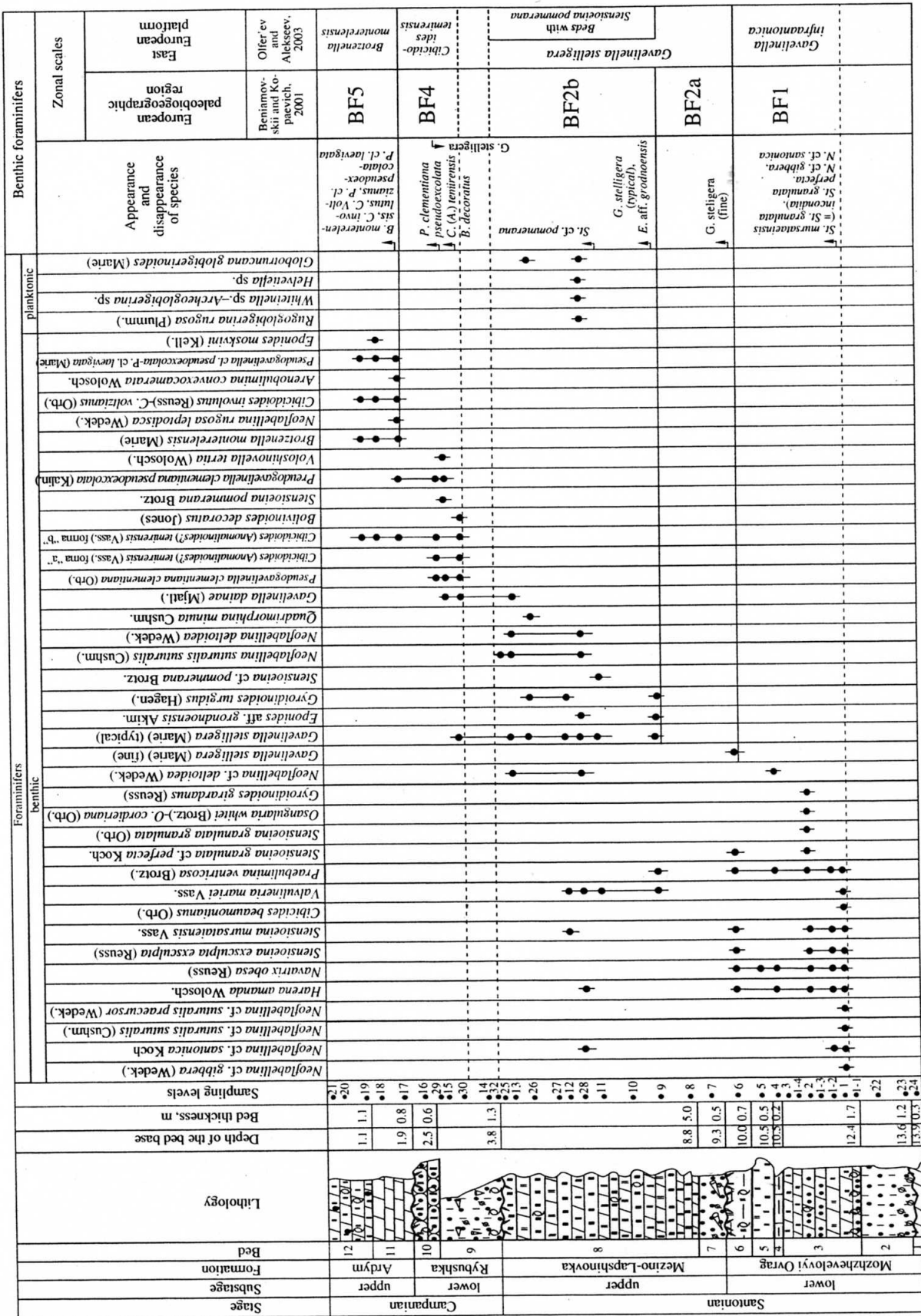


Fig. 5. Distribution of foraminifers in the Mezino-Lapshinovka section (legend as in Fig. 2).

The Mezino-Lapshinovka foraminiferal assemblage corresponds to that from the terminal part of the upper Santonian *Gavelinella stelligera* Zone in the East European platform defined by Olfer'ev and Alekseev (2003) in the rank of the *Stensioeina pommerana* Beds. According to Schönfeld (1990), in northwestern Germany the zonal species *Stensioeina pommerana* (Brotz.) appears in the uppermost Santonian *Stensioeina pommerana/Gaudryina franki* Zone. Beds with *Stensioeina pommerana* are correlative with the *Stensioeina pommerana* Subzone (BF2b) in the detailed upper Santonian–Maastrichtian zonal scale of the European paleobiogeographic region (Beniamovskii and Kopaevich, 1998, 2001), which represents a synthesis of two scales elaborated for the eastern part of the European paleobiogeographic region (Naidin *et al.*, 1984a, 1984b) and northwestern Germany (Koch, 1977; Schönfeld, 1990). Recently, the detailed correlation between these scales showed that the lower boundary of the *Stensioeina pommerana* Subzone (BF2b) in the synthesized scheme is placed incorrectly. In fact, it should be drawn inside the Santonian, since, as was mentioned, the first appearance of *Stensioeina pommerana* (Brotz.) is recorded in the terminal Santonian (Schönfeld, 1990).

It should be emphasized that the foraminiferal assemblage from the Mezino-Lapshinovka Formation is identical to that from *Pteria* Beds of the Ul'yanovsk region near the Volga River, where the beds are marked by the first appearance of *Eponides* aff. *grodnensis* Akim., *Stensioeina pommerana* Brotz., *Gavelinella stelligera* (Marie), and *G. dainae* (Mjatl.) (Beniamovskii *et al.*, 1988, p. 68).

The foraminiferal assemblage of the Rybushka Formation is established in Bed 9 (samples 30, 15, and 29). *Gavelinella stelligera* (Marie) and *G. dainae* (Mjatl.) known from the Mezino-Lapshinovka Formation remain abundant in the bed. Except for these species, the composition of the assemblage is different. *Pseudogavelinella clementiana clementiana* (d'Orb.), *Bolivinooides decoratus* (Jones), and *Cibicidoides* (*Anomalinooides?*) *temirensis* (Vass.) appear in Sample 30. The last taxon is represented by morphotypes "a" and "b." The first of them has a symmetrically biconvex test and symmetrical oval–triangular septal surface. The second morphotype demonstrates features reflecting the initial stage of transition to *Cibicidoides involutus* (Reuss) [= *C. aktulagayensis* (Vass.)]. It is characterized by a flatter spiral side and more distinct outlines of the septal surface with tendency for its incline toward the umbonal area.

Index species *Cibicidoides* (*Anomalinooides?*) *temirensis* (Vass.) and *Bolivinooides decoratus* (Jones) present in the assemblage suggest correlation of host deposits with the *Cibicidoides temirensis* Zone of the East European platform (Olfer'ev and Alekseev, 2003) or the *Bolivinooides decoratus decoratus* Zone (BF4) of the European paleobiogeographic region (Beniamovskii and Kopaevich, 2001).

The assemblage from overlying sediments (Sample 15) additionally includes *Voloschinovella tertia* (Wolosch.), *Pseudogavelinella clementiana pseudoexcolata* (Kalin.), typical *Stensioeina pommerana* (Brotz.), and planktonic forms of the *Heterohelix*, *Rugoglobigerina*, and *Globotruncana* genera.

The assemblage contained in uppermost Sample 29 from the Rybushka Formation is different in two features from the lower assemblage of that formation: first, *Gavelinella stelligera* (Marie) and *G. dainae* (Mjatl.) disappear and, second, occasional tests of *Brotzenella monterelensis* (Marie), an index species of the younger zone, appears at this level. In our opinion, appearance of the latter is a result of contamination from overlying Ardym sediments filling in crustacean burrows.

The compositional peculiarities of foraminiferal assemblage from the Rybushka Formation, which substantially less thick in the studied section than in stratotype (Ivanov, 1995, pp. 64–65), indicate that host deposits are likely correlative with the *Cibicidoides aktulagayensis* Subzone of the East European platform or with the BF4c Subzone of the European paleobiogeographic region (Beniamovskii and Kopaevich, 2001).

We failed to extract foraminifers from sandstones of Rybushka Formation (Bed 10), because they are strongly silicified.

The foraminiferal assemblage from the Ardym Formation is macerated from beds 11 and 12 (samples 17–19). It is marked by appearance of *Arenobulimina convexocamerata* Wolosch., *Neoflabellina rugosa leptodisca* (Wedek.), *Brotzenella monterelensis* (Marie), *Eponides moskvini* (Kell.), and *Cibicidoides involutus* (Reuss) in Sample 18. Tests of the last species occurring together with *Cibicidoides* (*Anomalinooides?*) *temirensis* (Vass.) forma "b" slightly differ from typical representatives of this taxon. In some features, it is close to *C. voltzianus* (d'Orb.), the evolutionary descendant of *C. involutus* (Reuss). Forms transitional to *Pseudogavelinella clementiana laevigata* (Marie) with reduced ornamentation on the spiral side occur among abundant *Pseudogavelinella clementiana pseudoexcolata* (Kalin.).

In its composition, the assemblage in question is comparable with that of the *Brotzenella monterelensis* local zone of the regional East European scale (Olfer'ev and Alekseev, 2003) or BF5 Zone of the European paleobiogeographic region (Beniamovskii and Kopaevich, 2001).

Forms present in the assemblage, which are transitional between *C. involutus* (Reuss) [= *C. aktulagayensis* (Vass.)] and *C. voltzianus* (d'Orb.), imply that the Ardym Formation of the studied section is correlative with the upper part of the *Brotzenella monterelensis* Zone.

Radiolarians

Three radiolarian assemblages are distinguished in the examined section (Fig. 6).

The most representative lower assemblage of diverse and abundant radiolarians is confined to beds 1–5 of the Mozhzhevelovyi Ovrage Formation. It includes *Alievium superbum* (Squin.), *A. praegallowayi* Pess., *Archaeospongoprimum bipartitum* Pess., *A. triplum* (Pess.), *Pseudoaulophacus venadoensis* Pess., *P. praefloresensis* Pess., *Orbiculiforma persenex* Pess., *Cavaspungia euganea* (Squin.), *Crucella cachensis* Pess., *Pyramispongia glascockensis* Pess., *P. costarricensis* (Schmidt-Effing), *Praeconocaryomma lipmanae* Pess., *Dictyomitra napaensis* Pess., and several new species. In the Californian sections, Pessagno (1976) defined the Turonian *Alievium superbum* Zone of the Pacific province, admitting simultaneously that this species may occur in the lower Coniacian as well. Subsequently, the indicated index species was found in the Turonian–Coniacian of the Pacific (Schaaf, 1986) and in the lower Coniacian Chernetovka Formation exposed in the Sobolevskoe quarry of the Kaluga region (data of Olfer'ev and Vishnevskaya). *A. praegallowayi* occurring in the assemblage was proposed by E. Pessagno as an index species for the synonymous zone corresponding to the entire Coniacian Stage, although he also supposed the species presence in the basal Santonian. It is important that epibole of *Archaeospongoprimum bipartitum* is characteristic, according to Pessagno, of the lower subzone of the *Alievium praegallowayi* Zone. In addition, almost all the above-mentioned species of the assemblage, except for *Alievium superbum* (Squin.), *Dictyomitra napaensis* Pess., and *Pyramispongia* forms, are known from the middle Coniacian–lower Santonian Zagorsk Formation of the Moscow syncline (Olfer'ev *et al.*, 2000). Based on the integral distribution range of radiolarians from the Mozhzhevelovyi Ovrage Formation, the assemblage can be dated back to the Turonian–Coniacian.

The second assemblage with *Pseudoaulophacus floresensis* is established in Bed 6 crowning the Mozhzhevelovyi Ovrage Formation (Sample 6) and also in Sample 12 from Bed 8 of the Mezino-Lapshinovka Formation. Present in this assemblage are *Pseudoaulophacus floresensis* Pess., *Prunobrachium sibiricum* (Lipm.), *Rhopalastrum attenuatum* Lipm., *R. tumidum* Lipm., *Crucella espartoensis* Pess., *Dictyomitra densicostata* Pess., and some other forms. All the species, except for the last one appearing in the upper part of the Coniacian, range from the Santonian to the Campanian, thus implying the Santonian–early Campanian age of host beds. Nevertheless, *Crucella chachensis* Pess., *Histiastrium latum* Lipm., *Euchitonia santonica* Lipm., *Orbiculiforma quadrata* Pess., and *Dictyomitra striata* Lipm., which disappear at the Santonian–Campanian boundary, point likely to the Santonian age of beds enclosing the *Pseudoaulophacus floresensis* assemblage.

The third radiolarian assemblage is defined in Bed 12 (samples 19 and 20) of the Ardym Formation. It consists of rare specimens belonging to five species, most of which are known from the older assemblage. Four of them are *Rhopalastrum attenuatum* Lipm., *Porodiscus cf. vulgaris* Lipm., *Xitus asymbatos* (Forem.), *Dictyomitra densicostata* Pess. The fifth form of the assemblage (*Orbiculiforma minticelloensis* Pess.) appears precisely at this level. The assemblage is the Campanian in age.

Calcareous nannoplankton

Sufficiently abundant calcareous nannofossils moderately or well preserved occur virtually throughout the section beginning from Bed 2 of the Mozhzhevelovyi Ovrage Formation (Fig. 7). The bed contains an extremely impoverished assemblage that includes *Micula staurophora* (Gard.) Stradn., *M. concava* (Stradn.) Verb., *Eiffellithus eximius* (Stov.) Perch-Niels., *Kamptenerius magnificus* Defl., and *Marthasterites furcatus* (Defl.) Defl. The first four species occur throughout the entire section, whereas the last one disappears at the base of the Rybushka Formation at the level of Sample 15. Based on the presence of *Micula staurophora* (Gard.) Stradn., the assemblage can be correlated with the Zone CC14 (Perch-Nielsen, 1985; Wagneich, 1992; Burnett, 1998). In this sample, like almost in all the samples from overlying sediments, the last species is associated with *Micula concava* (Stradn.) Verb., the appearance of which marks the lower boundary of the younger Zone CC15 (Perch-Nielsen, 1985). It should be noted also that Melinte (1999) assumes the appearance of this species in the terminal part of the Zone CC14 of Romania.

Beginning from Bed 3 of the Mozhzhevelovyi Ovrage Formation, the nannoplankton assemblage becomes more diverse, consisting of over 20 species (Fig. 7). Among them, worthy of mentioning is *Prediscosphaera grandis* Perch-Nielsen. Burnett (1998) correlated the appearance level of this species and *Micula concava* (Stradn.) Verb. with the base of the *Texanites texanus* ammonite zone that begins the Santonian Stage in the Upper Cretaceous scale of the East European platform (Olfer'ev and Alekseev, 2002). In opinion of Burnett, the same biotic event took place in the Boreal realm at the middle of Subzone UC11 and approximately corresponds to the base of the Santonian Stage.

In overlying beds 4 and 5 of the same formation, the nannoplankton assemblage is almost unchanged, incorporating additionally only three species of a wide stratigraphic range. Its composition becomes more diverse in the terminal part of the Mozhzhevelovyi Ovrage Formation (Bed 6; Fig. 7), although new forms appearing here are inappropriate for age determination.

A more substantial renewal of nannoplankton is recorded in the Mezino-Lapshinovka Formation, where its diverse assemblage includes 40 species. Basal sands of the formation (Bed 7) recorded first appearance of

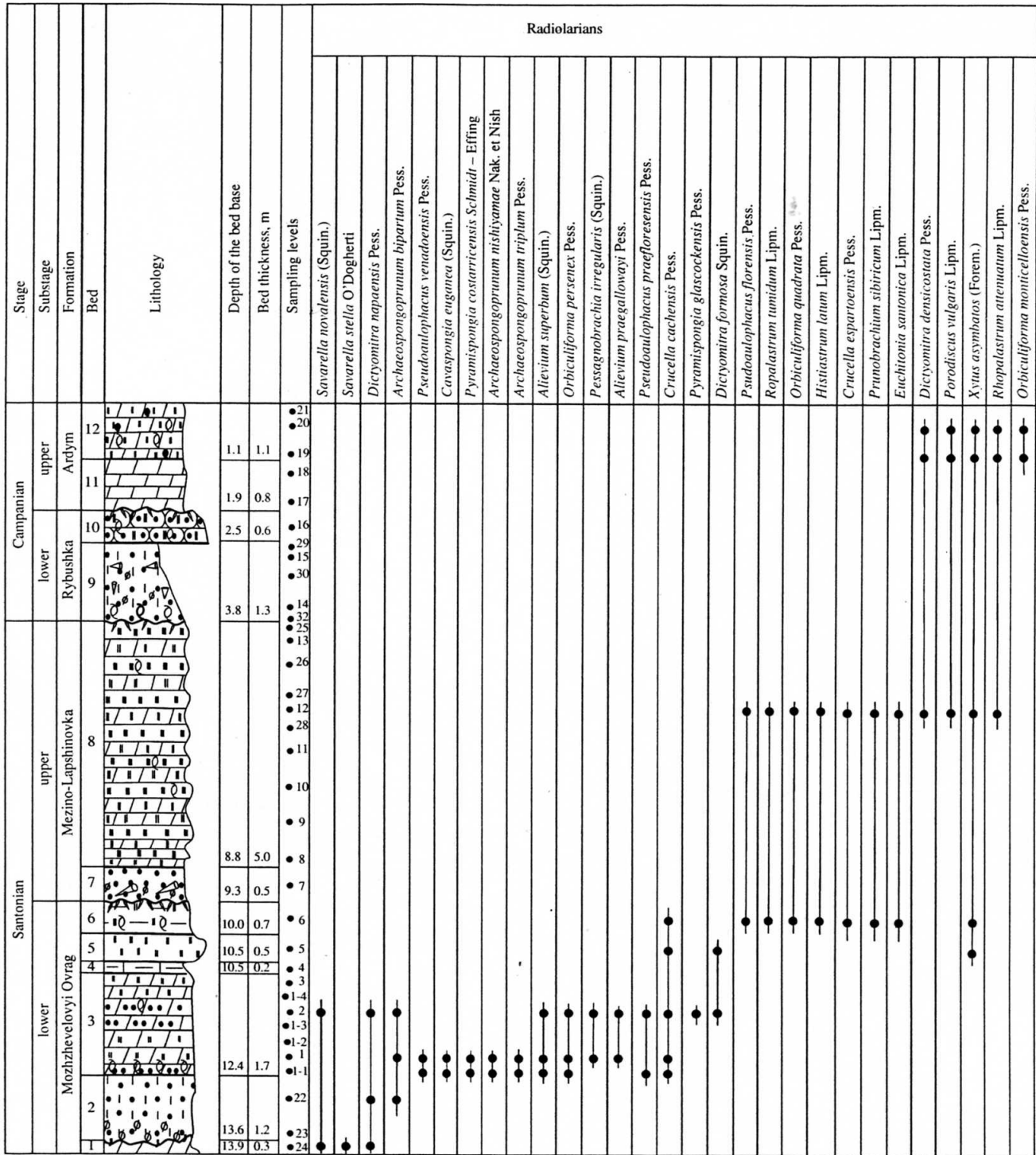


Fig. 6. Distribution of radiolarians in the Mezino-Lapshinovka section (legend as in Fig. 2).

Reinhardtites anthophorus (Defl.) Perch-Niels., and this event corresponds to the base of the synonymous Zone CC15 (Sissingh, 1977; Perch-Nielsen, 1985). This newcomer is a permanent component of assemblages higher in the section.

It is important that *Lithastrinus grillii* Stradn. appears first in Bed 8, (Sample 13), because this taxon

marks, according to Burnett (1998), the base of the Coniacian–lower Santonian Zone UC11. Simultaneously, species *Zeugarhabdotus diplogrammus* (Defl.) Gartn. present in samples 10 and 12 but absent in Sample 13, suggests, as it follows from the scheme by Burnett, that the interval in question is not older than the late Santonian (*Unitacrinus socialis* Zone).

The next notable change in composition of nannoplankton is recorded at the base of the Rybushka Formation (Fig. 7). A significant event detected at this level, i.e., the appearance of *Broinsonia parca parca* (Stradn.) Bukry, marks, according to many observations, the base of the Campanian Stage. Precisely, the appearance level of this form characterizes zones NC18 (Roth, 1978), CC18 (Perch-Nielsen, 1985), and UC14 (Burnett, 1998). At the same time, *Marthasterites furcatus* (Defl.) Defl., which should disappear at the base of the Zone CC19 (Sissingh, 1977; Wise, 1983; Doeven, 1983; Perch-Nielsen, 1985), is missing at this level. Sandstones of Bed 10 crowning the Rybushka Formation yield *Broinsonia parca constricta* Hattn. *et al.*, the taxon marking the lower boundary of subzones CC18b (Perch-Nielsen, 1985) and UC14b (Burnett, 1998).

The nannoplankton assemblage from the Ardym Formation (Bed 11) is characterized by the appearance of *Arkhangelskiella cymbiformis* Veksh., which was used by different researchers as the zonal index species. For instance, Sissingh (1977) correlated its first appearance with the base of the upper Maastrichtian Zone CC25. Perch-Nielsen (1985) proposed to use this species as an alternative marker for the base of the upper Campanian Zone CC21 in high latitudes. Burnett (1998) used the appearance of *A. cymbiformis* Veksh. to define the Zone UC13 at the base of the lower Campanian. These controversial opinions concerning the taxon stratigraphic range are explainable by the different understanding of its scope (Perch-Nielsen, 1985). In addition to forms of wide stratigraphic ranges, forms encountered at the level in question are *Calculites ovalis* (Stradn.) Prins et Siss. and *Ceratolithoides cf. aculeus* (Prins et Siss.) Stradn. (Fig. 7). The first species was considered as denoting the base of Zone CC19 in the zonal scale of Perch-Nielsen (1985), although its earlier appearance is established recently (Lamolda *et al.*, 2002; observations of Shcherbinina). The second form is known beginning from the Zone CC20 (Perch-Nielsen, 1985) or Subzone UC15b of the Boreal realm (Burnett, 1998).

The calcareous nannoplankton assemblage from Bed 12 of the Ardym Formation crowning the Mezino-Lapshinovka section includes first *Ceratolithoides verbeckii* Perch-Niel., *Prediscosphaera stoveri* (Perch-Niels.) Shaf. et Stradn., and *Lucianorhabdus arcuatus* Forchh. The first of these species marks the base of the Subzone CC18c (Perch-Nielsen, 1985) or Subzone UC14d in the Tethyan realm (Burnett, 1998) and the second form appears in the Subzone UC15d of the Boreal realm and transitional areas from this to the Tethyan realm.

AGES OF FORMATIONS

Ages of formations exposed in the Mezino-Lapshinovka quarry are estimated based on enclosed paleontological remains, and their stratigraphic positions in

the Upper Cretaceous succession of the Russian plate are given in accordance with the regional stratigraphic scheme of the East European platform (Olfer'ev and Alekseev, 2002, 2003). Shortly after the acceptance of this scheme, working groups of the International Subcommittee on Cretaceous Stratigraphy proposed stratotypes of lower boundaries for the Santonian (Lamolda *et al.*, 2002) and Maastrichtian (Odin, 2001) stages at substantially lower stratigraphic levels as compared with those traditionally accepted in Russia. In this connection, ages of Upper Cretaceous formations defined in the Volga region can be defined ambiguously depending on the viewpoint of different researchers on relevant boundaries. The problem is partly discussed in further sections of the paper. Nevertheless, to avoid insurmountable difficulties, we accepted ranges of units as they are defined in the standard scale outlined recently by two of us (Olfer'ev and Alekseev, 2002). It should also be kept in mind that Upper Cretaceous nanofossils from the Russian plate are inadequately studied and, accordingly, the reliable age estimates based on nannoplankton from local stratigraphic units are unknown in the plate. Therefore, we defined zonal subdivisions in this work mainly based on succession of species appearances in the type Upper Cretaceous sections of North Europe (Hardenbol *et al.*, 1998).

The Mozhzhevelovyi Ovrage Formation

In the examined section, this stratigraphic unit is represented only by its uppermost layers. In complete sections, it includes cardissoid marls with the sponge horizon at the base, which grade upward into "banded sequence" composed of alternating opokas, siliceous marls, and clays. The cardissoid marls are missing from sections near arches of positive structures. The "banded group" is referred to either the lower (Arkhangel'skii, 1912; Milanovskii, 1940; Glazunova, 1972) or the upper Santonian (Naidin and Morozov, 1986, p. 100).

Layers exposed in the Mezino-Lapshinovka quarry belong to the "banded sequence" that is confirmed by presence of abundant flakes of white mica characteristic of opokas from this part of the sections in the Volga River region (Arkhangel'skii, 1912). The recovered molluscan remains, except for *Oxytoma tenuicostata* (Roem.) and *Liostrrea wegmaniana* (d'Orb.), which Glazunova (1972) considered to be the late Santonian in age, are species of wide stratigraphic ranges. In addition, beds 3–6 enclose the assemblage of benthic foraminifers of the *Stensioeina granulata perfecta* Zone (Akimets *et al.*, 1991) or Zone XI of the European paleobiogeographic region (Beniamovskii and Kopaevich, 2001). Both zones correspond to the upper portion of the lower Santonian and to the terminal part of the lower Santonian *Gavelinella infrasantonica* Zone in the regional scale (Olfer'ev and Alekseev, 2003). It should be kept in mind, however, that in northwestern Germany, where the Santonian is divided into three substages (Schönfeld, 1990), the *Stensioeina granulata*

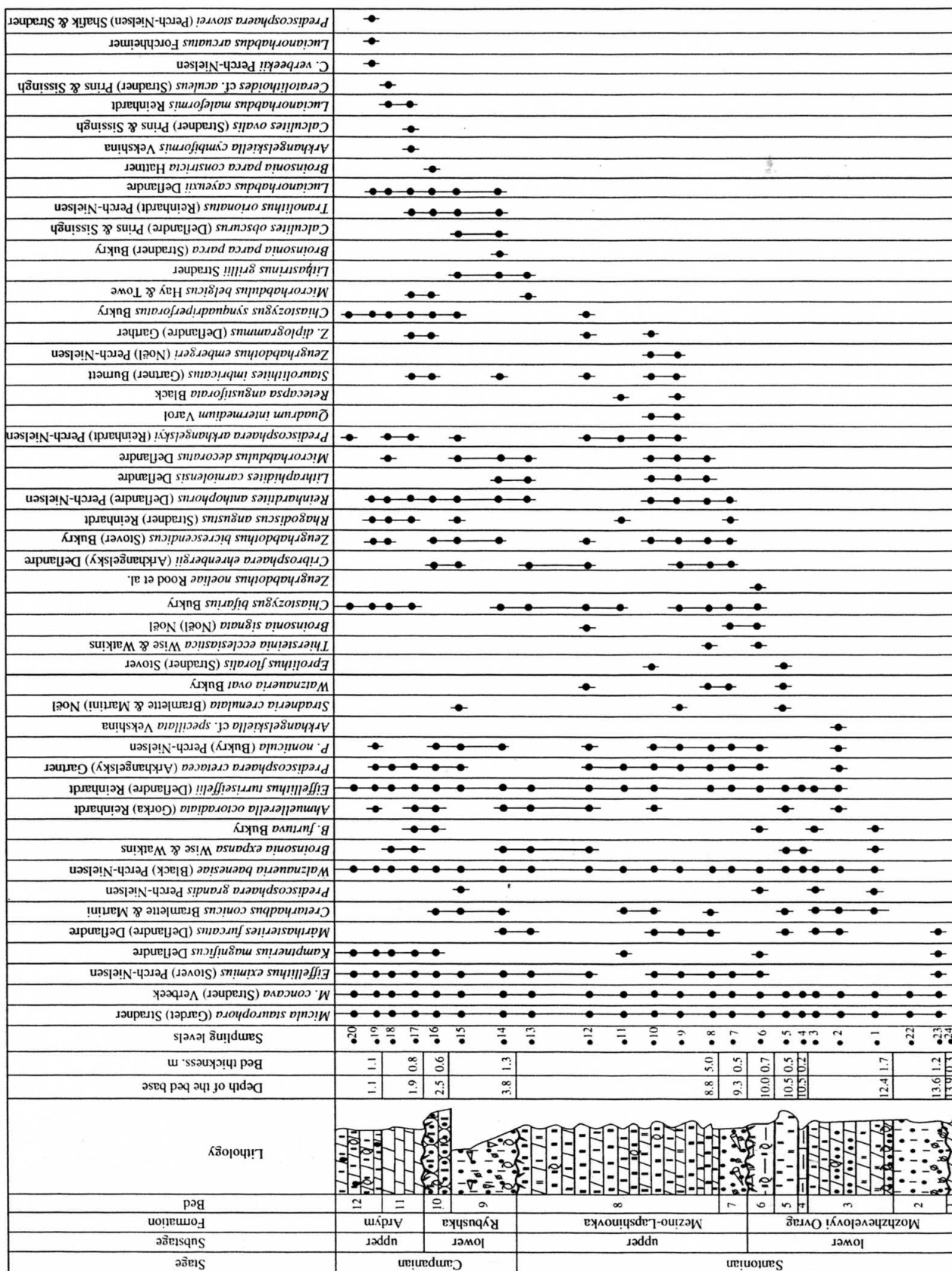


Fig. 7. Distribution of calcareous nannoplankton in the Mezino-Lapshinovka section (legend as in Fig. 2).

perfecta Zone spanning the middle–upper Santonian boundary layers is located above the *Cibicides eriksdalensis*–*Gavelinella vombensis* Zone. Thus, it should be correlated with the lower part of the upper Santonian Substage in case of the two-member subdivision of the stage. The *Cibicides eriksdalensis*–*Gavelinella vombensis* Zone can be considered as an equivalent of the *Gavelinella infrasantonica* Zone, because *Gavelinella vombensis* (Brotzen, 1945) is a senior synonym of *Gavelinella infrasantonica* (Balakhmatova, 1954) species (Beniamovskii and Kopaevich, 2001). Scarce small tests of *Gavelinella stelligera* (Marie) present in opokas terminating the Mozhzhevelovyi Ovrage Formation probably indicate transition to the upper Santonian *Gavelinella stelligera* Zone of the regional scale (Olfer'ev and Alekseev, 2003). It should be emphasized that the appearance of first non-typical tests of *Gavelinella ex gr. stelligera* in Mangyshlak is confined to the *Uitacrinus socialis* Zone (Naidin *et al.*, 1984b). This zone corresponds to the lower part of the upper Santonian Substage, when the stage is divided into three substages (Hancock and Gale, 1996; Lamolda and Hancock, 1996).

Based on radiolarians, the Mozhzhevelovyi Ovrage Formation is interpreted to be the Turonian–Santonian in age based on Pacific scales by Pessagno (1973, 1975, 1976) and on Tethyan scale by O'Doherty (1994), although all the taxa from the relevant assemblage, zonal species *Alievium superbum* included, either continue to exist or appear first in the Coniacian. Species, the lower distribution limit of which is restricted to the Coniacian, e.g., *Pseudoaulophacus venadoensis* Pess., *Archaeospongoprimum bipartitum* Pess., *A. triplum* Pess., and *A. nishiyanae* Nak. et Nish., likely point to the Coniacian age of the formation layers exposed in the quarry. On the other hand, similarity between the radiolarian assemblage in question and that from the middle Coniacian–lower Santonian Zagorsk Formation of the Moscow syncline (Olfer'ev *et al.*, 2000) implies the Coniacian–early Santonian radiolarian-based age of the Mozhzhevelovyi Ovrage Formation that is consistent with the transitional, Santonian or Santonian–Campanian affinity of assemblage from the uppermost Sample 6.

According to permanent occurrence of calcareous nannoplankton species *Micula staurophora* (Gard.) Stradn., the Mozhzhevelovyi Ovrage Formation can be correlated with the Zone CC14 corresponding to the Coniacian–lower Santonian in the Tethyan scale (Hardenbol *et al.*, 1998). Presence of *Micula concava* (Stradn.) Verb., the first appearance of which marks the base of the younger Santonian Zone CC15 (Verbeek, 1977; Perch-Nielsen, 1985), implies however that terminal beds of the unit may correspond to the Santonian. It should be emphasized that beginning from Bed 3 sediments permanently contain scarce specimens of *Pre-discosphaera grandis* Perch-Niels., the taxon that appears in northern Europe near the Coniacian–Santonian boundary (Burnett, 1988) simultaneously with *Micula concava* (Stradn.) Verb. On the other hand, sin-

gle specimens of *P. grandis* occur both below and above this level in the Olazagutia section of Spain proposed for the global stratotype of the Santonian lower boundary (Lamolda *et al.*, 2002). In addition, *Micula concava* is established in the upper Coniacian of the Carpathians in Romania (Melinte, 1999).

In general, data on all the organic remains suggest the early Santonian age of the Mozhzhevelovyi Ovrage Formation, although radiolarians from the unit are slightly older.

The Mezino-Lapshinovka Formation

As is shown above, inoceramids and belemnites unambiguously point to the late Santonian age of the Mezino-Lapshinovka Formation in its stratotype. Based on foraminifers, the lower part of Bed 8 can be reliably correlated with the upper Santonian *Gavelinella stelligera* Zone, as it is evident from appearance of typical large representatives of index species along with *Gyroidinoides turgidus* (Hag.) and *Eponides aff. grodnoensis* Akim. beginning from Bed 9. The assemblage from the upper part of Bed 8 (Sample 11) includes *Stensioeina cf. pommerana* Brotz., *Gavelinella dainae* (Mjatl.), *Quadrimorphina minuta* (Cushm.), and *Neoflabellina deltoidea* (Wedek.), and their host sediments are correlative therefore with the *Stensioeina pommerana* Beds (Olfer'ev and Alekseev, 2003). In northwestern Germany, the *Stensioeina pommerana*–*Eponides frankei* Zone corresponds to the upper part of *Marsupites* Beds (*Marsupites testudinarius* Zone) of the terminal Santonian. Thus, based on benthic foraminifers, the Mezino-Lapshinovka Formation should likely be correlated with the entire upper Santonian Substage.

Radiolarian assemblages from both the upper bed of Mozhzhevelovyi Ovrage Formation and the Mezino-Lapshinovka Formation are of the Santonian affinity, although its belonging to the basal part of the lower Santonian cannot be ruled out.

It is difficult to establish age of the Mezino-Lapshinovka Formation based on the calcareous nannofossils. Shcherbinina considers the Zone CC15 marked by the first appearance of *Reinhardtites anthophorus* (Defl.) Perch-Niels. as correlative with the upper Coniacian. In her opinion, this is also consistent with the first appearance of *Lithastrinus grillii* Stradn. near the top of the Mezino-Lapshinovka Formation. Based on the last species, Burnett (1998) defined Zone UC11 that was correlated by Shcherbinina with the Coniacian–Santonian boundary interval. In addition, it should be emphasized that *Thiersteinia ecclesiastica* Wise et Watk. and *Quadrum intermedium* Varol. disappear respectively in the lower and middle parts of the Mezino-Lapshinovka Formation. According to Burnett (1998), the first event is recorded inside the *Gauthiceras margae* Zone in the Southern realm and the second one in the *Peroniceras*

tridorsatim Zone, i.e., in the middle Coniacian of northern Europe.

The estimated older age of nannoplankton from the Mezino-Lapshinovka Formation is inconsistent with the data on other fossil groups. It can probably be explained by redeposition of nanofossils, which should disappear during the Coniacian, or by locally delayed appearance of younger index taxa, the phenomenon frequently observed in Upper Cretaceous section of high latitudes. In addition, the nannoplankton age younger than Coniacian is evident from several other facts. First, *Reinhardtites anthophorus* (Defl.) Perch-Niels., an index species of the lower Santonian Zone CC15 (Sissingh, 1977, 1978; Perch-Nielsen, 1985) occurs in the formation section beginning from its base. Second, *Zeughrabdotos diplogrammus* (Defl.) Gartn., which disappears in West Europe in the mid-upper Santonian *Uintacrinus socialis* Zone (Burnett, 1998), is present only in samples 10 and 12. Third, Ovechkina (2002) found *Lucianorhabdus cayeuxii* Defl. in the Mezino-Lapshinovka Formation of the Pudovkino section. This taxon characteristic of the upper Santonian Zone CC16 (Perch-Nielsen, 1985) appears in the Olzagutia section of Spain immediately below the recently proposed Coniacian–Santonian boundary.

The Rybushka Formation

In the examined section, the Rybushka Formation spanning the lower–upper Campanian boundary strata in the stratotype is separated from the Mezino-Lapshinovka Formation by a considerable hiatus. Correspondence of Bed 9 to the terminal lower Campanian is substantiated by presence of belemnites *Belemnellocamax mammillatus mammillatus* (Nilss.) and *B. mammillatus volgensis* (Najd.), and this part of the section can be attributed to the *Belemnellocamax mammillatus* Zone of the regional scale (Olfer'ev and Alekseev, 2003). The same stratigraphic interval is indicated by foraminifers characteristic of the upper part of the *Bolivinoidea decoratus decoratus* (BF4) Zone in the scale proposed for the European paleobiogeographic region (Beniamovskii and Kopaevich, 2001). The appearance of *Broinsonia parca parca* (Stradn.) Bukry among nanofossils also implies that Bed 9 is correlative with the lower Campanian.

In Bed 10, *Belemnellocamax* forms are accompanied by *Belemnitella mucronata mucronata* (Schloth.) and *B. mucronata senior* (Now.), which are of a little significance, because these subspecies occur in both the terminal lower and basal upper Campanian (Naidin, 1964). The appearance of *Broinsonia parca constricta* Hattn. in the nannoplankton assemblage suggests that sandstones of Bed 10 are not older than the lower Campanian Zone CC18 at least. Thus, the Rybushka Formation, which is of the early–late Campanian age considered in the standard Upper Cretaceous stratigraphic

scale, in the Mezino-Lapshinovka section is represented by lower Campanian strata only.

The Ardym Formation

Correlation of the Ardym Formation with the lower zone of the upper Campanian is unambiguously confirmed by ammonites *Hopliplacenticerias coesfeldense coesfeldense*, *H. coesfeldense* cf. *costulosum* (Schlüt.), *H. cf. vari* (Schlüt.), and *Trachyscaphites gibbus* (Schlüt.) found in the unit. This assemblage is typical of the West European *Hopliplacenticerias marroti* Zone. The late Campanian age of the formation is also consistent with finds of belemnites *Belemnitella mucronata mucronata* (Schloth.) and *B. mucronata senior* (Now.). Inoceramids *Cataceramus balticus* (Böhm.), *C. barabini* (Mort.), *C. buguntaensis* (Dobr. et Pavl.), *C. convexus* (Hall et Meek), *C. decipiens* (Zitt.), *C. regularis* (d'Orb.), and *C. wegneri* (Böhm.) occurring in the Ardym Formation are most characteristic of the upper Campanian, although their stratigraphic range spans the entire Campanian and Maastrichtian as well. The benthic foraminifer assemblage, which is typical of the upper portion of the *Brotzenella monterelensis* Zone, also supports the age estimated above.

At first sight, the successive appearance of *Broinsonia parca parca* (Stradn.) Bukry (Sample 14), *B. parca constricta* Hattn. et al. (Sample 16), and *Ceratholitoidea verbeckii* Perch-Nielsen (Sample 19) among calcareous nannoplankton indicates the early Campanian age of host sediments (subzones a, b, and c, respectively). This inference is however inconsistent with appearance of *Calculites ovalis* (Stradn.) Prins et Siss., which is characteristic of the upper Campanian Zone CC19, at the base of the Ardym Formation (Sample 17). The late Campanian age of nannoplankton is also supported by presence of *Prediscosphaera stovei* (Perch-Niels.) Shof. et Stradn. in Sample 19. Burnett (1998) reported on first appearance of this species in the upper Campanian *Caleola basiplanata*–*Trachyscaphites spiniger* Zone of northwestern Germany.

In the regional Upper Cretaceous stratigraphic scale of the East European platform, the Ardym Formation is correlated with standard *Bostrychoceras polyplacum* and *Didymoceras donezianum* zones. The new data show that the lower boundary of the formation should be placed at least inside the *Hopliplacenticerias marroti* Zone.

THE CONIACIAN–SANTONIAN BOUNDARY

As is evident from presented biostratigraphic data, there is a substantial discrepancy between ages of the Mozhevelovyi Ovrage and Mezino-Lapshinovka formations, which are estimated based on different fossil groups. Considerable difficulties in interpretation of calcareous nannoplankton assemblages are related, in our opinion, to three causes. These are (1) ambiguously understood and calibrated zonations of calcareous nan-

Changes in stratigraphic ranges of nannofossil zones and their correlation with zonations based on ammonites and inoceramids and with units of the standard scale

Regional scale of the Esat European platform				Cretaceous biostratigraphy (Hardenbol <i>et al.</i> , 1998)				Nannoplankton biostratigraphy (Burnett, 1998)						
General stratigraphic scale (Olfer'ev and Alekseev, 2002)			Regional units (Olfer'ev and Alekseev, 2002)	Geochronological scale		Biochronozones and biochronohorizons								
Stage	Substage	Zonation		Local zones	Stage	Substage	Zonation			Stage	Zonation			
		ammonite	nannoplankton				ammonite	inoceramids	nannoplankton		echinoids	nannoplankton		
Campanian	lower	<i>Placenticerias bidorsatum</i>		<i>Belemnitella praecursor mucronatiformis</i>	Campanian	lower	<i>Placenticerias bidorsatum</i> 83.46			Campanian	<i>Offaster pilula</i>	UC 14		
		CC 18 B. parca					<i>Endocostea baltica</i> 83.46	CC 18 <i>Aspidolithus parvus</i> 82.58	UC 13					
Santonian	upper	<i>Placenticerias polyopsis</i>		<i>Sphenoceramus patootensis/ Belemnitella praecursor praepraecursor</i>	Santonian	upper	<i>Placenticerias paraplanum</i> 84.60			Santonian	<i>Marsupites testudinarius</i>	UC 12		
		<i>Placenticerias paraplanum</i>					<i>Sphenoceramus pinniformis</i> 84.32	CC 17 <i>Calculites obscurus</i> 84.32						
	lower	<i>Texanites gallicus</i>				<i>Texanites texanus/Sphenoceramus cardissoides/Belemnitella propinqua propinqua</i>	middle	<i>Placenticerias polyopsis</i>	<i>Placenticerias polyopsis</i> 84.60			<i>Uintracrinus socialis</i>	UC 11	
		CC 15 Reinhardtites anthophorus	CC 16 Licianorhabdus cayeuxii						<i>Cordiceramus cordiformis</i> 84.90		CC 16 <i>Eprolithus floralis</i> <i>Licianorhabdus cayeuxii</i>			
Coniacian	middle	<i>Peronicerias tridorsatum</i>	CC 14 <i>Micula staurophora</i>	<i>Mapadiceramus subquadratus</i>	Coniacian	middle	<i>Texanites gallicus-Texanites tenans</i> 85.79			Coniacian	<i>Micraster coranguinum</i>	UC 10		
		<i>Gauthiericeras margae</i>					<i>Texanites texanus/Sphenoceramus cardissoides/Cladoceramus undulatopticatus</i> 85.66	CC 15 <i>L. septenarius</i> <i>Reinh. anthophorus</i> <i>Micula concava</i> <i>Lithastrinus grillii</i>						
Coniacian	upper	<i>Paretexanites serrato-marginatus</i>	CC 14 <i>Micula staurophora</i>	<i>Mapadiceramus subquadratus</i>	Coniacian	upper	<i>Paratexanites serrato-marginatus</i> 87.28			Coniacian	<i>Micraster cortestudinarium</i>	UC 9		
		<i>Gauthiericeras margae</i>					<i>V. involutus</i> <i>V. koeneni</i>	CC 14 <i>Micula decussata</i> <i>Micula staurophora</i> 88.55						
												CC 16		
												CC 17		
												CC 18		
												CC 15		
												CC 14		
												CC 13		

Ammonite stratigraphy of the Munster Basin (Kaplan and Kennedy, 2000)			Biostratigraphic scale of Europe (Troger, 2000)	Stratification of the Upper Cretaceous Kalaat-Senan section in Tunisia (Robaszynski <i>et al.</i> , 1998)			Stratification of the Coniacian-Santonian interval in the Olazagutia section (Navarra, Spain) (Lamolda <i>et al.</i> , 2002)			
Stage	Substage	ammonite zonation	Faunal zones of the Lagerdorf section, northwestern Germany	inoceramid zonation	Stage	intervals with ammonites	bioevents	nannoplankton zonation	Zonation	
									Stage	inoceramid
Campanian	lower	<i>Placenticerias bidorsatum</i>	<i>Goniteuthis granulata quadrata</i>	<i>Sphenoceras patootensiformis</i> (zone 29)	?			CC 18 ↑ <i>Broinsonia parca parca</i>	Santonian	<i>Cordiceramus cordinitalis</i>
	middle	<i>Kitchinites emscheris</i>	<i>Micraster rogalae/ G. wesfalica granulata</i> <i>Micraster rogalae/ Goniteuthis wesfalica</i>	<i>Cordiceramus cordiformis</i> (zone 27)	CC 16 ↑ <i>Calculites obscurus</i>					
						lower	<i>Micraster corangiunum/ Goniteuthis westfalica</i>	<i>Cladoceras undulatoplicatus</i> (zone 26)		
Coniacian	upper	<i>Texanites pseudo-texanus</i> <i>Paratexanites serrato-marginatus</i>	<i>Sphenoceras pachtii/Cladoceras undulatoplicatus</i> <i>Micraster bucailli/ Goniteuthis prae-westfalica</i>	<i>Sphenoceras pachtii</i> (zone 25) <i>Magadiceramus subquadratus</i> (zones 23, 24)	?				<i>Texanites</i> sp. <i>Parate-xates, Protexa-nites</i>	← <i>Pesudo-schloen-bachia incons-tans</i> ↑ <i>Parate-xanites serrato-margi-natus</i>
						CC 16 ↑ <i>Lucianor-habidus cayenxii</i> <i>Lithastrinus septenarius</i> ↑ <i>Lithastrinus grillii</i>				

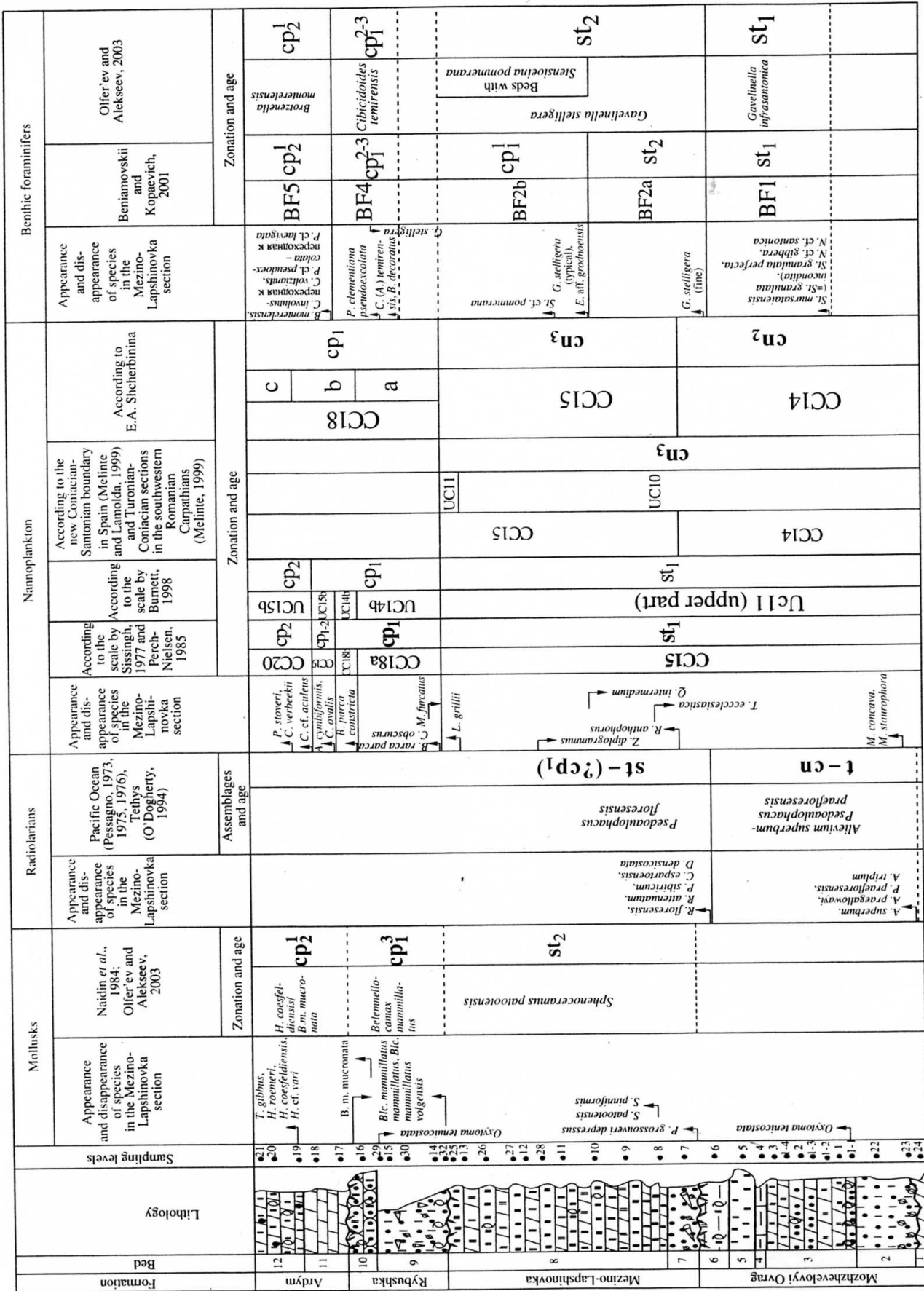


Fig. 8. Ages estimated for sediments exposed in the Mezino-Lapshinovka quarry based on different fossil groups (legend as in Fig. 2).



Plate I. Mollusks from the Mezino-Lapshinovka, Rybushka, and Ardym formations (natural size).

(1a, 1b) *Belemnitella praecursor* Stolley, specimen 4010, Bed 7: (a) dorsal view, (b) side view; (2a, 2b) *Actinocamax verus* cf. *fragilis* Arkhangelsky, specimen 4012, Bed 7: (a) ventral view, (b) side view; (3a, 3b) *Paractinocamax grossouvrei depressus* (Andreae), specimen 4008, Bed 7: (a) dorsal view, (b) side view; (4a, 4b) *Belemnelloamax mammillatus mammillatus* (Nilsson), specimen 4019, Bed 10: (a) dorsal view, (b) side view; (5) *Belemnelloamax mammillatus volgensis* Najdin, specimen 4005, Bed 10, dorsal view; (6a, 6b) *Belemnitella mucronata mucronata* Arkhangelsky, specimen 4015, Bed 12 (base): (a) dorsal view, (b) side view; (7) *Syncyclonema splendens* (Lahusen), specimen 4014, Bed 10.

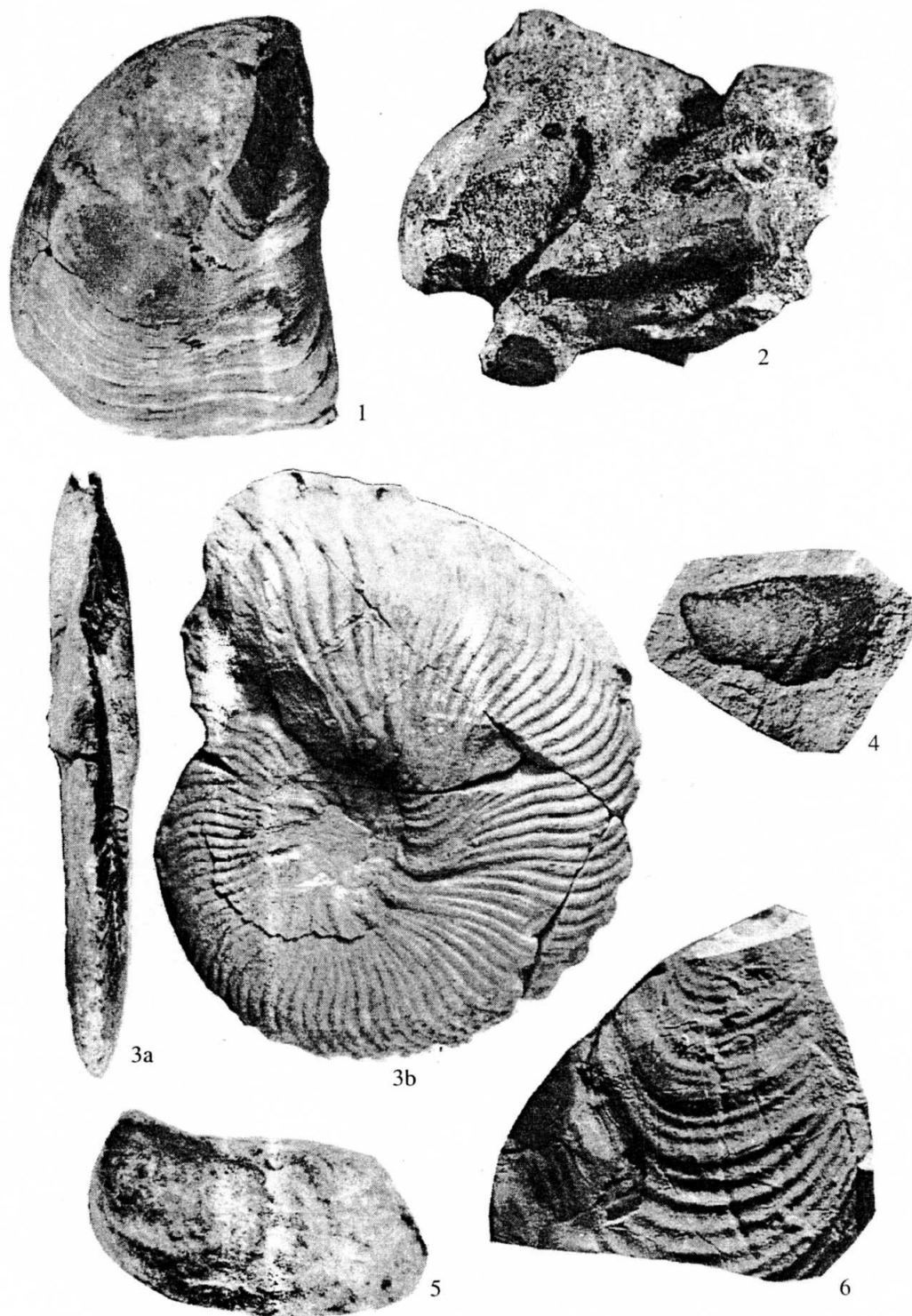


Plate II. Mollusks from the Rybushka and Ardym formations (natural size).

(1) *Monticulina vesicularis* (Lamarek), specimen 4011, Bed 12; (2) Accumulation of belemnite rostra in glauconitic sandstone, Bed. 10; (3a, 3b) specimen SVB 4037, lower part of Bed 12: (a) ventral view, (b) side view; (4) *Cataceramus barabini* (Morton), specimen 12/8, Bed 12; (5) *Cataceramus balticus* (Böhm.), specimen 12/3, Bed 12; (6) *Sphenoceramus patootensis*, specimen 8/38, Bed 8.

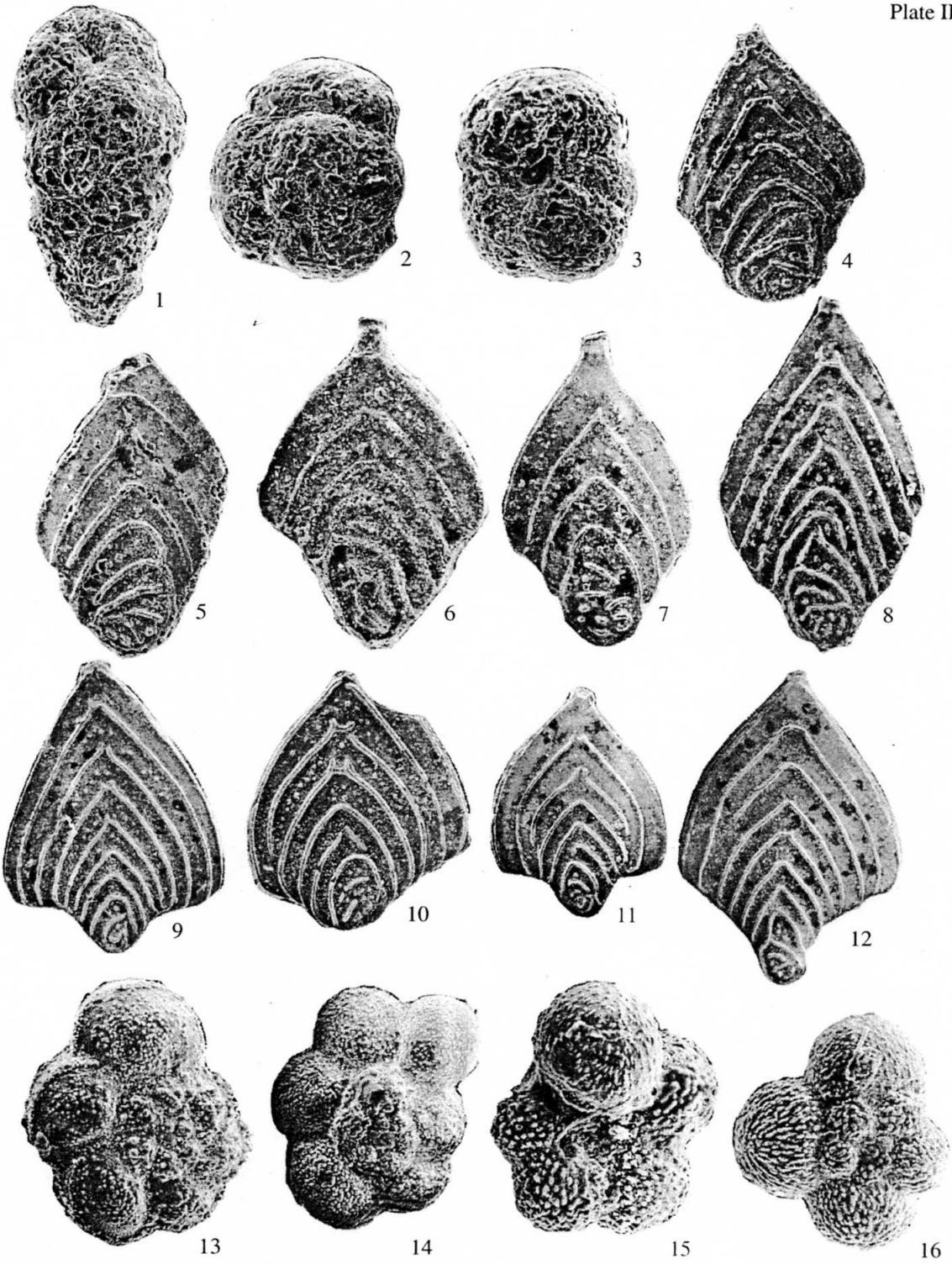


Plate IV. Benthic foraminifers from the Mozhzheveloyi Ovrage, Mezino-Lapshinovka, and Ardym formations (genera *Neoflabellina*, *Stensioeina*, *Osangularia*, *Gavelinella*, *Eponides*, *Quadriformina*, *Praebulimina*).

(1) *Neoflabellina rugosa leptodisca* (Wedekind), specimen GIN ML 14; Sample 17, Bed 11, Ardym Formation; $\times 40$; (2) *Neoflabellina* cf. *santonica* Koch, specimen GIN ML 15; Sample 1, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (3) *Neoflabellina suturalis suturalis* (Cushman), specimen GIN ML 16; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 60$; (4) *Stensioeina granulata granulata* (Olbertz), specimen GIN ML 17; spiral view; Sample 2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (5) *Stensioeina granulata* cf. *perfecta* Koch, specimen GIN ML 18, spiral view; Sample 2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (6) *Stensioeina granulata* cf. *perfecta* Koch, specimen GIN ML 19, spiral view; Sample 1/2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 130$; (7) *Stensioeina mursalaiensis* Vassilenko, specimen GIN ML 20, spiral view; Sample 1, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 110$; (8) *Stensioeina mursalaiensis* Vassilenko, specimen GIN ML 21, umbonal view; Sample 2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 110$; (9) *Osangularia whitei* (Brotzen), specimen GIN ML 22, spiral view; Sample 2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 125$; (10) *Gavelinella stelligera* (Marie), specimen GIN ML 23, spiral view; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 110$; (11) *Gavelinella stelligera* (Marie), specimen GIN ML 24, spiral view; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 90$; (12) *Gavelinella stelligera* (Marie), specimen GIN ML 25, umbonal view; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 90$; (13) *Gavelinella stelligera* (Marie), specimen GIN ML 26, umbonal view; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 120$; (14) *Gavelinella stelligera* (Marie), specimen GIN ML 27, side view; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 140$; (15) *Eponides* aff. *grodnoensis* (Akimez), specimen GIN ML 28, spiral view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 120$; (16) *Eponides* aff. *grodnoensis* (Akimez), specimen GIN ML 29, side view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 125$; (17) *Eponides* aff. *grodnoensis* (Akimez), specimen GIN ML 30, side view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 115$; (18) *Quadriformina minuta* (Cushman), specimen GIN ML 31, umbonal view; Sample 26, Bed 8, Mezino-Lapshinovka Formation; $\times 150$; (19) *Praebulimina ventricosa* (Brotzen), specimen GIN ML 32, spiral view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 120$; (20) *Praebulimina ventricosa* (Brotzen), specimen GIN ML 33, spiral view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 130$.

noplankton species that are sensitive in distribution to influence paleobiogeographic factors; (2) diversity in views on position of the Coniacian–Santonian boundary in West Europe; and (3) unfortunate selection of the GSSP for the boundary between stages (table).

At present, two nannoplankton scales are in use: the Tethyan zonation proposed by Sissingh (1977) and modified by Perch-Nielsen (1985) and the Boreal scale elaborated recently by Burnett (1998) mainly based on sections in England. The last scale becomes increasingly popular, although “it is lacking calibration of proposed stage boundaries based on levels substantiated by macrofaunal remains” (Naidin, 2002, p. 40).

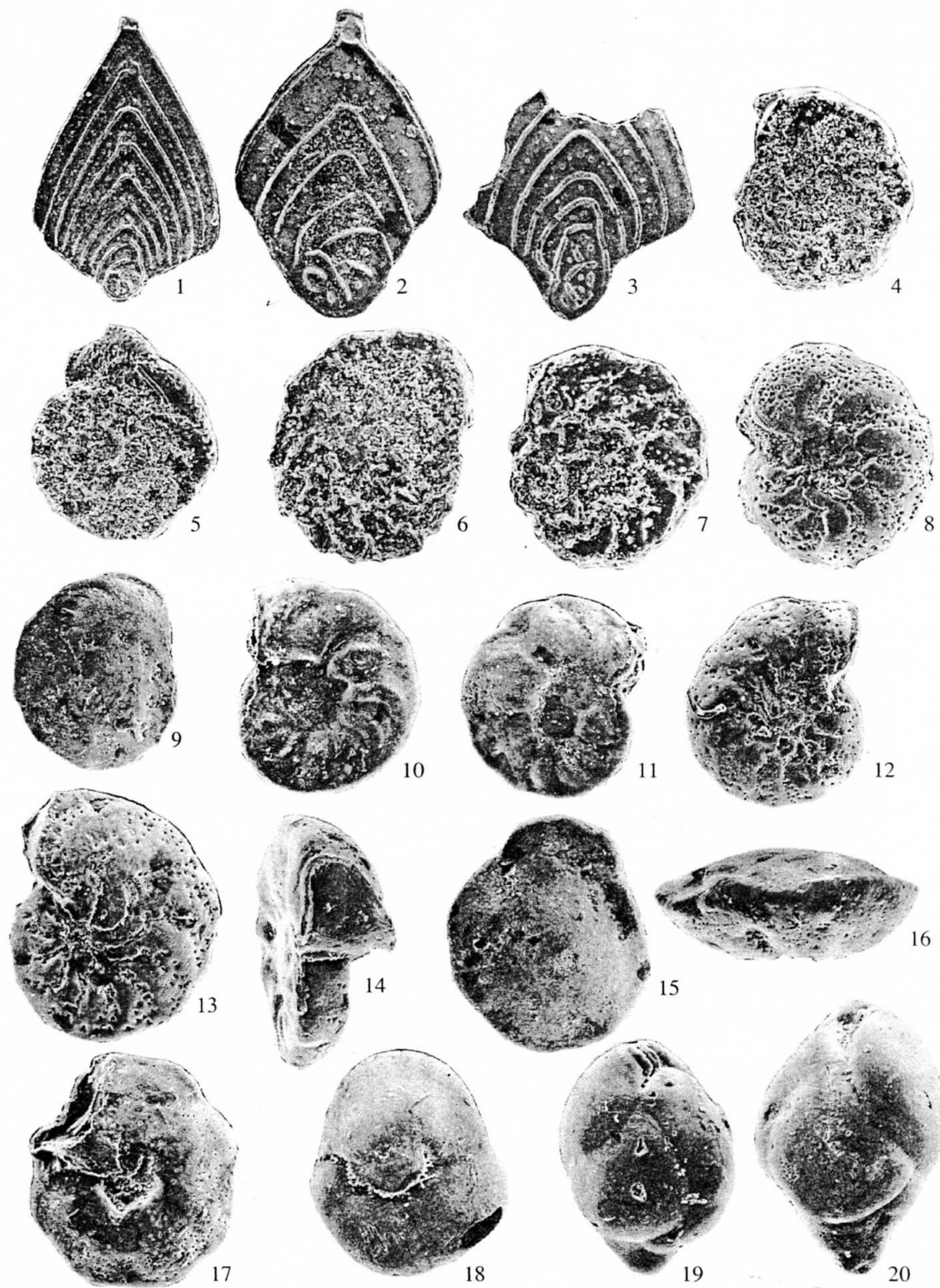
In the first scale, a certain attention is paid to paleobiogeographic differentiation of communities and asynchronous appearance and disappearance levels of many index species in different parts of their distribution areas. For example, C. von Salis demonstrated substantial difference in stratigraphic ranges of some taxa from Tethyan and Boreal realms beginning from the

Coniacian, as it is shown in “The Cretaceous chronostratigraphic framework of European basins” (Hardenbol *et al.*, 1998, Table 5). Similar comments exist also in zonation elaborated by Burnett. All this creates difficulties for zonal subdivision of the Upper Cretaceous sections based on nannoplankton, particularly in the case of sequences accumulated in the eastern part of the spacious West European–Russian sea.

Even greater difficulties are caused by recent innovations concerning position of the Coniacian–Santonian boundary. Already at the First International Symposium of 1984 on Stage Boundaries of the Cretaceous System, which was held in Copenhagen, most of participants tended to correlate the lower boundary of the Santonian Stage with the first appearance either of inoceramid species *Cladoceramus undulatopectatus* (Roem.) or ammonite subgenus *Texanites* (*Texanites*) emphasizing closeness or even synchronism of these biotic events (Birkelund *et al.*, 1984). In accordance with recommendations of the International Working

Plate III. Benthic foraminifers from the Mozhzheveloyi Ovrage and Mezino-Lapshinovka formations (genera *Harena*, *Novatrix*, *Neoflabellina*) and planktonic foraminifers from the Mezino-Lapshinovka Formation.

(1) *Harena amanda* (Woloschinova), specimen GIN ML 1, spiral view, Sample 1, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 90$; (2) *Novatrix obesa* (Reuss), specimen GIN ML 2, spiral view; Sample 1, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (3) *Novatrix obesa* (Reuss), specimen GIN ML 3, umbonal view; Sample 1/2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (4) *Neoflabellina* cf. *gibbera* (Wedekind), specimen GIN ML 4; Sample 1/2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 100$; (5) *Neoflabellina* cf. *gibbera* (Wedekind), specimen GIN ML 5; Sample 1/2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 90$; (6) *Neoflabellina* cf. *santonica* Koch, specimen GIN ML 6; Sample 1/2, Bed 3, Mozhzheveloyi Ovrage Formation; $\times 90$; (7) *Neoflabellina* cf. *santonica* Koch, specimen GIN ML 7; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 70$; (8) *Neoflabellina* cf. *gibbera* (Wedekind), specimen GIN ML 8; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 60$; (9) *Neoflabellina deltoidea* (Wedekind), specimen GIN ML 9; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 40$; (10) *Neoflabellina deltoidea* (Wedekind), specimen GIN ML 10; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 40$; (11) *Neoflabellina deltoidea* (Wedekind), specimen GIN ML 11; Sample 13, Bed 8, Mezino-Lapshinovka Formation; $\times 35$; (12) *Neoflabellina suturalis suturalis* (Cushman), specimen GIN ML 12; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 40$; (13) *Globotruncana globigerinoides* (Marie), specimen GIN ML 34, spiral view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 115$; (14) *Whiteinella* sp. or *Archaeoglobigerina* sp., specimen GIN ML 35, spiral view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 95$; (15) *Helvetiella* sp., specimen GIN ML 36, umbonal view; Sample 28, Bed 8, Mezino-Lapshinovka Formation; $\times 170$; (16) *Rugoglobigerina rugosa* (Plummer), specimen GIN ML 37, spiral view; Sample 37, Bed 8, Mezino-Lapshinovka Formation; $\times 135$.



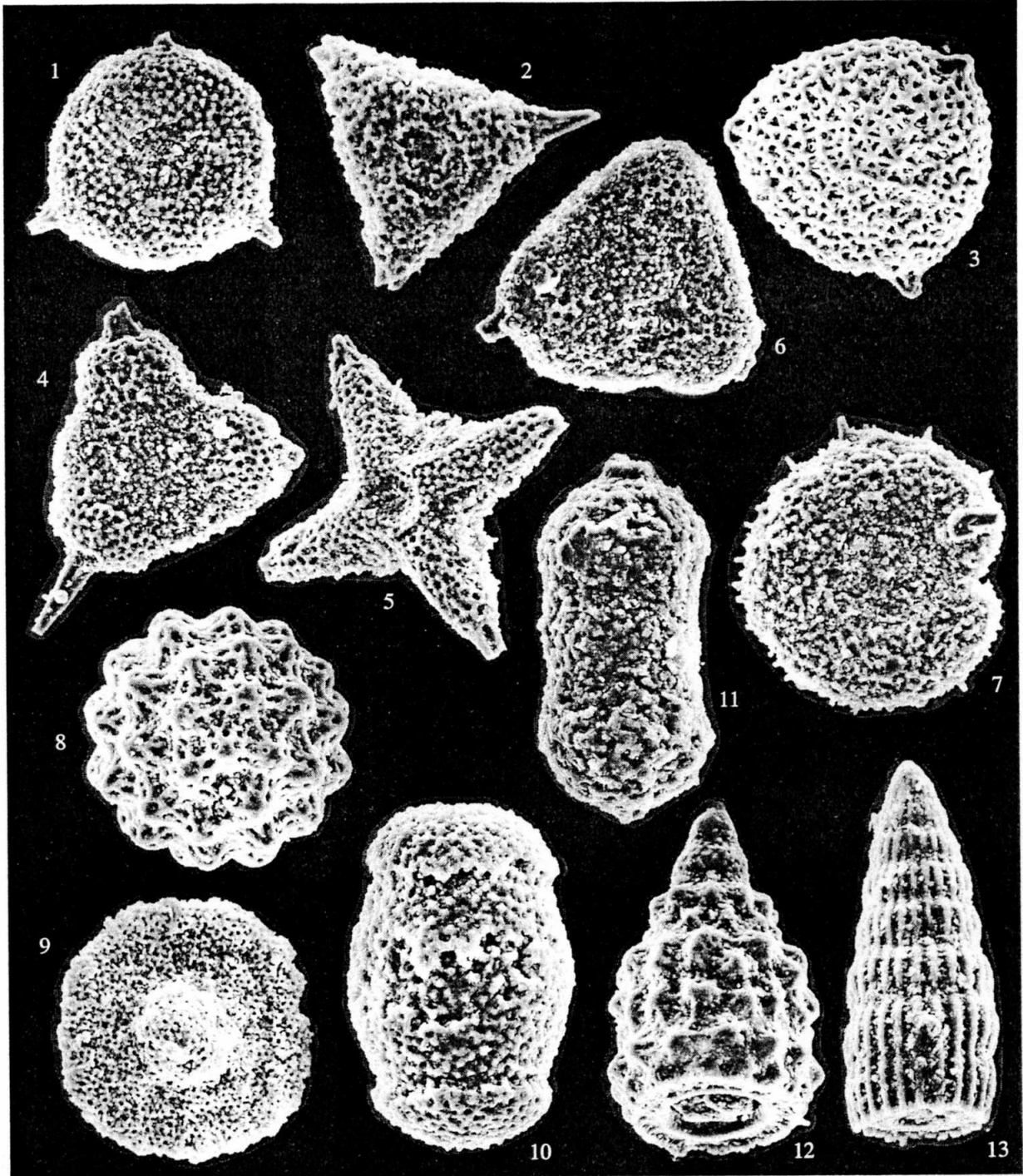


Plate V. Radiolarians from Turonian–Coniacian *Alievium superbum* and *Pseudoaulophacus praeflorescens* assemblages (Bed 2, Sample 22, figs. 9, 11, 13; Bed 3, Sample 1, figs. 1–2, 5–8; Bed 5, Sample 5, figs. 4, 10, 12).

(1, 2) *Pseudoaulophacus praeflorescens* Pessagno: (1) $\times 90$, (2) $\times 75$; (3) *Alievium* aff. *praegallowayi* Pess., $\times 90$; (4) *Euchitonia* cf. *santonica* Lipman, $\times 100$; (5) *Crucella cachensis* Pess., $\times 80$; (6) *Pseudoaulophacus venadoensis* Pess., $\times 110$; (7) *Orbiculiforma per-senex* Pess., $\times 100$; (8) *Praeconocaryomma universa* Pess., $\times 80$; (9) *Cavaspongia* sp. cf. *C. fiskensis* Pess., $\times 110$; (10) *Phaseliforma concentrica* (Lipman), $\times 100$; (11) *Archaeospongoprimum bipartitum* Pess., $\times 80$; (12) *Xitus asymbatos* (Foreman), $\times 100$; (13) *Dic-tyomitra striata* Lipman, $\times 100$.

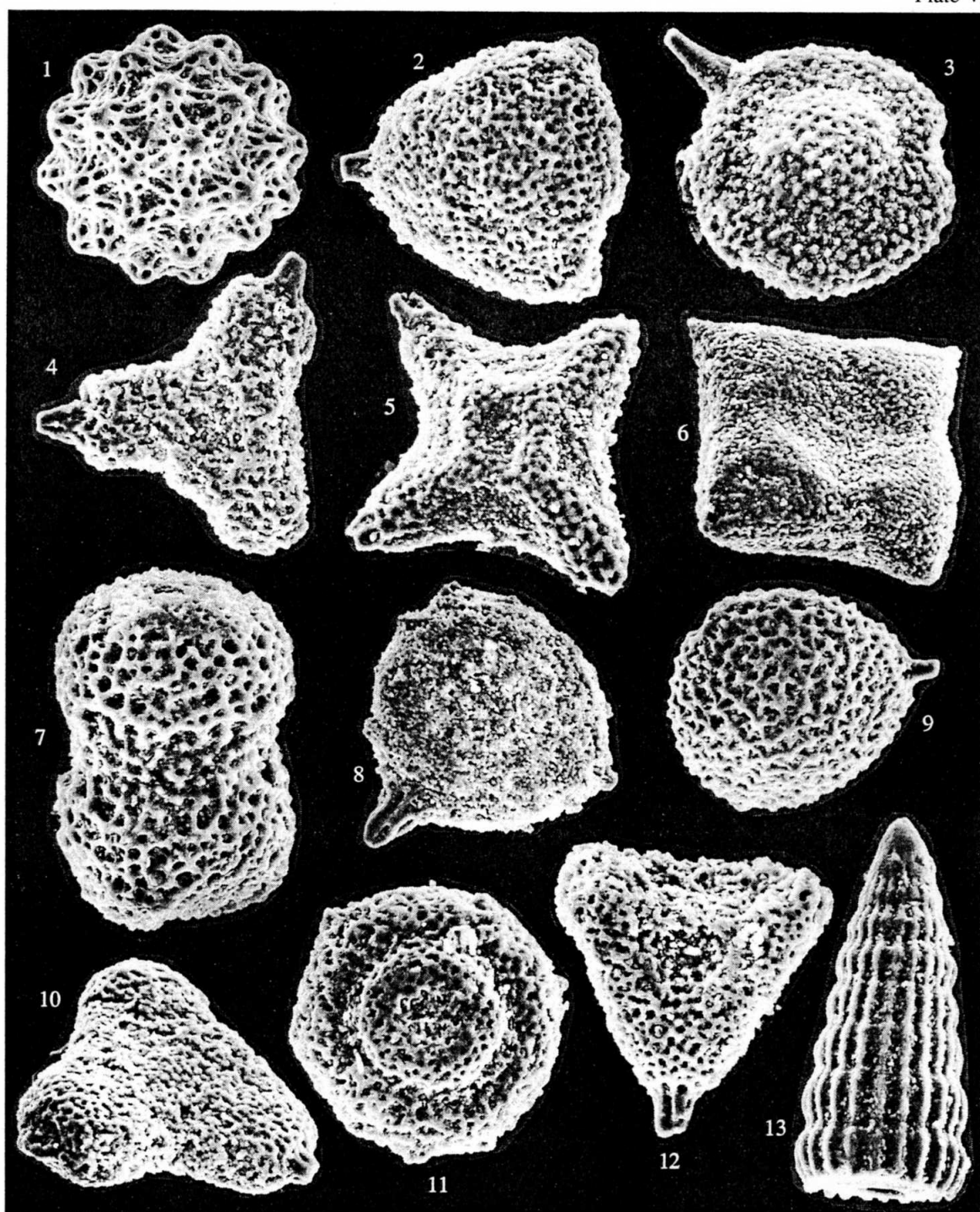
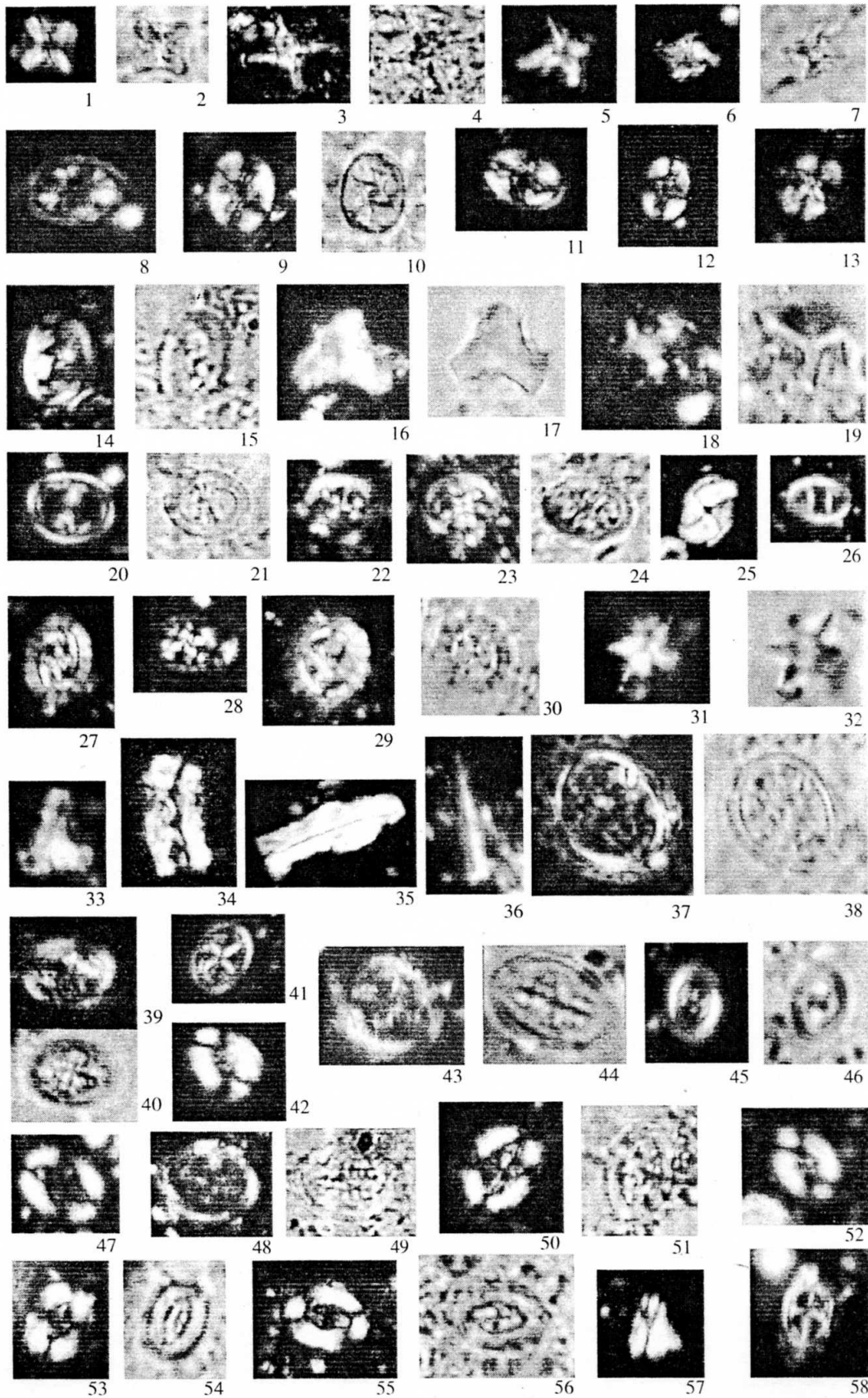


Plate VI. Radiolarians from Santonian *Pseudoaulophacus floresensis* assemblage (Bed 6, Sample 6, figs. 1–3; Bed 8, Sample 12, figs. 4–7) and from Turonian–Coniacian *Alievium superbum* and *Pseudoaulophacus praefloresensis* assemblages (Bed 3, Sample 1-1, figs. 8, 9; Bed 5, Sample 5, figs. 10–12).

(1) *Praeconocaryomma universa* Pess., $\times 100$; (2, 3) *Pseudoaulophacus floresensis* Pess., $\times 100$; (4) *Rhopalastrum attenuatum* Lipm., $\times 80$; (5) *Crucella* cf. *espartoensis* Pess., $\times 100$; (6) *Hestiastrum latum* Lipm., $\times 90$; (7) *Prunobrachium ornatum* (Lipm.), $\times 100$; (8) *Cavaspongia euganea* (Squin.), $\times 90$; (9) *Alievium superbum* (Squin.), $\times 90$; (10) *Euchitonia* aff. *santonica* Lipm., $\times 100$; (11) *Pseudoaulophacus* cf. *lenticulatus* (White), $\times 70$; (12) *Pseudoaulophacus* cf. *floresensis* Pess., $\times 90$; (13) *Dictyomitra striata* Lipman, $\times 80$.



Group on the Coniacian–Santonian Boundary, it was proposed at the Second International Symposium on Stage Boundaries of the Cretaceous System (Brussels, 1995) to be the base of the Santonian Stage, which corresponds to the first appearance level of *Cladoceramus undulatoplicatus* (Roem.).

In our opinion, selection of ammonites instead of inoceramids would be more reasonable to define that boundary, because the first appearance of the genus *Texanites* and, in particular, of *Texanites texanus* (Roem.) is synchronous with appearance of cardissoid sphenoceramids of the *Sphenoceramus pachtii*–*S. cardissoides* group widespread in the Boreal realm. In the mentioned fundamental work “The Cretaceous chronostratigraphic framework of European basins” (Hardenbol *et al.*, 1998, Table 5), J. Thiery with colleagues correlated the base of the Santonian Stage with the first appearance of *Texanites texanus* (Roem.) in southern Europe and *T. gallicus* Coll. in northern Europe. In opinion of A. Dondt, this event is synchronous with appearance of inoceramids *Cladoceramus undulatoplicatus* (Roem.) in central Europe and *Sphenoceramus cardissoides* (Goldf.) in East Europe. This standpoint was basic for elaboration of the regional Upper Cretaceous stratigraphic scale of the East European platform (Olfer'ev and Alekseev, 2002, 2003).

Lamolda and Hancock (1996), who noted the joint occurrence of *Texanites* forms and Coniacian inoceramid species *Magadiceramus subquadratus* (Schlüt.) in Texas and northern Spain, opposed this decision. In addition, they emphasized the earlier appearance of inoceramids from the *Sphenoceramus pachtii*–*S. cardissoides* group, as compared with first occurrence of *Cladoceramus undulatoplicatus* (Roem.) in Austria and Germany. Previously, similar facts were published by Tröger (1989) who defined the *Sphenoceramus pachtii*

Zone (25) at the base of the Santonian Stage and below *Cladoceramus undulatoplicatus* Zone (26). Subsequently, Kaplan and Kennedy (2000) correlated the *Sphenoceramus pachtii* Zone with the *Texanites pseudotexanus* ammonite zone (in their opinion, an equivalent of the *Texanites texanus* Zone) and attributed it to the terminal part of the Coniacian Stage. Subsequently, Tröger (2002) agreed with the Coniacian age of the Zone 25.

At the meeting in Brussels, sections of the Olazagutia quarry in the Navarra Province of Spain, Seaford Head site in the Sussex County of England, and Ten Mile Creek in Texas, the United States, were recommended as candidates for the global stratotype of the boundary in question (Lamolda and Hancock, 1996), and the first section was favored later on.

In the Olazagutia quarry, which was demonstrated to participants of the International Symposium on the Coniacian–Santonian boundary (Lamolda *et al.*, 2002), the 160-m-thick sequence of marls and clayey limestones spans interval from the middle Coniacian to middle Santonian. Occurrence of *Magadiceramus subquadratus subquadratus* (Roem.) that marks the base of the upper Coniacian is recorded at the level of 64.6 m. The overlying interval from 64.6 to 94.4 m is almost barren of macrofossils, except for echinoid species *Cardiaster integer* (Agass.) and *Micraster brevis* Desor. Nevertheless, this interval was attributed to the upper Coniacian *Magadiceramus subquadratus* Zone. The level of 94.4 m with *Cladoceramus undulatoplicatus* (Roem.) was taken for the base of the Santonian and, consequently, for the global stratotype of the stage lower boundary, although specimens of above taxon occur higher up to the level of 105.9 m.

The first ammonites in the section under consideration were found at levels of 139.2 and 151.6 m, where

Plate VII. Microphotographs of principal nannoplankton species from the Mezino-Lapshinovka section.

(1, 2) *Micula staurophora* (Gardet) Stradner, Sample 16: (1) polarized light, (2) nonpolarized light; (3–7) *Micula concavata* (Stradner) Verbeek: (3, 4) Sample 10: (3) polarized light, (4) nonpolarized light (5–7) Sample 16: (5, 6) polarized light, (7) nonpolarized light; (8) *Ahmuelerella octoradiata* Reinhardt, Sample 12, polarized light; (9–11) *Eiffellithus eximius* (Stover) Perch-Nielsen: (9) Sample 8, polarized light, (10, 11) Sample 10: (10) nonpolarized light, (11) polarized light; (12, 13) *Eiffellithus turriseiffeli* (Deflandre) Reinhardt, Sample 4: (12) polarized light, (13) nonpolarized light; (14, 15) *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen, Sample 13; (16–19) *Marthasterites furcatus* (Deflandre) Deflandre: (16, 17) Sample 9: (16) polarized light, (17) nonpolarized light, (18) Sample 2, polarized light, (19) Sample 5, nonpolarized light; (20, 21) *Reinhardtites* sp., Sample 10: (20) polarized light, (21) nonpolarized light; (22–24) *Chiastozygus bifarius* Bukry, Sample 8: (22, 23) polarized light, (24) nonpolarized light; (25) *Calculites ovalis* (Stradner) Prins et Sissingh, Sample 17, polarized light; (26) *Tranolithus orionatus* (Reinhardt) Perch-Nielsen, Sample 16, polarized light; (27) *Prediscosphaera arkhangel'skyi* (Reinhardt) Perch-Nielsen, Sample 9, polarized light; (28) *Prediscosphaera ponticola* (Bukry) Perch-Nielsen, Sample 14, polarized light; (29) *Prediscosphaera grandis* Perch-Nielsen, Sample 15, polarized light; (30) *Prediscosphaera cretacea* (Arkhangelsky) Gartner, Sample 14, polarized light; (31, 32) *Lithastrinus grillii* Stradner, Sample 14: (31) polarized light, (32) nonpolarized light; (33, 35) *Lucianorhabdus maleformis* Reinhardt, Sample 19, polarized light; (34) *Lucianorhabdus cayeuxii* Deflandre, Sample 16, polarized light; (36) *Acuturris scotus* (Risatti) Wind et Wise, Sample 15, polarized light; (37, 38) *Kampfterius magnificus* Deflandre, Sample 16: (37) polarized light, (38) nonpolarized light; (39, 40) *Broinsonia furtiva* Bukry, Sample 9: (39) polarized light, (40) nonpolarized light; (41) *Chiastozygus synquadriperforatus* Bukry, Sample 15, polarized light; (42) *Broinsonia parca constricta* Hattner, Sample 16, polarized light; (43, 44) *Broinsonia furtiva* Bukry, Sample 3, polarized light; (45, 46) *Zeughrabdothus noeliae* Rood *et al.*, Sample 6: (45) polarized light, (46) nonpolarized light; (47) *Broinsonia signata* (Noel) Noel, Sample 7, polarized light; (48, 49) *Arkhangelskiell cf. speculata* Vekshina, Sample 2: (48) polarized light, (49) nonpolarized light; (50, 51) *Broinsonia expansa* Wise et Watkins, Sample 13: (50) polarized light, (51) non-polarized light; (52) *Broinsonia* sp., Sample 13, polarized light; (53–56) *Broinsonia parca parca* (Stradner) Bukry, Sample 14: (53, 55) polarized light, (54, 56) non-polarized light; (57) *Ceratolithoides verbeeki* Perch-Nielsen, Sample 19, polarized light; (58) *Staurolithites imbricatus* (Gartner) Burnett, Sample 10, polarized light.

they are represented by typical Santonian forms *Placenticerus polyopsis* (Dujard.) and *Pseudoschloenbachia inconstans* (de Gross.). *Texanites* forms are unknown in the Olazagutia section, but judging from the neighboring Villamartin section their range can correspond approximately to the upper half of the barren interval of 64.6 to 94.4 m. In the Villamartin section, *Magadiceramus* forms occur in the interval of 48.5 to 58.7 m, which is overlain by a sequence lacking inoceramids, but containing *Texanites* species, *Texanites hispanicus* Coll. included. Appearance of the last taxon is recorded at the level of 85.0 m, while *Cladoceramus undulatoplicatus* (Roem.) first appears at the level of 144.7 m.

Nannofossils of the Olazagutia section were examined in the interval of 75.5 to 122.0 m by Melinte and Lamolda (2002) who concluded that the Santonian lower boundary should be inside the Zone CC16, i.e., substantially higher than in the scale of Perch-Nielsen (1985), where it is in the terminal part of the Zone CC14. Under assumption that this section is accepted for the GSSP of Santonian Stage, one should displace sequences traditionally referred to the Santonian, in particular, the Mozzhzhevelovyi Ovrage and Mezino-Lapshinovka formations, almost entirely down to the Coniacian, and such a decision would be far from being welcomed. As is shown above, a significant interval of the Olazagutia section is included into the Coniacian Stage without any proofs, although it should belong mostly to the Santonian, if we took into account the very short range of the *Magadiceramus subquadratus* Zone. Consequently, the level where *Cladoceramus undulatoplicatus* was found first does not represent the "appearance level" of this species. Thus, the Olazagutia section is unsuitable for the GSSP of the Coniacian-Santonian boundary.

AGE OF THE *PTERIA* BEDS

Lahusen (1873) was first to discover gray marl with shells of *Avicula tenuicostata* Roem. in the right side of the Volga River and to trace them from Simbirsk to the Podval'e Village of the Samara region. A year later, Trautschold (1874) also noted presence of *Avicula* marls in the Novodevich'e Village area. Stratigraphic position of these rocks between underlying Turonian chalk with abundant inoceramids and overlying Senonian glauconitic marl was established by Pavlov (1897) in the Simbirsk region, who referred siliceous marls with *Avicula tenuicostata* Roem. to the Turonian. Later on, Arkhangel'skii (1912), who elaborated the regional Upper Cretaceous scheme for the Saratov region, defined the *Inoceramus patchi* (now *Sphenoceramus cardissoides*) and *Pteria tenuicostata* zones in the former *Avicula* sequence. He referred both zones to the lower Senonian. Discussing the problem of the *Pteria tenuicostata* Zone age and taking into account presence of lower Senonian *Actinocamax verus* Mill. and *Belemnitella precursor* Stoll., which occur together with *Pte-*

ria tenuicostata (Roem.) known "only from the *Actinocamax* [now *Goniot euthis*] *quadratus* Zone of England, i.e., from the basal part of the upper Senonian," Arkhangel'skii (1912, pp. 198–199) believed that the zone should be correlated with the lower–upper Santonian boundary interval, contrary to Pavlov (1900), who initially considered the *Avicula* Marls first as the Turonian and later as Emsherian in age. Milanovskii (1940) defined *Inoceramus cardissoides* and *Pteria tenuicostata* zones in the previously undivided sequence of *Avicula* Marls and referred them to the lower and upper Santonian, respectively. It should be noted that Milanovskii placed the boundary between these units in the Nizhnyaya Bannovka section based on erosion signs in the form of glauconitic sandstone bed "with the uneven lower surface and rhizoconcretions penetrating the underlying opokas" (Milanovskii, 1940, p. 198, Bed 10).

D.P. Naidin (Naidin, 1960, 1979; Gerasimov *et al.*, 1962; Najdin, 1969; Naidin and Kopaeovich, 1977; Naidin *et al.*, 1984a, 1986) emphatically vindicated the Campanian age of beds with *Oxytoma tenuicostata* (Roem.), which he called the *Pteria* Beds, whereas other researchers considered them as Santonian in age. To solve the problem of the unit age, the Commission on the Cretaceous System of the USSR Interdepartmental Stratigraphic Committee organized four field symposia under scientific leadership of D.P. Naidin and G.N. Papulov with participation of specialists on different fossil groups. Sharing the standpoint of Arkhangel'skii on the probable partial correspondence of beds with *Pteria tenuicostata* (Roem.) to the *Actinocamax quadratus* Zone of England, Naidin correlated "*Pteria* Beds" with the *Goniot euthis granulata quadrata* Zone of Germany and southwestern Russia, although *Oxytoma tenuicostata* (Roem.) is virtually unknown in the last region. Pasternak (1959) found the only specimen of this form in a core from borehole drilled near the Berezina Village in western Ukraine and attributed the relevant bed to the upper Santonian.

Some researchers doubted correctness of correlation proposed by Naidin because of the wide stratigraphic range of *Oxytoma tenuicostata* (Roem.) known from the upper part of the lower Santonian "banded sequence" in the Lysaya Gora section of Saratov and at the Pudovkino site (Ivanov and Pervushov, 1998). In addition, Naidin himself noted presence of this species at the same stratigraphic level in the Sengilei section near Ul'yanovsk. Moreover, referring to results of H. Frebald, V. Minke, and D. Donovan obtained in eastern Greenland, Naidin (1979, p. 19) emphasized abundance of *Oxytoma tenuicostata* (Roem.) in the lower Santonian layers "with inoceramids close to *Inoceramus cardissoides* (Goldf.)." It seems therefore that this *Oxytoma* form is actually of a wide stratigraphic range and occurs in the lower Campanian Substage. For instance, this form is characteristic of the *Quadrata* Chalk in England and Poland, being confined in the Krakow suburbs to the upper part of the *Goniot euthis*

quadrata quadrata Zone, an equivalent of *Pilula* and *Senonensis* zones in Germany, and to higher stratigraphic levels. In addition, this taxon is known from *mammillatus* Beds of the Saratov region (Ivanov and Pervushov, 1998) and from their analogues in the Starodub area of the Bryansk region (materials by Olfer'ev). Glazunova (1972) found its abundant specimens of the taxon in basal layers of the upper Campanian *mucronata* Zone in the Ul'yanovsk region. Therefore, *Oxytoma tenuicostata* (Roem.) present in the *Quadrata* Chalk of West European sections cannot serve as evidence for the early Campanian age of *Pteria* Beds, which Naidin places at the base of the lower Campanian below the *Goniotethis quadrata quadrata* Zone of belemnite scale.

Naidin proposed to consider the Podval'e and Novodevich'e sites in the right side of the Volga River near Samara as the type area for the *Pteria* Beds. Defining the stratigraphic position of this unit within the Upper Cretaceous succession of the Volga River basin, he argued that it rests with a distinct hiatus upon the Santonian "banded sequence" and is overlain by "a sequence of bluish gray to gray opokas, siliceous clays, marls, glauconitic sands and sandstones containing rostra of belemnites *Belemnellocomax mammillatus* (Nils.) and *Belemnitella mucronata mucronata* Arkh. and belonging to the upper part of the lower Campanian" (Naidin, 1979, pp. 19–20). Precisely this stratigraphic position is characteristic of the Mezino-Lapshinovka Formation within the examined section.

Now, it is clear that the stratigraphic range of *Oxytoma tenuicostata* Biozone is extremely wide spanning at least the entire Santonian and Campanian. At the same time, the *Pteria* Beds of the Ul'yanovsk–Samara region (Sengilei, Podval'e, Usol'e, and Klimovka sections) or the Mezino-Lapshinovka Formation of the Saratov region, both yielding *Oxytoma tenuicostata* (Roem.) in abundance, cannot be attributed to the Campanian Stage. Data on all the examined orthostratigraphic groups and calcareous nannofossils indicate the late Santonian or even older age of the Mezino-Lapshinovka Formation.

CONCLUSION

Summarizing data on the reference section studied near the village of Mezino-Lapshinovka we arrived at the following inferences.

(1) Difference in ages estimated based on different fossils for sediments exposed in the Mezino-Lapshinovka quarry (Fig. 8) is a consequence of ambiguously interpreted ranges and boundary positions of units in the standard Cretaceous scale.

(2) Our studies show that ages estimated recently for radiolarian assemblages in different areas of the East European platform need a more reliable substantiation.

(3) The available parallel nannoplankton-based zonal scales elaborated for of the Mediterranean and

West European sections cannot be directly used for subdivision of the Upper Cretaceous sections in the Russian plate until a thorough study of this microphytoplankton group in reference sections of different structural–facies zones.

(4) Acceptance of the GSSP for the Coniacian–Santonian boundary in the Olazagutia section at the level proposed by the International Working Group (Lamolda *et al.*, 2002) will result in displacement of East European sequences with inoceramids of the *Sphenoceras cardissoides*–*S. pachti* group from the lower Santonian Substage down to the upper Coniacian Substage. The large interval of the Olazagutia section is included into the Coniacian Stage without sufficient substantiation, and it would be unreasonable to select the GSSP for the Coniacian lower boundary in this section.

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