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Upper Cretaceous Deposits in the Northwest of Saratov Oblast, Part 1: Litho- and Biostratigraphic Analysis of the Vishnevoe Section

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Abstract—The work is dedicated to multidisciplinary study of Upper Cretaceous deposits exposed at the day surface in a ravine near the village of Vishnevoe, the Petrovsk district of Saratov oblast. The exposed section includes deposits of the Bannovka, Mozzhevelovyi Ovrag, Mesino-Lapshinovka, Rybushka, Ardym, Lokh formations and of the Borisoglebsk sequence first distinguished in the Volga River basin. Age ranges of the formations studied are confirmed or defined more precisely (the Ardym and Lokh formations) based on fossil faunas of cephalopods, bivalves, radiolarians, planktonic and benthic foraminifers. The middle–upper Coniacian range of the Borisoglebsk sequence is substantiated. Distribution of brachiopods, sponges, radiolarians, ostracodes and calcareous nannoplankton in the section is established. Radiolarian assemblages are used to distinguish biostratigraphic subdivisions corresponding in rank to faunal beds. Based on nannofossil assemblages, zones and subzones of standard zonations after Perch-Nielsen (1985) and Burnett (1998) are established. Stratigraphic ranges of certain radiolarian, ostracode and calcareous nannoplankton taxa are verified.

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Key words: Turonian, Coniacian, Santonian, Campanian, and Maastrichtian stages, mollusks, brachiopods, sponges, benthic and planktonic foraminifers, radiolarians, calcareous nannoplankton zonation.

In 2001–2003, a group of geologists and paleontologists from Saratov and Moscow studied in collaboration the Upper Cretaceous reference section exposed in a small quarry near the village of Mesino-Lapshinovka in the Saratov oblast (Olfer'ev et al., 2004; Aleksandrova and Olfer'ev, 2005). According to its structural and facies characteristics, this section is within western part of the Ul'yanovsk–Saratov depression corresponding to the northern Saratov and Penza areas adjacent to the Volga River (*Stratigraphic*…, 2004). Because of hiatuses, the Mezino-Lapshinovka is lacking, however, the basal Cenomanian–Coniacian and Maastrichtian deposits and characterizes incompletely the entire stratigraphic succession of the Upper Cretaceous. To characterize the missed deposits, it was necessary, therefore, to seek for an exposed section that would include the upper Campanian, Maastrichtian and older strata. Our attention was attracted to the Upper Cretaceous section described by Mozgovoi (1969) in a ravine near the village of Vishnevoe (Kosolapovka) in the Petrovsk district of Saratov oblast 30 km north-northwestward of the Mezino-Lapshinovka quarry and 70 km away in the same direction from the oblast center (Fig. 1). In addition to continuous succession of the Campanian and Maastrichtian strata observable here, section of this ravine includes sandstones of the lower Campanian Rybushka Formation, which are also known in the Mezino-Lapshinovka section and represent a perfect reference horizon for the reliable upward extension of this section. The Upper Cretaceous deposits are exposed in the head area of the above steep ravine that is incised into surface of the Medveditsa–Chardym watershed area, being open into the last river directly neat the village of Vishnevoe. In terms of regional structure, the studied section is confined to northern flank of the Orkino uplift in western pericline of the Orkino–Irinovka swell. The Orkino uplift is surrounded by outcrops of Jurassic and Cretaceous deposits within the field of widespread Paleogene sediments. Beds in the ravine dip northwestward under angles 10°–20°. The laborious stripping of the section described by Olfer'ev has been performed under guidance of Ivanov and Sel'tser. Paleontological remains are collected and identified by Sel'tser (cephalopods

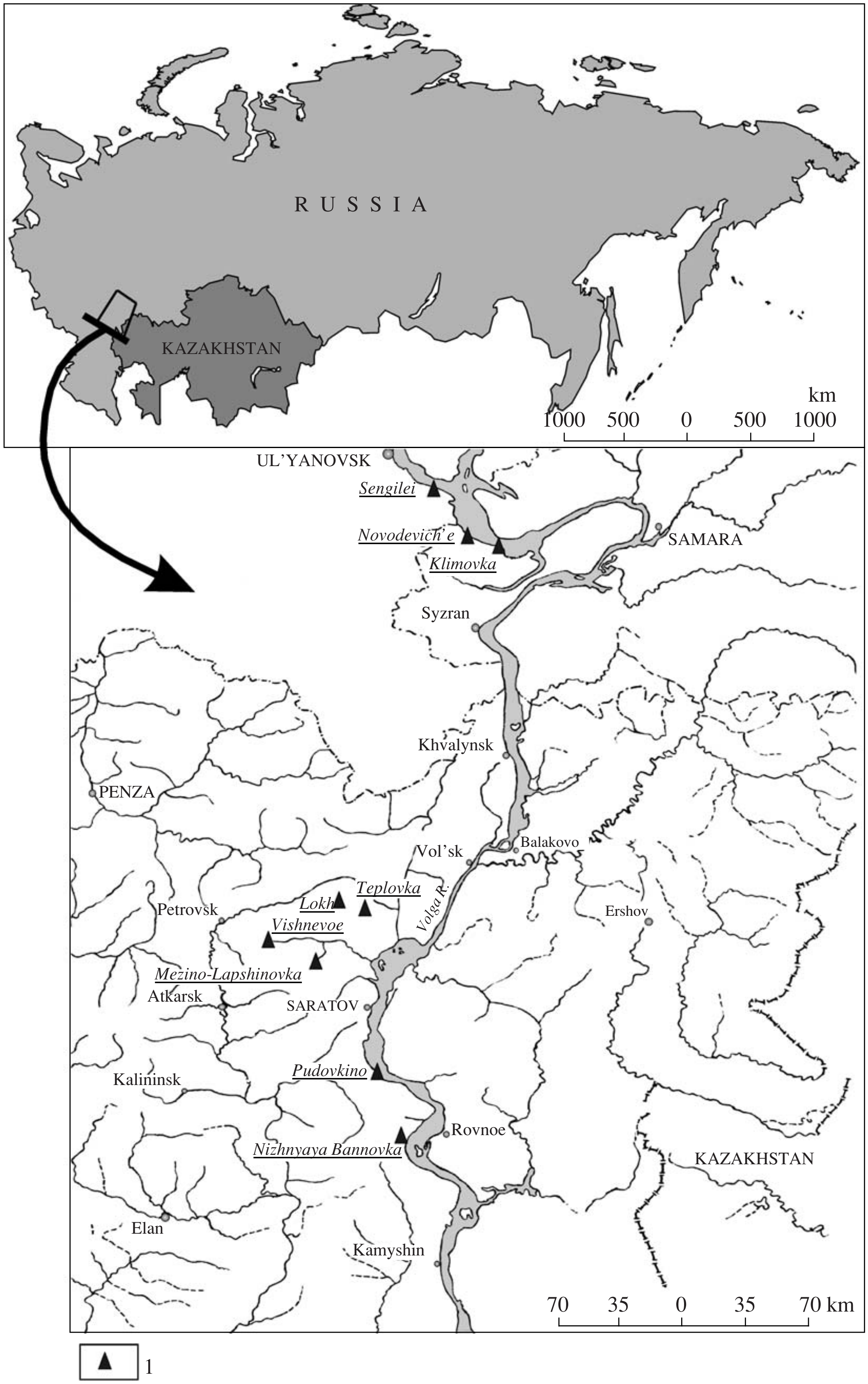


Fig. 1. Localities of the Vishnevoe section (1) and other sections of the Upper Cretaceous deposits studied earlier.

and brachiopods), Ivanov (gastropods, pectinoids and oysters), Kharitonov (inoceramids, gastropods and brachiopods), and Pervushov (sponges). Micropaleontological study has been carried out under leadership of A.S. Alekseev, the scientific editor of the manuscript. Foraminifers are determined by Beniamovski and Kopaevich, radiolarians by Vishnevskaya, ostracodes by Tesakova, and calcareous nannoplankton by Ovechkina and Shcherbinina.

INVESTIGATION HISTORY

Mozgovoi (1969, p. 139) who was first to describe in brief the outcrops in ravine near the village of Vishnevoe distinguished here the following five beds (from the base upward):

1. Glauconite-quartz sandstone with numerous rostra *Belemnitella mucronata mucronata* (Schloth.), *Belemnellocamax mammillatus volgensis* Najd. and rare *Paractinocamax grossouvrei pseudotoucasi* Najd. (4.5 m).

2. Light gray opoka with *Belemnitella mucronata senior* Now. in the lower part and *B. langei minor* Jeletz., *B. langei langei* Schatsky in the upper one (5.5 m).

3. Quartz-glauconite sandstone with basal quartz cement, rare phosphorite nodules, and rostra *B. langei najdini* Kong. (0.3 m).

4. Dark gray cherty clay with rare rostra *Belemnella licharewi* Jeletz. (21.0 m).

5. Yellowish gray marl with *B. lanceolata lanceolata* (Schloth.), *B. lanceolata gracilis* (Arkh.), and *B. lanceolata inflata* (Arkh.); at the base with rare rostra *B. licharewi licharewi Jeletz*. (6.0 m).

Generic names are quoted here and further in the work according to the current taxonomic nomenclature.

Mozgovoi attributed Bed 1 to the lower Campanian, beds 2 and 3 to the upper Campanian, and beds 4 and 5 to the Maastrichtian. In his work (1960–1970), Mozgovoi summarized the results obtained by scientists of the Saratov University from the Chair on Historical Geology and Paleontology and from the Research Institute of Geology during the first period of studying the Upper Cretaceous reference sections of the Volga River basin. In subsequent period of research in the Volga–Medveditsa interfluve after 1970, the section near the village of Vishnevoe has been documented under no. 118, as one can judge from work by Morozov and Pavlovskaya (1980). The results of multidisciplinary research, a presumable basis of monograph planned to be issued, have been archived in several volumes of preliminary reports. The project of ultimate publication has not been realized, and the reports turned out to be lost, unfortunately. Field records by Mozgovoi have been found nevertheless in the chair archive. They include not only the documentation concerning the Campanian–Maastrichtian interval, which has been submitted to publication in 1969, but also the description of entire section exposed near the village of Vishnevoe. His description is so close to our own that we have got opportunity to determine position of paleontological remains collected by Mozgovoi in our stratigraphic column and to characterize in full measure the Turonian interval of the section, which is buried now, the Cenomanian–Turonian boundary inclusive, under the landslide.

Bondarenko (1978) who visited the Vishnevoe section between 1971 and 1974 reported some facts essential for paleontological characterization of beds 3–5. In Bed 3, he collected intact rostra *Belemnella licharewi* with well-preserved alveolar part in addition to rounded fragments of *Belemnitella langei*, which are certainly redeposited. According to his data, Bed 4 is 13.5 but not 21.0 m thick that is close to our measurements (16.2 m). In lower part of this bed, Bondarenko collected and Mozgovoi determined rostra *B. licharewi*, pectinoids *Aequipecten rothomagense* (d'Orb.) and oysters *Monticulina vesicularis* (Lam.). At the same level most likely, M.V. Bondareva identified foraminifers *Gavelinella clementiana laevigata* (Marie), *Brotzenella taylorensis* (Carsey), *Sitella laevis* (Beiss.), *Silicosigmoilina volganica* (Kusn.), *Spiroplectammina suturalis* (Kalin.), *Ammodiscus incertus* d'Orb., *Stensioeina pommerana* Brotz. and some others (Bondarenko, 1978).

Work by Leongardt (1971) seems also containing important data on the Vishnevoe section. When visiting along with Mozgovoi a series of outcrops of the Campanian and Maastrichtian deposits in the Saratov oblast, Leongardt sampled with interval of one meter all lithological varieties observable in outcrops for foraminiferal analysis. She did not list the visited sections in her work, but from Fig. 4 it is clear that one of them is near the village of Vishnevoe. Using stratigraphic scheme by Mozgovoi, Leongardt distinguished the *Cibicidoides temirensis* Zone of the lower Campanian and correlated it with the *Belemnitella mucronata* Zone of belemnite scale; in the upper substage she distinguished the *Cibicidoides aktulagayensis* Zone correlative with *B. langei* Zone. In the Maastrichtian, belemnites of the *Belemnella licharewi* Zone occur in association with foraminiferal assemblage of the *Cibicidoides voltzianus* Zone according to her conclusion, whereas the *B. lanceolata* Zone contains foraminifers of the *Bolivina incrassata incrassata* Zone.

Other publications dedicated to analysis of fossils from clays of the *Belemnella licharewi* Zone, which have been attributed by G.A. Zhukova to the Nalitovo Formation of the Penza oblast (Olfer'ev and Alekseev, 2005), contain only summary lists of taxa collected from different localities, and the Vishnevoe section is not mentioned among them (Bondareva, 1970; Baryshnikova, 1978).

As is shown on geological map, sheet N-38-XXXIV (Chibrikova, 1953), Cenomanian deposits near the village of Vishnevoe should occur immediately under stratigraphic succession of the Santonian, Campanian, and Maastrichtian strata. To our surprise, we actually got an opportunity to collect paleontological samples, observe and describe stratigraphic succession spanning the Turonian–Maastrichtian interval, when rocks in ravine northward of this village have been stripped for examination. When manuscript of this work was under preparation, we managed to find additional data on the Vishnevoe section in the archived report "Mesozoic and Cenozoic of the Middle and Lower Volga" (1980), editors F.I. Koval'skii and V.G. Ochev. Despite the shortness, this information is very important, and we quote it below without cuts: "In section near the village of Vishnevoe (Petrovsk district), the chalk-like marl with inoceramids, overlying the Cenomanian sands, is sandy in its lower part, containing phosphorites at the base. The bed is 1.5 m thick. The assemblage of microfauna is of the late Turonian age. In northwestern part of the Saratov dislocations, like in the Vishnevoe reference section, the Coniacian resting on the Turonian is represented by inoceramid-bearing sandy chalk with phosphorites at the base, fauna of the Coniacian lower zone is associated with redeposited Turonian species. Thickness 4.7 m" (p. 47). Unfortunately, the report is lacking data on taxonomic composition of microfaunal assemblages, and names of researches who studied the assemblages are not indicated. Anyway, the quoted information is well consistent with our observations. As is said further in the report, the Campanian sediments "near the village of Vishnevoe are clearly divisible in two members. Near the base, the lower member is composed of greenish gray glauconite-quartz sandstones containing belemnites and sponges (thickness 0.2 m). Higher in the section, sandstones are less compact, opoka-like in places. Thickness 2.5 m. Fossils found at this level are *Hoplitoplacenticeras vari* Schlüt., belemnites and foraminifers of the lower substage. The upper member is composed of dark to yellowish gray opoka-like clay with interlayers of dark gray opoka and opoka-like sandstone with glauconite grains in lower part. Thickness 8.5 m. Belemnites and foraminifers of the upper substage frequently occur in these sediments. Total thickness 11 m" (p. 75).

DESCRIPTION AND SUBDIVISION OF THE SECTION

The reference section of the Upper Cretaceous described below visualizes the results of our observations in one exposure of rocks but not a composite scheme joining up separate outcrops remote from each other. Studying the exposure, we managed to correct stratigraphic range of the Mezino-Lapshinovka Formation, which was misleadingly estimated during investigation of the formation stratotype (Olfer'ev et al., 2004). The beds are numbered from the top downward beginning from the slope edge that is at the altitude of ~245 m above sea level. The exact positions of paleontological remains in the beds sampled are shown in Figs. 2–4. The succession of beds exposed in the ravine walls is as follows.

Lokh Formation

1. Marl, yellowish to greenish gray, slightly siliceous, medium-flaggy, sandy at the base. The bed yields ammonites *Acanthoscaphites* cf. *tridens* (Kner), *Hoploscaphites constrictus* (Sow.), *Hauericeras sulcatum* (Kner), *Baculites* cf. *vertebralis* (Lam.), *?Pseudokossmaticeras* sp., belemnites *Belemnella lanceolata lanceolata, B. lanceolata inflata, B. lanceolata gracilis, B. sumensis sumensis* Jeletz., inoceramids *Cataceramus* cf. *alaeformis* (Zekeli), *C. balticus tsankovi* (Khar.), *Spyridoceramus caucasicus* (Dobr.), pectinoids *Neithea striatocostata* (Goldf.), *Oxytoma danica volgensis* Param., *Limaria geinitzi* (Hagen.), oysters *Pycnodonte praesinzowi* (Arkh.), *Volgella porrecta* A. Ivanov, gastropods *Calliostoma (?) mariae* (G. Müller), *Turritella sexlineata* (Roem.), *Euthriofusus carinatus* (Münst.), *Aporrhais granulosa* (Müller), and brachiopods *Terebratulina gracilis* Schloth., *Carneithyris carnea carnea* (Sow.), *C. gracilis* (Sahni), *C. circularis* Sahni, and *Kingenella nilssoni* (Lundgren). We failed to found belemnite species *Belemnella angusta* Najd. described by Bondarenko from this bed. Marl is enriched in glauconite near the base. Transition to the underlying bed is gradual; thickness 2.5 m, interval 0–2.5 m.

2. Glauconite sand, fine- to medium-grained, greenish gray, locally cemented by carbonate material. Content of this material is quickly increasing upward in the bed containing abundant fragments of belemnite rostra. Among the latter, we identified a whole, somewhat rounded rostrum *Belemnella licharewi licharewi*, fragmented casts *Baculites* sp. and shells *Entolium* sp., which cannot be identified more precisely. The lower contact is distinct, with clear marks of scouring; thickness 0.8 m, interval 2.5–3.3 m.

Nalitovo Formation

3. Siliceous marl, grayish brown, flaggy, bioturbated, with fucoidal structures oriented parallel to bedding planes. Marl grades downward into slightly calcareous, siliceous clay. Mozgovoi collected from this bed and identified belemnite rostra *Belemnella licharewi.* Within the upper 0.5 m, marl is strongly eluviated, transformed into clay. Transition to underlying bed is gradual; thickness 10.0 m, interval 3.3–13.3 m.

4. Cherty clay, black or gray when dry, slightly calcareous, indistinctly flaggy and splintery, easily crumbling by weathering. Irregularly distributed black and gray patches are observable in the upper part. In this bed, Mozgovoi determined belemnite rostra *Belemnella licharewi*, and Bondarenko collected bivalve mollusks *Aequipecten rothomagensis* and *Monticulina vesicularis.* The lower boundary is noticeable; thickness 6.0 m, interval 13.3–19.3 m.

5. Siliceous marl, greenish gray, grading upward into variegate siliceous clay. The lower contact is very distinct; thickness 0.2 m, interval 19.3–19.5 m.

6. Glauconite sandstone, fine-grained, greenish gray, with basal carbonate cement. The bed contains rostra *Belemnitella langei najdini* and oyster shells *Kosmospirella* sp. and *Pycnodonte* sp., which cannot be identified in the species rank. Bondarenko (1978) collected rostra *Belemnitella langei* with indications of redeposition and *Belemnella licharewi*, some with retained alveolar part, which have been buried in situ. The lower contact is very distinct; thickness 0.5 m, interval 19.5–20.0 m.

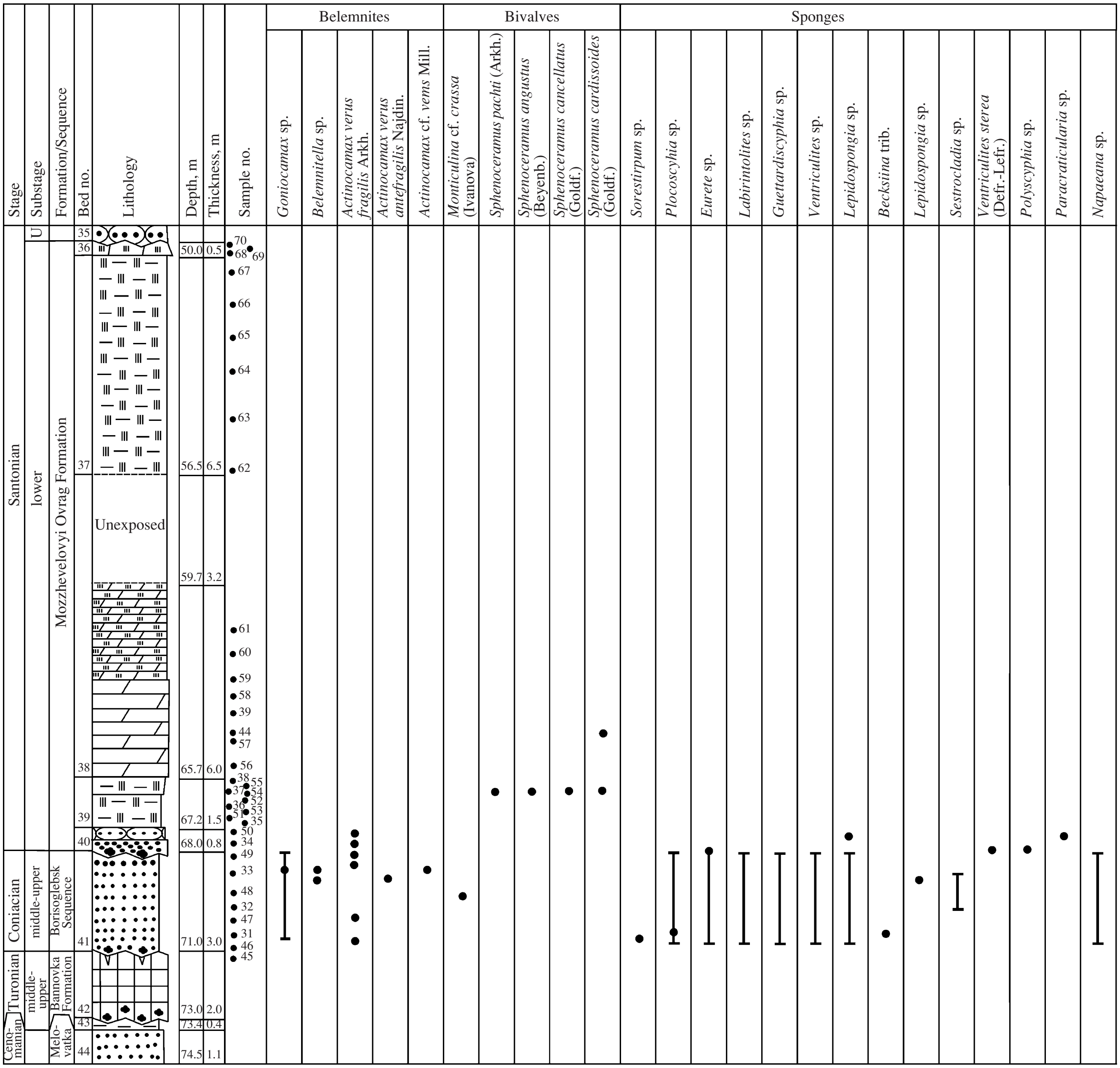


Fig. 2. Distribution of invertebrate remains in the Borisoglebsk Sequence, Bannovka and Mozzhevelovyi Ovrag formations of the Vishnevoe section (symbols as in Fig. 5).

Ardym Formation

7. Opoka, light gray with bluish gray patches and stains, thick- to medium-bedded, containing rostra *Belemnitella mucronata postrema* Najd., *B. langei langei*, inoceramids *Cataceramus barabini* (Mort.), *C. regularis* (d’Orb.), *C. pseudoregularis* (Sorney), *C. decipiens* (Zitt.), *C.* aff. *dariensis* (Dobr. et Pavl.), *Cordiceramus* aff. *boehmi* (G. Müll.), and pectinoids *Mimachlamys cretosa* (Defr.). Opoka encloses thin (0.1–0.2 m) interlayers of brownish siliceous marl, the thickest of which (0.5 m, interval 21.0–21.5 m) bears *Baculites* remains and shells *Oxytoma psilomonica* A. Ivanov, *Hyotissa* cf. *semiplana* (Sow.). The lower contact is perceptible; thickness 4.5 m, interval 20.0–24.5 m.

8. Opoka, light gray with gray stains, very hard, forming a ledge on slope, representing a relief marker bed, in which rostrum *Belemnitella* sp. indet. has been found. The lower contact is distinct; thickness 0.8 m, interval 24.5–25.3 m.

9. Opoka, light gray or grayish brown when wet, slightly silicified near the top and well lithified at the base. The bed with indistinct platty jointing contains rostra *Belemnitella* cf. *postrema, B. mucronata mucronata*, molds of imprecisely identifiable pectinoids *Limaria* sp., oysters *Hyotissa* sp., *Pycnodonte* sp., *Margostrea* sp., and fragmented casts *Baculites* sp.; thickness 1.2 m, interval 25.3–26.5 m.

10. Highly silicified marl, white to light gray when wet, with brownish tint and smoky stains, splitting into large

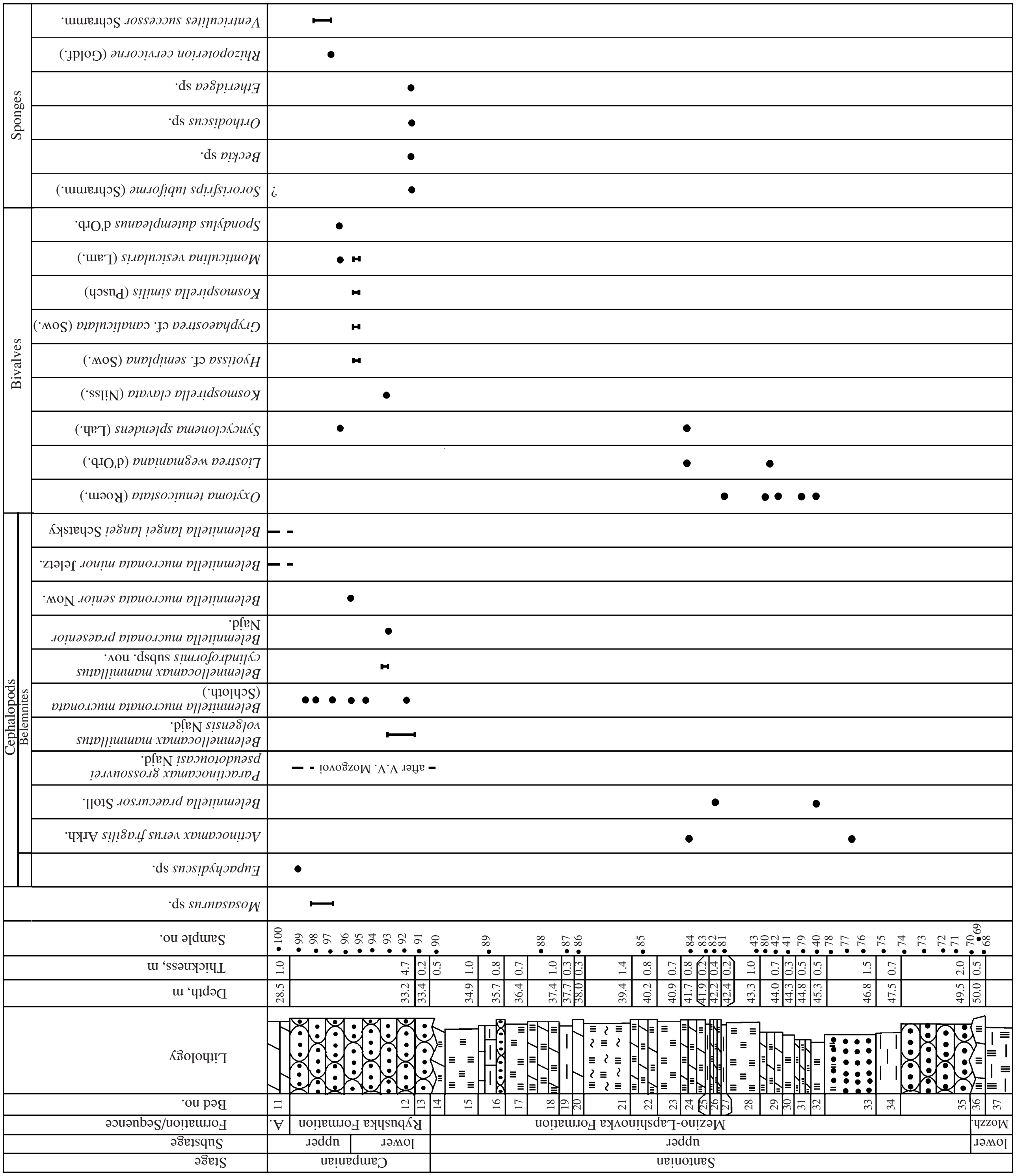


Fig. 3. Distribution of invertebrate remains in the Mezino-Lapshinovka and Rybushka formations of the Vishnevoe section (Mozzh.—Mozzhevelovyi Ovrag Formation, A.—Ardym Formation; symbols as in Fig. 5).

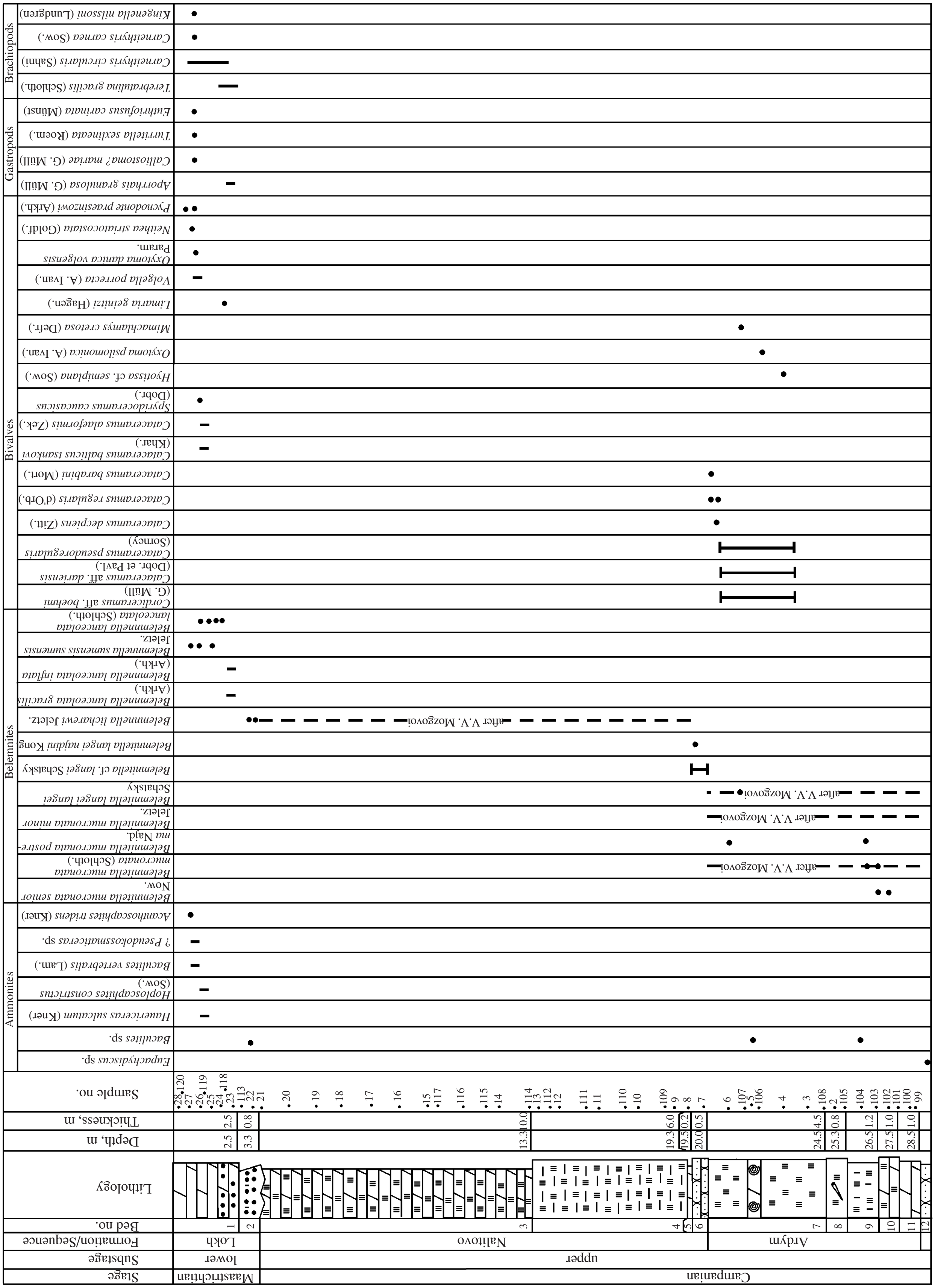


Fig. 4. Distribution of invertebrate remains in the Ardym, Nalitovo, and Lokh formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

blocks and having hackly fracture. Rock contain rostra *Belemnitella mucronata mucronata* and *B. mucronata senior.* Transition to underlying bed is gradual; thickness 1.0 m, interval 26.5–27.5 m.

11. Silicified marl, light gray, with irregularly dispersed glauconite grains tending to be concentrated toward the base. Transition to underlying bed is gradual; thickness 1.0 m, interval 27.5–28.5 m.

In the interval of 20.0–28.5 m (beds 7–11), Mozgovoi collected and identified belemnite rostra *Belemnitella mucronata senior, B. mucronata minor*, and *B. langei langei.*

Rybushka Formation

12. Inequigranular glauconite sandstone, predominantly fine-grained, gray with greenish brown tint, cemented by calcareous cherty material; being variably hard, the rock is intensively bioturbated. The following fossils have been collected from the bed: vertebrae of *Mososaurs*, molds and fragmented casts of *Eupachydiscus* sp., rostra *Belemnitella mucronata mucronata, B. mucronata senior, B. mucronata praesenior* Najd., *Belemnellocamax mammillatus volgensis, B. mammillatus cylindroformis* subsp. nov., oysters *Hyotissa* cf. *semiplana, Monticulina vesicularis, Kosmospirella similis* (Pusch), *K. clavata* (Nilss.), *Gryphaeostrea* cf. *canaliculata* (Sow.), pectinoids *Syncyclonema splendens* (Lah.), *Spondylus dutempleanus* d'Orb., sponges *Rhizopoterion cervicorne* (Goldf.), *Sororistirps tubiformis* (Schramm.), *Ventriculites successor* Schramm., *Beckia* sp., *Orthodiscus* sp., and *Etheridgea* sp. The *Belemnellocamax* forms and *B. mucronata praesenior* are confined to the bed lower part (interval 30.6–33.4 m). According to report of 1980, ammonite *Hoplitoplacenticeras vari* has been found in the same interval and rostrum *B. mucronata senior* a bit higher (level of 30.5 m); thickness 4.7 m, interval 28.5–33.2 m.

13. Glauconite-quartz sandstone, fine-grained, greenish gray, very hard, with basal cherty cement. Clear scouring marks are visible at the lower distinct contact; thickness 0.2 m, interval 33.2–33.4 m.

In the interval of 28.5–33.4 m (beds 12 and 13), Mozgovoi collected and identified belemnite rostra *B. mucronata mucronata, Belemnellocamax mammillatus volgensis*, and *Paractinocamax grossouvrei pseudotoucasi.*

Mezino-Lapshinovka Formation

14. Very clayey marl grading in places into calcareous clay; the rock of pale-gray to brownish coloration is vaguely bedded because of irregularly distributed clay material and contains insignificant admixture of aleuritic quartz grains. Near the top, abundant tracks of burrowing organisms are up to 1 cm in diameter and filled with sand of overlying bed. The lower contact is distinct; thickness 0.5 m, interval 33.4–33.9 m.

15. Opoka, light gray, with gray stains in areas of intense silification, irregularly calcareous, ferruginous along fractures, clayey near the base. Transition to underlying bed is gradual; thickness 1.0 m, interval 33.9–34.9 m.

16. Silicified marl, brownish gray with ferruginous tint, pelitomorphic, containing admixture of mica and glauconite, vaguely bedded in places. At the base, there is an interlayer (4 cm) of fine-grained glauconite-quartz sandstone with cherty cement. The lower contact is distinct; thickness 0.8 m, interval 34.9–35.7 m.

17. Opoka, light gray to grayish brown when wet, silty and clayey in the bed lower part, having glauconite admixture and bioturbation marks. Transition to underlying bed is gradual; thickness 0.7 m, interval 35.7–36.4 m.

18. Silicified silty marl, bioturbated, with fine mica flakes, almost imperceptible bedding and distinct lower contact; thickness 1.0 m, interval 36.4–37.4 m.

19. Clay, black to greenish gray, homogeneous, splintery, with fine mica flakes and indistinct flaggy bedding; thickness 0.3 m, interval 37.4–37.7 m.

20. Strongly silicified marl, grayish brown, rusty and ferruginous near the base, silty, micaceous, not hard. Transition to underlying bed is gradual; thickness 0.3 m, interval 37.7–38.0 m.

21. Opoka of megalump structure, light gray with gray smoky stains, hard, flaggy near the top, containing perceptible admixture of dark gray silty material. Transition to underlying bed is gradual; thickness 1.4 m, interval 38.0–39.4 m.

22. Marl, strongly silicified, near the top especially, grayish brown in coloration. Transition to underlying bed is gradual; thickness 0.8 m, interval 39.4–40.2 m.

23. Opoka, hard, light gray. Transition to underlying bed is gradual; thickness 0.7 m, interval 40.2–40.9 m.

24. Siliceous marl of lumpy structure, grayish brown, containing belemnite rostra *Actinocamax verus fragilis* Arkh., bivalves *Liostrea wegmaniana* (d'Orb.) and *Syncyclonema splendens.* Transition to underlying bed is gradual; thickness 0.8 m, interval 40.9–41.7 m.

25. Clay, dark gray, easily recognizable because of coloration, silty at the base, enclosing here glauconite lenticles. The lower contact is distinct; thickness 0.1 m, interval 41.7–41.8 m.

26. Siliceous marl, brownish gray, splintery, bioturbated, enclosing rare glauconite nests and lenticles. Belemnite rostra *Belemnitella praecursor* Stoll. have been found in the bed that is 0.4 m thick; interval 41.8–42.2 m.

27. Clay, dark brown with black interlayers and lenses, flaggy, silty and calcareous in upper part, silicified close to the base. Small light-colored fucoids are indicative of intense bioturbation. The bed bears shells of *Oxytoma tenuicostata* (Roem.) and other small thin-walled bivalves occurring in association with small *Actinocamax* rostra. Transition to underlying bed is gradual; thickness 0.1 m, interval 42.2–42.3 m.

28. Opoka, light gray, enclosing nests, lenses and interlayers of dark gray silicified opoka splitting into large acute-angled lumps; dispersed glauconite grains and fragmented shells of thin-walled bivalves are confined to the bed upper part. The lower contact is fairly distinct; thickness 1.0 m, interval 42.3–43.3 m.

29. Tripoli-like marl, light gray, slightly silicified in places, grading into calcareous tripolite clay; rock contains admixture of silty to sandy material and shells of *O. tenuicostata* and *Liostrea wegmaniana.* The lower contact is distinct; thickness 0.7 m, interval 43.3–44.0 m.

30. Opoka, hard, light gray with darker patches and stains. The lower contact is distinct; thickness 0.3 m, interval 44.0–44.3 m.

31. Tripoli-like marl, light gray, grading into highly calcareous tripolite clay; this weakly siliceous bed is softer than underlying and overlying opokas and contains in abundance the fragments of oyster shells, inoceramid prismatic layer,

and valves of *O. tenuicostata.* The lower contact is distinct; thickness 0.5 m, interval 44.3–44.8 m.

32. Opoka, light gray with creamy tint neat the base and with gray to dark gray patches and stains indicative of inhomogeneous silicification; this rock with semiconchoidal fracture encloses glauconite lenses, nests, and interlayers. Valves of *O. tenuicostata* and rostra of *B. praecursor* and *Actinocamax* forms represent fossils of the bed having the distinct lower contact; thickness 0.5 m, interval 44.8–45.3 m.

33. Sand grading into fine-grained quartz-glauconite sandstone, dark to greenish gray, with basal siliceous (opaline) cement, containing brown phosphate grains; characteristic of this calcareous to weakly clayey rock is irregular distribution of clastic material and bioturbation (subvertical crab burrows with ferruginate or silicified walls). Opoka nests (0.4 to 0.7 cm in diameter) in the bed upper part are lacking sand admixture. Frequently occurring in sandstone are *O. tenuicostata* valves and *Actinocamax verus fragilis* rostra. The lower contact is distinct; thickness 1.5 m, interval 45.3–46.8 m.

34. Tripolite clay, brown to dark gray, with wavy lamination in the bed upper part, where gray lenticles and laminae contain glauconite grains of sand size. Near the top and base, the rock grades into mottled, irregularly silicified opoka. The lower contact is distinct; thickness 0.7 m, interval 46.8–47.5 m.

35. Quartz-glauconite sandstone, mostly small- to fine-grained, enclosing lenses of medium-grained sandstone; rocks are grayish green to dark gray with greenish black interlayers, silty, calcareous, and irregularly silicified. The clayey upper part of the bed is intensively bioturbated, with talassinoid tracks. Cement is of the basal type, and sandstone grades locally into opoka because of irregular distribution of clastic material. The lower contact is distinct, with scouring marks; thickness 2.0 m, interval 47.5–49.5 m.

Mozzhevelovyi Ovrag Formation

36. Marl, brownish gray, with numerous large fucoids left by burrowing organisms and filled with dark green glauconite sand derived from overlying bed. Transition to underlying bed is gradual; thickness 0.5 m, interval 49.5–50.0 m.

37. "Banded series" – alternating layers of greenish brown siliceous lumpy marl, light gray irregularly calcareous opoka, and bioturbated silty, clayey or calcareous tripoli. All the layers 0.3 to 1.0 m thick are interrelated with each other via gradual transitions. Apparent thickness of this series is 6.5 m; interval 50.0–56.5 m.

The next interval (56.5–59.7 m) downward the slope is unexposed. It is estimated to be 3.2 m wide. According to records of Mozgovoi, there should be also outcrops of the "banded series."

38. Siliceous marls with lenses and patches of silicification in the bed upper part, where marl grades into calcareous opoka; marls are light gray to greenish brown, tripolite, lumpy, containing small thin-walled shells of bivalves *Volgella* sp., molds of *Sphenoceramus cardissoides* (Goldf.), and sponge skeletons. Transition to underlying bed is gradual; thickness 6.0 m, interval 59.7–65.7 m.

39. Tripolite clay, greenish brown, with lumpy fracture, slightly silicified near the top, barren of carbonate material, containing molds of *Sphenoceramus cardissoides* (Goldf.), *S. pachti* (Arkh.), *S. angustus* (Beyenb.), *S.* cf. *cancellatus* (Goldf.), and *Liostrea* sp.; in the lower part, clay is sandy, bearing rare small phosphorite nodules. Clastic material irregularly distributed in the rock is concentrated in thin lenticles and nests near the base. Transition to underlying bed is gradual; thickness 1.5 m, interval 65.7–67.3 m.

40. Quartz-glauconite sand, medium- to coarse-grained, light yellowish gray, slightly calcareous and clayey; brown and black phosphorite nodules up to 1 cm in diameter are dispersed throughout the bed. In the upper part (0.3 m), sand grades into sandstone with opaline cement. Fossils found in the bed are belemnite rostra *Actinocamax verus fragilis*, thin-walled shells *Neithea* sp., inoceramid remains, shark teeth, and phosphatic clasts representing skeletal fragments of large sponges *Paracraticularia* sp., *Lepidospongia* sp., *Polyscyphia* sp., and *Ventriculites sterea* (Defr.-Lefr.). The basal horizon (0.1 m) corresponds to accumulation of small (0.5 to 1.5 cm) black and brown phosphorite nodules in quartz-glauconite matrix. Phosphorite nodules and fragmented sponge skeletons are concentrated largely above the bed lower contact ("sponge horizon"), which is distinct, with marks of scouring; thickness 0.8 m, interval 67.2–68.0 m.

Borisoglebsk Sequence

41. Quartz-glauconite sand, light gray with yellowish green tint, highly calcareous, grading locally into loose sandstone with carbonate cement; abundant fucoids indicative of intense bioturbation are filled with light colored carbonate material. Sand contains small (up to 5 mm) dispersed phosphorite nodules and diverse fossils: fragments of sponges *Plocoscyphia* sp., *Napaeana* sp., *Lepidospongia* sp., *Ventriculites* sp., *Guettardiscyphia* sp., *Labyrintolithes* sp., *Eurete* sp., *Sestrocladia* sp., *Sororistrips* sp., *Aphrocallistes* sp., *Becksiina* sp., belemnite rostra *Actinocamax verus fragilis* Arkh., *A. verus verus* Mill., *A. verus antefragilis* Najd., *Belemnitella* sp., pectinoids *Chlamys* sp., inoceramid remains with attached oyster shells *Monticulina* sp. and *Pycnodonte* sp., which crumble easily in hands. Species *Monticulina* cf. *crassa* (Ivanova) is identified as well. At the base, sand is fine- to coarse-grained, containing abundant phosphorite clasts of gravel size (0.5–1.0 cm). Pockets of the lower contact suggest scouring of underlying deposits and a considerable hiatus in sedimentation; thickness 3.0 m, interval 68.0–71.0 m.

Bannovka Formation

42. Chalk-like marl, light gray to white, homogeneous, fairly compact, locally with ferruginate spots; fucoids of subvertical and subhorizontal orientation, which are abundant below the top within the interval of 10 to 15 cm thick, are filled with calcareous inequigranular sand with gravel, i.e., with sedimentary material of overlying bed. Very compact, intensively bioturbated marl at the top corresponds to hardground and forms a ledge in the slope; apparent thickness 0.2 m. Interval below is unexposed.

According to data of Mozgovoi, this marl bed is 2.0 m thick in eastern outskirts of the village, where he sampled brachiopod shells and *Actinocamax* rostra from the bed and detected phosphorite nodules at its base. Consequently, interval of the bed corresponds to 71.0–73.0 m.

43. Clay, aleuritic, dark gray with greenish tint; sponge impressions and remains of inoceramid prismatic layer have been found in the upper light-colored calcareous interval and sand nests a the base; thickness 0.4 m, interval 73.0–73.4 m.

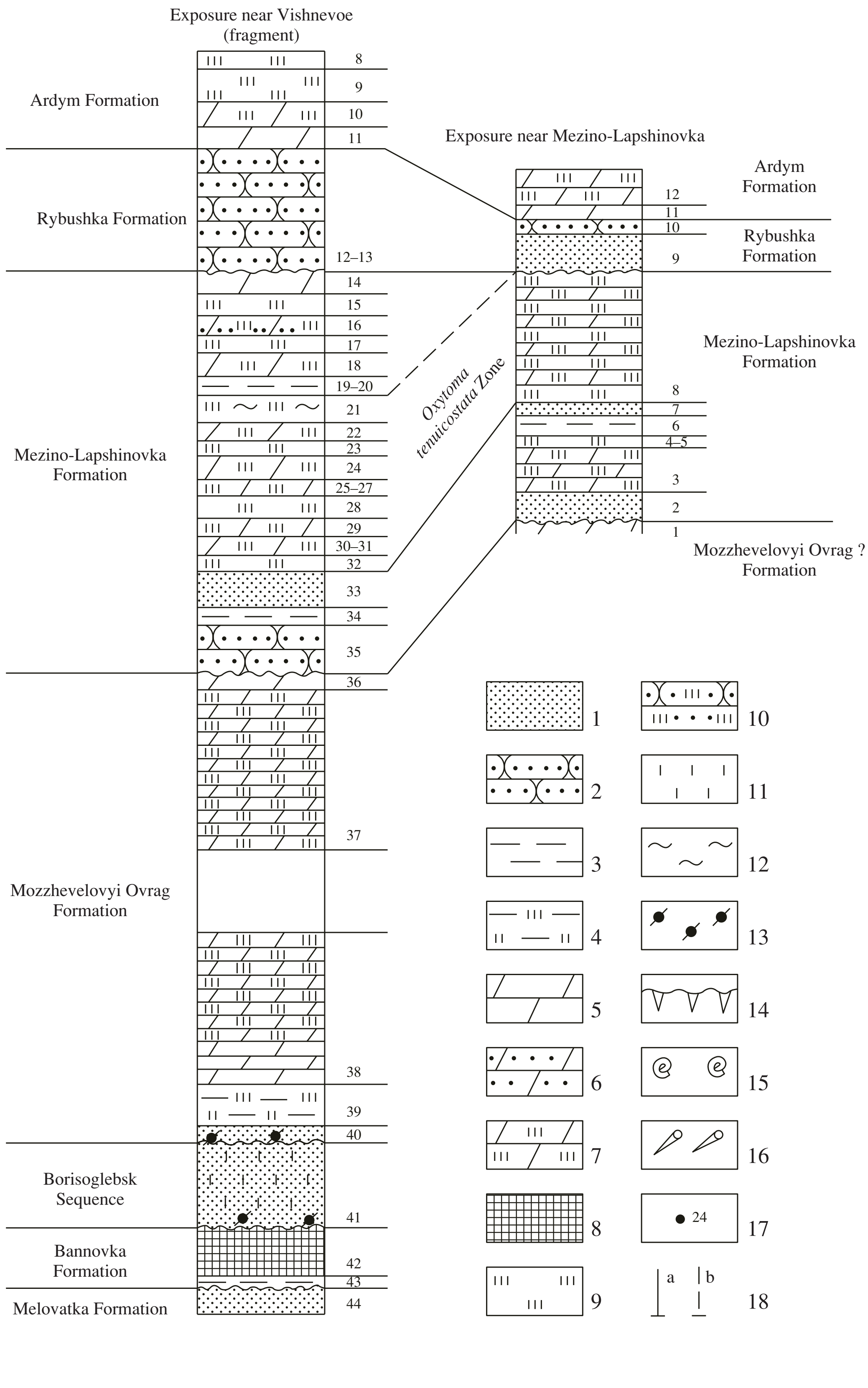


Fig. 5. Correlation of the Vishnevoe and Mezino-Lapshinovka sections: (1) sand; (2) sandstone; (3) clay; (4) siliceous clay; (5) marl; (6) sandy marl; (7) siliceous marl; (8) chalk; (9) tripoli and opoka; (10) cherty sandstone; (11) calcareous rocks; (12) silty rocks; (13) phosphoritic pebbles and gravel; (14) hardground; (15) ammonite and (16) belemnite occurrence levels; (17) occurrence levels of organic remains; (18) interval bearing fossils (a) established and (b) presumable.

Melovatka Formation

44. Quartz sand, fine- to medium-grained, light yellowish to greenish gray, containing small nodules of sandy phosphorite near the top; apparent thickness 1.1 m, interval 73.4–74.5 m.

LOCAL STRATIGRAPHIC UNITS

Local stratigraphic units of the section correspond to formations of the Upper Cretaceous stratigraphic chart approved in 2001 for the East European platform (*Stratigraphic…*, 2004; Olfer'ev and Alekseev, 2005). Many of the formations have been originally distinguished by Pervushov and Ivanov, members of the authors' team.

The Cenomanian *Melovatka Formation* corresponds in range to sands of the Bed 44, whereas the *Bannovka Formation* spans the chalk-like marls of Bed 42 coupled, tentatively to some extent, with irregularly calcareous clays of Bed 43 containing fragments of inoceramid prismatic layer. Clays of this type are known in the Gulyushevo Formation of the Turonian in the Ul'yanovsk oblast of the Volga region. The Bannovka Formation is 2.4 m thick.

The *Borisoglebsk Sequence* is distinguished for the first time in the Saratov oblast. In the section under consideration, this unit rests with a hiatus and scouring marks on the Turonian Bannovka Formation, being overlain in turn by the Mozzhevelovyi Ovrag Formation of the Santonian. Calcareous sands of Bed 41 attributed to the sequence are identical to Borisoglebsk deposits of the Tambov and Khoper monoclines, where they occur at the same stratigraphic level. Sediments of the Borisoglebsk Sequence are likely widespread in the study region, although formerly they have not been referred to an individual stratigraphic unit, being regarded in borehole sections as either the Cenomanian sands, or a part of the lower Santonian "Sponge Horizon" until the discovery of foraminifers in the respective sandy marls. Koval'skii and Ochev (1980) who discovered these microfossils attributed their host rocks to the Coniacian stage. The Borisoglebsk Sequence is 3.0 m thick.

The *Mozzhevelovyi Ovrag Formation* (joint interval of beds 36–40) includes the "Sponge Horizon" (Bed 40), "*cardissoides* marls" (beds 38, 39), and the Banded Series (beds 36, 37), being 18.5 m thick in total.

This unit is overlain with distinct scouring marks by the *Mezino-Lapshinovka Formation* (beds 14–35). Basal sands of the latter (beds 33 and 35) are separated by clay that is 0.7 m thick. This clay intercalation between sands established in the Vishnevoe section evidence the formerly misleading determination of lower boundary of the Mezino-Lapshinovka Formation in its stratotype (Olfer'ev et al., 2004). The formation base defined in the stratotype at the Bed 7 lower boundary corresponds to basal level of Bed 33 in the Vishnevoe section, and interval of beds 2–6 in the Mezino-Lapshinovka quarry should be correlated with beds 34 and 35 of the described section (Fig. 5). Being 16.1 m thick in total, the formation is more complete here than in the stratotype. This is evident from the fact that beds 21–31 of the Vishnevoe section, which bear abundant shells *Oxytoma tenuicostata*, are equal in thickness to Bed 8 of the Mezino-Lapshinovka section, where this bed contains shells of the same species from the base up to the top. On the other hand, *Oxytoma* forms have not been found within upper beds 14–20 of the Mezino-Lapshinovka Formation in the studied section. It is likely therefore that the analogs of these beds have been eroded from section of the Mezino-Lapshinovka quarry during the pre-Rybushka time.

The *Rybushka Formation* of sands and sandstones overlies with a considerable hiatus the Bed 14 of marls of the Mezino-Lapshinovka Formation. The relevant break in sedimentation is evident from abundant fucoids in marls, which are filled with overlying quartz-glauconite sand. In the Vishnevoe section, the Rybushka Formation is more complete than in the Mezino-Lapshinovka quarry, as it is thicker (4.9 versus 1.9 m) and lacking scouring marks at the contact with overlying sediments in contrast to the quarry section, where these marks are well observable. Because of the gradual transition into overlying sediments, positioning of the Rybushka Formation upper boundary in the Vishnevoe section is problematic to some extent. Besides, an upper part of this formation yields here ammonites characteristic of the lower zone of the upper Campanian and concurrent assemblage of foraminifers, whereas the respective sands and sandstones of the Mezino-Lapshinovka quarry bear only belemnites and foraminifers of the lower Campanian.

The *Ardym Formation* conformably resting on the Rybushka Formation includes beds 7–11 of interlayering opokas and siliceous marls. Its total thickness is 8.5 m.

The *Nalitovo Formation* of siliceous clays overlies the above unit with scouring. According to Bondarenko (1978), at the base of clays there is a sandstone bed up to 0.5 m thick, traceable throughout the Lower Volga region, and when the bed is pinching out, the basal clay becomes enriched in glauconite grains of sand size fraction. In the studied section, basal sand of the Nalitovo Formation corresponds to Bed 6 underlying beds 5 and 4 of siliceous clays, which are more calcareous in upper part and grade upward into siliceous marls of Bed 3. The formation is 16.7 m thick in total.

The *Lokh Formation* represented at the base by glauconite sands of Bed 2 with redeposited belemnite rostra typical of Bed 3 overlies the Nalitovo siliceous marls with scouring. Basal sands grade upward first into sandy and then into pure marls of Bed 1. The apparent thickness of both beds is 3.3 m.

BIOSTRATIGRAPHIC ANALYSIS

Mollusks

In sands of the *Borisoglebsk Sequence*, molluscan fauna is represented by remains of belemnites and oys-

Plate I

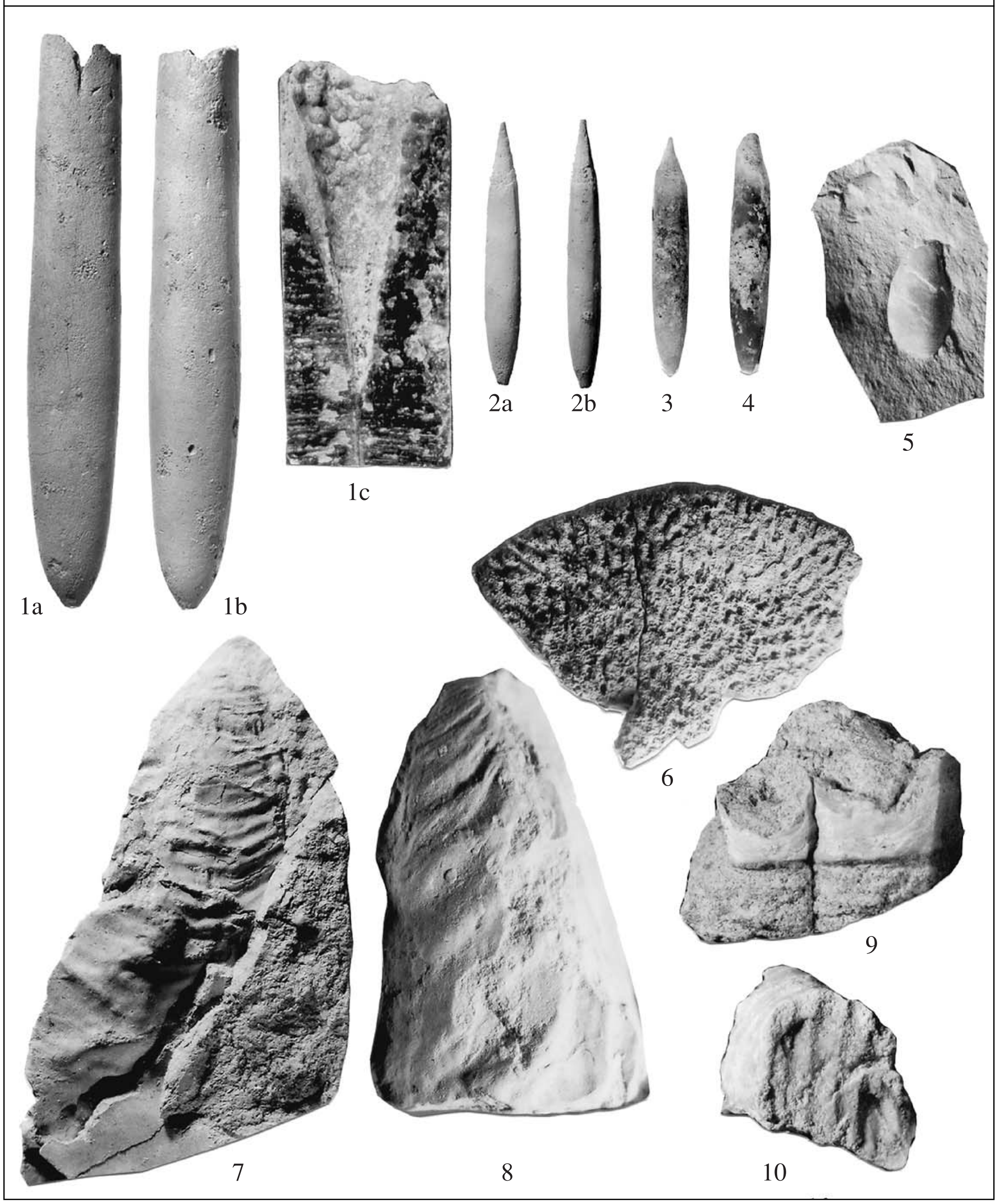


Plate I. Mollusks and sponges of the Borisoglebsk sequence (1–4, 6, 9, 10), Mozzhevelovyi Ovrag (7, 8) and Mezino-Lapshinovka (5) formations from the Vishnevoe section (natural size of all specimens).

(1) *Belemnitella* sp., Specimen no. Vsh-77, Saratov, SGU: (a) ventral view, (b) dorsal view, (c) a fragment of alveolar part as seen when split in wntrodorsal direction (×2); Bed 41, interval 69.3–69.5 m. (2) *Aatinocamax verus antefragilis* Najdin, Specimen no. Vsh-71, Saratov, SGU: (a) lateral view, (b) ventral view; Bed 41, sampling level 68.9–69.1 m. (3, 4) *A. verus fragilis* Arkhangelsky: (3) Specimen no. Vsh-101, Saratov, SGU, ventral view, Bed 41, sampling level 69.0 m; (4) Specimen no. Vsh-104, Saratov, SGU, ventral view, Bed 41, sampling level 68.5 m. (5) *Liostrea wegmaniana* (d`Orbigny), Specimen no. Vsh-127, Saratov, SGU, Bed 29, sampling level ~43.6 m. (6) *Sestrocladia* sp., Specimen no. H/3911, Saratov, SGU, a fragment of cup wall, Bed 41, sampling level 69.0 m. (7) *Sphenoceramus angustus* (Beyenburg), Specimen no. Vsh-132, Saratov, SGU, Bed 39, sampling level 66.4 m. (8) *S. pachti* (Arkhangelsky), Specimen no. 3/5, Saratov, SGU, Bed 39, sampling level 66.4 m. (9, 10) *Monticulina* cf. *crassa* (Ivanova): (9) Specimen no. Vsh-126; (10) Specimen no. Vsh-127, Saratov, SGU, xenomorphic attachment lamella with impression of dermal sculpture of sponge skeleton, Bed 41, sampling level 68.5 m.

ters. The assemblage of cephalopod mollusks is very unusual. In addition to forms of wide (Coniacian–Santonian) stratigraphic ranges (*Actinocamax verus verus, A. verus fragilis*) and *Goniocamax* rostra of unclear species affinity, it includes *Actinocamax verus antefragilis* (Plate I) found in situ and known before in Russia only from the Gulyushevo Formation of the lower Turonian, the Surskoe site of the Ul’yanovsk oblast (Naidin, 1964a). Christensen (1997), who analyzed stratigraphic ranges of belemnites in the North European province concluded that this species is confined only to the lower–middle Coniacian in West Europe (Bornholm Island, Denmark). Besides, we found in situ at three levels in the Borisoglebsk sands the *Belemnitella* forms whose first occurrence in the lower Santonian is established in West Europe (Christensen, 1997) and in the East European platform (Naidin, 1964b). According to Nikitin (1958) however, *B. propinqua* (Mob.) from the Lyubozhichi section at the Desna River, Bryansk oblast, is confined to marls bearing foraminifers of the Coniacian *Gavelinella kelleri* local zone (Olfer’ev and Alekseev, 2005), and Arkhangelskii (1912) reported long ago on occurrence of the same species in the Turonian of the Volga region. In opinion of Naidin (1964b), these *Belemnitella* forms from two regions should be classed with *Actinocamax intermedius* Arkh. Among bivalve mollusks represented by inoceramids, pectinoids, and oysters of undeterminable species affinity, generic composition of which was listed in the bed 41 characteristics, we managed to identify only *Monticulina crassa.* This taxon was known before only from the lower Santonian of the Volga region.

In the overlying Mozzhevelovyi Ovrag Formation, macrofossils are commonly rare. An exception is Bed 40 of basal “sponge” sand that yields abundant belemnite rostra *Actinocamax verus fragilis*, bivalves of the genus *Neithea*, and unidentifiable fragments of inoceramid shells. Inoceramids *Sphenoceramus cardissoides, S. pachti, S. angustus*, and *S.* cf. *cancellatus* have been collected at two levels (66.0 and 64.2 m) in beds 38 and 39 of the so-called “*cardissoides* marls.” Tröger who considered this assemblage as typical of Zone 25 correlated it with the *Texanites texanus* ammonite zone that was recently attributed in West Europe to the terminal Coniacian (Kaplan and Kennedy, 2000; Tröger, 2002), although earlier it was considered as corresponding in age to the lower Santonian (Tröger, 1989). In Germany, *Sphenoceramus pachti* and *S. cardissoides* also occur in the lower–middle Santonian (Hiss et al., 2000). In addition to inoceramids, “*cardissoides* marls” of the Mozzhevelovyi Ovrag Formation bear fragmented shells of oysters *Liostrea* sp. and *Volgella* sp. The formation upper part known under name of the “Banded Series” is barren of macrofossils.

The *Mezino-Lapshinovka Formation* bears the more diverse macrofossils. Belemnite rostra *Actinocamax verus fragilis* are found in its basal sands of Bed 33 and in the middle part known under name of the “Pteriacea Beds” bearing abundant pectinoid shells *Oxytoma tenuicostata* detected in beds 28–32 of the studied section. Higher (Bed 24) we collected rostra *Belemnitella praecursor* typical of the upper Santonian and found in association with oysters *Liostrea wegmaniana* characteristic of the Pteriacea Beds and pectinoids *Syncyclonema splendens* formerly unknown from this stratigraphic level. Terminal beds 14–23 of the Mezino-Lapshinovka Formation are barren of macrofauna.

The most diverse spectrum of mollusks is detected in sands and sandstones of the Rybushka Formation (Plates II and III). In this subdivision, we found fragmented cast of ammonite *Eupachydiscus* sp. and rostra *B. mucronata mucronata* dispersed throughout the Bed 12. Belemnites *Belemnitella mucronata praesenior, Belemnellocamax mammillatus volgensis* Najd., *B. mammillatus cylindroformis* subsp. nov. are confined to the formation lower part; *Belemnitella mucronata senior* to the upper one. It is impossible to establish the exact position of belemnite rostrum *Paractinocamax grossouvrei pseudotoucasi* found by Mozgovoi. The analyzed vertical distribution of belemnites suggests that lower part of the Rybushka Formation (interval 30.6–33.4 m) corresponds to the *Belemnellocamax mammillatus* local zone of the lower Campanian, whereas the higher interval (28.5–30.6 m) is correlative with *Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata* Zone of the upper Campanian. Pectinoid shell *Syncyclonema splendens* detected in terminal part of the formation represents a taxon frequently occurring in the Campanian and Maastrichtian strata of the Russian plate (Kotsyubinskii and Savchinskaya, 1974). Ammonite *Hoplitoplacenticeras vari* was found earlier in the same interval. Oysters *Hyotissa* cf. *semiplana* and *Gryphaeostrea* cf. *canaliculata* confined to sands and sandstones of the Rybushka Formation are of a wide (Cenomanian–Maastrichtian) stratigraphic range; the narrower Santonian–Maastrichtian range is characteristic of *Kosmospirella clavata, K. similis, Monticulina vesicularis*, and *Spondylus dutempleanus.*

Sediments of the *Ardym Formation* bear ammonites of the genus *Baculites* of unidentifiable species affinity. Belemnites *Belemnitella mucronata mucronata, B. mucronata senior*, and *B. mucronata postrema* (Plate IV) from lower beds 9 and 10 of this subdivision occur as well in terminal beds of the Rybushka Formation, and their host deposits correspond to lower zone of the upper Campanian. In marls and opokas of Bed 7, they give place to *B. langei langei*, and consequently this bed is correlative with the *B. langei/Didymoceras donezianum* local subzone of the upper Campanian. Unfortunately, we failed to determine the occurrence level of rostra *B. mucronata minor* found by Mozgovoi and regarded earlier as a subspecies of *B. langei* (*B. langei minor* in nomenclature of Naidin). Hence, the base of the *Belemnitella mucronata minor/Bostrychoceras polyplocum* local subzone remains undetected in the Ardym Formation section. Marls and opokas of Bed 7 also bear diverse inoceramid species *Cataceramus barabini, C. decipiens, C.* aff. *dariensis*, and *C. regularis*, which are known as well from the Ardym Formation exposed in the Mezino-Lapshinovka quarry (Olfer’ev et al., 2004). Besides, we detected *'ordiceramus* aff. *boehmi* and *Cataceramus pseudoregularis* in

Plate II

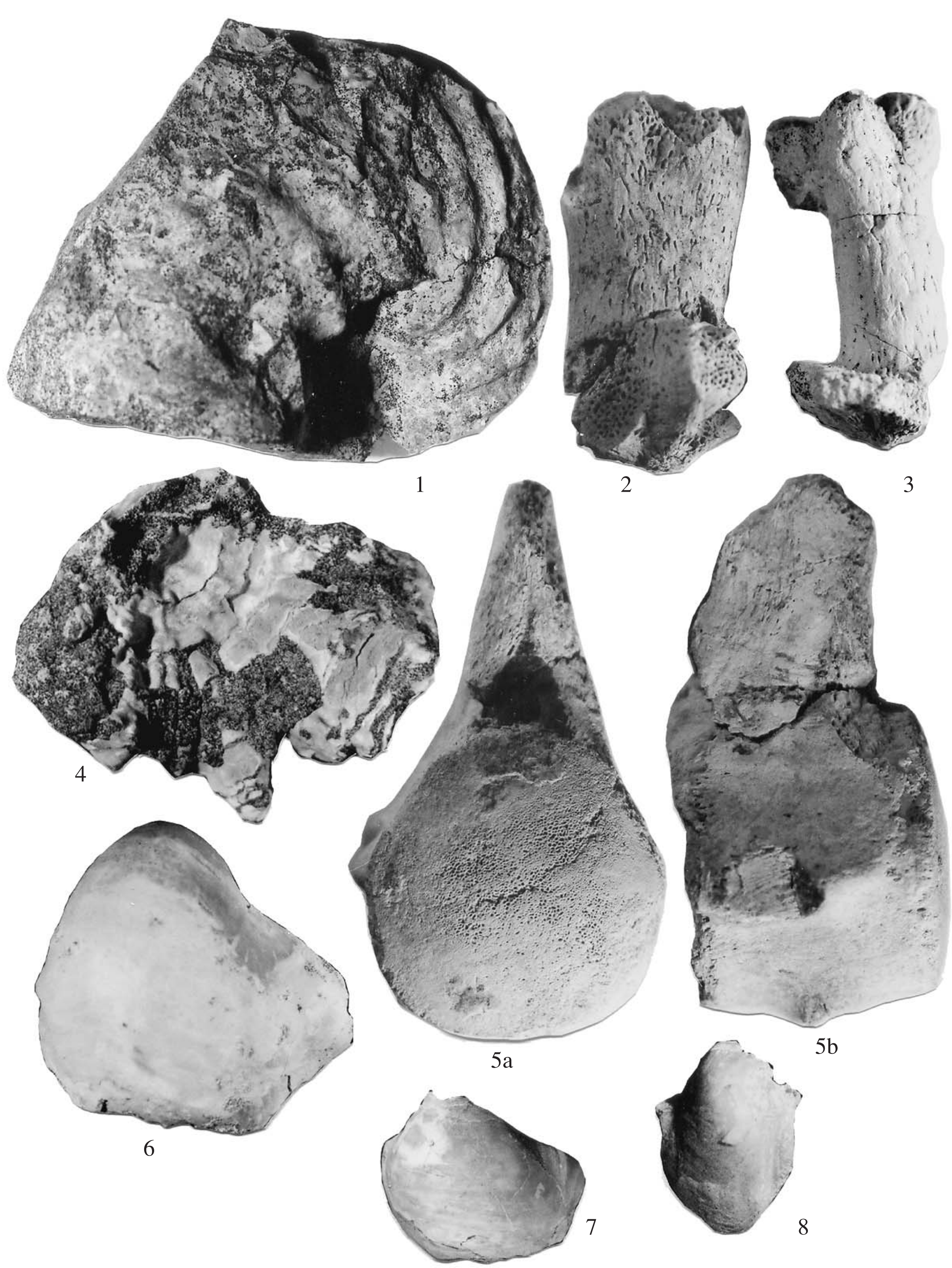
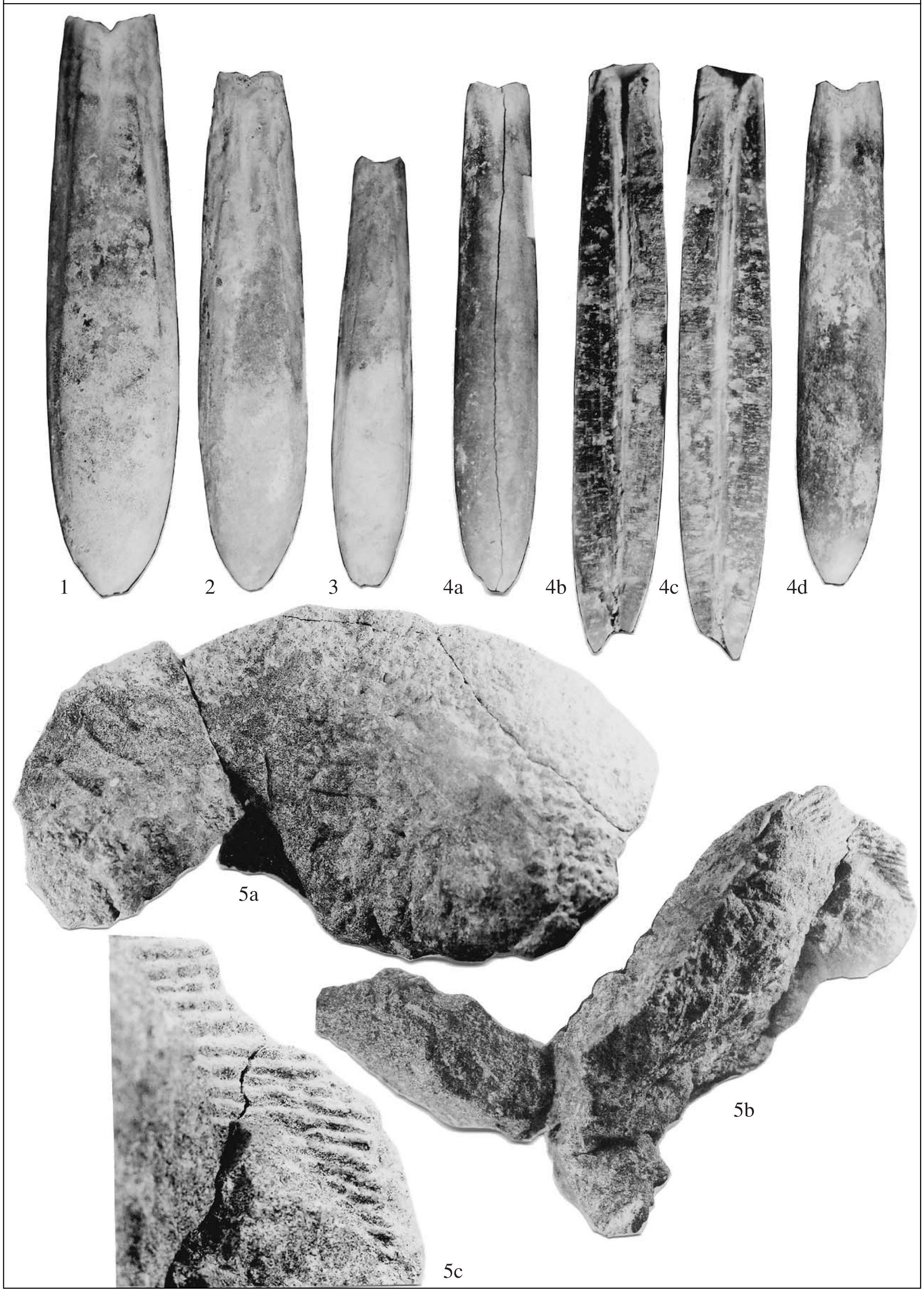


Plate II. Mollusks, sponges and vertebrates of the Rybushka Formation from the Vishnevoe section (natural size of all specimens). (1) *Eupachydiscus* sp., Specimen no. Vsh-137, Saratov, SGU, deformed shell fragment, Bed 12, sampling level 28.8 m. (2, 3) *Rhizoporterion cervicorne* (Goldfuss): (2) Specimen no. H/3975, (3) Specimen no. H/3976, Saratov, SGU, Bed 12, sampling level ~30.0 m. (4) *Hyotissa* cf. *semiplana* (Sowerby), Specimen no. Vsh-138, Saratov, SGU, Bed 12, interval 30.8–31.0 m. (5) A vertebra of *Mososaurs*, Specimen no. Vsh-141, Saratov, SGU: (a) frontal view, (b) lateral view, Bed 12, interval 29.2–29.7 m. (6) *Kosmospirella similes* (Pusch), Specimen no. Vsh-114, Saratov, SGU, Bed 12, interval 30.8–31.0 m. (7) *Monticulina vesicularis* (Lamarak), Specimen no. Vsh-115, Saratov SGU, Bed 12, interval 30.8–31.0 m. (8) *Gryphaeostrea* cf. *canaliculata* (Sowerby), Specimen no. Vsh-113, Saratov, SGU, Bed 12, interval 30.8–31.0 m.

Plate III



the same bed. The *Cataceramus* species listed above are most characteristic of the upper Campanian and lower Maastrichtian. Among bivalves from the Bed 7, we also identified pectinoid shells *Oxytoma psilomonica, Mimachlamys cretosa*, and oysters *Hyotissa* cf. *semiplana.* In the East European platform, the first and last taxa occur beginning from terminal beds of the lower Campanian; the second taxon is of the Turonian–Maastrichtian stratigraphic range.

In the *Nalitovo Formation*, macrofossils are rare. Mozgovoi collected belemnite rostra *Belemnitella langei najdini* from basal sandstone (bed 6) of the formation, which corresponds therefore to the synonymous local subzone of the Tereshkino Horizon. Bondarenko (1978) and we found in this bed rostra *B.* cf. *langei* apparently redeposited from the Ardym Formation. We did not detect macrofossils in overlying siliceous clays and marls of beds 3 and 4, where Mozgovoi and Bondarenko found rare belemnite rostra *Belemnella licharewi.*

Composition of macrofossils considerably changes in the *Lokh Formation.* A corroded rostrum *B. licharewi licharewi* most likely redeposited from the Nalitovo Formation was found in association with fragmented cast of *Baculites* sp. in the Bed 2 of basal sand. Ammonites *Hoploscaphites constrictus, Acanthoscaphites* cf. *tridens, Baculites* cf. *vertebralis, ?Pseudokossmaticeras* sp., and belemnites *Belemnella lanceolata lanceolata, B. lanceolata inflata, B. lanceolata gracilis*, and *B. sumensis sumensis* (Plate V) collected from overlying marls of Bed 1 are characteristic of the Maastrichtian, mostly of the lower substage. Associated inoceramids *Cataceramus* cf. *alaeformis, C. balticus tsankovi, Spyridoceramus caucasicus*, pectinids *Oxytoma danica volgensis, Neithea striatocostata*, oysters *Pycnodonte praesinzowi, Volgella porrecta*, and *Limaria geinitzi* suggest the same stratigraphic level of the host marls, although some of these taxa appear already in the upper Campanian. The inferred Maastrichtian age of the Lokh Formation marls is consistent as well with composition of gastropod assemblage from Bed 1 that includes *Aporrhais granulosa, Calliostoma(?) mariae, Euthriofusus carinatus*, and *Turritella sexlineata.*

Brachiopods

We found brachiopods only in marls of Bed 1 of the Lokh Formation. The found specimens are identified as *Carneithyris carnea carnea, C. circularis, C. gracilis, Terebratulina gracilis*, and *Kinginella nilssoni.* The listed taxa and gastropods from the Lokh Formation enhance characterization of the Maastrichtian molluscan community of the Volga region. It is necessary to mention, however, that Asgaard (1975) and Simon (1998, 2000), who revised composition of the genus *Carneithyris*, showed that it includes only two species *C. carnea* (J. Sow.) and *C. subcardinalis* (Sahni). The first species is widespread in the upper Campanian–lower Maastrichtian and the second one in the Maastrichtian only. Our specimens classed with *Carneithyris circularis* and *C. gracilis* belong most likely to the last taxon.

Sponges

We found sponges at three stratigraphic levels: in the Borisoglebsk Sequence, "sponge horizon" of the Mozzhevelovyi Ovrag Formation, and in the Rybushka Formation. Phosphatization extent of sponge skeletons from the Borisoglebsk Sequence is imperceptible to very low in general except for single phosphatic representatives of the genus *Plocoscyphia*, which are strongly rounded. Species *Ventriculites* sp., *Lepidospongia* sp. and *Napaeana* sp. prevailing in Bed 41 occur in association with serrate *Eurete* sp., a whole skeleton *Labyrintolites* sp. and well-preserved juvenile form *Becksiina trib.* The last species represents an early form in phylogenetic lineage of this group. In addition, we detected *Sestrocladia* sp., *Aphocallistes* sp., *Guettardiscyphia* sp. and *Sororistrips* sp. in the Borisoglebsk Sequence. In opinion of Pervushov, the above assemblage is characteristic as a whole of the lower Santonian despite absence of the guide sponge genera typical of this substage.

Sponges from basal Bed 40 of the Mozzhevelovyi Ovrag Formation are phosphatic to a variable extent, and their skeletons bear dissolution marks. Species collected from this bed are *Ventriculites sterea, Lepidospongia* sp., *Pararticularia* sp., serrate *Polyscyphia* sp., and spinose *Eurete* sp. The assemblage includes mostly the fragmented and rounded redeposited sponge skeletons. It corresponds in age to the early Santonian.

The sponge assemblage from sands and sandstones of the Rybushka Formation is characteristic of the *Ortodiscus poculum–Rhizopoterion cervicorne–Sororistrips tubiformis* Beds (Pervushov, 1998). Besides *Rhizopoterion cervicorne* and *Sororistrips tubiformis*, it includes *Ventriculites successor, Ortodiscus* sp., *Etheridgea* sp. and *Becksia* sp.

Plate III. Belemnites and sponges of the Rybushka Formation from the Vishnevoe section (natural size of all specimens).

(1, 2, 3) *Belemnellocamax mammillatus volgensis* Najdin, specimens of different ontogenetic stages: (1) specimen no. Vsh-132, (2) specimen no. Vsh-133, (3) specimen no. Vsh-134, Saratov, SGU (all rostra in dorsal view), Bed 12, interval 32.0–33.2 m. (4) *B. mammillatus cylindroformis* Seltzer, subsp. nov., holotype, Specimen no. SVB-28/137, Saratov, SGU: (a) dorsal view, (b, c) dorsoventral split-off (×1.1), (d) ventral view, Bed 12, interval ~31.7–32.0 m. (5) *Ventriculites successor* Schrammen, Specimen no. H/4142 (×0.5), Saratov, SGU: (a) view of the paragaster plane, (b) lateral view, (c) wall fragment with dermal sculpturing (×1), Bed 12, interval 29.3–30.0 m.

Plate IV

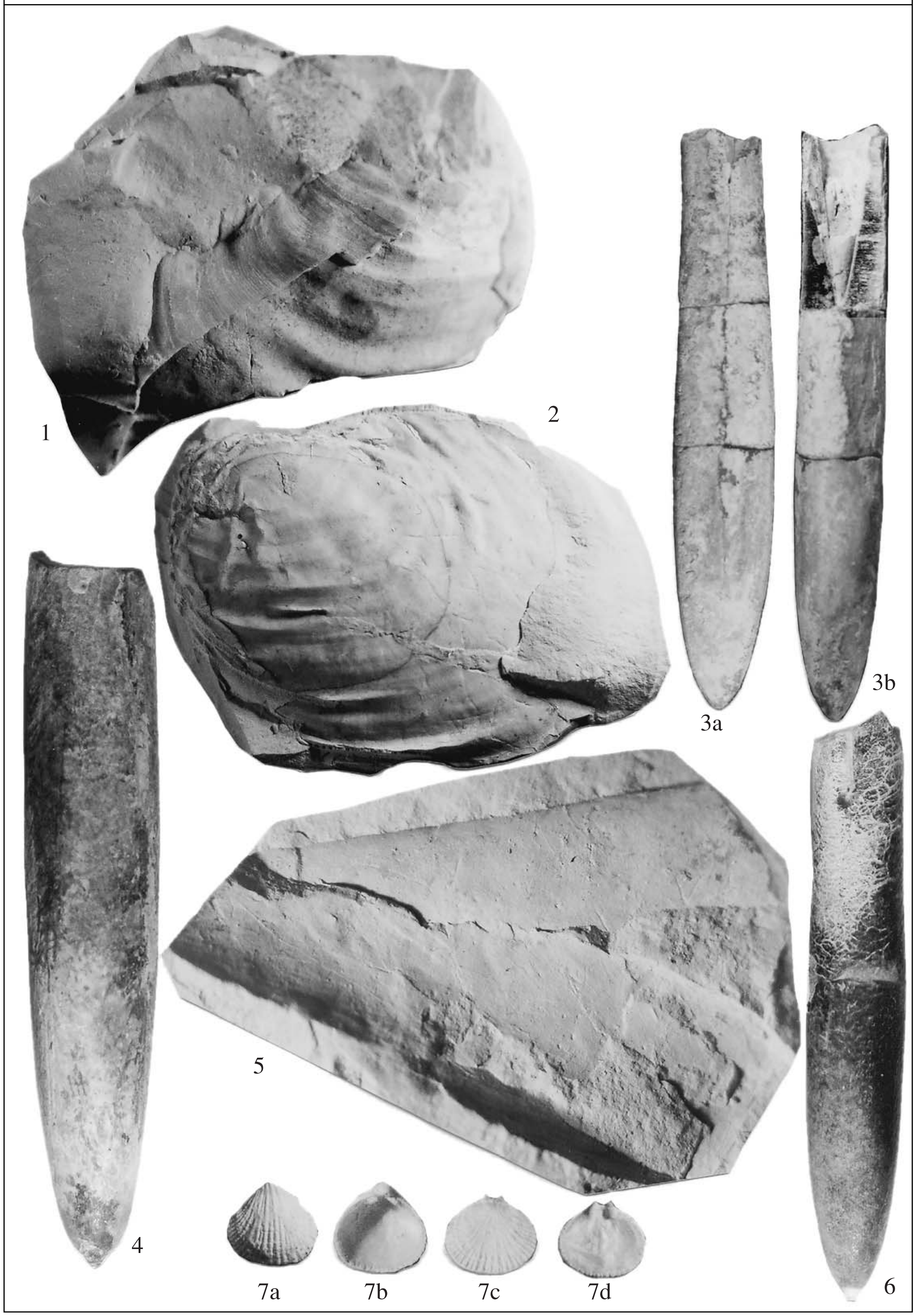


Plate IV. Mollusks and brachiopods of the Ardym (1, 2, 4–6), Nalitovo (3) and Lokh (7) formations from the Vishnevoe section (natural size of all specimens).
(1) *Cataceramus* aff. *dariensis* (Dobrov et Pavlova), Specimen no. 7/6, Saratov, SGU, Bed 7, interval ~20.9–23.0 m. (2) *C. pseudoregularis* (J. Sornay), Specimen no. 7/8, Saratov, SGU, Bed 7, interval ~20.9–23.0 m. (3) *Belemnitella* cf. *langei* Schatsky, Specimen no. Vsh-103, Saratov, SGU: (a) dorsal view, (b) lateral view of alveolar part open by dorsoventral split, Bed 6, sampling level 19.7 m. (4) *B. mucronata senior* Nowak, Specimen no. Vsh-80, Saratov, SGU, dorsal view, Bed 10, sampling level 26.7 m. (5) *Baculites* sp., Specimen no. Vsh-134, Saratov, SGU, accumulation of shell fragments, Bed 7, interval 22.8–23.0 m. (6) *B. mucronata mucronata* (Schlotheim) sensu Arkhangelsky, Specimen no. Vsh-92, Saratov SGU, ventral view, Bed10, sampling level 26.7 m. (7) *Terebratulina gracilis* (Schlotheim), Saratov, SGU: (a, b) specimen no. Vsh-139/1, ventral valve from outside and inside; (c, d) specimen no. Vsh-139/2, dorsal valve from outside and inside, Bed 1, interval ~1.6–2.4 m.

Foraminifers

Samples for micropaleontological analyses have been collected throughout the section with intervals of one meter except for the beds of lesser thickness, where sampling intervals were short enough to get representative data on microfauna of these beds. Near the boundaries between beds, which bear marks of erosion or break in sedimentation, sampling interval were decreased down to 0.1 m. In total, we selected and examined 120 samples. Schemes of sampling are shown in Figs. 6–8. Foraminifers, radiolarians and ostracodes have been macerated using conventional methods. Sieves with opening diameters of 0.5, 0.315 and 0.16 mm have been used to divide preparations containing foraminifers into respective fractions.

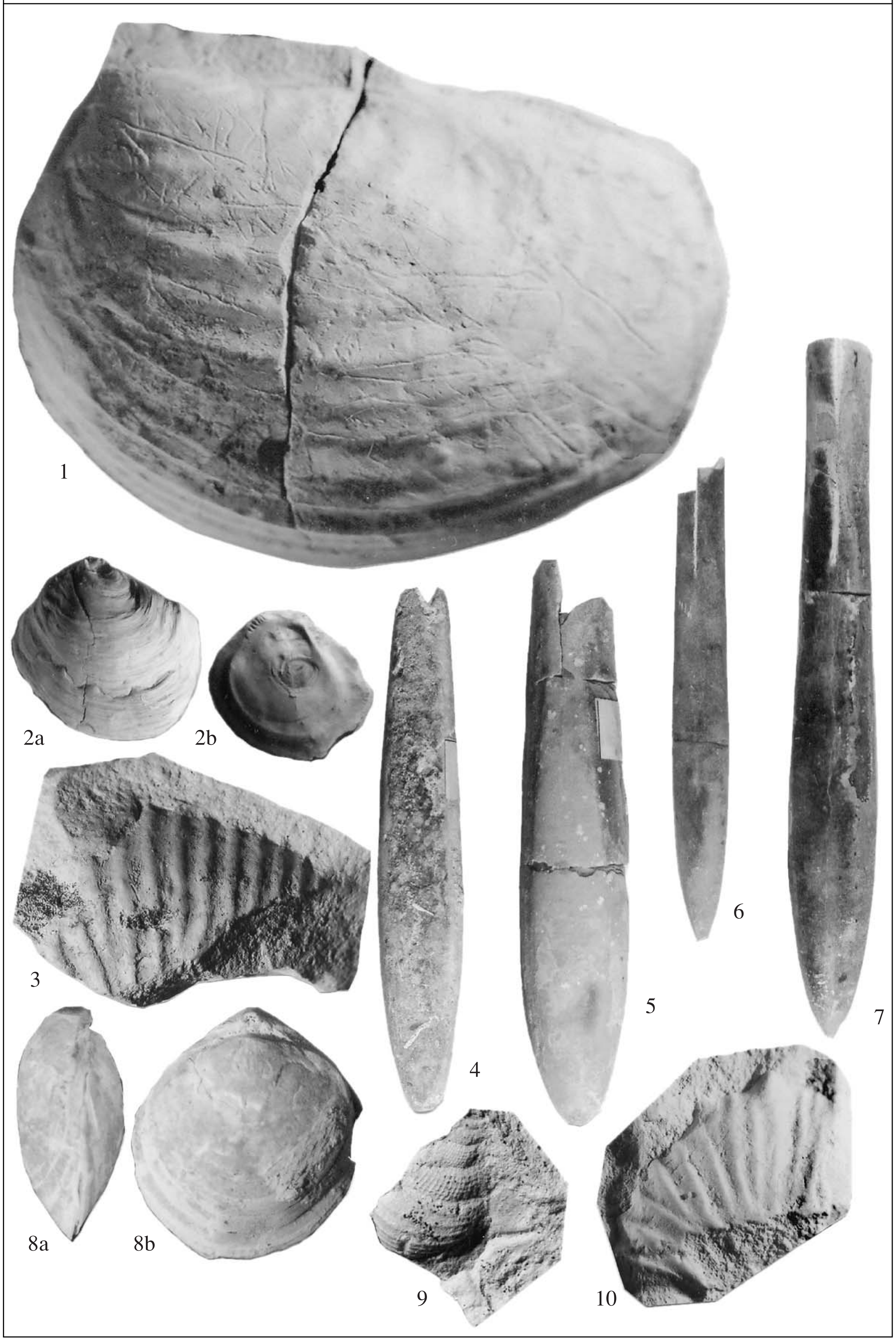
Foraminifers distributed irregularly are detected in all stratigraphic subdivisions of the section. The most representative assemblages of these microfossils are found in the Bannovka, Rybushka and Lokh formations, at the base of the Borisoglebsk Sequence, and also in the "*cardissoides* marls" of the Mozzhevelovyi Ovrag Formation, near the base of "Pteriacea Beds" in the Mezino-Lapshinovka Formation, and at the base of the Ardym Formation. The Banded Series of the Mozzhevelovyi Ovrag Formation yielded poorly preserved agglutinated taxa only, and greater interval of the Mezino-Lapshinovka Formation is barren of foraminifers. Foraminiferal assemblages of low diversity are characteristic of the Ardym (larger part) and Nalitovo formations.

The oldest foraminiferal assemblage is established in the terminal part of the Bannovka Formation interval that is exposed (Bed 42, Sample 45). Species identified here are *Ataxoorbignyina nautiloides* (Brotz.), *Gavelinella ammonoides* (Reuss), *G. kelleri* (Mjatl.) [= *G. schloenbachi* (Reuss)], *G. moniliformis ukrainica* Vass., *Osangularia whitei praeceps* (Brotz.) [in Russian publications, younger synonym of this subspecies is termed as *O. dorsoconvexa* (Wolosch.)], and *Reussella kelleri* Vass. (Plate VI). All the listed species appear in the *Gavelinella moniliformis* local zone of the middle–upper Turonian (Grigyalis et al., 1980; *Practical…*, 1991; Olfer'ev and Alekseev, 2003) and continue to exist in the Coniacian. The assemblage is lacking however any species that appears in the basal Coniacian, and the Bannovka Formation is estimated to be the middle–late Turonian in age.

Significant compositional changes in foraminiferal assemblages are observable beginning from the base of the Borisoglebsk Sequence (Bed 41, samples 31 and 46), which overlies the Bannovka Formation. The distinct turnover is evident here from disappearance of nearly all the earlier species except for *Reussella kelleri* and from appearance of the following new taxa: *Pasternakia* sp., *Bovilinopsis embaensis* (Mjatl.), *Palmula baudouiniana* (d'Orb.), *Stensioeina emscherica* (Baryschn.) [the form defined earlier as *S. granulata granulata* (d'Orb.)], *Gavelinella thalmanni* (Brotz.), *G. costulata* (Mjatl.), *G. pertusa* (Marss.), *G. vombensis* (Brotz.) [older synonym of *G. infrasantonica* (Balakhm.)], *Praebulimina ventricosa* (Brotz.), associated with abundant planktonic foraminifers *Marginotruncana marginata* (Reuss) and *Archaeoglobigerina cretacea* (d'Orb.) (Plate VII). The new assemblage is characteristic of the *Gavelinella thalmanni* local zone of the middle–upper Coniacian in the East European platform (Olfer'ev and Alekseev, 2003) or of the *Stensioeina granulata granulata* Zone (IX) in the Mangyshlak–East Caspian region (Naidin et al., 1984a, 1984b; Beniamovski and Kopaevich, 2001). The *Gavelinella kelleri* local zone of the lower Coniacian is missing from the Vishnevoe section. In addition to taxonomic diversity decrease in middle and upper parts of the Borisoglebsk Sequence, there is established appearance of *Praebulimina gracilis* (Vass.) and first smaller foraminifers *Gavelinella stelligera* (Marie).

Next changes in composition of foraminifers are recorded in basal beds of the Mozzhevelovyi Ovrag Formation that overlies the Borisoglebsk Sequence with scouring. In fact, sands of the "sponge horizon" (Bed 40, samples 34 and 50) bear only *Ataxoorbignyna orbignynaeformis* (Mjatl.) and *Ataxophragmium compactum* Brotz., and most of taxa typical of the Borisoglebsk assemblage disappear above the base of the "*cardissoides* marls" (samples 36, 51, and 53) giving place to *Cibicides excavatus* Brotz., *Pyramidulina* aff. *obscura* Reuss, and morphotypes characterizing transition from *Neoflabellina santonica* Koch to *N. gibbera* (Wed.) and from *Stensioeina exsculpta* (Reuss) to *S. gracilis* (Brotz.). Abundant planktonic foraminifers represent at this level about one third of the assemblage. Besides *Marginotruncana marginate* known from the Borisoglebsk Sequence, we identified among planktonic forms *Heterohelix globulosa* (Ehrenb.), *Marginotruncana lapparenti* (Brotz.), *Whiteinella bornholmensis* (Douglas et Rankin), *Globotruncana bulloides* Vogler and *G.* sp. Species *Osangularia whitei, Gavelinella vombensis* and *G. pertusa* established in underlying deposits occur persistently. The assemblage as a whole is traceable upward in "*cardissoides* marls" up to the depth of 64.0 m (samples 39 and 59). In the Russian plate, it is typical of the lower Santonian *Gavelinella infrasantonica* local zones or of an upper part of the *Stensioeina exsculpta exsculpta* Zone (X) in the Mangyshlak-East Caspian region. The early Santonian age of the assemblage is confirmed by occurrence of morphotypes transitional from *Stensioeina exsculpta* to *S. gracilis*, which are detected in the study section and the Shakh-Bogota section of Mangyshlak (Beniamovski and Sadekov, 2005). In Mangyshlak, this level is immediately above the first datum of *Cladoceramus undulatoplicatus* (Roem.), the inoceramid taxon marking lower boundary of the Santonian Stage in West Europe (Lamolda and Hancock, 1996). Owing to occurrence of morphotypes transitional between *Neoflabellina santonica* and *N. gibbera, "cardissoides* marls" can be correlated with the lower–middle Santo-

Plate V



nian (provided the three-member division of the stage) *N. santonica* Zone of northwestern Germany (Koch, 1977). Species *Gavelinella vombensis* occurring in the Borisoglebsk sands and "*cardissoides* marls" suggests correspondence of respective strata to the *Gavelinopsis eriksdalensis–Gavelinella vombensis* Zone of the upper Coniacian–lower Santonian also distinguished in northwestern Germany (Schönfeld, 1990; Hiss et al., 2000). Presence of planktonic *Globotruncana bulloides* is characteristic of the Santonian not only in Europe (Maslakova, 1978; Caron, 1985), but also in coastal outcrops of the Gulf of Mexico (Pessagno, 1967).

In the interval of 50.0–54.0 m corresponding to terminal part of the "Banded Series" in the Mozzhevelovyi Ovrag Formation (Bed 37, samples 64, 66, and 67), we found only poorly preserved agglutinated foraminifers *Glomospira charoides* Jones et Parker, *Psammosphaera?* sp., *Sacammina?* sp., *Ammodiscus* sp., *Rhizammina* sp., *Spiroplectammina?* sp. and *Ataxophragmium?* sp. Assemblages of this kind untypical of the European paleobiogeographic province (Beniamovski and Kopaevich, 2001) are more characteristic of the Upper Cretaceous in the West Siberian province of Arctic region (Subbotina et al., 1964).

The next assemblage of the Mezino-Lapshinovka Formation is confined to the section interval of 43.3–45.5 m (Sample 78). It includes the first occurring *Harena amanda* (Wolosch.), *Arenobulimina brotzeni* Wolosch., *Novatrix obesa* (Reuss), morphotypes transitional from *Neoflabellina suturalis* (Cushm.) to *N. deltoidea* (Wed.), and abundant typical specimens of *Gavelinella stelligera.* These newcomers occur in association with still existing *Praebulimina ventricosa* and *Cibicides excavatus* known from underlying beds. Simultaneously, *Globigerinelloides asper* (Ehrenb.) appears for the first time in the assemblage of planktonic foraminifers. The benthic assemblage corresponds to that from the lower part of the *Gavelinella stelligera* local zone distinguished in the upper Santonian of the Russian plate (Olfer'ev and Alekseev, 2003) or from the upper Santonian Subzone BF 2a known in the European paleobiogeographic province (Beniamovski and Kopaevich, 2001). In Sample 79, we detected first occurrence of stratigraphically important species *Angulogavelinella sibirica* (Neckaja) defined formerly as *Eponides* aff. *grodnoensis* Akim. (Beniamovski et al., 1988) and associated planktonic taxa *Globotruncana cretacea* (d'Orb.) and *Heterohelix* sp. As is known, *Angulogavelinella sibirica* occurs in association with *Stensioeina pommerana* in the Russian plate. The last taxon is index species of synonymous beds in the Upper Cretaceous foraminiferal zonation accepted for the East European platform. These beds correlated with terminal part of the upper Santonian *Gavelinella stelligera* local zone (Olfer'ev and Alekseev, 2003) have been ranked as Subzone BF 2b of the European paleobiogeographic province (Beniamovski and Kopaevich, 2001). In northwestern Germany, an equivalent of the latter is the *Stensioeina pommerana–Gaudryina frankei* Zone concurrent to the *Marsupites testudinarius* Zone (Schönfeld, 1990), the top of which is suggested to be at the level of the Santonian–Campanian boundary (Hancock and Gale, 1996). The recent comprehensive examination of morphology and stratigraphic distribution of *Stensioenia* forms showed that first occurrence of *Stensioeina pommerana* is recorded in strata bearing the upper Santonian crinoids in the Shakh-Bogota, Aksyirtau and Sulukapy sections of Mangyshlak (Beniamovski and Sadekov, 2005). After the late Santonian appearance in the Russian plate, distribution area of *Angulogavelinella sibirica* extended during the Campanian eastward to the Bashkirian Cis-Urals, where abundant representatives of this taxon have been found in the *Cibicidoides temirensis* local zone of the lower Campanian (Beniamovski et al., 2004), and westward to Poland (Gawor-Biedova, 1992).

In lower half of the Rybushka Formation transgressively overlying the Mezino-Lapshinovka Formation (section interval of 30.4–33.4 m Bed 12, samples 93–95), foraminiferal assemblages still contain *Ataxophragmium compactum, Gavelinella stelligera* and *Cibicides excavatus.* Except for this, taxonomic composition of foraminifers is completely changed. Their assemblage from the designated interval includes *Plectina ruthenica* (Reuss), *Gavelinella dainae* (Mjatl.), *Pseudogavelinella clementiana clementiana* (d'Orb.), *P. clementiana pseudoexcolata* (Kal.), *Cibicidoides temirensis* (Vass.), *Pullenia jarvisi* Cushm., and *Globigerinelloides volutus* (White), which appear for the first time. In Sample 95, we established first occurrence of forms transitional from *Cibicidoides temirensis* (Vass.) to *C. aktulagayensis* (Vass.) whose tests are larger in size, having flat spiral sides and more distinct triangular

Plate V. Mollusks and brachiopods of the Lokh Formation from the Vishnevoe section (natural size of all specimens).

(1) *Cataceramus balticus tsankovi* (Khar.), Specimen no. 1/8, Saratov, SGU, Bed 1, interval 1.0–1.3 m. (2) *Volgella porrecta* A. Ivanov, Specimen no. Vsh-92, Saratov, SGU: (a) left valve, external view and (b) internal view, Bed 1, interval ~0.8–1.1 m. (3) *Pseudokossmaticeras* sp., Specimen no. Vsh-118, Saratov, SGU, ventrolateral fragment of whorl, Bed 1, interval ~0.7–1.0 m. (4) *Belemnella licharewi licharewi* Jeletzky, Specimen no. Vsh-123, Saratov, SGU, dorsal view, Bed 2, sampling level 2.9 m. (5) *B. lanceolata inflata* (Arkhangelsky), Specimen no. Vsh-124, Saratov, SGU, dorsal view, Bed 1, interval 2.0–2.4 m. (6) *B. lanceolata gracilis* (Arkhangelsky), Specimen no. Vsh-98, Saratov, SGU, ventral view, Bed 1, interval 2.1–2.4 m. (7) *B. lanceolata lanceolata* (Schlotheim), Specimen no. Vsh-110, Saratov, SGU, ventral view, Bed 1, interval 1.6–1.7 m. (8) *Carneithyris circularis* Sahni, Specimen no. Vsh-120, Saratov, SGU: (a) lateral view, (b) view of dorsal valve, Bed 1, interval 0.4–2.0 m. (9) *Aporrhais* cf. *granulose* (Müller), Specimen no. Vsh-115, Saratov, SGU, Bed 1, interval 1.9–2.3 m. (10) *Acanthoscaphites* cf. *tridens* (Kner), Specimen no. 8/4, a fragment of early whorl, Bed 1, sampling level 0.6 m.

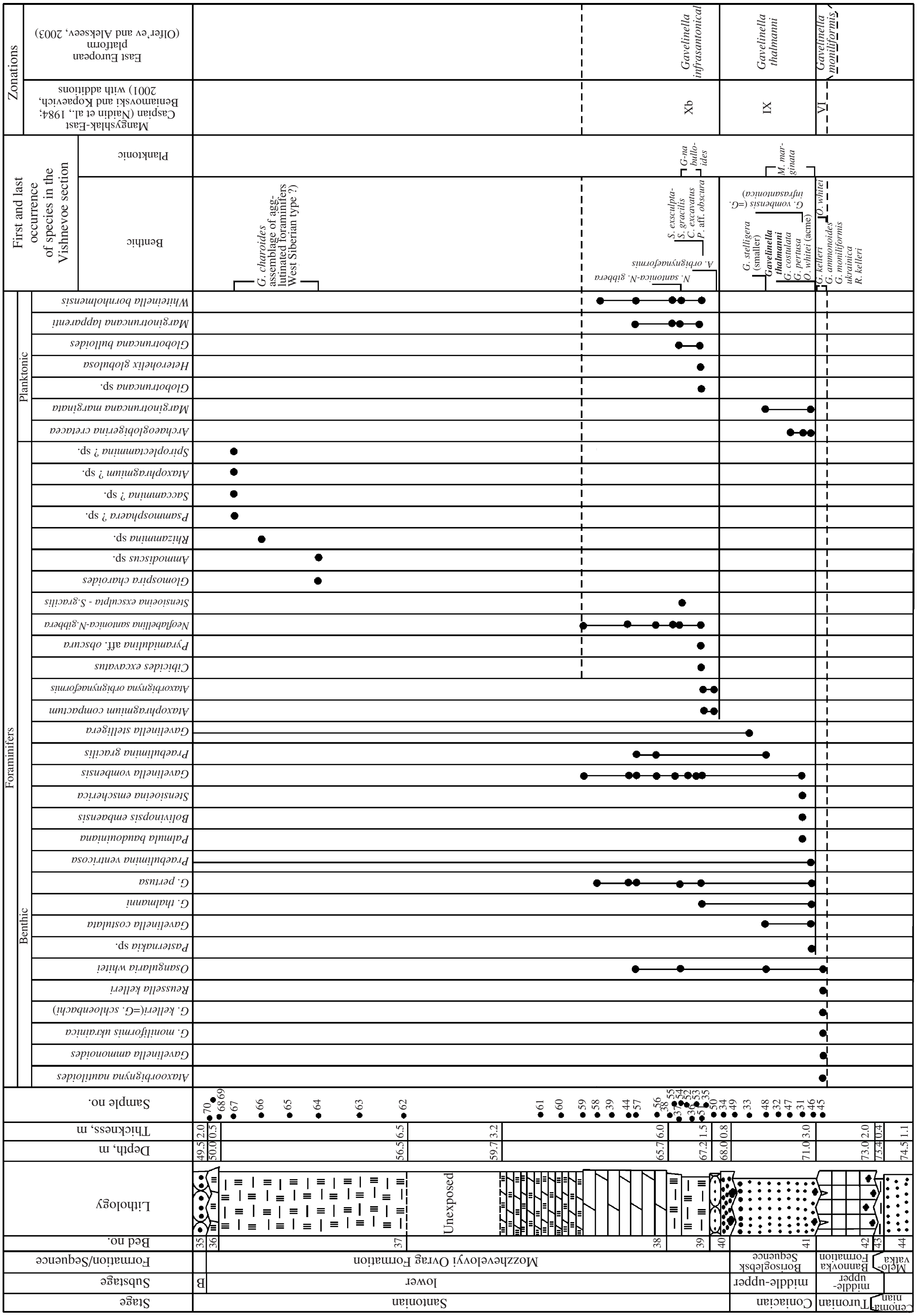


Fig. 6. Distribution of foraminifers in the Borisoglebsk Sequence, Bannovka and Mozzhevelovyi Ovrag formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

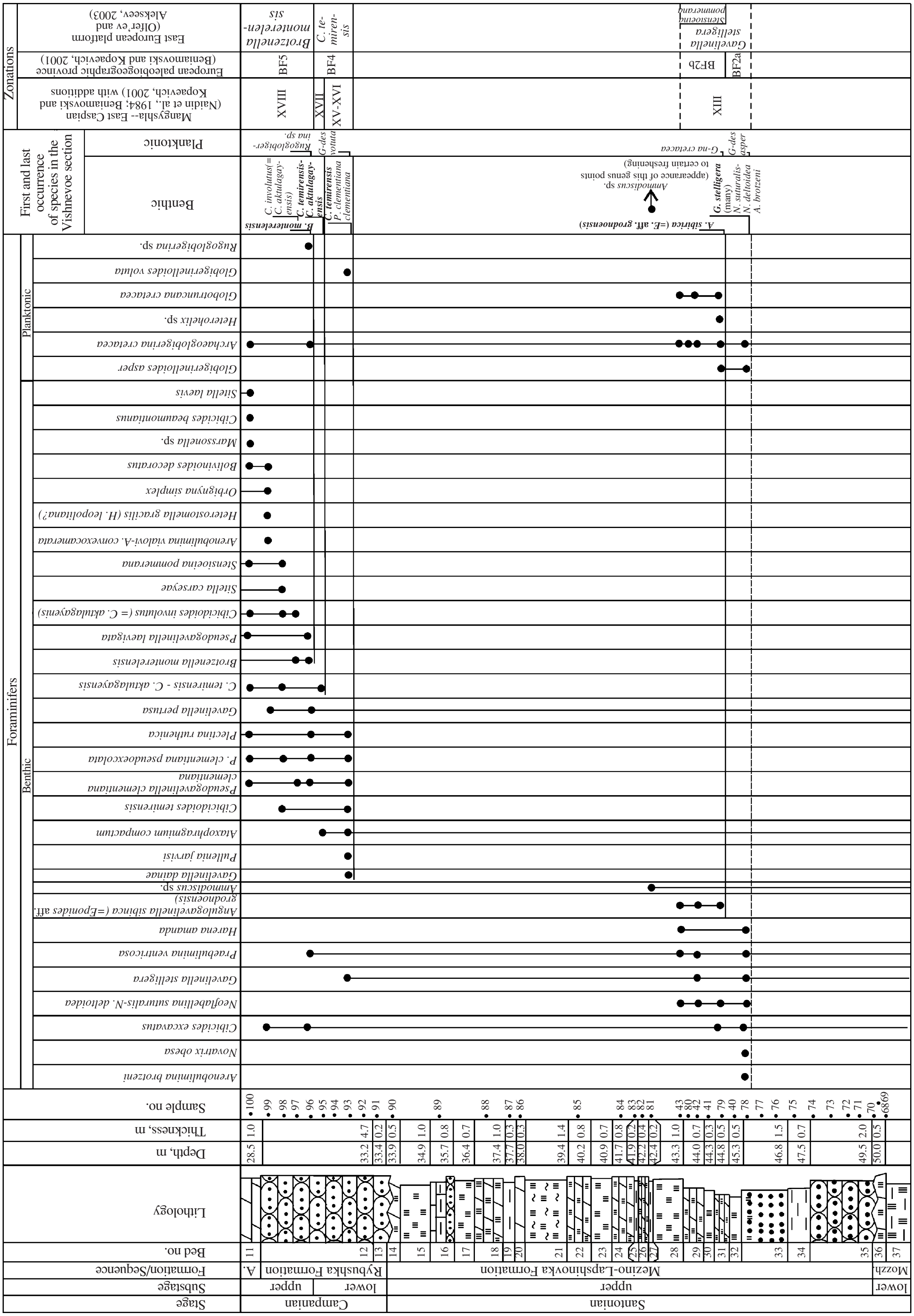


Fig. 7. Distribution of foraminifers in the Mezino-Lapshinovka and Rybushka formations of the Vishnevoe section (Mozzh.—Mozzhevelovyi Ovrag Formation, A.—Ardym Formation; symbols for lithology as in Fig. 5).

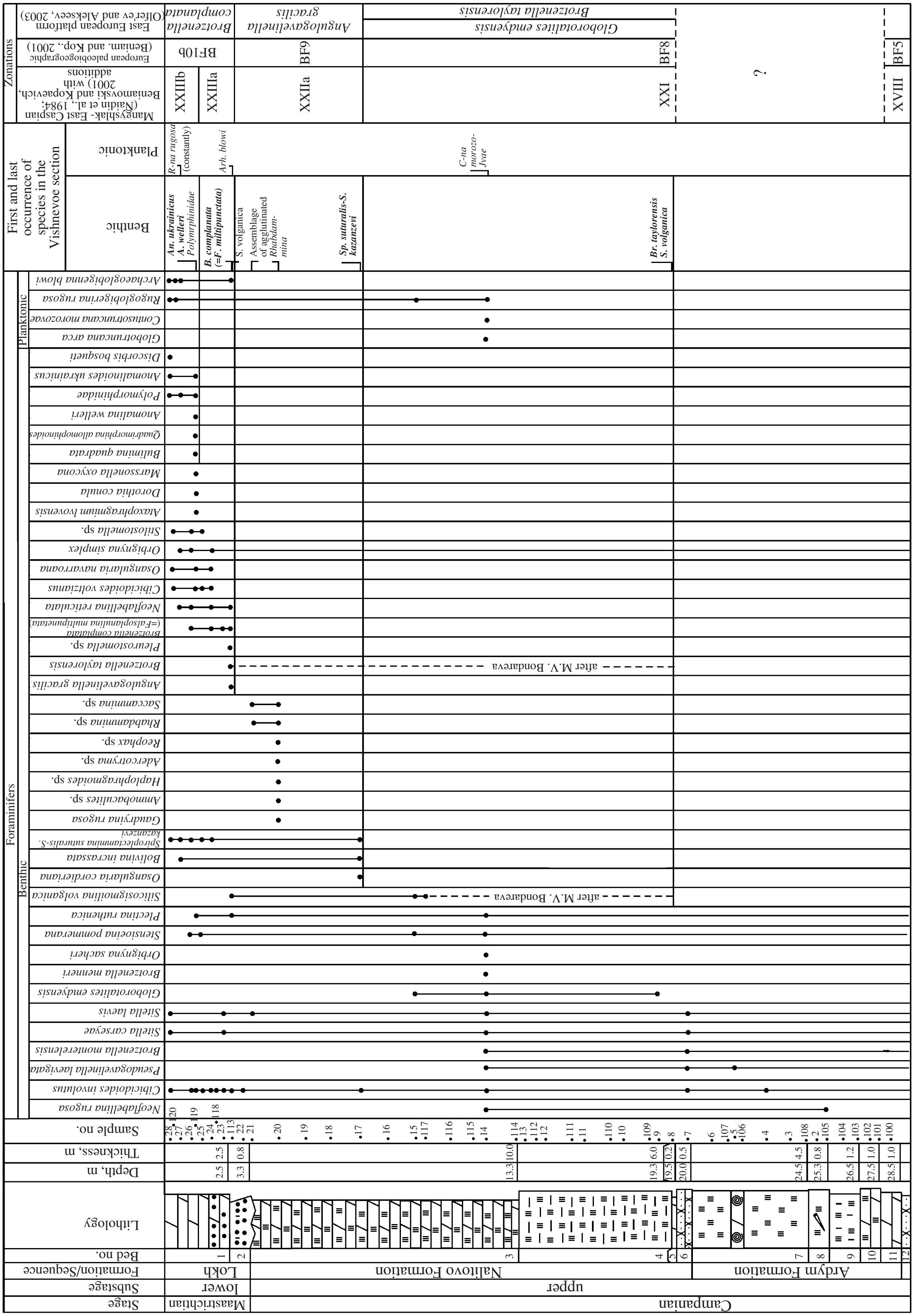


Fig. 8. Distribution of foraminifers in the Ardym, Nalitovo and Lokh formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

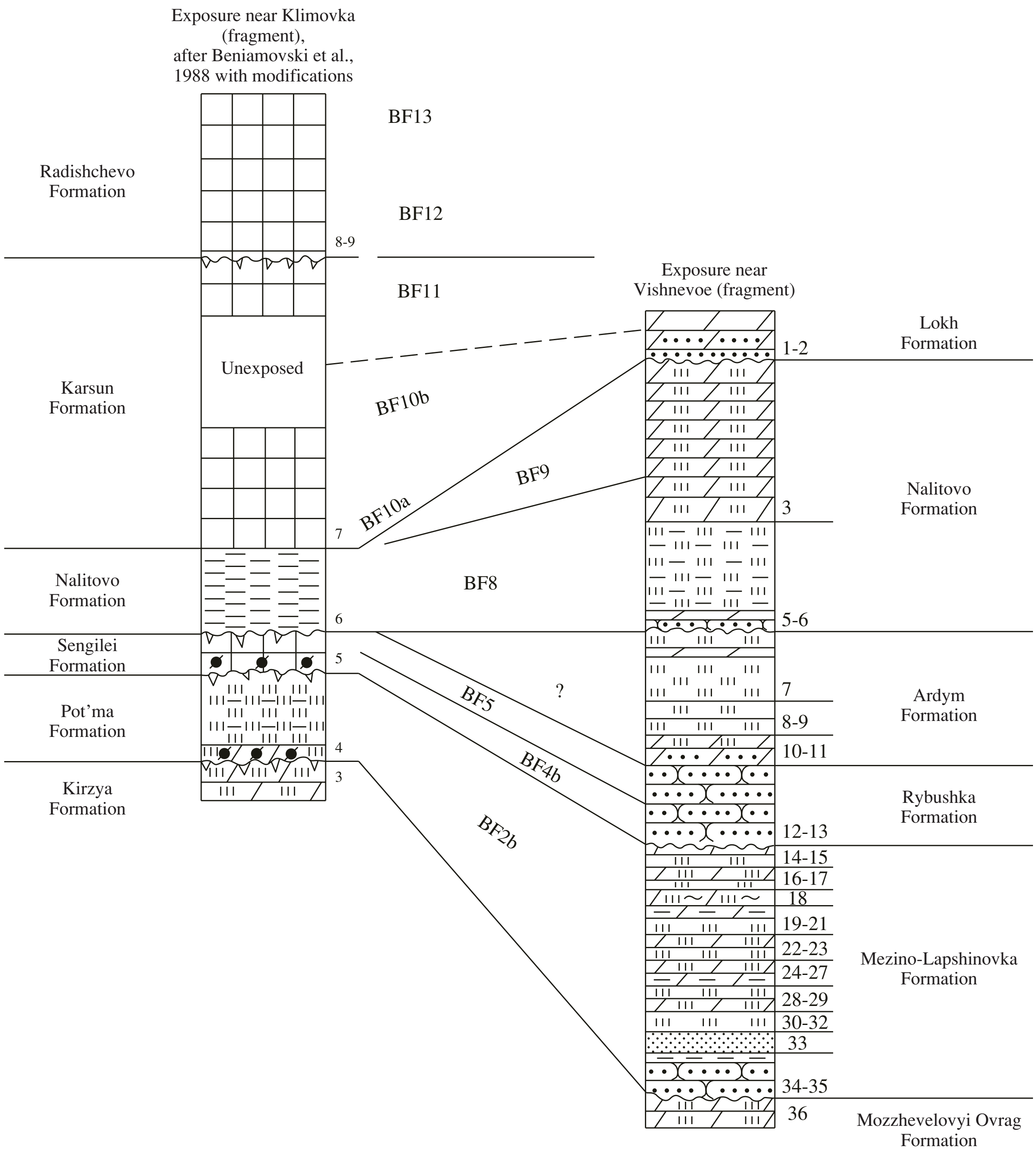


Fig. 9. Correlation of the Klimovka and Vishnevoe sections (symbols as in Fig. 5); indices of foraminiferal assemblages: (BF 2b) *Stensioeina pommerana*, (BF 4b) *Cibicidoides temirensis*, (BF 5) *Brotzenella monterelensis*, (BF 8) *Neoflabellina praereticulata–Brotzenella taylorensis*, (BF 9) *Angulogavelinella gracilis–Bolivinoides peterssoni*, (BF 10a) *Neoflabellina reticulate–Bolivina decurrens*, (BF 10b) *Brotzenella complanata*, (BF 11) *Bolivinoides draco draco*, (BF 12) *Gavelinella danica–Brotzenella praeacuta*, (BF 13) *Hanzawaia ekblomi–Pseudotextularia elegans.*

contours of septal surface that tends to be more inclined toward umbo. Presence of *Cibicidoides temirensis* means that the assemblage belongs to the synonymous local zone of the lower Campanian in the East European regional scale and respectively to Zone BF 4 of the European paleobiogeographic province or to joint interval of zones XV–XVII in the scale of the Mangyshlak–East Caspian region.

In upper sands and sandstones of the Rybushka Formation (Bed 12, interval of 28.5–30.4 m), there is recorded successive appearance of the following foraminiferal species: *Pseudogavelinella laevigata* (Marie) and *Brotzenella monterelensis* (Marie) in Sample 96; *Cibicidoides involutus* (Reuss) in Sample 97; *Stensioeina pommerana* and *Sitella carseyae* (Plumm.) in Sample 98; *Bolivinoides decoratus* (Jones), *Orbignyna sim-*

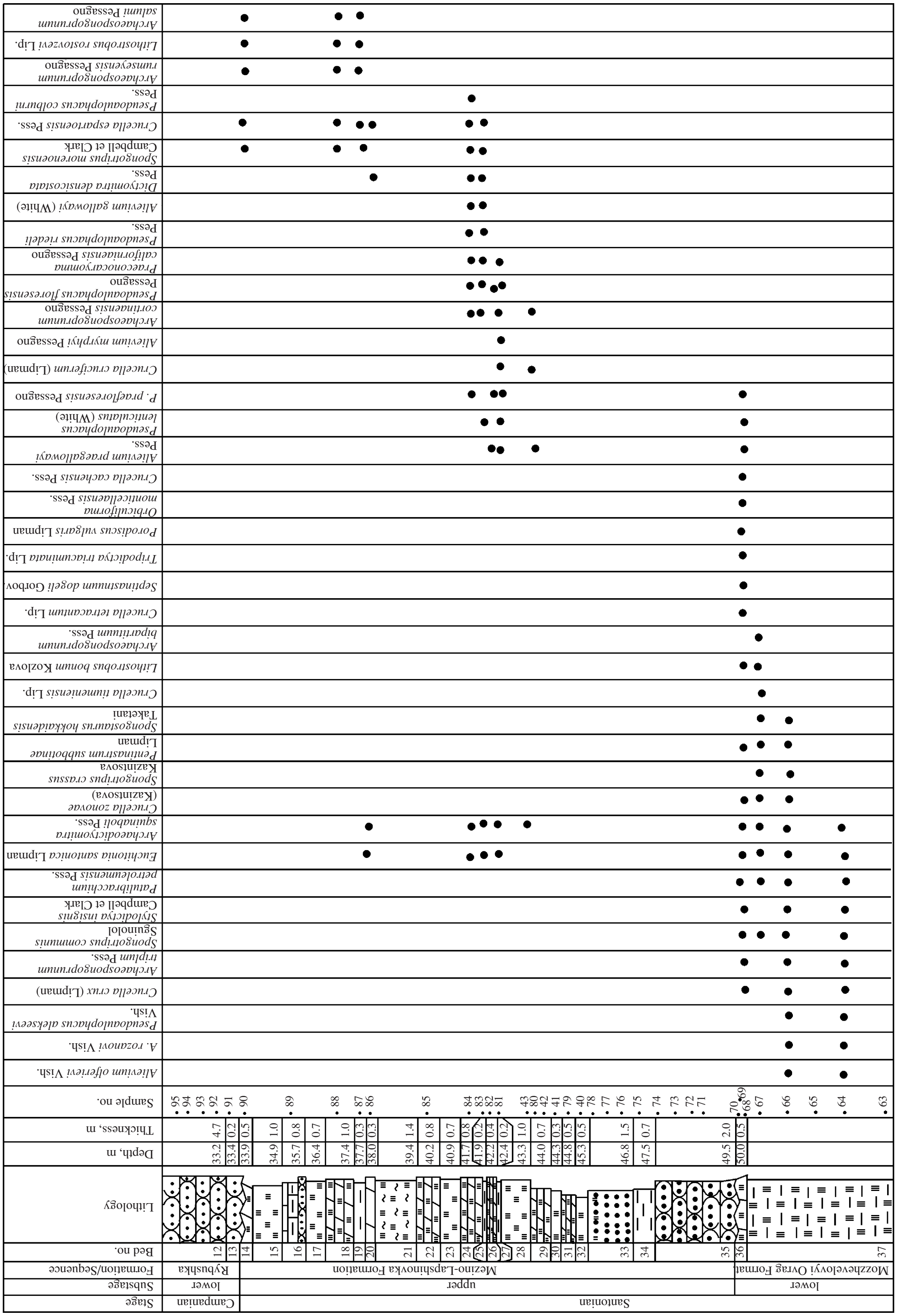


Fig. 10. Distribution of radiolarians in the Mozzhevelovyi Ovrag and Mezino-Lapshinovka formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

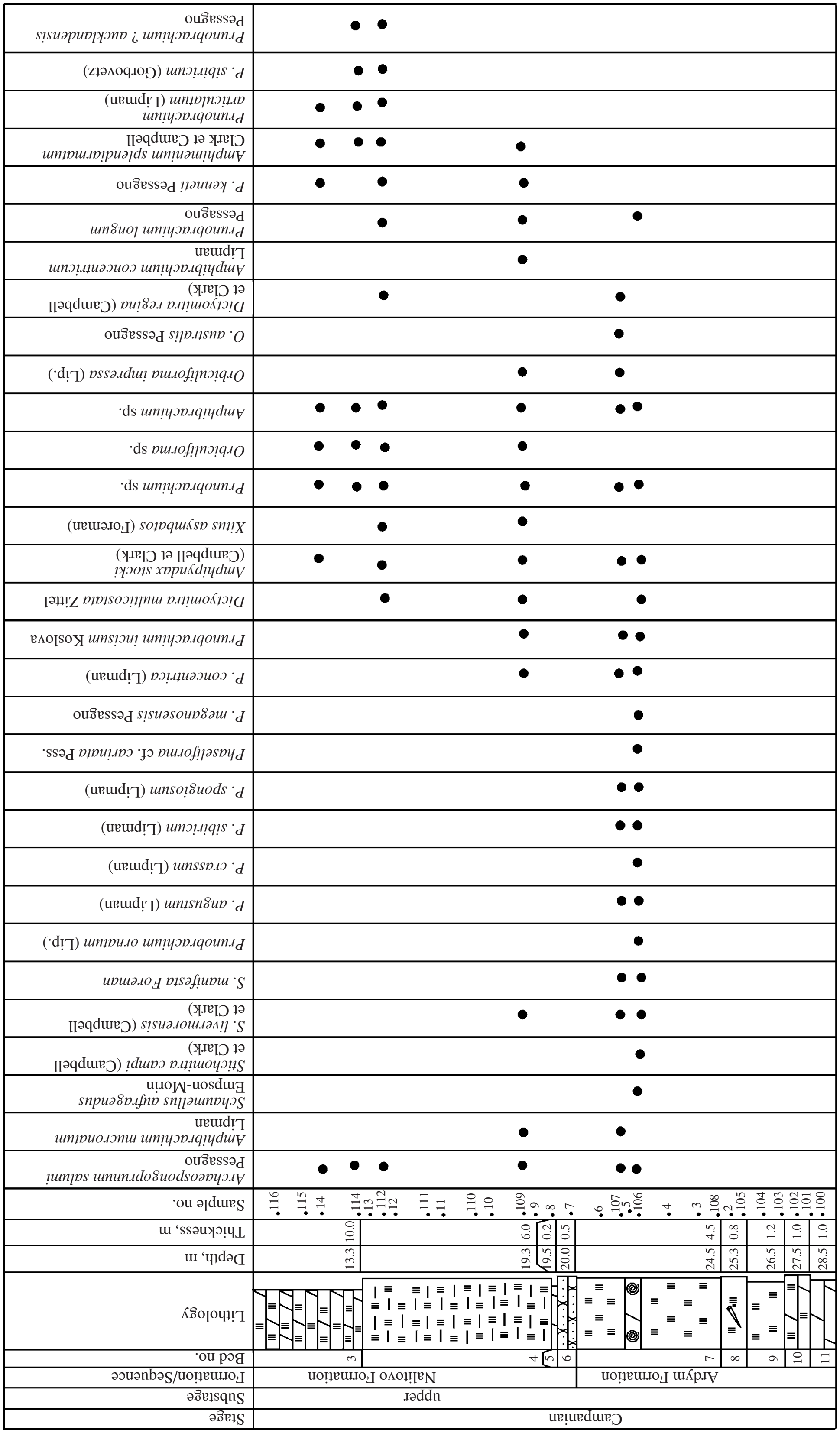
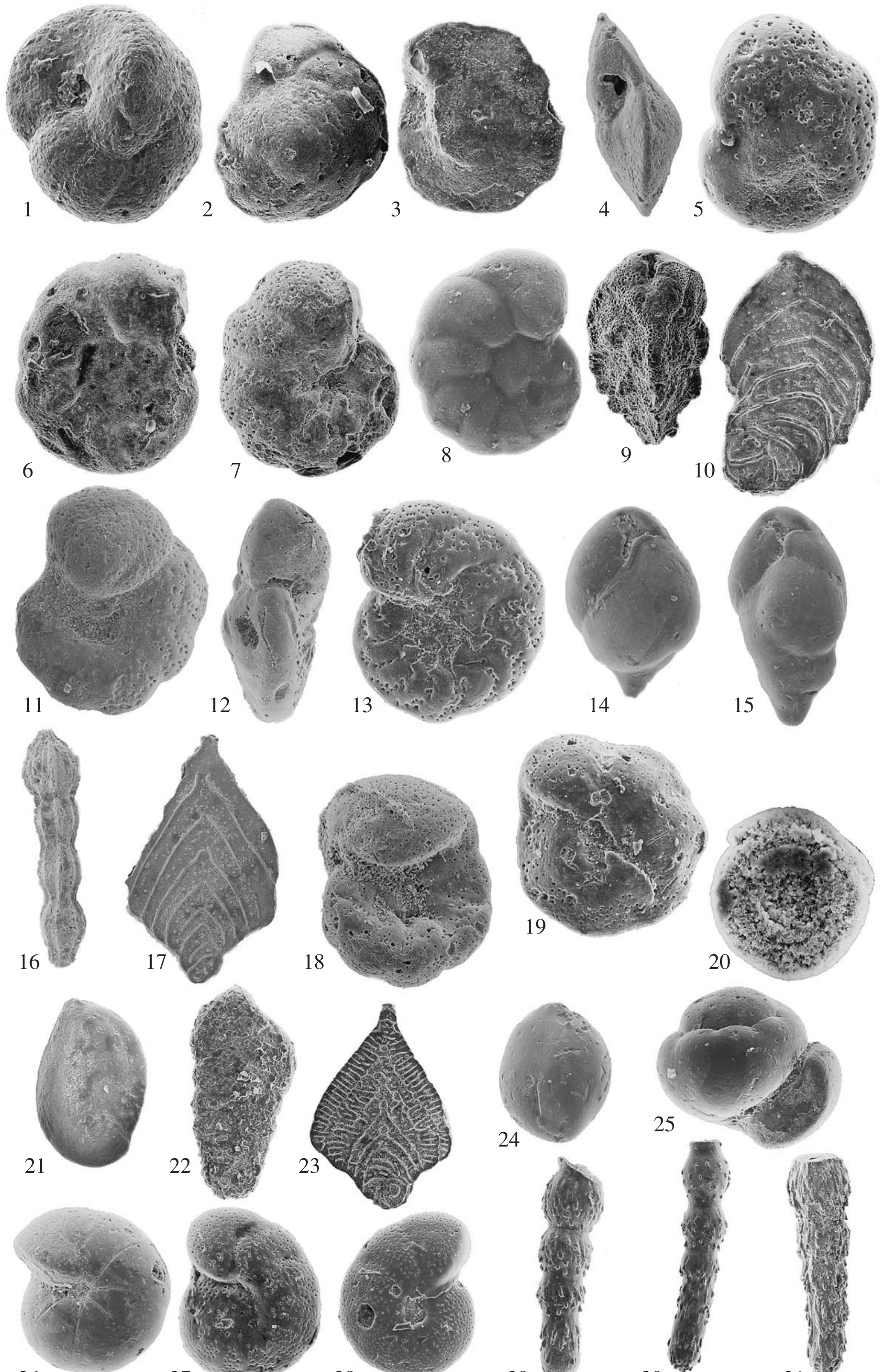


Fig. 11. Distribution of radiolarians in the Ardym and Nalitovo formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

Plate VI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plex (Reuss), morphotypes transitional from *Arenobulimina vialovi* Wolosch. to *A. convexocamerata* Wolosch., and *Heterostomella gracilis* Hofker (probable synonym of *H. leopolitana* Olsewski) in Sample 99. At the same time, we established presence of rare planktonic forms *Rugoglobigerina* sp., which do not occur in lower strata. The described assemblage belongs to the *Brotzenella monterelensis* local zone of the upper Campanian in the East European regional scale and to zones BF 5 of the European province and XVIII of the Mangyshlak–East Caspian region. Absence of the *Gavelinella clementiana clementiana* local zone and probably of basal interval of the *Cibicidoides temirensis* Zone characterizes stratigraphic diapason of hiatus between the Mezino-Lapshinovka and Rybushka formations.

Foraminiferal assemblage from basal Bed 11 of the Ardym Formation (section interval of 27.5–28.5 m) is comparable in composition with that from the Rybushka sandstones, but it includes new species *Sitella laevis* known from the base of the *Globorotalites emdyensis* local zone of the upper Campanian (*Practical…,* 1991). In siliceous marls and opokas, which compose larger part of the formation (beds 7–10, interval 20.0–27.5 m), we detected single transit species *Cibicidoides beaumontianus* (d'Orb.), *C. involutus, Pseudogavelinella laevigata, Brotzenella monterelensis*, and *Neoflabellina rugosa* (d'Orb.), which do not specify age of their host deposits.

In the Nalitovo Formation, foraminifers are rare as well. Species from sandstones of Bed 6 (section interval of 19.5–20.0 m, Sample 7) are identical to foraminifers from the underlying Ardym Formation. In lower part of Bed 4 (Sample 9 from the level of 19.0 m below the section top), we identified *Globorotalites emdyensis* Vass., the index species of synonymous local zone. The first occurrence level of this species known in West European sections as *G. hiltermanni* Kaever marks lower boundaries of Zone BF 6 in the European paleobiogeographic province and Zone XIX of the Mangyshlak–East Caspian scale.

In the formation middle part (12.4 m below the section top, Bed 3, Sample 14), a group of species inherited from underlying deposits coexists with first appearing *Orbignyna sacheri* (Reuss) and *Brotzenell menneri* (Kell.). Last taxon, the descendant of *B. monterelensis* (Marie), appears somewhat later than the ancestral form. Planktonic foraminifers occurring at the same level are *Globotruncana arca* (Cushm.), *Rugoglobigerina rugosa* (Plumm.) and *Contusotruncana morozovae* (Vass.). The last planktonic form is index species of the upper Campanian zone in the Crimea–Caucasus region (Maslakova, 1978).

In upper part of the Nalitovo Formation, three facts concerning foraminiferal assemblages are of importance.

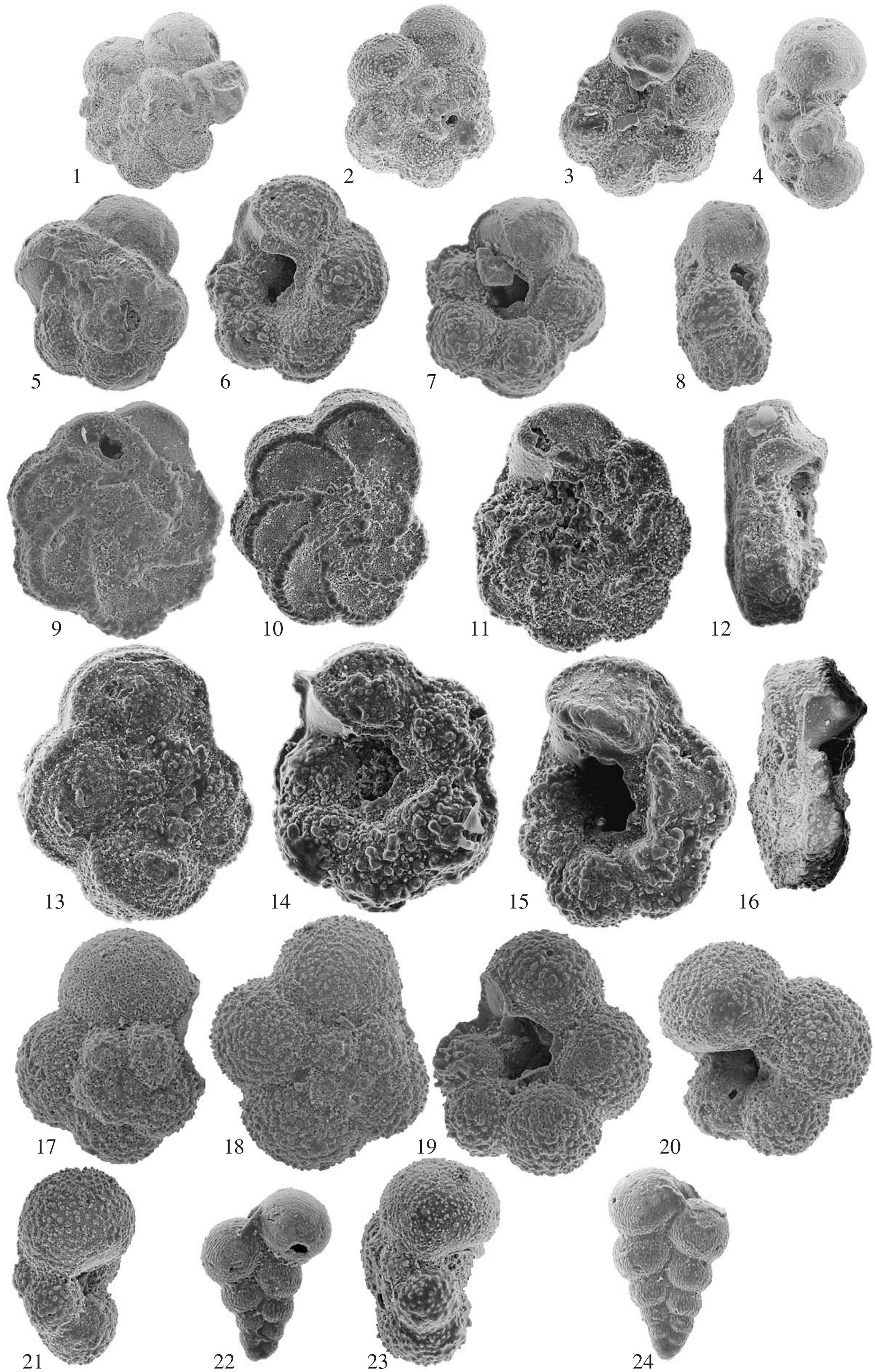
The first one is occurrence of endemic species *Silicosigmoilina volganica* at the levels of 9.8 and 9.3 m below the section top (samples 117 and 15). At the base of the Nalitovo clays exposed near the Klimovka Village at the right side of the Volga River in the Samara–Ul'yanovsk region, the first occurrence of this taxon marks the lower boundary of Zone XXI of the Mangyshlak–East Caspian scale (Beniamovski et al., 1988). This zone is correlative in turn with the *Brotzenella taylorensis* local subzone of the regional scale and with Zone BF 8 of the European province (Fig. 9).

The next event is appearance of morphotypes transitional from *Spiroplectammina suturalis* to *S. kasanzevi* Dain and associated *Bolivina incrassata* (Reuss) two

Plate VI. Benthic foraminifers of the Bannovka (1–9), Mozzhevelovyi Ovrag (14–18), Mezino-Lapshinovka (19–20), Nalitovo (21), Lokh (22–31) formations and Borisoglebsk sequence (10–13); all the figured specimens are stored at the Geological Institute RAS.

(1) *Ataxoorbignyna nautiloides* (Brotz.), Specimen GIN WSH 1 (×60); apertural side, sample 45; Bed 42. (2) *Osangularia whitei praeceps* (Brotz), Specimen GIN WSH 2 (×100); spiral side; Bed 42, sample 45. (3) *O. whitei praeceps* (Brotz), Specimen GIN WSH 3 (×120); umbonal side, Bed 42, sample 45. (4) *O. whitei praeceps* (Brotz), Specimen GIN WSH 4 (×120); apertural side, Bed 42, sample 45. (5) *Gavelinella moniliformis ukrainica* Vass, Specimen GIN WSH 5 (×140); spiral side; Bed 42, sample 45. (6) *G. ammonoids* (Reuss), Specimen GIN WSH 6 (×90); spiral side; Bed 42, sample 45. (7) *G. ammonoids* (Reuss), Specimen GIN WSH 7 (×80); umbonal side; Bed 42, sample 45. (8) *G. kelleri* (Mjatl.), Specimen GIN WSH 8 (×110); spiral side; Bed 42, sample 45. (9) *Reussella kelleri* Vass., Specimen GIN WSH 9 (×90); Bed 42, sample 45. (10) *Palmula baudouiniana* (d'Orb.), Specimen GIN WSH 10 (×35); Bed 41, sample 31. (11) *Gavelinella costulata* (Mjatl.), Specimen GIN WSH 11 (×100); umbonal side; Bed 41, sample 46. (12) *G. vombensis* (Brotz.), Specimen GIN WSH 12 (×100); apertural side; Bed 41, sample 46. (13) *G. stelligera* (Marie), Specimen GIN WSH 13 (×100); spiral side; Bed 41, sample 33. (14) *Praebulimina ventricosa* (Brotz.), Specimen GIN WSH 14 (×135); Bed 39, sample 54. (15) *Sitella gracilis* (Vass.), Specimen GIN WSH 15 (×100); Bed 39, sample 54. (16) *Pyramidulina* aff. *obscura* (Reuss), Specimen GIN WSH 16 (×35); Bed 39, sample 51. (17) *Neoflabellina santonica* (Koch) transitional to *N. gibbera* (Wed.), Specimen GIN WSH 17 (×30); Bed 39, sample 54. (18) *Cibicides excavatus* Brotz, Specimen GIN WSH 18 (×100); umbonal side; Bed 39, sample 51. (19) *Angulogavelinella sibirica* (Neckaja) [= *Eponides* aff. *grodnoensis* Akim.], Specimen GIN WSH 19 (×115); umbonal side; Bed 29, sample 42. (20) *Ammodiscus* sp., Specimen GIN WSH 20 (×00); Bed 27, sample 81. (21) *Silicosigmoilina volganica* (Kusn.), Specimen GIN WSH 21 (×60); Bed 3, sample 15. (22) *Spiroplectammina suturalis* Kal., Specimen GIN WSH 22 (×47); Bed 1, sample 24. (23) *Neoflabellina reticulata* (Reuss), Specimen GIN WSH 23 (×43); Bed 1, sample 26. (24) *Globulina* sp., Specimen GIN WSH 24 (×60); Bed 1, sample 26. (25) *Gyroidinoides* sp., Specimen GIN WSH 25 (×70); apertural side; Bed 1, sample 27. (26) *Gyroidinoides* sp., specimen GIN WSH 26; umbonal side; Bed 1, sample 27. (27) *Anomalina welleri* (Plumm.), Specimen GIN WSH 25 (×85); spiral side; Bed 1, sample 26. (28) *Anomalina welleri* (Plumm.), Specimen GIN WSH 28 (×85); umbonal side, Lokh Formation, Bed 1, sample 26. (29) *Nodogenerina* sp., Specimen GIN WSH 29 (×50); Bed 1, sample 26. (30) *N.* sp., Specimen GIN WSH 30 (×35); Bed1, sample 26. (31) *N.* sp., Specimen GIN WSH 31 (×35); Bed 1, sample 26.

Plate VII



meters higher in the section (Sample 17). The appearance level of transitional morphotypes marks the base of the *Angulogavelinella gracilis* local zone, because *Spiroplectammina suturalis* is one of species characteristic of this zone, the terminal one in the Campanian Stage of the East European platform. In original understanding, the *Angulogavelinella gracilis* Zone (XXII) spanned the terminal Campanian and basal Maastrichtian in the Mangyshlak–Caspian region (Naidin et al., 1984a, 1984b; Beniamovski et al., 1988; *Practical…*, 1991). Afterward, this zone was correlated with two subdivisions of the West European scale: the *Angulogavelinella gracilis/Bolivinoides peterssoni* Zone (BF 9) of the upper Campanian and the *Neoflabellina reticulata/Bolivinoides deccurens* Subzone (BF 10a) of the lower Maastrichtian (Beniamovski and Kopaevich, 1998) that facilitated division of Zone XXII into subzones XXIIa and XXIIb. Individual character of the latter has been recently substantiated by micropaleontological data on the Campanian–Maastrichtian boundary beds in reference section of the Aktulagai Plateau at the right side of the Emba River, the East Caspian region (Naidin and Beniamovski, 2006). The lower subzone corresponds to the upper Campanian *Angulogavelinella gracilis* local zone of the East European scale, and the upper one is equivalent of the lower Maastrichtian *Neoflabellina reticulata* local zone.

Third, the appearance of *Bolivinoides incrassata* may characterize certain deepening of the basin, as this form is mentioned among comparatively deep-water cosmopolitan taxa, which populated the Atlantic outer shelves of Europe and North America in the late Campanian–Maastrichtian (van Morkhoven et al., 1986).

In terminal part of the Nalitovo Formation (4.4 m below the section top, Sample 20), we detected a peculiar assemblage of *Gaudryina rugosa* d'Orb., *Ammobaculites* sp., *Haplophragmoides* sp., *Rhabdammina* sp., *Adercotryma* sp., *Reophax* sp., and *Saccammina* sp.

Ending consideration of foraminifers from the Nalitovo Formation, we should mention that Leongardt (1971) distinguished two foraminiferal assemblages from this subdivision: the lower one from basal clays containing rostra *Belemnitella licharewi*, and the upper assemblage occurring near the formation top. In the first assemblage, she identified *Bolivina kalinini* Vass., *Cibicidoides voltzianus* d'Orb., *Heterostomella foveolata* (Marss.), *Bolivinoides miliaris* Hilt. et Koch, and *Silicosigmoilina volganica*, whereas the second one included single *Neoflabellina reticulata* (Reuss) and *Bolivina deccurens* (Ehrenb.). According to presence of index species, the lower assemblage corresponds to the level of the upper Campanian *Bolivinoides draco miliaris* local subzone (XX) that is consistent to some extent with our results, and the upper one could be concurrent to the lower Maastrichtian local subzone XXIIb, the analog of the *Neoflabellina reticulata* local zone in the East European scale. The last interpretation contradicts, however, the data of M.V. Bondareva (see in Bondarenko, 1978) who identified *Brotzenella taylorensis* and *Silicosigmoilina volganica* in the Vishnevoe section near the base of the Nalitovo clays containing rostra *Belemnella licharewi.* These foraminiferal taxa undoubtedly belong to the *Brotzenella taylorenis* local subzone (XXI) or to Zone BF 8. The same assemblage of foraminifers is known from the base of Nalitovo clays in the Klimovka section. Based on these data, we attributed clays of Bed 4 to Zone BF 8 of the European paleobiogeographic province, but not to the interval of zones BF 6–BF 7. The lower Maastrichtian foraminifers described by Leongardt from the Nalitovo Formation top are most likely redeposited from the Lokh Formation discordantly overlying the Nalitovo strata.

A significant compositional turnover in foraminiferal assemblages is observable across the boundary between the Nalitovo and Lokh formations. Agglutinated foraminifers characteristic of terminal strata of the Nalitovo Formation do not cross this boundary and

Plate VII. Planktonic foraminifers of the Borisoglebsk sequence (1–6) and Mozzhevelovyi Ovrag (7–24); all the figured specimens are stored at the Geological Institute RAS.

(1) *Archaeoglobigerina cretacea* (d'Orb.), Specimen GIN VSH 32 (×70); spiral side; Bed 41, sample 46. (2) *A. cretacea* (d'Orb.), Specimen GIN VSH 33 (×75); spiral side; Bed 41, sample 46. (3) *A. cretacea* (d'Orb.), Specimen GIN VSH 34 (×80); umbonal side; Bed 41, sample 46. (4) *A. cretacea* (d'Orb.), Specimen GIN VSH 35 (×80); view of peripheral edge; Bed 41, sample 46. (5) *Marginotruncana marginata* (Reuss), Specimen GIN VSH 36 (×75); spiral side; Bed 41, sample 46. (6) *M. marginata* (Reuss), Specimen GIN VSH 37 (×110); umbonal side; Bed 41, sample 46. (7) *M. marginata* (Reuss), Specimen GIN VSH 38 (×130); umbonal side; Bed 39, sample 51. (8) *M. marginata* (Reuss), Specimen GIN VSH 39 (×130); view of peripheral edge; Bed 39, sample 51. (9) *M. lapparenti* (Brotz.), Specimen GIN VSH 40 (×125); spiral side; Bed 39, sample 54. (10) *M. lapparenti* (Brotz.), Specimen GIN VSH 41 (×100); spiral side; Bed 39, sample 51. (11) *M. lapparenti* (Brotz.), Specimen GIN VSH 42 (×110); umbonal side; Bed 39, sample 51. (12) *M. lapparenti* (Brotz.), Specimen GIN VSH 43 (×110); view of peripheral edge; Bed 39, sample 51. (13) *Globotruncana bulloides* Vogler, Specimen GIN VSH 44 (×115); spiral side; Bed 39, sample 51. (14) *G. bulloides* Vogler, Specimen GIN VSH 45 (×145); umbonal side; Bed 39, sample 51. (15) *G. bulloides* Vogler, Specimen GIN VSH 46 (×90); umbonal side; Bed 39, sample 51. (16) *G. bulloides* Vogler, Specimen GIN VSH 47 (×120); view of peripheral edge; Bed 39, sample 51. (17) *Whiteinella bornholmensis* (Douglas et Rankin), Specimen GIN VSH 48 (×150); spiral side; Bed 39, sample 51. (18) *W. bornholmensis* (Douglas et Rankin), Specimen GIN VSH 49 (×130); spiral side; Bed 39, sample 51. (19) *W. bornholmensis* (Douglas et Rankin), Specimen GIN VSH 50 (×100); umbonal side; Bed 39, sample 51. (20) *W. bornholmensis* (Douglas et Rankin), Specimen GIN VSH 51(×85); umbonal side; Bed39, sample 51. (21) *W. bornholmensis* (Douglas et Rankin), Specimen GIN VSH 52 (×135); view of peripheral edge; Bed 39, sample 51. (22) *Heterohelix globulosa* (Ehrenb.), Specimen GIN VSH 53 (×140); Bed 39, sample 51. (23) *Whiteinella bornholmensis* (Douglas et Rankin), Specimen GIN VSH 54 (×135); view of peripheral edge; Bed 39, sample 54. (24) *Heterohelix globulosa* (Ehrenb.), Specimen GIN VSH 55 (×140); Bed 39, sample 54.

give way to many new secretory species appearing in the Lokh Formation. Species typical of the *Brotzenella complanata* local zone at the mid-lower Maastrichtian level in the East European scale for the Upper Cretaceous and correlative Subzone BF 10b (European scale) and Zone XXIII (Mangyshlak–East Caspian scale) occur beginning from Bed 2, the basal one in the formation (section interval of 2.5–3.3 m, Sample 113). Taxa identified here are *Brotzenella complanata* (Reuss) [=*Falsoplanulina multicamerata* (Bandy) in nomenclature of Frenzel, 2000)], *Angulogavelinella gracilis, Brotzenella taylorensis, Neoflabellina reticulata, Osangularia navarroana* (Cushm.), *Nodogenerina* sp., and planktonic *Archaeoglobigerina blowi* Pess. In the same sample, we established last occurrence of *Silicosigmoilina volganica* that is most likely redeposited from the Nalitovo clays. Thus, distribution of benthic foraminifers suggests a hiatus between the Nalitovo and Lokh formations corresponding in range to the *Neoflabellina reticulata* local zone or to Subzone XXIIb. The assemblage from higher interval of the Lokh Formation is more diverse, including additional species *Ataxophragmium lvovensis* Wolosch., *Dorothia conula* (Reuss), *Marssonella oxycona* (Reuss), *Anomalinoides ukrainicus* Wolosch., *Bulimina quadrata* Plumm., *Quadrimorphina allomorphinoides* (Reuss), *Anomalina welleri* (Plumm.), representatives of Polymorphinidae, and fairly abundant specimens of *Rugoglobigerina rugosa.* Species *Anomalinoides ukrainicus* and *Anomalina welleri* appearing in Sample 119, where abundance and diversity of planktonic forms is increased, suggest that the studied section includes the *Anomalinoides ukrainicus* Subzone (XXIIIb), which represents a reliable correlation level traceable in the East European paleobiogeographic province (*Practical...*, 1991; Beniamovski and Kopaevich, 2001) and in the Aktulagai section (Naidin and Beniamovski, 2006).

Ostracodes

Ostracodes have been detected in five samples collected from the Mezino-Lapshinovka and Lokh formations. In total, we identified 21 ostracode forms, two new species included; 8 taxa are classed in open nomenclature, and 11 species are well known from the Upper Cretaceous deposits of Europe, Asia and America (Lyubimova et al., 1960; Khokhlova, 1960; Sharapova, 1937, 1939; Bosquet, 1854; Deroo, 1966; Herrig, 1966; Reich and Frenzel, 2002; Szczechura, 1965). Most of the specimens are preserved very well. In addition, we found larval shells of some species indicative of autochthonous burial and low hydrodynamic activity near the bottom. These features are characteristic of ostracode assemblages from all the samples.

Ostracodes of the Mezino-Lapshinovka Formation (plates VIII, IX) are found in the section intervals of 44.3–44.8 m (Bed 31, Sample 79) and 43.3–44.0 m (Bed 29, samples 42, 43, and 80). Ostracode assemblages from separate studied samples are largely similar to each other. In the lower Sample 79 (44.6 m below the section top), we identified the following 10 taxa: *Cytherella obovata* Jones et Hinde, *C. contracta contracta* Veen, *Cytherelloidea vishnevoensis* sp. nov., *Cythereis ornatissima* (Reuss), *Spinicythereis acutiloba* (Marsson), *Pterygocythere serrulata* (Bosquet), *Neocythere arenosa aculeata* Andreev, *Mauritsina mandelstami* sp. nov., *Golcocythere quadrulatus* (Sharapova), and *Eucythere* sp. In Sample 42 from the level of 43.9 m below the section top, subspecies *Cytherella contracta contracta* has not been detected, but the assemblage includes extra species *Eucythere* aff. *tenuis* Herrig, *Krithe simplex* (Jones et Hinde), *Physocythere minuticosta* (Szczechura), *Pterygocythere* sp. and *"Exophthalmocythere"* sp. In Sample 80 from higher level of 43.6 m, we identified all the taxa occurring in two lower samples, except for *"Exophthalmocythere"* sp. and *Eucythere* aff. *tenuis* plus associated *Cytherella ovata* (Roemer) and a form of the genus *"Cytherura"* of undeterminable species affinity. The ostracode assemblage from Sample 43, sampling level of 43.3 m, is close in composition to that from Sample 42. Additional forms of this assemblage are *Cythereis* aff. *lonsdeliana* Jones, *Paracypris depressa* Bonnema and *Xectoleberis* sp. Smooth-walled shells of eurybiontic representatives of the genus *Cytherella* prevail in all the samples. Most frequent among the sculptured forms are representatives of genera *Mauritsina, Golcocythere, Neocythere*, and *Spinicythereis*, while percentage of habitants of muddy grounds (genera *Pterygocythere* and *Cythereis*) is very low, though

Plate VIII. Ostracodes of the Mezino-Lapshinovka Formation from the Vishnevoe section (beds 29 and 31, intervals 43.3–44.0 and 44.3–44.8 m); all the figured specimens are stored at the Chair of Paleontology, Moscow State University.

(1) *Cytherella ovata* (Roemer). 309-48; right valve of female carapace, lateral view. (2, 3) *C. contracta contracta* Veen.: (2) 309-2; left valve of male carapace, lateral view; (3) 309-3; right valve of male carapace, lateral view. (4–6) *C. obovata* Jones et Hinde: (4) 309-1; right valve of male carapace, lateral view; (5) 309-39; left valve of male carapace, internal view; (6) 309-40; left valve of male carapace, lateral view. (7–9) *Cytherelloidea vishneviensis* sp., nov.: (7) 309-34; left valve of male carapace, lateral view; (8) 309-4; right valve of female carapace, lateral view.; (9) 309-5; left valve of female carapace, lateral view. (10) *Paracypris depressa* Bonnema. 309-37; right valve, internal view. (11–14) *Eucythere* sp.: (11) 309-30; right valve of male carapace, lateral view; (12) 309-22; right valve of female carapace, lateral view; (13) 309-54; right valve of female carapace, internal view; (14) 309-33; left valve of male carapace, lateral view. (15–17) *Eucythere* aff. *tenuis* Herrig.: (15) 309-26; right valve of larva, lateral view; (16) 309-32; right valve of larva, internal view; (17) 309-28; left valve, lateral view. (18) *Physocythere minuticosta* (Szczechura). 309-49; right valve, lateral view.

Plate VIII

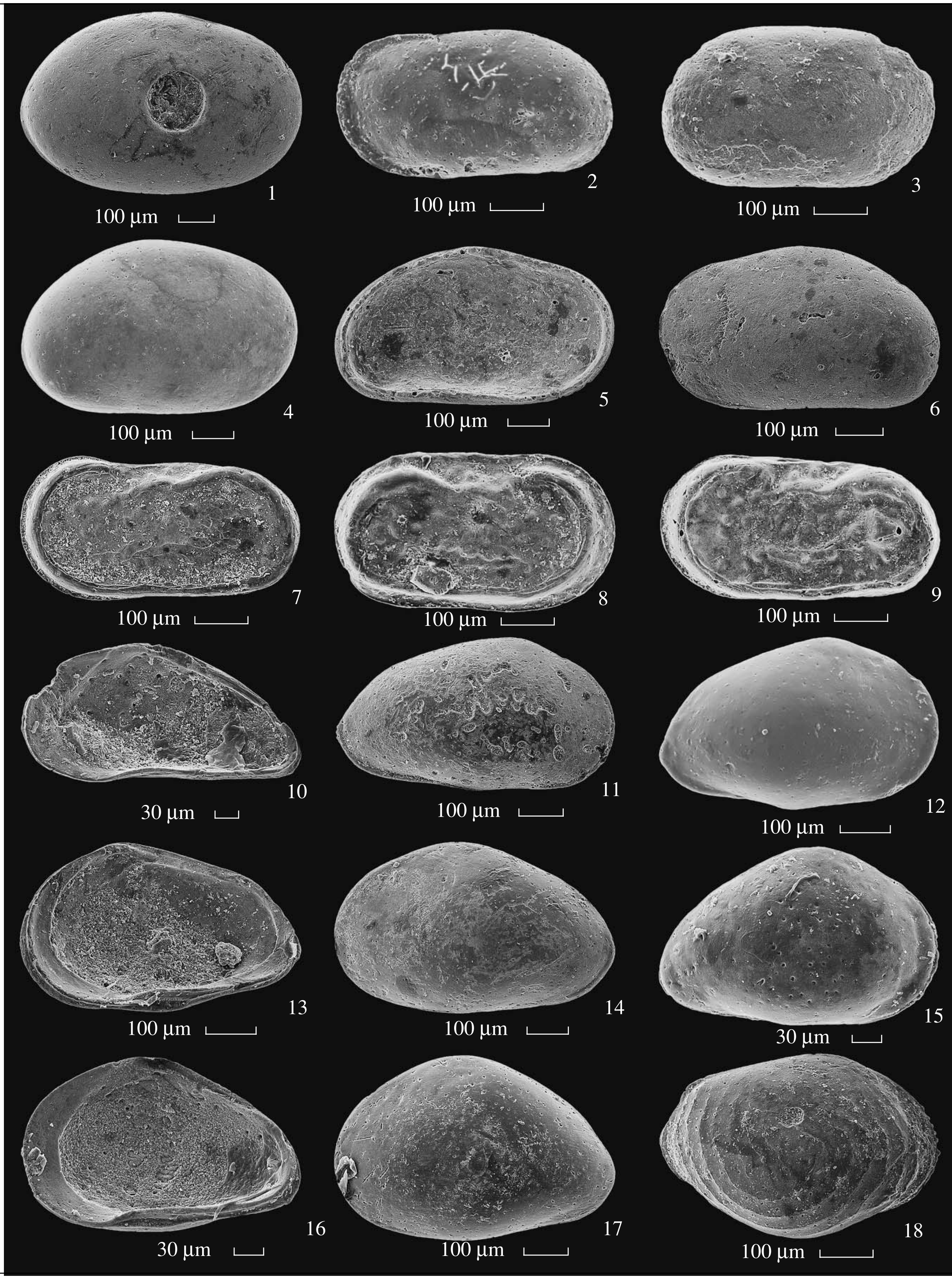

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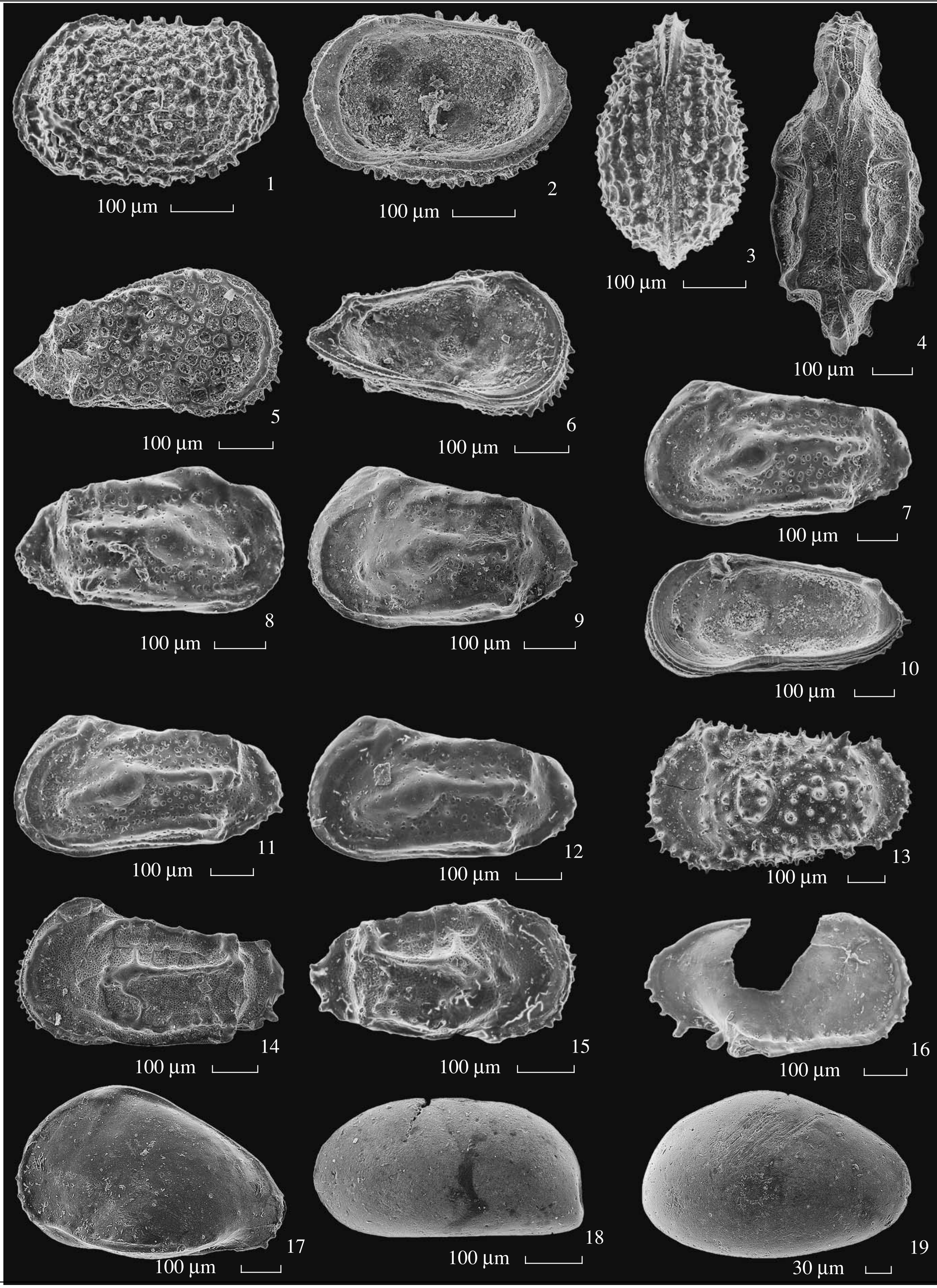
Plate IX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growing upward in the section. The community of ostracodes developed under very favorable environments of a warm shallow-water basin, presumably in the upper subtidal zone. Boring marks left by algae on some shells also evidence a shallow-water habitat of the community.

Most of species listed above are of very wide stratigraphic ranges. For instance, *Cythereis ornatissima, C. lonsdeliana, Cytherella ovata,* and *Spinicythereis acutiloba* occur in the Upper Cretaceous and Paleogene. The first taxon is known from the Senonian of Belgium and the Upper Cretaceous of England (Bosquet, 1854), from the lower Maastrichtian of Germany (Herrig, 1966), the Coniacian of Czechia (Pokorny, 1977), the Maastrichtian of West Siberia and Pripyat depression (Khokhlova, 1960). The second species has been found in the Maastrichtian of the Emba region (Sharapova, 1939), the Upper Cretaceous of England, the Campanian of Belarus, the upper Campanian and lower Maastrichtian of Poland, the Maastrichtian of Holland, and the lower Maastrichtian of the Rügen Island (Szczechura, 1965). The third taxon has been reported from the Upper Cretaceous deposits of England, Bulgaria, Poland and Czechia, from the Cenomanian and Turonian of Germany, the Campanian of Delaware, the United States (Herrig, 1966), and Saratov oblast (Sharapova, 1939), from the Maastrichtian of the Rügen Island (Reich and Frenzel, 2002), the L'viv basin of Ukraine (Didenko, 2002), and the Ozinki area (Sharapova, 1939), and from the upper Maastrichtian–lower Danian of the Mangyshlak (Tesakova, 1992). The last form is characteristic of the Upper Cretaceous in England, the Campanian in Belarus, the upper Campanian–Eocene in Poland, the Maastrichtian in Holland, the lower Maastrichtian in Germany, the Paleocene in Denmark (Szczechura, 1965, 1989), the Campanian–Paleocene of the Emba region (Sharapova, 1937), the upper Campanian in the Parisian basin (Deroo, 1966), the lower Maastrichtian in Germany (Herrig, 1966), the Maastrichtian in the L'viv basin (Didenko, 2003), the Maastrichtian–Danian boundary beds in the Mangyshlak (Tesakova, 1992). The Turonian–Maastrichtian distribution range is typical of *Cytherella contracta contracta* and *Pterygocythere serrulata.* The first subspecies is known from the Turonian and Campanian of the Emba region (Sharapova, 1937), the Maastrichtian and Danian of Mangyshlak (Tesakova, 1992), the Maastrichtian of the L'viv basin (Didenko, 2003), the lower Maastrichtian of Germany and Holland (Herrig, 1966). The other taxon has been established in the Turonian–Coniacian of Central Asia (Andreev, 1986), the Campanian of Belarus, the upper Campanian–lower Maastrichtian of Poland, the Maastrichtian of Holland and Belgium (Szczechura, 1965, 1989), and in the upper Maastrichtian of the Parisian basin (Deroo, 1966). The narrower (Campanian–Maastrichtian in general) stratigraphic ranges are characteristic of *Neocythere arenosa aculeata* described from respective deposits of Central Asia (Andreev, 1986) and of *Cytherella obovata* and *Krithe simplex*, which are established in the Campanian of England and Ozinki section of the Saratov oblast (Sharapova, 1939) and in the Maastrichtian of West Siberian lowland (Lyubimova et al., 1960). The same interval constrains distribution of *Physocythere multicostata* known from the Campanian–Maastrichtian of Poland (Szczechura, 1965, 1989), the Cis-Urals, northern Kazakhstan and West Siberia (Nikolaeva et al., 1999) or from the Maastrichtian of the Rügen Island (Herrig, 1966) and Mangyshlak (Tesakova, 1992). Species *Paracypris depressa* has been detected in the lower Maastrichtian of Germany (Herris, 1966) and in the lower Danian of Mangyshlak (Tesakova, 1992). Finally, *Golcocythere quadralatus* has been known so far only from the Campanian deposits of the Ozinki site (Sharapova, 1939). In the Vishnevoe section, the described assemblage is confined to the "Pteriaceae Beds" of the Mezino-Lapshinovka Formation.

The ostracode assemblage from upper Bed 1 of the Lokh Formation (sampling level 0.5 m, Sample 120) is remarkably different in composition. Being less diverse, it includes the following eight taxa: *Cytherella obovata, C. contracta contracta, C.* sp., *Cythereis ornatissima, Krithe simplex, Paracypris depressa, Agrilloecia* sp., and *Eucythere* sp., which are represented by single specimens except for *Cytherella obovata.* Species *Cythereis ornatissima*, the only ornamented form, is represented by one valve fragment. Accordingly, this assemblage consists predominantly of smooth-walled nonspecialized eurybionts. On the

Plate IX. Ostracodes of the Mezino-Lapshinovka Formation from the Vishnevoe section (beds 29 and 31, intervals 43.3–44.0 and 44.3–44.8 m) all the figured specimens are stored at the Chair of Paleontology, Moscow State University.

(1–3) *Neocythere arenosa aculeata* Andreev: (1) 309-10; left valve of female carapace, lateral view; (2) 309-37; right valve of female carapace, internal view; (3) 309-12; whole carapace, ventral view. (4, 14, 15) *Golcocythere quadrulatus* (Sharapova): (4) 309-45; whole carapace, dorsal view; (14) 309-44; left valve of male carapace, lateral view; (15) 309-20; right valve of male carapace, lateral view. (5, 6) *Spin9icythereis acutiloba* (Marsson): (5) 309-46; right valve of male carapace, lateral view; (6) 309-19; right valve of male carapace, internal view. (7–12) *Mauritsina mandelstami* sp., nov.: (7) 309-14; left valve of male carapace, lateral view; (8) 309-18; right valve of female carapace, lateral view; (9) 309-43, left valve of female carapace, lateral view; (10) 309-15; right valve of male carapace, internal view; (11) 309-13, left valve of male carapace, lateral view; (12) 309-16, left valve of male carapace, lateral view. (13) *Cythereis ornatissima* (Reuss). 309-6; left valve of male carapace, lateral view. (16) *Pterygocythere serrulata* (Bosquet). 309-8; right valve, lateral view. (17) *P.* sp., 309-25; left valve of male carapace, lateral view. (18) *Krithe simplex* (Jones et Hinde). 309-27; left valve of female carapace, lateral view. (19) *Xestoleberis* sp., 309-38; left valve of male carapace, lateral view.

other hand, the newly appeared genus *Agrilloecia* and associated genera *Krithe* and *Cytherella* present in the assemblage, which is lacking the ornamented shallow-water ostracodes and Cytherelloidea, are indicative of deeper and colder habitats, which appeared in the Lokh time. This is consistent with the decreased abundance and species diversity of this ostracode community.

Radiolarians

Radiolarian skeletons are irregularly distributed in Upper Cretaceous deposits of the Vishnevoe section. They are concentrated at three levels: in the "Banded Series" of the Mozzhevelovyi Ovrag Formation (interval of 49.5–56.5 m), in the Mezino-Lapshinovka Formation (33.9–42.4 m) and in the Ardym–Nalitovo boundary beds (13.3–24.5 m), being divisible into six radiolarian assemblages. The section intervals containing these assemblages can be ranked as faunal beds, as their assemblages are traceable in remote sections of the East European platform but do not represent a continuous succession and thus cannot define biostratigraphic zones according to standard regulations. Radiolarian skeletons from the Mozzhevelovyi Ovrag and Mezino-Lapshinovka formation are mostly well preserved in contrast to radiolarians from the Ardym and Nalitovo formations, which bear dissolution marks, being replaced sometimes by carbonate material or even rounded like, for instance, their skeletons from the Nalitovo Formation representing the genus *Prunobrachium.*

The *Euchitonia santonica–Archaeospongoprunum triplum* Beds are established in terminal part of the Mozzhevelovyi Ovrag Formation (interval 49.5–56.5 m), which corresponds to upper half of the "Banded Series" (beds 36 and 37, samples 64–69). The respective radiolarian assemblage includes *Archaeodictyomitra squinaboli* Pessagno, *Crucella aster* (Lipman), *C. zonovae* (Kazintsova), *C. latum* (Lipman), *C. membraniferum* (Lipman), *Euchitonia santonica* Lipman, *E. triradiata* Lipman, *Spongotripus communis* Squinabol, *S. morenoensis* Campbell et Clark, *S. crassus* Kazintsova, *Archaeospongoprunum bipartitum* Pessagno, *A. triplum* Pessagno, *Prunobrachium ornatum* (Lipman), *P. aucklandensis* Pessagno, *P. spongiosum* (Lipman), *Stylodictya insignis* Campbell et Clark, *Patulibracchium petroleumensis* Pessagno, *Spongurus marcaensis* Pessagno, *Pentiastrum subbotinae* Lipman, *Spongostaurus hokkaidensis* Taketani, *Lithostrobus bonum* Kozlova, *L. rostovzevi* (?) Lipman, *Phaseliforma carinata* Pessagno, *P. concentrica* (Lipman), *Pseudoaulophacus lenticulatus* (White), *Amphipyndax stocki* (Campbell et Clark), *A. uralica* (Gorbovetz), *Xitus asymbatos* (Foreman) and others (Fig. 10). In total, we counted more than 30 species, dominant among which are spongy spumellarians. Among nasselarians there are low-conical forms of the genus *Amphipyndax* having cephalis of complex morphology (*A. stocki* and *A. uralica*) and a few multijointed dictyomitrids and xitids. Deserving a special attention are *Archaespongoprunum triplum* and *Archaeodictyomitra squinaboli*, the upper stratigraphic limit of which corresponds to the Santonian base (Pessagno, 1976). In addition, the assemblage includes *Euchitonia santonica* widespread in Santonian sediments (Lipman, 1952; Vishnevskaya and De Wever, 1999) and *Archaeospongoprunum bipartitum*, a characteristic form of the Coniacian and lower Santonian (Pessagno, 1976; Popova-Goll et al., 2005). The combination of species listed above suggests the Coniacian–early Santonian age of the assemblage.

Radiolarians of the *E. santonica–A. triplum* Beds are comparable in composition (8 taxa in common, the index species *E. santonica* inclusive) with the late Coniacian–Santonian *E. santonica–Pseudoaulophacus praefloresensis* assemblage distinguished by Bragina et al. (1999) in the Volgograd oblast. We do not exclude as well that the beds can be correlated with summary interval of deposits containing the *A. triplum–A. bipartitum* (Coniacian) and *E. santonica* (Santonian) assemblages in the Moscow syneclise (Vishnevskaya, 2001).

The Mezino-Lapshinovka Formation is barren of radiolarians in its basal interval of 42.4–49.5 m (beds 28–35), where we studied 15 samples.

The next two assemblages are established in middle part of the Mezino-Lapshinovka Formation, in the so-called "Pteriaceae Beds" (interval 37.7–42.4 m).

The *Pseudoaulophacus floresensis–Alievium praegallowayi* Beds are of a narrow range (41.9–42.4 m), confined to lithologic beds 26 and 27 (samples 81 and 82). The beds are marked by appearance of *Dictyomitra densicostata* Pessagno, *Alievium murphyi* Pessagno, *A. praegallowayi* Pessagno, *Crucella cruciferum* (Lipman), *Pseudoaulophacus praefloresensis* Pessagno, *P. floresensis* Pessagno, *Amphibrachium (?) mucronatum* Lipman, *Praeconocaryomma californiaensis* Pessagno, *P. lipmanae* Pessagno, and *P. universa* Pessagno. In total, radiolarian assemblage of these beds consists of more than 20 species, being dominated like the assemblage of the Mozzhevelovyi Ovrag Formation by spongy, mostly discoidal forms. It is noteworthy that representatives of the genus *Archaeodictyomitra* are rare in the assemblage, and their place is occupied by narrow-ribbed species of the genus *Dictyomitra.* Species *Crucella cruciferum, C. aster, C. latum, Alievium murphyi, A. praegallowayi*, and some other terminate their evolution in the beds upper part. The disappearance level of last taxon determines upper boundary of the beds. The *P. floresensis–A. praegallowayi* assemblage likely corresponds in age to the initial late Santonian based on joint occurrence of its index species. *A. praegallowayi* becomes extinct in the mid-Santonian time, whereas *P. floresensis* appears in the terminal early Santonian. It should be noted, however, that the *A. praegallowayi* distinguished in California is concurrent there to the *Globotruncana cachensis* foraminiferal zone of the Coniacian and to the *Marginotrun-*

cana renzi Zone of the same age in the Caribbean region (Pessagno, 1976). Consequently, stratigraphic range of *A. praegallowayi* seems to be wider than it was thought before.

Radiolarians of the *Pseudoaulophacus floresensis–Alievium praegallowayi* Beds are well correlative in composition with the Santonian *Pseudoaulophacus* subassemblage from the Saratov oblast (Kazintseva, 2000).

The *Crucella espartoensis–Alievium gallowayi* Beds are confined to the section interval of 37.7–41.9 m, were radiolarians (Plate X) are detected in beds 20, 24, and 25 (samples 83, 84, and 86). We failed to find microfauna in the interval of 38.0–40.9 m, where beds 21–23 are composed of hard opokas resistant to disintegration. Radiolarians of the other beds are represented by 28 taxa. Individual character of their assemblage is evident from first occurrence of *Prunobrachium crassum* (Lipman), *P. sibiricum* (Lipman), *Crucella espartoensis* Pessagno, *Pseudoaulophacus riedeli* Pessagno, *P. colburni* Pessagno, *Alievium gallowayi* (White), *Orbiculiforma impressa* (Lipman), *O. multa* (Kozlova), *Paronaella tumida* (Lipman), *Rhopalastrum attenuatum* Lipman, *Stichomitra campi* (Campbell et Clark), and *S. livermorensis* (Campbell et Clark). In the Vishnevoe section only, this assemblage includes *P. riedeli, P. colburni, O. multa*, and *A. gallowayi.* Besides, we established in the beds the last occurrence of *Archaeospongoprunum bipartitum, Spongurus marcaensis, Pseudoaulophacus praefloresensis, P. floresensis, Praeconocaryomma californiaensis, P. lipmanae* and *P. universa.*

Both index species of the beds have been described from the Santonian–basal Campanian of California (Pessagno, 1976). The Santonian *A. gallowayi* Zone distinguished in California has been regarded as equivalent of the *Globotruncana coronata* or *G. bulloides* foraminiferal zones, whereas the *C. espartoensis* Zone of lower Campanian radiolarians from this region has been correlated with the *Archaeoglobigerina blowi* Subzone of the lower Campanian foraminifers. Deserving attention is the fact that characteristic Campanian species *Stichomitra campi* and *S. livermorensis* jointly present in the assemblage terminate their evolution in the Santonian along with *Archaespongoprunum bipartitum* (Pessagno, 1976). In opinion of Lipman (1952), *Rhopalastrum attenuatum* is most characteristic of the "Pteriaceae Beds." Kazintseva suggested earlier considering this form as zonal index species of the upper Santonian (Olfer'ev and Alekseev, 2005). Based on data presented above, the assemblage can be regarded as corresponding in age to the late Santonian.

Radiolarian assemblage of the *Crucella espartoensis–Alievium gallowayi* Beds is very similar to the *A. gallowayi* assemblage of the Saratov region (Kazintseva, 2000).

The *Lithostrobus rostovzevi–Archaeospongoprunum rumseyensis* Beds are confined to the interval of 33.4–37.7 m in terminal part (beds 14–19) of the Mezino-Lapshinovka Formation. Their radiolarian assemblage (samples 87, 88, and 90) includes more than 20 species, most remarkable among which are conical cyrtoid forms of the genus *Lithostrobus* with tests bearing massive apical horn. Species appearing in the beds are *Archaeospongoprunum salumi* Pessagno, *A. rumseyensis* Pessagno, *Schaumellus aufragendus* Epson-Morin, *Stichomitra manifesta* Foreman, *Lithostrobus turritellum* Lipman, and *L. rostovzevi* Lipman. In this assemblage only, we established presence of *A. rumseyensis* that terminated its evolution in the terminal Santonian along with *S. aufragendus, L. turritellum* and *L. rostovzevi* characteristic of the Santonian–Campanian interval, and this determines confinement of this taxon to the terminal upper Santonian and lower Campanian probably.

Radiolarian assemblage of the *L. rostovzevi–A. rumseyensis* Beds is well correlative with the *L. rostovzevi* assemblage of the upper Santonian–lower Campanian that has been distinguished in the Moscow syneclise (Vishnevskaya and De Wever, 1998).

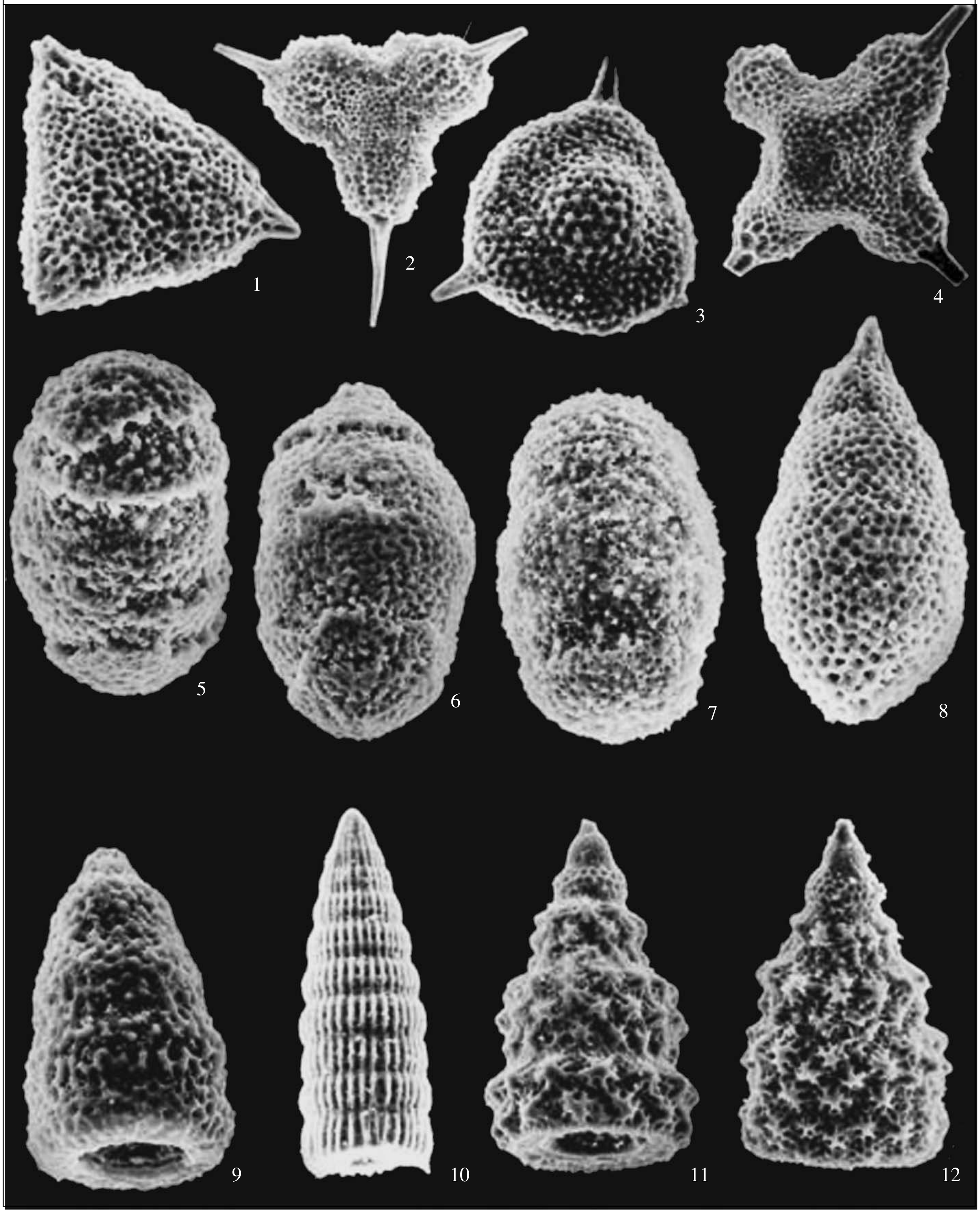
In the section interval of 22.0–33.4 m (Rybushka and basal Ardym formations), radiolarians have not been found.

Radiolarians of the *Prunobrachium mucronatum* Beds (Plate XI) have been discovered in the section interval of 21.5–22.0 m, the Ardym Formation. Radiolarian assemblage is considerably renewed here (bed 7, samples 106 and 107) owing to appearance of the Campanian species *Phaseliforma meganoensis* Pessagno, *Orbiculiforma australis* Pessagno, *Amphibrachium concentricum* Lipman, *A. sibiricum* (Gorbovetz), *Prunobrachium angustum* (Lipman), *P. mucronatum* (Lipman), *P. incisum* Kozlova, and numerous high-conical forms of the genus *Amphipyndax.* In the beds there is recorded the last occurrence of *Prunobrachium spongiosum, P. crassum, Stichomitra campi*, and *Archaeospongoprunum salumi*; the distribution range of the last species is constrained by the lower Campanian. It is necessary to mention in addition that *Phaseliforma meganoensis* appears in the upper Campanian, and consequently the assemblage under consideration can be regarded as characteristic of the early–late Campanian transition. Species *P. angustum* and *A. concentricum* are identified in this assemblage only.

The *P. mucronatum* Beds represent probably an equivalent of upper Campanian deposits containing the Assemblage 2 in the Volgograd region (Bragina et al., 1999). Radiolarians of both stratigraphic subdivisions are very close in composition to the late Campanian *P. angustum* assemblage described from the Saratov region (Kazintseva, 2000).

The *Prunobrachium articulatum* Beds are confined to the section interval of 13.3–19.3 m corresponding to lower part of the Nalitovo Formation. The respective radiolarian assemblage is established in samples 109 and 112 from Bed 4. Characteristic of this assemblage

Plate X



that includes more than 10 species is appearance of the upper Campanian index species *Prunobrachium articulatum* (Lipman). In addition to this taxon, the assemblage includes abundant radiolarian tests elongated along the vertical axis. These are representatives of genera *Amphymenium, Amphibrachium*, and *Prunobrachium*, among which we identified *Amphymenium sibiricum* (Lipman), *Amphibrachium* concentricum, *Prunobrachium* incisum, *P.* mucronatum, *P. longum* Pessagno, *P. aucklandensis, Phaseliforma concentrica*, spongy discoid *Orbiculiforma impressa*, and high-conical *Amphipyndax stocki.*

The genus *Prunobrachium* existed for a short time and became extinct at the Campanian–Maastrichtian boundary time. According to analyzed paleogeographic distribution, radiolarians of this genus are distinctly of the bipolar type and belong to species of temperate and high latitudes. Their occurrence zones are almost symmetrical relative to the equator being situated within 35–62°N in the Northern Hemisphere and 50–52°S in the Southern Hemisphere. Species occurring in the upper Campanian, predominantly boreal deposits of northeastern Russia are *Prunobrachium crassum, P. articulatum, P. incisum, P. sibiricum* (Gorbovetz), *P. californicum* (Campbell et Clark), *P. kennetti* Pessagno, *P. longum*, and *P. aucklandensis.* Characteristic of the upper Campanian deposits in the South Pacific (Campbell Plateau east of New Zealand) are species *P. aucklandensis, P. longum, P. kennetti*, and *P. sibiricum.* In the upper Campanian deposits of North America (California), there are widespread *P. californicum, P. longum*, and *P. kennetti.* Radiolarians of the genus under consideration inhabited areas near coastlines of comparatively shallow cold-water or cool basins (Amon, 2000).

The *Prunobrachium articulatum* Beds are well traceable in sections of the Russian plate, West Siberia and Subpolar Urals thus representing a perfect biostratigraphic marker in terminal part of the upper Campanian (*Practical*…, 1999).

The *P. articulatum* Beds are correlative with synonymous zone of the terminal upper Campanian (Kozlova and Gorbovets, 1966; Vishnevskaya, 2001). Radiolarian assemblage of the beds is close in composition to *P. articulatum* assemblage from the Upper Cretaceous formations of the Saratov oblast (Kazintseva, 2000).

Calcareous Nannoplankton

Calcareous nannofossils are very irregularly distributed throughout the section occurring in all stratigraphic subdivisions. They are most abundant and diverse in the section lover part: in the terminal bed of the Bannovka Formation, Borisoglebsk Sequence, and near the base of the Mozzhevelovyi Ovrag Formation in the "*cardissoides* marls" (samples 31–38 and 45–59). The nannoplankton assemblage from the respective section interval consists of more than 50 species, but their diversity declines quickly toward middle part of the Mozzhevelovyi Ovrag Formation, and the upper bed of the "Banded Series" is practically barren of nannofossils. The good to moderate preservation state of nannoplankton excludes diagenetic influence on composition of the distinguished assemblages.

The nannoplankton assemblage of Sample 45 collected from the Bannovka Formation includes abundant *Watznaueria barnesae* (Black) Perch-Nielsen and significant amount of larger *Zeugrhabdothus* spp., *Eiffellithus* spp. and *Gartnerago segmentatum* (Stover) Thierstein. Primitive representatives of the genus *Micula* also present in the assemblage (Fig. 12) are intermediate forms in the *Quadrum–Micula* evolutionary lineage and occur in transitional interval between zones CC13 and CC14 of the terminal upper Turonian and lower Coniacian.

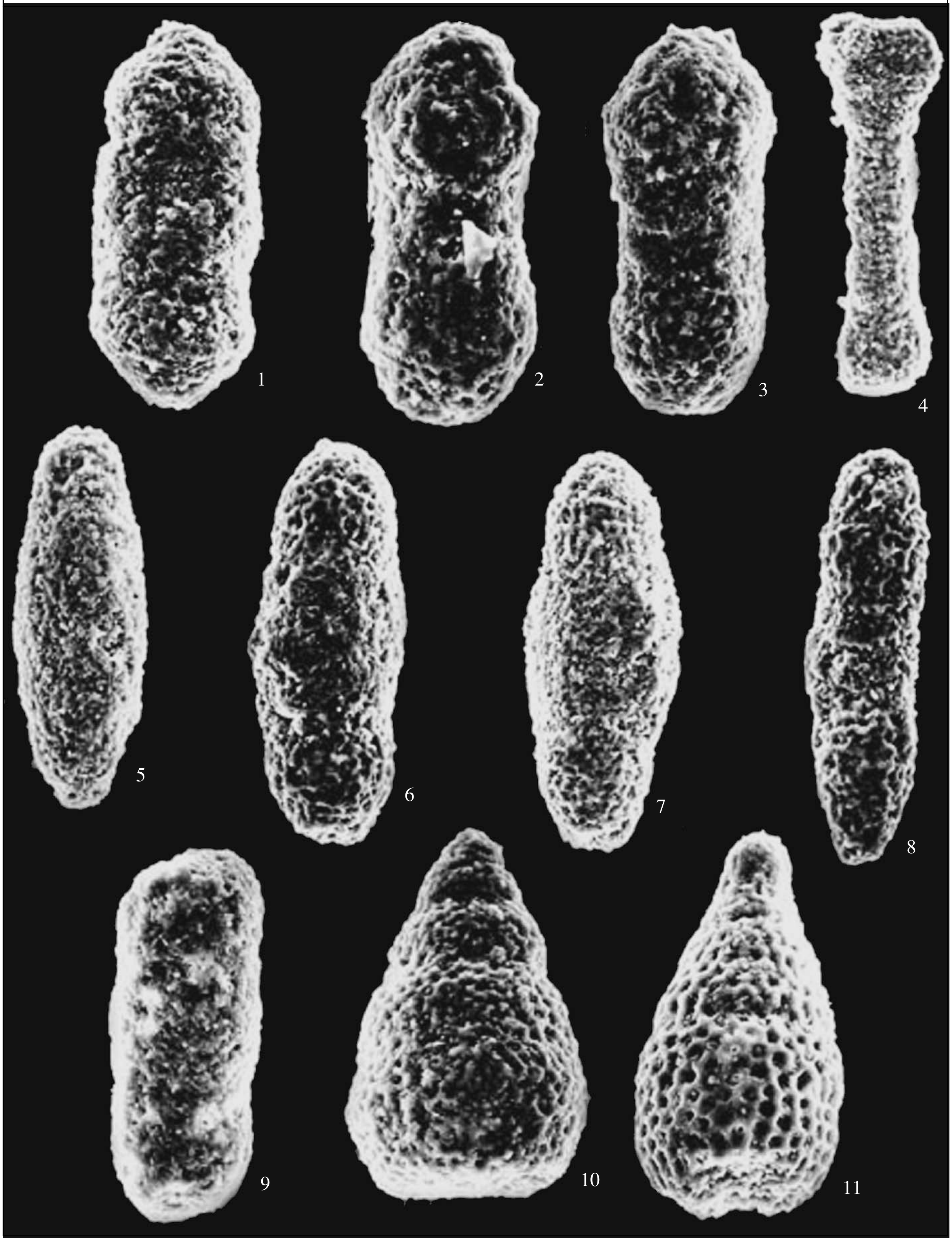
At the base of the Borisoglebsk Sequence (Sample 46), we detected numerous well-evolved *Micula staurophora* (Gardet) Stradner and *M. concave* (Stradner) Veerbek characteristic of the upper part of Zone CC14 of the middle–upper Coniacian. Hence, the hiatus between the Bannovka Formation and Borisoglebsk Sequence spans most likely a greater part of Zone CC14. Abundance of *Watznaueria barnesae* is considerably reduced in sands of Bed 41, where more numerous forms are *Prediscospaera* spp., *Broinsonia* spp., and *Helicolithus trabeculatus* (Gorka) Verbeek. It is likely that this change in proportion of warm- and cold-water forms is indicative of the late Coniacian cooling episode. The first occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen that marks the base of Zone CC15 is established in Sample 33. In uppermost part of the Borisoglebsk Sequence (Sample 49), the nannoplankton assemblage of sharply reduced diversity is represented mostly by rare *Micula staurophora, M. concave* and *Watznaueria barnesae.*

An assemblage comparable with that of Sample 49 is established also in the "sponge horizon" (Bed 40) of the Mozzhevelovyi Ovrag Formation. In overlying opokas of Bed 39, abundance of nannoplankton is somewhat higher though not reaching the degree typical of the Borisoglebsk Sequence. The preservation state of nannofossils is much worse here, and placoliths bear

Plate X. Radiolarians of the Mezino-Lapshinovka Formation from the Vishnevoe section (beds 24 and 25, interval 40.9–41.9 m, samples 83–84); all the figured specimens are stored at the Center of Micropaleontological Collections, Geological Institute RAS.

(1) *Spongotripus morenoensis* Campbell et Clark, ×150; (2) *Paronaella tumida* (Lipman), ×50; (3) *Pseudoaulophacus floresensis* Pessagno, ×150; (4) Crucella espartoensis Pessagno, ×110; (5–7) *Phaseliforma concentrica* (Lipman), ×200; (8) *Eucyrtis* aff. *carnegiensis* Campbell et Clark., ×300; (9) *Stichomitra* sp., ×200; (10) *Dictyomitra densicostata Pessagno*, 150; (11, 12) *Xitus asymbatos (Foreman)*, 200.

Plate XI



dissolution marks. The respective assemblage seems to be close in species composition to the assemblage from terminal part of the Borisoglebsk Sequence and likely corresponds also to the same Zone CC15. In overlying "*cardissoides* marls, nannoplankton is again of lowered diversity. We noted here disappearance of *Eprolithus floralis* (Stradner) Stover (above Sample 34) and *Lithastrinus septenarius* Forchheimer (above Sample 52). However, the respective levels cannot be regarded as corresponding to reliable evolutionary events because of low abundance and local absence of nannofossils in overlying sediments of the Mozzhevelovyi Ovrag Formation.

In terminal beds of the last formation corresponding to the "Banded Series" (Bed 37, Sample 63), we established first occurrence of *Lucianorhabdus cayeuxii* Deflandre and *Biscutum magnum* Wind among nannofossils. This means that the relevant calcareous nannoplankton is affiliated with Zone CC16 of the middle Santonian (provided three-member division of the stage). At the same level, we detected first occurrence of *Prediscosphaera spinosa* (Bramlette et Martini) Gartner, *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, and *Arkhangelskiella specillata* Vekshina.

Calcareous nannoplankton from deposits of the Mezino-Lapshinovka Formation does not reveal essential compositional changes. Occurring here in separate intervals, it is of low diversity in general. The most representative assemblage is found in lower part of the *Pteriaceae Beds* (samples 78–81). It includes over 20 species of relatively wide stratigraphic ranges (Fig. 13). Fist occurring among them are *Cylindralithus serratus* Bramlette et Martini, *Vekshinella angusta* (Stover) Verbeek, *Microrhabdulus belgicus* Hay et Towe, and *Stradneria crenulata* (Bramlette et Martini) Noël. Important in addition is presence in this assemblage of *Zeugrhabdotus diplogrammus* (Deflandre) Gartner, the species terminating its evolution in the middle of Zone UC12 or in the *Uintacrinus socialis* Zone of echinoids (Burnett, 1998).

A cardinal change in coccolithoforid community is recorded across the boundary between the Mezino-Lapshinovka and Rybushka formations. Twelve new nannofossils appearing above the base of the latter (Bed 12, Sample 92) are *Thoracosphaera saxea* Stradner, *Staurolithus imbricatus* (Gartner) Burnett, *Zeugrhabdotus embergerii* (Noël) Perch-Nielsen, *Prediscosphaera intercisa* (Deflandre) Shumenko, *P. arkhangelskyi* (Reinhardt) Perch-Nielsen, *Calculites obscurus* (Deflandre) Prins et Sissingh, *C. ovalis* (Stradner) Prins et Sissingh, *Broinsonia signata* (Noël) Noël, *B.* enormis (Shumenko) Manivit, *B. parca parca* (Stradner) Bukry, *B. parca constricta* Hattner and *Orastrum campanensis* (Čepek) Wind. The last three forms are characteristic of the lower Campanian Zone CC18.

An analogous assemblage is established in basal beds 10 and 11 of the Ardym Formation (Fig. 14). In the Bed 9 however (sample 103, depth 26.5 m), the assemblage is lacking *Marthasterites furcatus* (Deflandre) Deflandre, the species persistently present in nannoplankton assemblages beginning from the Bannovka Formation, and this event determines the upper boundary of Zone CC18. Among nannofossils from beds 8 and 9, there are no zonal index taxa, and the respective assemblage can be regarded as indicative of zonal interval CC19–CC22b only. Species *Reinhardtites levis* Prins et Sissingh first occurring at the base of Bed 7 (Sample 3) marks the base of Subzone CC22c, which is inside the *Belemnitella mucronata minor* Zone in opinion of Burnett (1998). The last occurrence of *Eiffellithus eximius* (Stover) Perch-Nielsen and *Orastrum campaniensis* is established in terminal part of the Ardym Formation (Sample 106). According to Burnett, absence of the last species in overlying deposits may determine position of the lower boundary of the *Belemnitella mucronata minor* and *Didymoceras donezianum* zones.

Species appearing at the base of the Nalitovo Formation (beds 6, 5 and basal part of Bed 4, section interval 18.4–20 m, samples 7, 8, and 109) are *Helicolithus trabeculatus* (Gorka) Veerbek, *Manivitella solida* (Stover) Hill., *Tetrapodorhabdus decorus* (Deflandre) Wind et Wise, and *Microrhabdulus undosus* Perch-Nielsen. It is important to note that *Reinhardtites anthophorus* occurs persistently in all the analyzed samples from the above interval that corresponds, consequently, to the terminal part of Subzone CC22a. According to published data, the top of this subzone in Western Europe is either inside the *Didymoceras donezianus* and *Belemnitella langei langei* zones (von Salis in Hardenbol, 1998), or coincides with the base of the *Micraster grimmensis–Cardiaster granulosus* Zone (Hiss et al., 2000), whereas Burnett (1998) suggests that it is in lower part of the latter and, consequently, directly above the base of the *Nostoceras hyatti* Zone. A greater part of Bed 4 and Bed 5 are mostly barren of calcareous nannoplankton except for Sample 17 from the depth 7.1 m. Among newcomers identified in this sample, it is necessary to mention *Marcalius inversus* (Deflandre)

Plate XI. Radiolarians of the Nalitovo (1–4) and Ardym (5–11) formations from the Vishnevoe section; all the figured specimens are stored at the Center of Micropaleontological Collections, Geological Institute RAS.

(1) *Prunobrachium longum* Pessagno, ×250, Bed 4, sample 109; (2, 3) *Amphibrachium concentricum* Lipman, ×250, Bed 4, sample 109; (4) *Prunobrachium? aucklandensis* Pessagno, ×130, Bed 4, sample 109; (5) *Prunobrachium angustum* (Lipman), ×130, Bed 7, sample 107; (6, 7) *P. sibiricum* (Lipman), ×130, Bed 7, sample 107; (8) *P. mucronatum* (Lipman), ×150, Bed 7, sample 107; (9) *P. spongiosum* (Lipman), ×250, Bed 7, sample 107; (10) *Stichomitra manifesta* Foreman, ×300, Bed 7, sample 107; (11) *Amphipyndax stocki* (Campbell et Clark), ×300, Bed 7, sample 107.

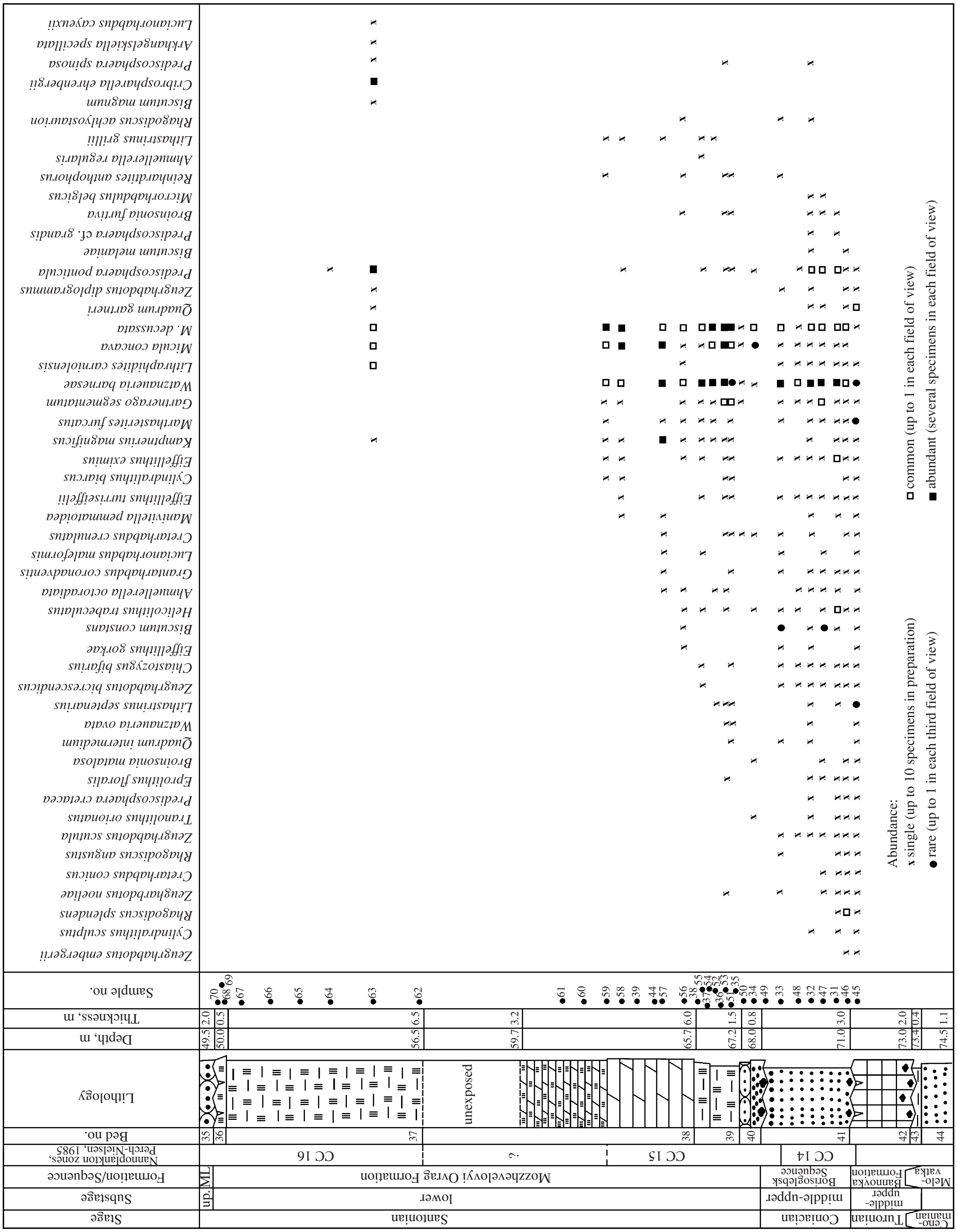


Fig. 12. Distribution of calcareous nannoplankton in the Borisoglebsk Sequence, Bannovka and Mozzhevelovyi Ovrag formations of the Vishnevoe section (up.—upper, ML—Mezino-Lapshinovka Formation, symbols for lithology as in Fig. 5).

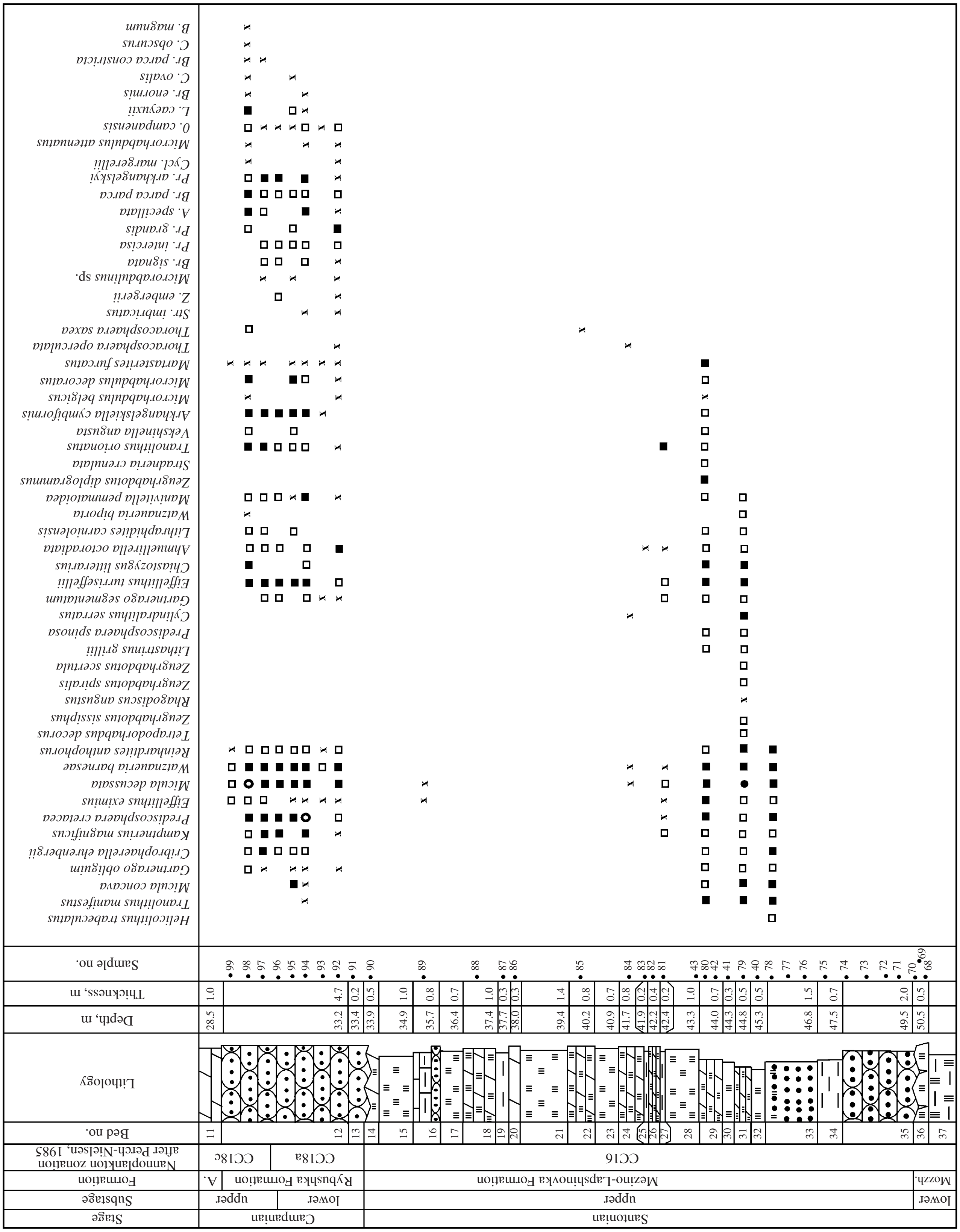


Fig. 13. Distribution of calcareous nannoplankton in the Mezino-Lapshinovka and Rybushka formations of the Vishnevoe section (Mozzh.—Mozzhevelovy; Ovrag Formation, A.—Ardym Formation, symbols for lithology as in Fig. 5).

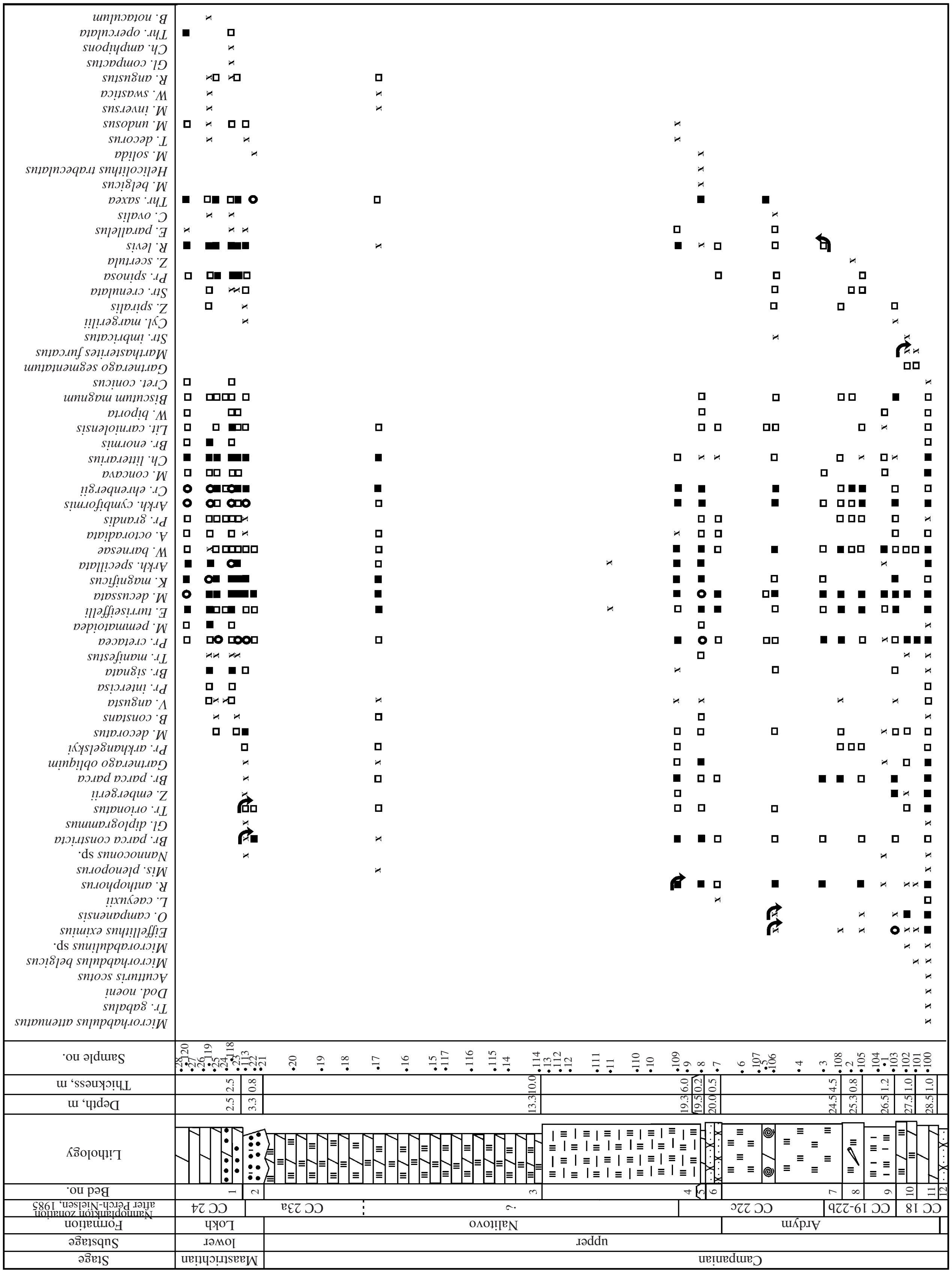


Fig. 14. Distribution of calcareous nannoplankton in the Ardym, Nalitovo, and Lokh formations of the Vishnevoe section (symbols for lithology as in Fig. 5).

Bramlette et Manivit, *Watznaueria swastika* Stradner et Steinmetz and *Rhagodiscus angustus* (Stradner) Reinhardt. Species *Reinhardtites anthophorus* is absent at this level, and its disappearance means that the respective assemblage belongs to younger Subzone CC23a spanning the Campanian–Maastrichtian boundary strata.

The assemblage of calcareous nannoplankton from basal Bed 2 of the Lokh Formation (samples 22 and 113) is without cardinal changes as compared to the upper Nalitovo assemblage. It includes new species *Chiastozygus amphipons* (Bramlette et Martini) Gartner, *Glaucolithus compactum* (Burnett) Perch-Nielsen, *Thoracosphaera operculata* Bramlette et Martini, still occurring *Tranolithus orionatus* (Reinhardt) Perch-Nielsen, and *Broinsonia parca constricta* (Stradner) Bukry. Presence of the last taxon suggests that the assemblage belongs to Subzone CC23a. In marls of overlying Bed 1, we established first occurrence of *Biscutum notaculum* Wind et Wise and disappearance of *Tranolithus orionatus.* These facts evidence correspondence of respective nannofossil assemblage to Zone CC24 correlative with the *Belemnella sumensis* local zone of the lower Maastrichtian (Hiss et al., 2000; Olfer'ev and Alekseev, 2005).

In the next paper, we are going to discuss problems of the Upper Cretaceous chronostratigraphy in the northwest of the Saratov oblast.

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