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Upper Cretaceous Deposits in the Northwest of Saratov Region, Part 2: Problems of Chronostratigraphy and Regional Geological History

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Abstract—Problems of geochronological correlation are considered for the formations established in the study region with due account for data on the Mezino-Lapshinovka, Lokh and Teplovka sections studied earlier on the northwest of the Saratov region. New paleontological data are used to define more precisely stratigraphic ranges of some stratigraphic subdivisions, to consider correlation between standard and local zones established for different groups of fossils, and to suggest how the Upper Cretaceous regional scale of the East European platform can be improved. Considered in addition are paleogeographic environments in the study region during the Late Cretaceous epoch and principal stages of the regional geological evolution.

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This work is continuation of the first part (Olfer'ev et al., 2007),[1] where we considered characterization of regional stratigraphic subdivisions of the Upper Cretaceous, the first distinguished Borisoglebsk Sequence inclusive, and biostratigraphic zonations for different groups of fossils in the Vishnevoe section.

Lithostratigraphy of the Vishnevoe section is well correlative with the local stratigraphic chart approved for western part of the Ul'yanovsk–Saratov depression (*Stratigraphic Chart…*, 2004). Characteristic features enabling identification of all subdivisions in the section (Melovatka, Bannovka, Mozzhevelovyi Ovrag, Mezino-Lapshinovka, Rybushka, Ardym and Lokh formations) are known from that chart. An exception is the Borisoglebsk Sequence distinguished for the first time in the section and formerly known in the Tambov and Khoper monoclines only.

In this work, we consider biotic events recorded not only in the Vishnevoe section, but also in the Lokh, Teplovka (Alekseev et al., 1999) and Mezino-Lapshinovka (Olfer'ev et al., 2004) sections studied earlier. Paleontological data on these sections are used to specify ranges of some local subdivisions known on the northwest of the Saratov region and to get insight into general composition of the Late Cretaceous biota. Correlation with the general scale is based on the standard ammonoid zonation (Olfer'ev and Alekseev, 2002). Geochronological dates for biostratigraphic zones are estimated based on the work by Hardenbol et al. (1998) and used for chronometric calibration of boundaries separating local zones of mollusks and benthic foraminifers in the regional scale for the East European platform (Figs. 4, 5; Olfer'ev and Alekseev, 2003). The Late Cretaceous paleogeographic environments in the Volga River basin are considered, the trend and possible factors of sea-level fluctuations are discussed, and the regional geological history is elucidated.

MAIN BIOSTRATIGRAPHIC MARKERS

Melovatka Formation (Cenomanian)

The Melovatka Formation 68 to 78 m thick is unexposed in the currently studied section. The respective sediments have been recovered by survey boreholes (4, 7, 19 and 26) in the Petrovsk area (map sheet N-38-XXXIV). Zozyrev (2006) divided the formation into three units: the lower (Medveditsa), middle (Krasno-

[1] See "Stratigraphy and Geological Correlation," **15** (6), 2007.

yar), and upper (Kalininsk) subformations. Sediments of the lower subformation (13–16 m) commonly rest on eroded surface of the Albian deposits that is evident from basal accumulations of phosphorite nodules. This subformation is composed of fine-grained glauconite-quartz sands with thin aleurite and clay interlayers. Sands recovered by Borehole 4 (Berezovka site) contain foraminifers *Gavelinella cenomanica* (Brotz.), *Valvulineria lenticula* (Reuss), and *Marginulina jonesi* Reuss of the *Gavelinella cenomanica* local zone. The middle subformation of dark gray sandy clay grading upward into greenish gray micaceous clayey aleurite is 27 to 38 m thick. At the Antipovka site (Borehole 19), these sediments contain, in addition to pectinacean bivalves *Entolium orbiculare* (Sow.), the foraminifers *Lingulogavelinella globosa* (Brotz.) and *Valvulineria lenticular* of the *Lingulogavelinella globosa* local zone. The upper subformation (15–29 m) is represented by fine-grained feldspar-quartz sandstones containing glauconite admixture and foraminifers of the *L. globosa* local zone. Sands of Bed 44 formerly exposed in ravine near the Vishnevoe village should be attributed to this subformation. In the standard borehole logs, the lower and upper subformations are easily recognizable, as they are marked by distinct positive anomalies of apparent resistance in contrast to clays of the upper Albian and middle (Melovatka) subformation.

Bannovka Formation (Turonian)

This stratigraphic unite of the Vishnevoe section has been studied only in its terminal part (0.5 m) that bears assemblages of foraminifers and calcareous nannoplankton. Foraminifers are typical of upper part of the Turonian *Gavelinella moniliformis* local zone that is inferable from occurrence of *Ataxoorbignyna nautiloides, Osangularia whitei praeceps*, and *Reussella kelleri*, the taxa characteristic of the Coniacian and appearing in the uppermost Turonian of the Russian plate (Golubtsov et al., 1978; Olfer’ev et al., 2004). On the other hand, the foraminiferal assemblage includes species typical of the overlying *Gavelinella kelleri* local zone of the lower Coniacian. Koval’skii and Ochev (1980) who studied foraminifers from chalk-like marl with inoceramids in the Vishnevoe site were of the same opinion.

Calcareous nannofossils suggest somewhat different age for marls of the Bannovka Formation. In addition to the middle–upper Turonian species *Lithastrinus septenarius, Lucianorhabdus maleformis* Reinhardt, *Eiffellithus eximius* (Stover) Perch-Nielsen, and *Kamptnerius magnificus* Deflandre (Burnett, 1998), the nannoplankton assemblage includes primitive representatives of the genus *Micula.* The latter are transitional forms in the *Quadrum–Micula* phylogenetic lineage, which are characteristic of the boundary interval between CC13 and CC14 zones of the lower Coniacian. Their occurrence could be related, however, to the assemblage contamination with allogenic taxa, which penetrated via tracks of burrowing organisms from sands of Bed 42 of the overlying Borisoglebsk Sequence. Accordingly, the Bannovka Formation should be attributed, like everywhere in the Saratov region near Volga River, to the middle–upper Turonian that is consistent with the fact that inoceramids of the *Mytiloides labiatus* local zone have never been found in its basal part (Kharitonov et al., 2001, 2003).

Nevertheless, new data on the Lokh section situated 20 km to the east-northeast of the Vishnevoe section point to doubtable status of the above dating. Sandy grumous chalk grading into calcareous sand (0.9 m) is exposed here below soil and overlies with a sharp contact the glauconite-quartz sand of the Cenomanian Melovatka Formation. The sandy chalk yielded rostrum *Goniocamax intermedius* (Arkh.) and foraminifers *Whiteinella holzli* (Hagn et Zeil), *Hedbergella baltica* (Dougl.), *Globorotalites hangensis* Vass., *Pseudovalvulineria nana* (Akim.), *Lingulogavelinella globosa, Gavelinella vesca* (Bykova) and others of the *Globorotalites hangensis/Pseudovalvulineria nana* local zone. According to Beniamovski (2006), this lower Turonian zone is correlative with two lower local zones of the Turonian molluscan fauna. If this correlation is correct, then stratigraphic range of the Bannovka Formation must be spanning the entire Turonian. According to conclusion of S.S. Dem’yankov, nannoplankton from the Lokh section is represented by species of wide stratigraphic ranges, but it includes *Kamptnerius magnificus*, the form that appears in the *Pseudaspidoceras flexuosum* Zone of the lower Turonian (Burnett, 1998).

Borisoglebsk Sequence (middle–upper Coniacian)

The middle–upper Coniacian range of this stratigraphic subdivision is confirmed by occurrence of foraminiferal assemblage characteristic of the middle Coniacian (s. str.) *Gavelinella thalmanni* local zone and lower part of the *Gavelinella infrasantonica/Stensioeina exsculpta exsculpta* Zone distinguished by Beniamovski (2006) in the terminal Coniacian–lower Santonian. In the assemblage, *Stensioeina emscherica, Gavelinella costulata, G. thalmanni*, abundant *Osangularia whitei whitei* (Brotz.) and *O. whitei praeceps* are associated with typical upper Coniacian *Bolivinopsis embaensis, Gavelinella vombensis*, and Santonian *Praebulimina ventricosa* (Brotz.), which are identified in Sample 31. Among these species, there is also *Palmula baudouiniana*, the upper distribution limit of which is constrained in the East European platform by the Coniacian (Golubtsov et al., 1978). Besides it is remarkable that lower boundary of West European *Gavelinopsis eriksdalensis/Gavelinella vombensis* Zone is, according to first occurrence of *Gavelinella vombensis*, in the middle of the *Paratexanites serratomarginatus* ammonoid and *Magadiceramus subquadratus* inoceramid zones of the upper Coniacian (Hiss et al., 2000).

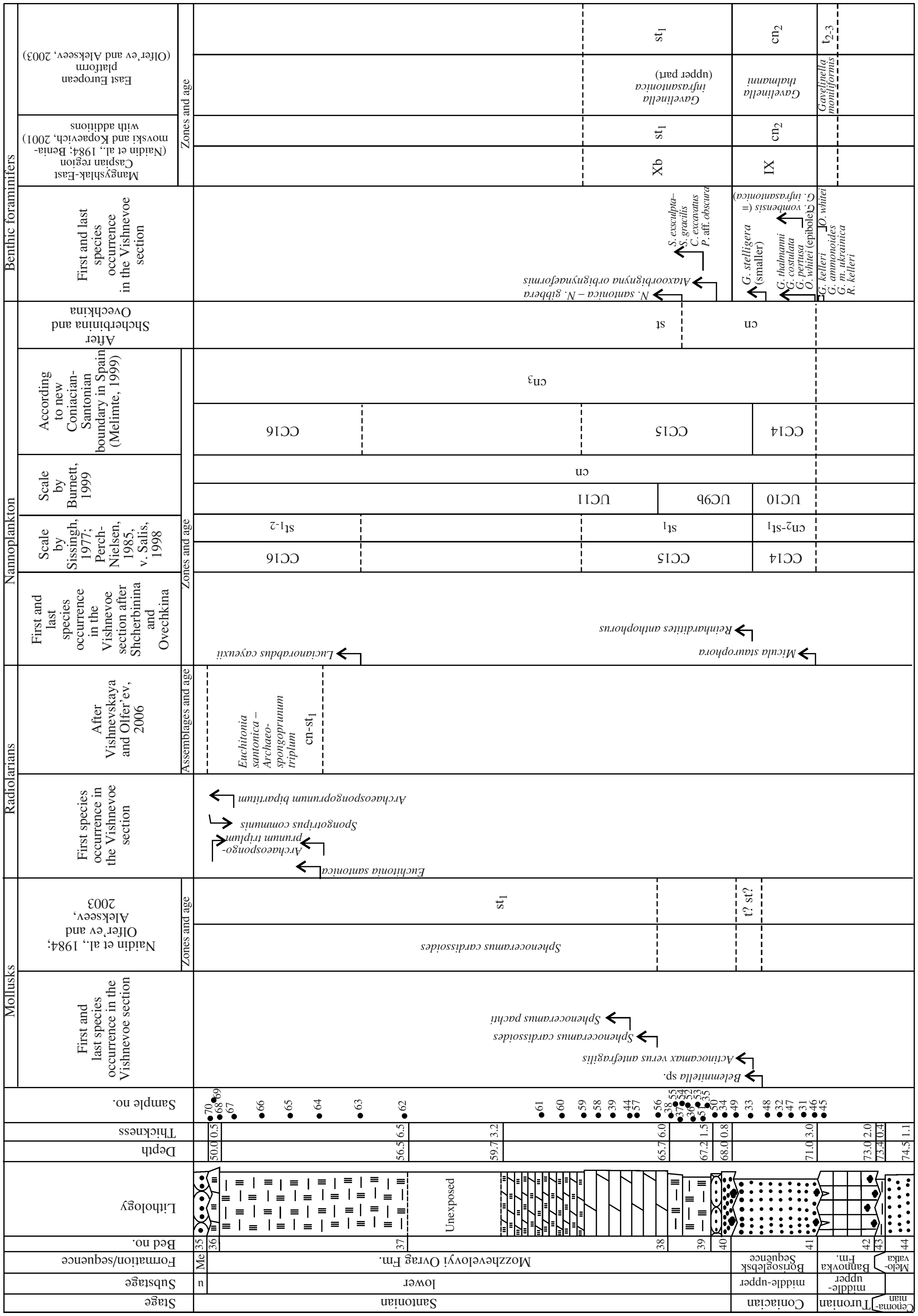


Fig. 1. Chronostratigraphic position of the Borisoglebsk Sequence, Bannovka and Mozzhevelovyi Ovrag formations in the Vishnevoe section according to different fossil groups (abbreviations "u" for upper and Me for Mezino-Lapshinovka; symbols for lithology as in Fig. 6).

Taxa abundant among nannofossils are *Micula staurophora* [= *M. decussata* Vekshina] and *M. concava.* The first taxon is index species of Zone CC14; its first occurrence marks the zone base (Perch-Nielsen, 1985; von Salis in Hardenbol et al., 1998). This zone spans the middle Coniacian–lower Santonian. Burnett (1998) also correlated the *Micula staurophora* appearance level with the lower–middle Coniacian boundary. The first occurrence level of *Micula concave* is defined controversially: according to Perch-Nielsen, it is at the base of the lower Santonian Zone CC15, whereas Burnett correlated it with the middle of Subzone UC11c or with the base of the *Texanites texanus* ammonoid zone, considering the latter as the Coniacian in age. In the regional stratigraphic chart of Upper Cretaceous in the East European platform and in the chronostratigraphic scale of the Cretaceous in Europe (Hardenbol et al., 1998), the designated zone is localized at the Santonian base. Anyway, hiatus between the Bannovka Formation and Borisoglebsk Sequence corresponds to the early Coniacian, as one can conclude based on foraminifers, or to the basal interval of the middle–upper Coniacian Zone CC14 according to distribution of nannoplankton (Fig. 1). Occurrence of *Reinhardtites anthophorus* characteristic of Zone CC15 in Sample 33 from terminal part of the Borisoglebsk Sequence can be regarded as a consequence of redeposition from sands of the Mozzhevelovyi Ovrag Formation.

Belemnite rostra *Actinocamax verus verus* and *A. verus fragilis* from the Borisoglebsk sands are of the Coniacian–Santonian age. The associated *Actinocamax antefragilis* formerly attributed to the lower Turonian (Naidin, 1964b) is known in Sweden from the Coniacian only (Christensen, 1997), and this confirms the Coniacian age of the Borisoglebsk Sequence. On the other hand, if opinions of Naidin (1964a, 1964b, 1974) and Christensen (1997) concerning distribution of *Belemnitella* species in the Upper Cretaceous are correct, then rostra of this genus from the unit under consideration suggest the Santonian age of their host deposits.

Sediments of the Borisoglebsk Sequence are apparently widespread on the north of the Saratov region. In vicinity to the Mezino-Lapshinovka site, Sel'tser attributed to this subdivision the calcareous sands occurring below the "Sponge Horizon" and resting on rocks of the Melovatka Formation. As it seems, sediments of the Borisoglebsk Sequence have been formerly united in borehole sections with deposits of either the Cenomanian, or the Sponge Horizon, being unidentified as rocks of separate stratigraphic unit. According to Zozyrev (2006), gamma-logs of boreholes 19 (Antipovka site) and 26 (Elkhovka site) drilled in the Petrovsk area show the distinct peak of radioactivity in the middle of the "Turonian" sandy-carbonate member. This peak corresponds to phosphorite interlayer separating the Borisoglebsk Sequence from the Bannovka Formation.

The middle–upper Coniacian Borisoglebsk Sequence formerly known in the Tambov monocline only and distinguished now in the Saratov area near the Volga River offers a new approach to solving problems of geological survey of Coniacian deposits in the region, which remained unsolved since the early works by Arkhangelsky (1912) and Milanovskii (1940). The sequence certainly deserves the formation rank.

Mozzhevelovyi Ovrag Formation (Lower Santonian)

The Mozzhevelovyi Ovrag Formation is of three-member structure. Sands of the Sponge Horizon contain belemnite rostra *Actinocamax verus fragilis* also known from the Borisoglebsk Sequence. Sponge remains in the horizon experienced a considerable phosphatization in contrast to weakly fossilized sponges of the Borisoglebsk Sequence. They bear marks of dissolution and rounding. The prevalent sponge taxa are the lower Santonian *Ventriculites sterea, Lepidospongia* sp., *Pararticularia* sp., serrate forms *Polysciphia* sp. and echinate *Eurete* sp. Agglutinated benthic foraminifers are represented by the Coniacian–Santonian species *Ataxophragmium compactum* and Santonian *Ataxoorbignyna orbignynaeformis.* The nannoplankton assemblage of low diversity includes *Micula staurophora, M. concava, Watznaueria barnesae*, single *Broinsonia matalosa* (Stover) Burnett, *Tranolithus orionatus* (Reinhardt) Perch-Nielsen, *Grantarhabdus coronadvensis* (Reinhardt) Grün, *Cretarhabdus crenulatus* Bramlette et Martini [= *Stradneria crenulata* (Bramlette et Martini) Nöel], *Helicolithus trabeculatus* and *Prediscosphaera ponticula* (Bukry) Perch-Nielsen. According to occurrence of *Reinhardtites anthophorus* in terminal beds of the underlying Borisoglebsk Sequence, the assemblage belongs to Zone CC15 of the lower Santonian.

Carbonate tripoli clays and tripoli mars irregularly silicified and known under name the "*Cardissoides* Marls" contain most diverse paleontological remains. The assemblage of bivalve mollusks consists of inoceramids *Sphenoceramus cardissoides, S. pachti, S. cancellatus*, and *S. angustus.* The first three species are characteristic of the *Sphenoceramus cardissoides* Zone. In the unified stratigraphic charts of 1954 and 1958 authorized for the Upper Cretaceous of the Russian platform (*Resolutions of the All-Union…*, 1955, 1962), this zone was attributed to the lower Santonian. As an equivalent of the *Texanites texanus* Zone of ammonoid scale, it is similarly set at the Santonian base in the later chart of 2001 (*Stratigraphic Chart…*, 2004). In the Boreal belt, sphenoceramids of the *pachti/cardissoides* group are also typical of the Santonian. Based on these data, H. Ernst and K. Wood (see in Hiss et al., 2000) correlated the lower Santonian of northwestern Germany with the *Cladoceramus undulatoplicatus* and *Sphenoceramus* ex gr. *pachti/cardissoides* inoceramid zones or Zone 26 in nomenclature by Tröger (1989). Moreover, the acme zone of aforementioned sphenoce-

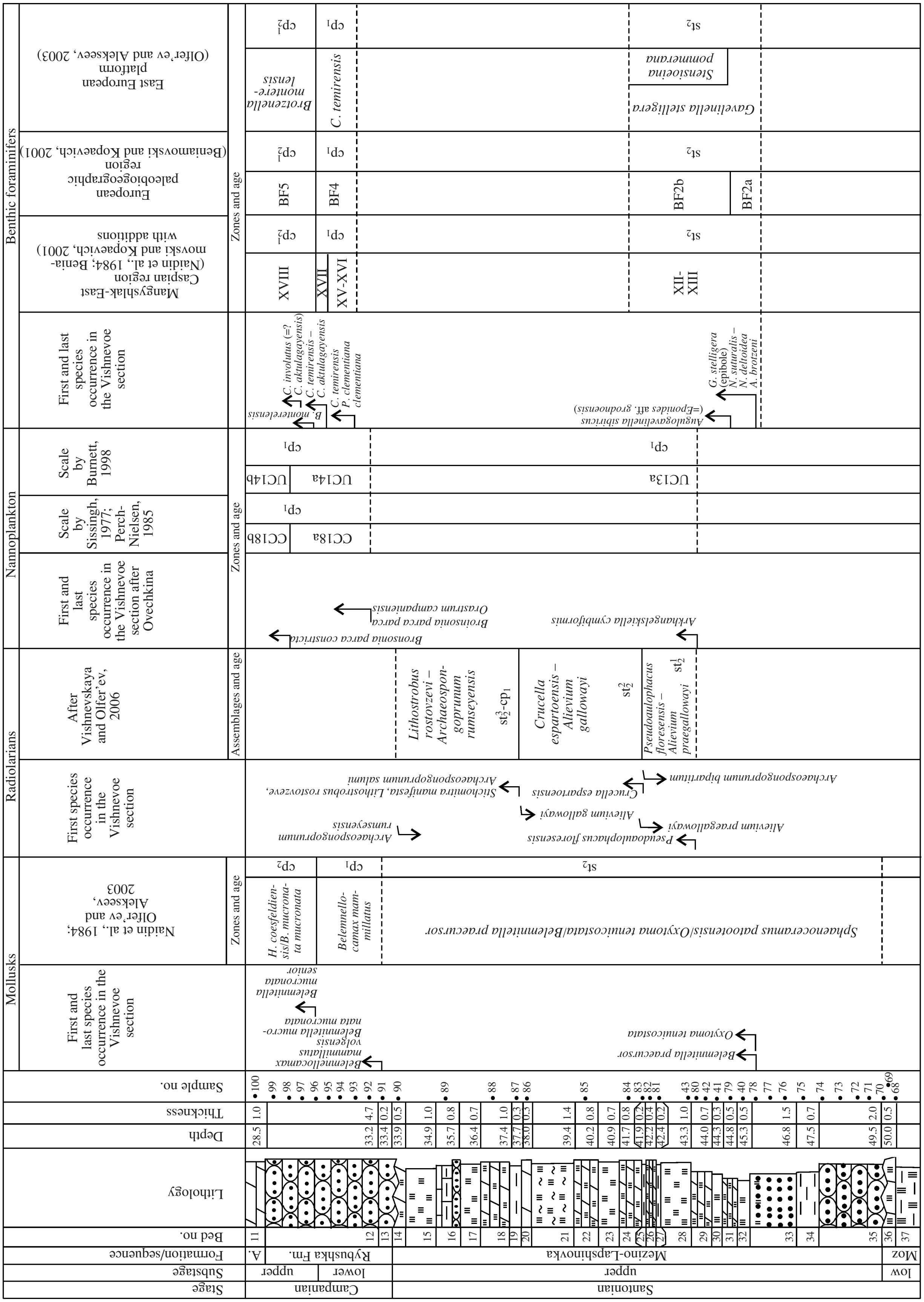


Fig. 2. Chronostratigraphic position of the Mezino-Lapshinovka and Rybushka formations in the Vishnevoe section according to different fossil groups (abbreviations "l" for lower, Moz for Mozzhevelovyi Ovrag, and A for Ardym; symbols for lithology as in Fig. 6).

ramids corresponds to the base of the middle Santonian Substage, being correlative with the *Cordiceramus cordiformis* and *Sphenoceramus* ex gr. *pachti/cardissoides* zones or Zone 27 in the scale by Tröger. The *Cardissoides* Beds of the Vishnevoe section correspond the this level exactly in our opinion.

In last decades, views on the age of sphenoceramids changed because of a certain Tröger's inconsistency to a great extent. Revising his former viewpoint, Tröger (2000) arrived at the conclusion that *Sphenoceramus pachti* existed already in the late Coniacian, because in Germany it was found below the first occurrence level of *Cladoceramus undulatoplicatus* (Roem.), the index species of the Santonian base. Based on the *Sphenoceramus pachti* appearance in the terminal Coniacian, Tröger distinguished Zone 25 of his scale, although in the same work he argued for synchronous appearance of *Sphenoceramus cardissoides* and *Cladoceramus undulatoplicatus*, correlating this biotic event with the Coniacian–Santonian boundary. Later on, Tröger (2002) reported on occurrence of *Sphenoceramus cardissoides cardissoides* (Goldf.) in the late Coniacian below the earliest *Cladoceramus undulatoplicatus.* A. Dondt (see in Hardenbol et al., 1998) was of opinion that only the subspecies *Sphenoceramus cardissoides subcardissoides* (Schlüt.) appears in the Coniacian, whereas *S. cardissoides cardissoides* marks the Santonian base. According to Tröger (2000), the upper limit of *S. cardissoides* distribution coincides with the base of the *Marsupites testudinarius* Zone of the terminal Santonian, if the stage is divided into three substages, whereas *Sphenoceramus pachti* is still occurring at higher levels up to the Campanian base. Accordingly, sphenoceramids collected from beds 38 and 39 of the *Cardissoides* Marls cannot define unambiguously to which the Coniacian or Santonian interval belong the marls. An exception is *Sphenoceramus angustus* known exclusively from the upper Santonian and lower Campanian (Zone 29 after Tröger, 2000).

Foraminifers evidence in favor of the early Santonian age of the *Cardissoides* Marls. This is evident from first occurrence of morphotypes characterizing transition from *Stensioeina exsculpta exsculpta* to *S. exsculpta gracilis*, which have been found in the Mangyshlak sections higher than inoceramids *Cladoceramus undulatoplicatus* (Beniamovski and Sadekov, 2005). The terminal part of Bed 39 contains morphotypes exemplifying transition from *Neoflabellina santonica* to *N. gibbera*, which are characteristic of the lower–middle Santonian in Germany (Koch, 1977). They occur in association with *Gavelinella vombensis* and *G. thalmanni* typical of the upper Coniacian. Based on these data, Beniamovski (2006) distinguished the lower Santonian subzone BFUC8b *Neoflabellina gibbera/N. santonica/Stensioeina* aff. *gracilis* in upper part of the *Gavelinella vombensis/Stensioeina exsculpta exsculpta* Zone. Species *Globotruncana bulloides* Vogler occurring at the same level in the Mediterranean region (Maslakova, 1978; Pessagno, 1976; Caron, 1985) is also indicative of the Santonian Age.

At the base of *Cardissoides* Marls, calcareous nannoplankton of Zone CC15 is more diverse than in sands of the Sponge Horizon. Sissingh (1977, 1978) and Perch-Nielsen (1985) who substantiated validity of Zone CC15 attributed it to the lower Santonian. Burnett (see in Schönfeld and Schulz, 1996) was of opinion that this zone spans the upper Coniacian–middle Santonian interval, but in the later chart she correlated the subzones UC11a and UC11b (jointly concurrent to Zone CC15) with the middle Coniacian (Burnett, 1998; Burnett and Whitham, 2000), i.e., with the ammonoid *Gauthiericeras margae* Zone and basal part of the *Micraster bucailli/Gonioteuthis praewestfalica* Zone of northwestern Germany. E. von Salis (see in Hardenbol et al., 1998) attributed Zone CC15 to middle part of the lower Santonian that is correct in our opinion.

Melinte and Lamolda were close in their age assessments of Zone CC15 (Lopes et al., 1992; Lamolda et al., 1999; Melinte and Lamolda, 2002) to the last opinion of Burnett based on the data obtained for the Santonian Stage boundaries in the Olazagutia section of Sierra de Cantabria in Spain (altitude 94.4 m). The first occurrence level of *Cladoceramus undulatoplicatus* that corresponds to the Santonian Stage lower boundary is recorded in that section 30 m above the occurrence level of the late Coniacian species *Magadiceramus subquadratus subquadratus* (Roem.). Hence, it is still necessary to verify age of this 30-m-thick interval.

Below the presumable Santonian base, there are zones CC15, CC16 and CC17 (basal part), which are established based on successive occurrence of *Reinhardtites anthophorus, Lucianorhabdus cayeuxii* and *Calculites obscurus*, the respective index species of the designated zones. In northwestern Germany, boundary between CC15 and CC16 zones is close to the lower–middle Santonian transition, whereas boundary between zones CC16 and CC17 coincides with the base of the *Marsupites testudinarius* Zone, i.e., with the Upper Santonian base (Hiss et al., 2000). Among the factors responsible for such a cardinal difference between age assessments of zones CC15 and CC16 in the Tethyan and Boreal belts, we can mention the diachronous appearance of index species owing to paleobiogeographic control and water mass movements, controversially understood ranges and geochronology of different nannoplankton zonations, subjective views of researchers on the Coniacian–Santonian boundary position in Europe, and lame stratotype of transition between the stages.

Interpretation of paleontological data on upper part of the Mozzhevelovyi Ovrag Formation, which is known as "Banded Group," is much more controversial. Arkhangelsky (1912) who was first to distinguish this banded sequence included in it also the *Cardissoides* Marls, pointing out that inoceramids are confined to the lower marl beds only. Milanovskii (1928, 1940), Morozov et al. (1967), and Glazunov (1972) attributed the Banded Group to the lower Santonian. Separating this group from the *Cardissoides* Marls, Naidin (1979) suggested the late Santonian age for the group and the early Campanian age for the overlying *Pteria* Beds named for occurrence of *Oxytoma* [= Pteria] *tenicostata* and ranked later on as the Mezino-Lapshinovka Formation. Being in disagreement with Naidin's opinion that the *Pteria* Beds are of the early Campanian age, some of us (Sel'tser and Kharitonov) tend to attribute the Banded Group in its narrow sense to the upper Santonian.

Solely radiolarians and nannoplankton have been established in the Banded Group of the Vishnevoe section. The *Euchitonia santonica–Archaeospongoprunum triplum* radiolarian assemblage is estimated to be of late Coniacian–early Santonian age. Assemblages of close composition are known from the Mozzhevelovyi Ovrag Formation in the Volgograd region near the Volga River (Assemblage 1 in terminology of Bragina et al., 1999), Kirza Formation of the Ul'yanovsk region (Vishnevskaya and Popova, 1999), Kirsanov Formation of the Tambov monocline (Popova-Goll et al., 2005), and Zagorsk Formation of the Moscow syneclise (Vishnevskaya, 1987). In the Upper Cretaceous stratigraphic chart of the East European platform, all these subdivisions are attributed to the lower Santonian.

Data on calcareous nannoplankton introduce dissonance into age determinations of the Banded Group (Fig. 1). *Lucianorhabdus cayeuxii*, the index species of Zone CC16 appearing in the group is constrained in distribution by the middle and basal upper Santonian (Hardenbol et al., 1998) or by the middle Santonian only (Hiss et al., 2000). The first occurrence of this index species is recorded in terminal beds of the lower Santonian, if the stage is divided in two substages. In the Olazagutia section mentioned above, Melinte dated this event by the late Coniacian however, whereas Burnett and Whitham (2000) agued for the event confinement to the middle of the middle Coniacian Zone UC10. Occurrence of *Quadrum gartneri* Prins et Perch-Nielsen among nannofossils can be regarded as confirming the Coniacian age of the Banded Group, as the upper distribution limit of this taxon corresponds to the Santonian base.

Occurrence of species *Biscutum magnum* Wind and *Arkhangelskiella specillata* Vekshina among nannofossils is in disagreement with the last statement. According to Hardenbol et al. (1998), the first one appeared in the lower Campanian. Burnett and Whitham (2000) also reported recently that first occurrence of this taxon is confined to the basal Campanian (Subzone UC13b), although Burnett (1998) correlated earlier this biotic event with the base of the Upper Santonian *Marsupites testudinarius* Zone of echinoids. Species *Arkhangelskiella specillata* is characteristic of the Campanian Zone CC18 (Dmitrenko et al., 1988).

Mezino-Lapshinovka Formation (Upper Santonian)

The Mezino-Lapshinovka Formation is apparently more complete in the Vishnevoe section than in its stratotype. Besides, its position in the Upper Cretaceous succession of Saratov region near the Volga River is better understandable here.

The formation is of three-member structure. Its basal member is predominantly of sandy composition. The overlying "*Pteria* Beds" contain abundant shells of *Oxytoma tenuicostata.* The terminal part presumably missing from the stratotype section bears only radiolarians.

Let us consider uncertainties concerning the Santonian Stage division into substages in the regional part of Upper Cretaceous stratigraphic chart for the East European platform, as this division is unregulated at present (Lamolda and Hancock, 1996). Whereas three substages are distinguished in Western Europe, in the scale substantiated in Russia (Olfer'ev and Alekseev, 2002), the Santonian Stage is divided in two substages only to be in compliance with the earlier scheme of N.N. Bobkova and V.N. Vereshchagin (*Resolutions of the ISC…*, 1981). In the Russian scale, the *Cladoceramus undulatoplicatus* and *Cordiceramus cordiformis* zones are attributed to the lower substage; the *Sphenoceramus pinniformis* and *S. patootensis* zones to the upper one. All the index taxa listed above have been regarded formerly as species of the genus *Inoceramus.* This explains why the boundary between substages was defined in the general scale at the level separating the *Texanites gallicus* and *Placenticeras paraplanum* ammonite zones: the basal levels of the *Sphenoceramus pinniformis* and *Placenticeras paraplanum* zones can be regarded as isochronous, corresponding in age to 84.60 Ma (Hardenbol et al., 1998). To keep the succession principle, the scale was based on the regional charts by Naidin et al. (1984a, 1984b), where the lower substage corresponded to the range of *Sphenoceramus cardissoides* and *Cladoceramus undulatoplicatus* zones of inoceramids, and the upper one spanned the interval of the *Sphenoceramus patootensis* Zone. Stratigraphic position of the *Cordiceramus cordiformis* and *Sphenoceramus pinniformis* zones corresponding to the middle Santonian in Western Europe remained unclear in this situation. The base of *Sphenoceramus pinniformis* Zone coincides with lower boundary of the *Stensioeina incondita* Zone (Schönfeld, 1990). The first occurrence level of this foraminiferal species corresponds to the base of the upper Santonian Substage. In agreement with the concept of Naidin who argued that the upper Santonian corresponds in range to the *Sphenoceramus patootensis* Zone and *Marsupites* Beds correlative with this zone, the *Stensioeina incondita* Zone was regarded until recent time as the lower Santonian unit (Beniamovski, 2006), although the younger synonym of this species [*Stensioeina mursataiensis* Vass.] used to be considered as the upper Santonian taxon in publications of Russian stratigraphers (Vasilenko, 1961; Golubtsov et al., 1978). We suggest to include the *Sphenoceramus pinniformis* local zone (single specimens of these inoceramids are known from the Penza region near the Volga River) and correlative *Stensioeina incondita* local zone of foraminifers into the Upper Cretaceous scale of the East European platform as concurrent lower units of the of the upper Santonian. It is unreasonable to include the *Cordiceramus cordiformis* local zone into the lower Santonian, because its index species is unknown so far in the East European platform and there is no information about other fossil groups from the respective stratigraphic interval.

The Mezino-Lapshinovka Formation overlies with hiatus the Mozzhevelovyi Ovrag Formation. Basal part of the former (beds 35 and 34) is composed of irregularly silicified quartz-glauconite sandstones and overlying sandy tripoli opokas silicified also. The same rocks of beds 3–6 in the Mezino-Lapshinovka section (Olfer'ev et al., 2004) were misleadingly attributed to the Mozzhevelovyi Ovrag Formation (st. 1, Fig. 5). Shells collected from the beds exemplify the upper Santonian pectinaceans *Oxytoma tenuicostata* and oysters *Liostrea wegmaniana, Acutostrea acutirostris*, (Nilss.) and *Gryphaeostrea lateralis* (Nilss.). Taxa first occurring at this level are *Stensioeina granulata incondita* [= *S. mursataiensis* Vass.] and *S. granulata perfecta* Koch. In northwestern Germany, these are the index subspecies of the upper Santonian subzones of the *Sphenoceramus pinniformis* Zone, if the stage is divided in two substages (Schönfeld and Schulz, 1996; Hiss et al., 2000).

Belemnite rostra *Actinocamax verus fragilis* were found in basal sands of Bed 33, while concurrent Bed 7 of the Mezino-Lapshinovka section yielded *Paractinocamax grossouvrei depressus* (Andreae) and *Belemnitella praecursor.* The upper Santonian *Gavelinella stelligera* is dominant species of foraminifers from this level of the Vishnevoe section (Fig. 2).

The most complete paleontological characteristics are obtained for beds 21–32 of the Mezino-Lapshinovka Formation, which bear abundant shells of *Oxytoma tenuicostata.* In upper part (Bed 24) of these *Pteria* Beds, there were collected rostra *Belemnitella praecursor* characteristic of the upper Santonian, oysters *Liostrea wegmaniana* (Glazunova, 1972), and pectinaceans *Syncyclonema splendens.*

Species *Angulogavelinella sibirica* [= *Eponides* aff. *grodnoensis*] occurring on the Russian plate in association with *Stensioeina pommerana* appears among foraminifers beginning from basal level of the *Pteria* Beds. In terminal part of the upper Santonian *Gavelinella stelligera* local zone, distribution range of the mentioned taxon corresponds to biostratigraphic unit ranked as the *Stensioeina pommerana* Beds. Interval of the beds corresponds in western Germany to the *Stensioeina pommerana–Gaudryina frankei* Zone of foraminiferal scale, being concurrent to upper part of the *Marsupites testudinarius* Zone (Schönfeld, 1990; Schönfeld and Schulz, 1996; Hiss et al., 2000). Coexistence of *Angulogavelinella sibirica* and *Stensioeina pommerana* was established as well in Bed 8 of the Mezino-Lapshinovka quarry, which is correlated with beds 21–32 of the Vishnevoe section (st. 1, Fig. 5).

Two radiolarian assemblages were identified in the Mezino-Lapshinovka Formation. The lower *Pseudoaulophacus floresensis–Alievium praegallowayi* assemblage is confined to beds 26 and 27. It is close in composition to the *Pseudoaulophacus floresensis* assemblage known from beds 6 and 8 of the Mezino-Lapshinovka section and from the Pot'ma Formation of the Ul'yanovsk region near the Volga River (Bragina, 1987; Vishnevskaya and Popova, 1999). Upper part of the *Pteria* Beds contains the *Crucella espartoensis–Alievium gallowayi* assemblage like on the south of the Saratov region (Kazintsova, 2000).

Nannoplankton assemblage of the formation is confined in the Vishnevoe section to beds 29 and 31 in lower part of the *Pteria* Beds. It includes species *Zeugrhabdotus diplogrammus* whose evolution is terminated in the *Uintacrinus socialis* Zone of southern England (Burnett, 1998). In the *Pteria* Beds of the Vishnevoe section and in correlative Bed 8 of the Mezino-Lapshinovka section, this taxon was found in their lower part only.

The *Lithostrobus rostovzevi–Archaeospongoprunum rumseensis* assemblage represents radiolarians from terminal part of the Mezino-Lapshinovka Formation (beds 14–20). It is most close in composition to assemblages from the Sokolovo Formation of the Voronezh anteclise (Tambov monocline and Murom–Lomov depression) (Popova-Goll et al., 2005) and from the Dmitrov Formation of the Moscow syneclise (Vishnevskaya, 1987).

Rybushka Formation (Lower–Upper Campanian)

Sands and sandstones of the Rybushka Formation overlie with hiatus the hardground of a low maturity degree at the top of the Mezino-Lapshinovka Formation. The hiatus spans greater part of the early Campanian, as is estimated. The formation range corresponds to the lower–upper Campanian boundary beds. Basal beds of the unit (30.6–33.4 m) contain belemnites *Belemnitella mucronata praesenior* and *Belemnellocamax mammillatus volgensis* of the terminal local zone of the lower Campanian. Foraminifers are characteristic of the *Cibicidoides temirensis* local zone, but forms appearing in its topmost part represent morphotypes transitional from *Cibicidoides temirensis* to *C. aktulagayensis*, the index species of subzone correlative with the *Belemnellocamax mammillatus* local zone of cephalopods. Hiatus at the Rybushka Formation base corresponds to interval of the *Gavelinella clementiana clementiana* local zone coupled with the *Cibicidoides temirensis* subzone.

The formation upper part (28.5–30.6 m) bearing ammonites *Hoplitoplacenticeras vari*, belemnites *Belemnitella mucronata mucronata, B. mucronata senior*, and pectinaceans *Syncyclonema splendens* belongs to the upper Campanian. This inference is consistent with appearance here of foraminifers *Brotzenella monterelensis* and *Heterostomella gracilis.* The last species is characteristic of the upper Campanian *Heterostomella leopolitana* Zone in Western Europe (Schönfeld and Schulz, 1996).

The diverse nannoplankton assemblage of the Rybushka Formation is represented by *Orastrum campaniensis, Biscutum magnum, Broinsonia parca parca, B. parca constricta, Calculites obscurus*, and *C. ovalis.* First occurrence of nearly all these species, except for *Biscutum magnum*, is recorded in the Rybushka Formation of both the Vishnevoe and Mezino-Lapshinovka sections. Two first species determine in combination the base of the lower Campanian subzone UC13b (Burnett and Whithem, 2000). The first occurrence level of *Orastrum campaniensis* is suggested to be at the Campanian base in the scale by Hardenbol et al. (1998) also. Presence of *Broinsonia parca parca* is indication of lower boundary of Subzone CC18a (Perch-Nielsen, 1985) or Subzone UC14a (Burnett, 1998). *Broinsonia parca constricta* appearing higher is the index species of subzones CC18b (Perch-Nielsen, 1985) or UC14b (Burnett, 1998), and the next appearing species is *Calculites ovalis* that determines the base of Zone CC19 (Perch-Nielsen, 1985).

As compared to the Mezino-Lapshinovka section, the Rybushka Formation of the Vishnevoe section is more complete and thicker, since the upper Campanian macro- and microfauna has been found here in its upper part. This fauna is unknown from the Mezino-Lapshinovka quarry, where the formation section is crowned by a distinct hardground. In the Vishnevoe section, transition from the Rybushka sands to marls of the Ardym Formation is gradual, and sediments of the Rybushka Formation are 4.9 m thick in this section.

Ardym Formation (Upper Campanian)

In stratigraphic chart, this formation is attributed to the *Belemnitella langei* Zone in middle part of the upper Campanian Substage, but in section of the Mezino-Lapshinovka quarry, this subdivision is of a wider stratigraphic range. Ammonites *Hoplitoplacenticeras coesfeldiense coesfeldiense* (Schlüt.), *H. coesfeldiense* cf. *costulosum* (Schlüt.), *H.* cf. *vari*, and *Trachyscaphites gibbus* (Schlüt.) of the West European *Hoplitoplacenticeras marroti* zone, the lower one in the Campanian Stage, occur here in basal marls (Sel'tser, 2004). Belemnites *Belemnitella mucronata mucronata* and *B. mucronata senior* characteristic of this level have been found as well.

In the Vishnevoe section, ammonites are unknown from basal interval of the Ardym Formation, but belemnite taxa, which have been found in the Mezino-Lapshinovka section, occur here in association with *Belemnitella mucronata postrema.* Accordingly, this interval is correlative with the *Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata* local zone. In both sections, *Cataceramus* forms widespread in the upper Campanian–lower Maastrichtian are abundant among inoceramids. In upper part of the Ardym Formation (interval 20.0–21.0 m of Bed 7), there were found rostra *Belemnitella langei langei* of synonymous local subzone (Fig. 3).

Foraminifers of the Ardym Formation from the Mezino-Lapshinovka section belong to upper part of the *Brotzenella monterelensis* local zone, as it contains forms transitional from *Cibicidoides aktulagayensis* to *C. voltzianus.* However, the comparable assemblage from Bed 11 of the Vishnevoe section includes *Sitella laevis* characteristic of the overlying *Globorotalites emdyensis* local zone.

Radiolarians of the *Prunobrachium mucronatum* assemblage typical of the basal lower Campanian have been found in upper part of the Ardym Formation (Bed 7). The *Prunobrachium angustum* assemblage of close composition is known from the Ardym Formation of the Pudovkino section (Kazintsova, 2000) and Zarya Formation of the Volgograd region near the Volga River (*Patellula planoconvexa–Amphibrachium mucronatum–Amphipyndax tylotus* assemblage 2 after Bragina et al., 1999).

In two lower beds of the Ardym Formation, nannofossils are identical in composition to those of the Rybushka Formation and correspond to assemblage of Subzone CC18b, but at the base of Bed 9, species *Marthasterites furcatus* (Deflandre) Deflandre is missing from the nannoplankton assemblage that defines lower boundary of Zone CC19. The assemblage from beds 8 and 9 corresponds to the interval of zonal units CC19–CC22b spanning terminal part of the lower Campanian in the scale by Hardenbol et al. (1998). The index species *Reinhardtites levis* of Subzone CC22c appears at the base of Bed 7, and this level approximately corresponds to the lower–upper Campanian boundary in the Boreal belt. Burnett (1998) determined this bioevent inside the *Belemnitella mucronata minor* Zone of the upper Campanian. Transitional beds between the Rybushka and the Ardym formations with nannofossils of subzones CC18b–CC22b contain remains of the Upper Campanian cephalopods. The last occurrence of *Orastrum campaniensis* is established in Sample 106 of Bed 7, and according to data of Burnett, this level is sufficiently close to boundary between the *Bostrychoceras polyplocum* and *Belemnitella langei* zones, being just somewhat lower.

In general, biota of the Ardym Formation from the Vishnevoe section corresponds to the *Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata* (topmost part), *Bostrychoceras polyplocum/Belemnitella minor*, and *Didymoceras donezianum/Belemni-*

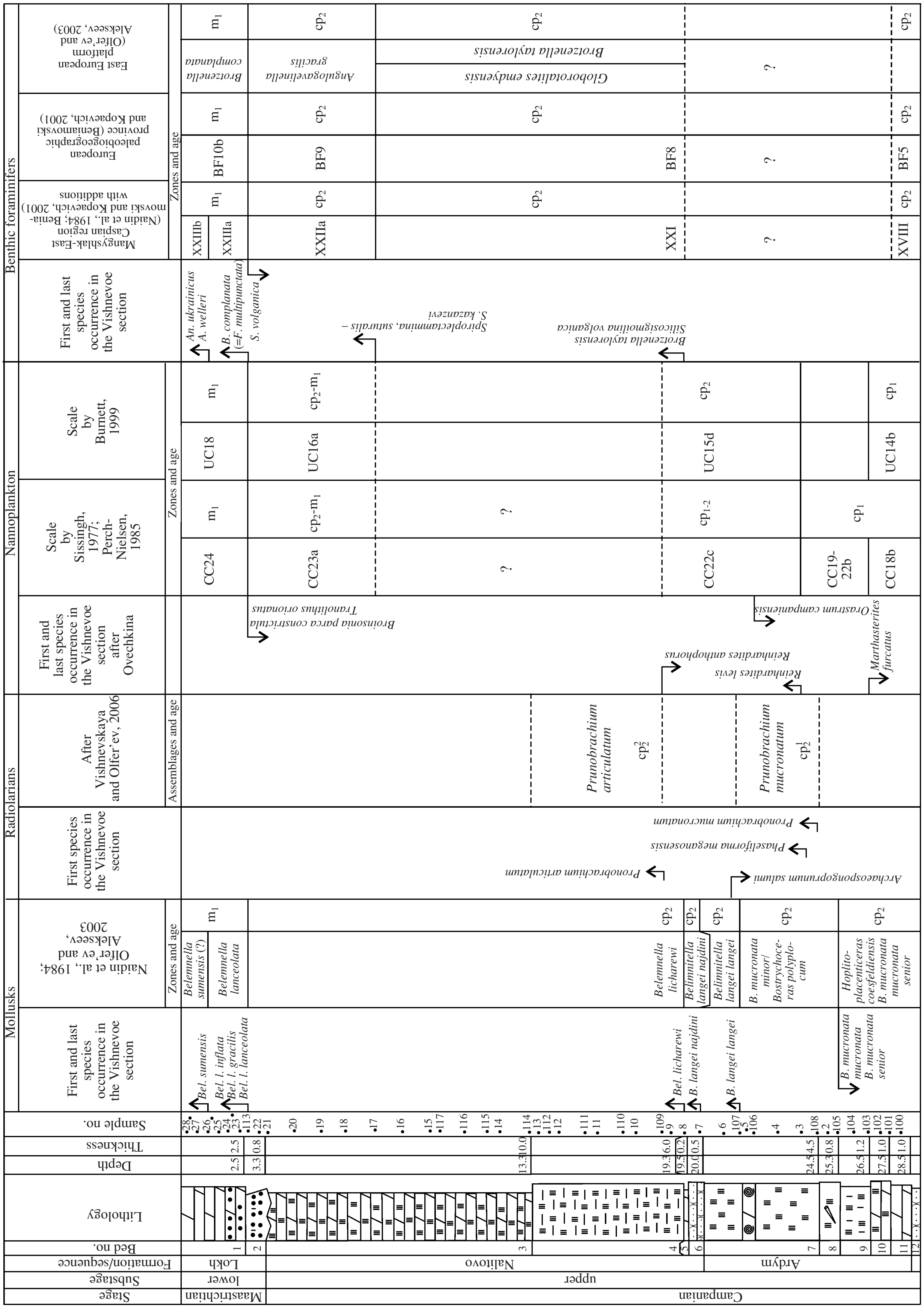


Fig. 3. Chronostratigraphic position of the Ardym, Nalitovo and Lokh formations in the Vishnevoe section according to different fossil groups (symbols for lithology as in Fig. 6).

tella langei langei (basal part) local zones of the upper Campanian. The *Bolivina incrassata/Bolivinoides draco miliaris* Subzone spans interval of the hiatus in the section.

Nalitovo Formation (Terminal Upper Campanian)

The Nalitovo Formation is perfect stratigraphic marker recognizable from southern boundaries of Mordovia and Chuvashia on the north to Rostov-on-Don on the south. The sequence of cherty clays termed as the Nalitovo Formation by G.A. Zhukova (see in Olfer'ev and Alekseev, 2005) has been distinguished first by Milanovskii (1928, 1940). As the sequence was sandwiched between the lower (*mucronata*) and upper (*lanceolata*) horizons of the Cretaceous, Milanovskii attributed it conventionally to the Campanian Stage. Derviz (1959) regarded the clays under consideration as the Maastrichtian deposits. In the less definite interpretation of Naidin (see in Gerasimov et al., 1962), the clays were attributed to the upper Campanian on the north of the study region (Shilovka section) and to the Maastrichtian on the south (Pudovkino and Nizhnyaya Bannovka sections). Beginning since the early work, Naidin (1960) persistently defined the *Belemnella licharewi* Subzone as lower unit of the Maastrichtian *Belemnella lanceolate* Zone. Accordingly, the Nalitovo Formation was attributed to the Maastrichtian based on *Belemnella licharewi* and its varieties found by V.V. Mozgovoi in cherty clays of the Saratov region. In recent years however (Olfer'ev and Alekseev, 2003), it has been shown that cherty clays of the formation correspond to the terminal Campanian in compliance with the early opinion of Milanovskii.

A characteristic sandstone bed at the base of the Nalitovo Formation, which is traceable throughout the Saratov region according to observations of N.A. Bondarenko and in the Rostov area according to oral communication of T.E. Ulanovskaya, rests on the Ardym Formation, suggesting the sediment rewashing in contact zone between two subdivisions. In this bed of the Vishnevoe sections, belemnites *Belemnitella langei najdini* have been found by Mozgovoi (1969) and rostra of *Belemnella licharewi* and redeposited *Belemnitella langei* by Bondarenko (1978). This combination of belemnite taxa is characteristic of the *Belemnitella langei najdini* Subzone of the Tereshka Horizon.

The nannoplankton assemblage of basal sandstone shows disappearance of *Eiffellithus eximius* and *Orastrum campaniensis*, although *Reinhardtites anthophorus* is still occurring at this level. The respective composition of nannofossils is characteristic of subzones CC22c or UC15d, and of the *Belemnitella langei* s.l. Zone (Burnett, 1998).

The formation is largely composed of cherty clays with carbonate admixture in upper part, where Mozgovoi have determined *Belemnella licharewi*, the index species of synonymous zone.

Foraminiferal assemblage from basal interval of cherty clays (Bed 4) includes species *Brotzenella taylorensis* and *Silicosigmoilina volganica* of the upper Campanian *Brotzenella taylorensis* local zone. Morphotypes transitional from *Spiroplectammina suturalis* to *S. kasanzevi*, which are common taxa of the *Angulogavelinella gracilis* local zone crowning the Campanian Stage in Western Europe, appear in upper part of Bed 3 near the formation top.

The *Prunobrachium articulatum* radiolarian assemblage discovered in the Nalitovo Formation lower part (Bed 4) is known from the upper Campanian deposits of different regions of the world. In the Russian plate, radiolarians of this assemblage occur in the formation sections at the Lysaya Gora site in Saratov, Nizhnyaya Bannovka site on the south of the Saratov region (Kazintsova, 2000), Tushna and Shilovka sites near Ul'yanovsk (Vishnevskaya and Popova, 1999; Vishnevskaya, 2001).

Nannoplankton from Bed 5 and basal interval of Bed 4 is close in composition to assemblage characteristic of Subzone CC22c and occurring also in the Ardym Formation. Species *Reinhardtites anthophorus* disappears in Bed 3 (Sample 17), and this event determines interval of Subzone CC23a extending from the middle of *Belemnitella langei langei* Zone up to the Maastrichtian base (Hardenbol et al., 1998). Burnett (1998) ranked the same interval as Subzone UC16a and correlated it with the upper Campanian *Micraster grimmensis/Cardiaster granulosus* Zone of West European scale. All these data suggest the Campanian age of the Nalitovo Formation.

Lokh Formation (Lower Maastrichtian)

Sediments of the Lokh Formation overlie the eroded eluviated surface of the Nalitovo cherty clays. Basal sands of the formation grade upward into slightly siliceous marls. The early Maastrichtian age of the formation is confirmed by different groups of fossils found in sediments: by ammonites *Hoploscaphites constrictus, Acanthoscaphites tridens*, belemnites *Belemnella lanceolata lanceolata, B. lanceolata gracilis, B. lanceolata inflata,* inoceramids *Spyridoceramus caucasicus*, pectinaceans *Oxytoma danica volgensis, Neithea striatocostata*, and oysters *Pycnodonte praesinzowi.* Rostrum *Belemnella licharewi* found in basal sands is redeposited, being perforated by burrowing organisms and rounded. Rostra *Belemnella sumensis* characteristic of the terminal lower Maastrichtian appear in the formation upper part.

Foraminifers of the *Brotzenella complanata* local zone occur beginning from the formation base. In the formation stratotype, where its basal and terminal beds are missing, foraminifers of this zone have not been detected. Clays and marls of the stratotype contain only foraminifers of the *Neoflabellina reticulate* local zone. In topmost marls of the Lokh Formation (Bed 1),

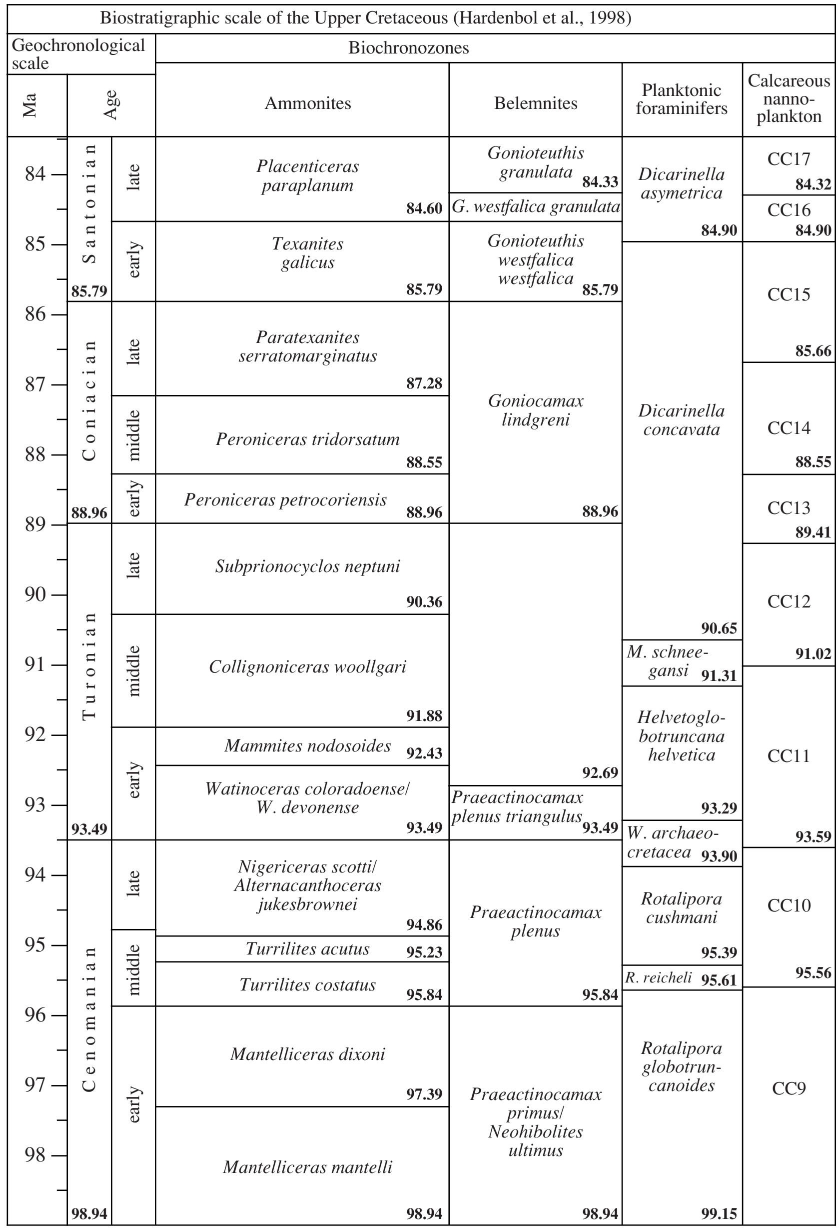


Fig. 4. Chronostratigraphic chart of the Cenomanian–Santonian in the East European platform (BFUC denotes Benthic Foraminifera Upper Cretaceous).

Anomalinoides ukrainicus and *Anomalina welleri* appear among foraminifers occurring in association with belemnites *Belemnella sumensis* and characterizing upper part of the *Brotzenella complanata* local zone that crowns the stratotype section.

The greater stratigraphic range of the formation is evident from the recently revised nannoplankton distribution in the stratotype. Initially it was assumed that the Lokh Formation range corresponds solely to Subzone CC23a, because the subspecies *Broinsonia parca constricta* is distributed up to the formation top (Alekseev et al., 1999). However, this subspecies episodically occurring in the upper 4-m-thick interval of the type section is most likely redeposited here (Ovechkina and Alekseev, 2005). At the same time, this interval yields *Reinhardtites levis* characteristic of subzones CC23b–CC24. Consequently, terminal part of the stratotype can be correlated with Bed 1 of the Vishnevoe section, where disappearance of *Broisonia parca constricta* and *Tranolithus orionatus* is recorded along with first occurrence of *Reinhardtites levis.* Hence, this part is correlative with Zone CC24.

Based on new data, we suggest a new variant of correlation between the nannoplankton zonation and local zones of belemnites and benthic foraminifers (Figs. 4, 5),

Regional scale of the Upper Cretaceous in the East European platform (Olfer'ev and Alekseev, 2003, 2005 with modifications), dating of bioevents after Hardenbol et al., 1998				Benthic Foraminifera zonation in the East European province (Beniamovski, 2006, with modifications)		
Local zones						
Ammonites	Belemnites	Inoceramids	Benthic foraminifers	Zones and subzones		Index
	Belemnitella praecursor praepraecursor	*Sphenoceramus patootensis*	*Stensioeina pommerana* 83.65	*Ataxoorbignyna inflata*		BFUC11b
				S. pommerana/Bolivinoidws strigillatus		BFUC11a
			Gavelinella stelligera	*Gavelinella stelligera*		BFUC10
		Sphenoceramus pinniformis 84.60	*Stensioeina incondita*	*Stensioeina incondita*		BFUC9
Textanites texanus	*Belemnitella propinqua*	*Sphenoceramus cardissoides*	*Gavelinella infrasantonica/ Stensioeina exsculpta exsculpta*	*Stensioeina exsculpta exsculpta*	*Neoflabellina gibbera/Stensioeina* ex gr. *gracilis/Ataxoorbignyna variabilis* (=*A. orbignynaeformis*)	BFUC8b
		Magadiceramus subquadratus 87.91			*S. exsculpta exsculpta/ Neoflabellina suturalis/ Cibicidoides eriksdalensis*	BFUC8a
		Volviceramus involutus / *V. koeneni* 88.55	*Gavelinella thalmanni* 88.68	*Pseudovalvulineria thalmanni/ P. vombensis* (=*Gavelinella infrasantonica*)/*Stensioeina emscherica* (acme)		BFUC7
		C. crassus – C. deformis / *C. brongniarti*	*Gavelinella kelleri*	*Gavelinella kelleri*	*Gavelinella costulata*	BFUC6b
		C. rotundatus 88.96			*Stensioeina emscherica*	BFUC6a
		M. scupini – M. incertus / *M. striatoconcentricus*	*Gavelinella moniliformis*	*Stensioeina praeexsculpta/ Ataxophragmium compactum*	*Reussela kelleri/Osangularia whitei*	BFUC5c
					A. compactum	BFUC5b
		M. costellatus 90.74			*Stensioeina praeexsculpta*	BFUC5a
		Inoceramus lamarcki		*Gavelinella moniliformis/ G. ammonoides*	*Gavelinella moniliformis ukrainica*	BFUC4b
		Inoceramus apicalis 91.50			*G. moniliformis moniliformis/ G. ammonoides*	BFUC4a
		M. subhercynicus–M. hercynicus 91.63 / *M. labiatus – M. kossmati*	*Gavelinella nana*	*Globorotalites hangensis/Pseudovalvulineria nana*	*Globorotalites hangensis*	BFUC3b
	P. plenus triangulus	93.49			*Reussella turonica/ Pseudovalvulineria nana*	BFUC3a
Acanthoceras rhotomagense		*Mytiloides hattini/ Inoceramus cripsii*	*Lingulogavelinella globosa* 94.71	*Lingologavelinella globosa*	*Berthelina berthelini/ Pseudovalvulineria vesca*	BFUC2b
					Lingologavelinella globosa (s.s.)	BFUC2a
Turrilites costatus/ Schloenbachia varians 98.94	*Praeactinocamax primus primus/ Neohibolites ultimus*	*Inoceramus cripsii*	*Gavelinella cenomanica*	*Pseudovalvulineria cenomanica/ Lingologavelinella formosa* (=*L. jarzevae*)	*Lingologavelinella baltical/L. formosa* (=*L. jarzevae*)	BFUC1b
					Pseudovalvulineria cenomanica/ Hoeglundina dorsoplana	BFUC1a

which differs from biostratigraphic scale published by Hardenbol et al. (1998).

CHRONOSTRATIGRAPHY OF UPPER CRETACEOUS SUCCESSION IN NORTHWESTERN SARATOV REGION

Being essentially specified based on paleontological data for different fossil groups from the studied sections, the ranges of local stratigraphic subdivisions elucidate the general chronostratigraphic structure of the Upper Cretaceous deposits in middle and lower reaches of the Volga River to the extent, when it can be compared with the West European chronostratigraphic scale substantiated by Hardenbol et al. (1998).

The well-known and popular geochronological scales elaborated by Obradovich (1993) and Gradstein et al. (1995, 1999, 2004) include dates of the stage boundaries only, whereas Hardenbol and his colleagues managed to date also the boundaries of biostratigraphic zones and levels of important biotic events for different orthostratigraphic groups of fossils. Broadly using their dates in our earlier works (Olfer'ev and Alekseev, 2002, 2003), we established that the dates are valid in Eastern Europe as well. The difference between the Upper Cretaceous chronostratigraphic scales of Eastern and West-

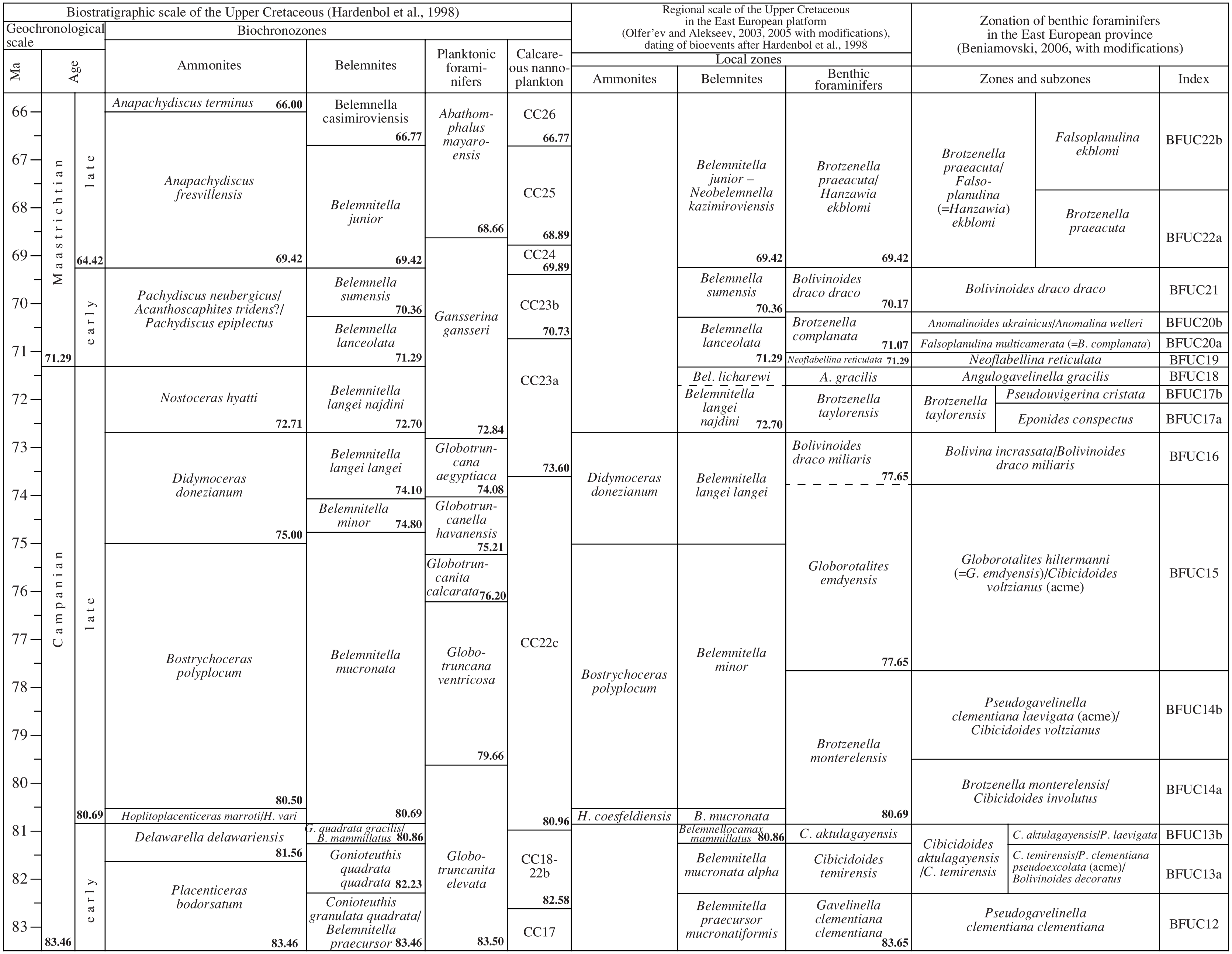


Fig. 5. Chronostratigraphic chart of the Campanian–Maastrichtian in the East European platform (BFUC denotes Benthic Foraminifera Upper Cretaceous).

ern Europe turned out to be essential for the upper Campanian only. Already at the early stage of our research, we considered new variants of correlation between biostratigraphic zonations of nannoplankton, cephalopods, bivalve mollusks, and benthic foraminifers.

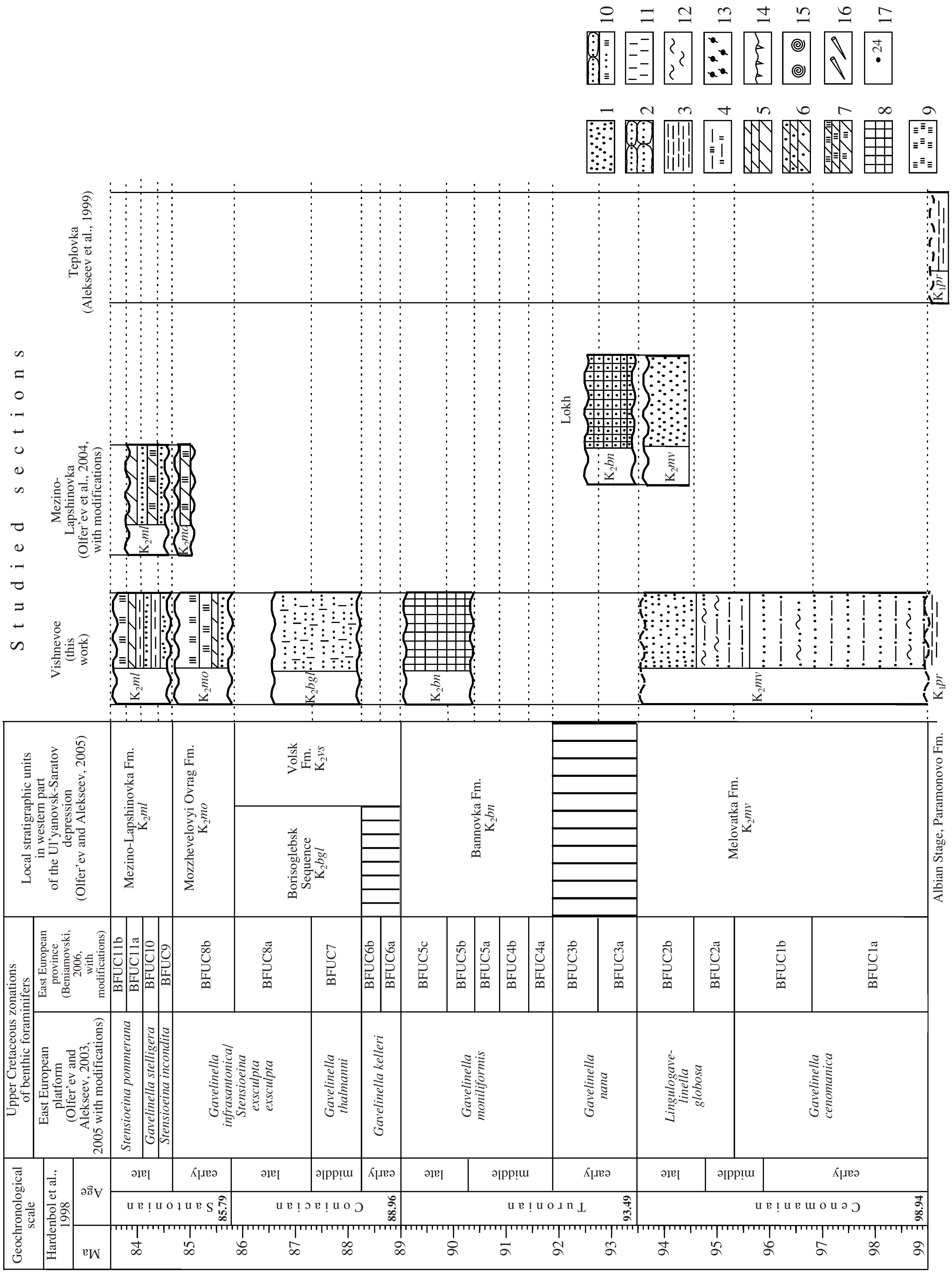
The boundary between the Melovatka and Bannovka formations is apparently most problematic in the general structure of Upper Cretaceous deposits in the study region. Paleontological characterization of the first formation is certainly inadequate, and single foraminifers and nannoplankton species found in this unit are unsuitable for getting insight into the substage division of their host rocks. Recent revision of ammonites known for a long time and attributed to the lower Cenomanian (Sel'tser, 2005) has shown that they represent in fact the middle Cenomanian species *Schloenbachia* cf. *subvarians* Spath, *S. coupei* (Brong.), and *S.* cf. *semenovi* Manija. Consequently, the commencement of the Late Cretaceous marine sedimentation should be constrained as yet by the date of 95.23 Ma. Data on termination of this transgression are unavailable, because reliable biostratigraphic markers of the upper Cenomanian have not been found.

The Bannovka Formation overlying the Melovatka sands with erosion marks has been considered earlier as spanning the interval of the middle–upper Turonian, because chalk resting on the phosphorite bed in the formation section contains *Inoceramus apicalis* Woods and ammonites *Lewesiceras peramplum* Mant., *L. levesiense* (Mant.), *L. mantelli* Wright et Wright, and *Scaphites geinitzi* d'Orb. According to the other opinion lacking paleontological substantiation, the basal phosphorite horizon and overlying sandy marl up to 1 m in thickness can be of the early Turonian age (Kharitonov et al., 2001, 2003). Our data on the Lokh section show that the Melovatka sands are overlain here, with distinct contact though without phosphorite pebbles, by very sandy chalk containing foraminifers of the lower Turonian *Pseudovalvulineria nana* Zone (in nomenclature of Beniamovski and Kopaevich). A similar lower Turonian assemblage of foraminifers and nannoplankton of Zone CC11 are known in addition from the Nikolina Gora section near the town Surskoe of the Ul'yanovsk region (Glazunova, 1972; unpublished data of Shcherbinina and Beniamovski). Foraminifers of the *Stensioeina praeexsculpta/Ataxophragmium compactum* local zone confined to terminal beds of the Bannovka Formation in the Vishnevoe section suggest that in the Volga River basin this formation corresponds to the Turonian Stage in its whole range and has been deposited during the time span of 88.96–93.49 Ma (Figs. 6, 7). A high sea-level rise and associated maximum expansion of the Turonian transgression took place 91.50 Ma ago. This is confirmed by observations within spacious areas, where the *Inoceramus apicalis* Zone transgressively overlaps the Cenomanian sediments.

Accumulation period of the Borisoglebsk Sequence attributed to the middle–upper Coniacian corresponds to 85.79–88.68 Ma. Its lower boundary defined at the first occurrence level of foraminifers characteristic of the *Gavelinella thalmanni* local zone is somewhat older than the middle Coniacian base (88.55 Ma). Consequently, the break in sedimentation between the Bannovka and Borisoglebsk deposits spans interval of 88.68–88.96 Ma. According to preliminary data, the *Gavelinella kelleri* local zone of the early Coniacian is also missing from the "Bolshevik" quarry section in the Volsk area. It is likely that the early Coniacian hiatus is of a regional character in the Volga River middle reaches, although this stage can be represented in its whole range in some sections of the Ul'yanovsk–Saratov depression. For instance, presence of the lower Coniacian in the Nizhnyaya Bannovka section is confirmed based on the found inoceramids (Kharitonov et al., 2001), planktonic and benthic foraminifers (unpublished data of Kopaevich), and nannoplankton of Zone CC12 (Ovechkina, 2004). In northern part of the depression, G.A. Zhukova (see in Olfer'ev and Alekseev, 2005) established that widespread sediments of the middle–upper Coniacian Surskoe Formation overlie in places the lower Coniacian Kuvai Sequence of local extent.

The Mozzhevelovyi Ovrag Formation overlies with erosion marks the Borisoglebsk Sequence, but it is difficult to assess the hiatus range between the Sponge Horizon and underlying sediments. We can assume only that this hiatus corresponds to some part of the lower Santonian *Neoflabellina gibbera/Stensioeina* ex gr. *gracilis/Ataxoorbignyna orbygninaeformis* local subzone (Beniamovski, 2006). Based on the appearance level of inoceramids *Sphenoceramus cardissoides cardissoides* and *S. pachti*, the base of *Cardissoides* Marls is dated at 85.79 Ma, being coincident with the Santonian Stage lower boundary. The upper boundary of *Cardissoides* Marls is dated at 84.90 Ma, as nannoplankton of Zone CC16 appears at the respective level in the Banded Group. Accumulation of this group terminated at 84.60 Ma, i.e., at the appearance time of foraminifers of the *Stensioeina incondite* local zone that overlies the Banded Group in the Mezino-Lapshinovka section. In Germany, basal level of this local zone is concurrent to lower boundary of the *Sphenoceramus pinniformis* Zone, and the latter is correlated with basal interval of the ammonoid *Placenticeras paraplanum* Zone of the upper Santonian. These data determine the early Santonian age of the Banded Group. The entire accumulation period of the Mozzhevelovyi Ovrag Formation is constrained by the time span of 84.60–85.79 Ma.

The base of the Mezino-Lapshinovka Formation (84.60 Ma) is established quite reliably, but terminal moment of this unit accumulation is problematic however. In the Boreal belt of Europe, the Santonian–Campanian transition is approximately concurrent to boundary between the *Stensioeina pommerana* and *Gave-*


Studied sections
Vishnevoe (this work)
Mezino-Lapshinovka (Olfer'ev et al., 2004, with modifications)
Lokh
Teplovka (Alekseev et al., 1999)
Geochronological scale
Hardenbol et al., 1998
Ma
Age
Upper Cretaceous zonations of benthic foraminifers
East European platform (Olfer'ev and Alekseev, 2003, 2005 with modifications)
East European province (Beniamovski, 2006, with modifications)
Local stratigraphic units in western part of the Ul'yanovsk-Saratov depression (Olfer'ev and Alekseev, 2005)
Santonian
Coniacian
Turonian
Cenomanian
85.79
88.96
93.49
98.94
Stensioeina pommerana
Gavelinella stelligera
Stensioeina incondita
Gavelinella infrasantonica Stensioeina exsculpta exsculpta
Gavelinella thalmanni
Gavelinella kelleri
Gavelinella moniliformis
Gavelinella nana
Lingulogavelinella globosa
Gavelinella cenomanica
BFUC11b
BFUC11a
BFUC10
BFUC9
BFUC8b
BFUC8a
BFUC7
BFUC6b
BFUC6a
BFUC5c
BFUC5b
BFUC5a
BFUC4b
BFUC4a
BFUC3b
BFUC3a
BFUC2b
BFUC2a
BFUC1b
BFUC1a
Mezino-Lapshinovka Fm. K2ml
Mozzhevelovyi Ovrag Fm. K2mo
Borisoglebsk Sequence K2bgl
Volsk Fm. K2vs
Bannovka Fm. K2bn
Melovatka Fm. K2mv
Albian Stage, Paramonovo Fm.
K2ml
K2mo
K2bgl
K2bn
K2mv
K1pr

linella clementiana clementiana zones. In the scale of Hardenbol et al., the first occurrence of both index species is considered as isochronous (83.65 Ma). We accept tentatively this date close to the Santonian–Campanian boundary (83.46 Ma) for the upper age limit of the Mezino-Lapshinovka Formation.

The regional hiatus established between the Mezino-Lapshinovka and overlying Rybushka Formation suggests that the lower Campanian Substage is almost entirely missing from the Upper Cretaceous succession of the study region. According to position of lower boundaries of the *Gavelinella clementiana clementiana* and *Belemnellocamax mammillatus* local zones, the hiatus spans interval of 80.86–83.65 Ma.

The Rybushka Formation corresponding to basal part of sedimentary cycle that includes also the overlying Ardym Formation was deposited during a short time span (not longer than 0.25 m.y.). Upper boundary of the first formation is inside the *Hoplitoplacenticeras marroti/H. vari* Zone at the level of 80.50–80.69 Ma. In the Mezino-Lapshinovka and Vishnevoe sections, boundaries between the *Belemnellocamax mammillatus* and *Hoplitoplacenticeras coesfeldiense* local zones, on the one hand, and the *Cibicidoides aktulagayensis* and *Brotzenella monterelensis* local zones, on the other, are concurrent (80.69 Ma) and coincide with the boundary between subzones CC18a and CC18b of the nannoplankton zonation. This is inconsistent with the scale of Hardenbol and his colleagues who estimated the time span of 80.96–82.58 Ma for the undivided interval of subzones CC18–CC22b in the Boreal belt (Figs. 5, 6). Nannoplankton characteristic of these zones has been found also in the Ardym Formation. We estimated the accumulation time of the Rybushka Formation as corresponding to 80.61–80.86 Ma (Fig. 7). It was problematic, however, to date boundaries of the Ardym and Nalitovo formations because of controversial correlation of zones and biotic events in the scales of Western and Eastern Europe. Succession of ammonite zones is identical in both scales. In the first one, the *Bostrychoceras polyplocum* ammonite zone is correlated with the *Belemnitella mucronata* Zones of belemnites, while the *Didymoceras donezianum* Zone spans the interval of *Belemnitella minor* and *Belemnitella langei langei* zones. The other situation is observable on the Russian plate. As is established in several works (Mikhailov, 1951; Bushinskii, 1954; Naidin and Morozov, 1986), cement marls of the Amvrosievka section containing ammonites *Hoplitoplacenticeras coesfeldiense* and belemnites *Belemnitella mucronata* are overlain by silicified marls with ammonites *Bostrychoceras polyplocum* (Roem.) and belemnites *Belemnitella minor* and *B. langei langei.* According to Bushinskii (1954, p. 127), rare rostra *B. langei* are confined to the section upper part only, where rocks are enriched in sandy fraction. Mikhailov described *Bostrychoceras polyplocum* var. *doneziana* from silicified marls, the taxon attributed later on to the species of the genus *Didymoceras.* The *Didymoceras donezianum* Zone was individualized in Poland above the *Bostrychoceras plyplocum* Zone by Blaszkiewicz (1979) who also defined the *Belemnitella langei* Zone above the latter most likely by analogy with sections in northern Germany.

Analysis of successive zones established for benthic foraminifers does not solve the posed problem also. The succession of the *Globorotalites emdyensis* [= *G. hiltermanni*], *Bolivina incrassata/Bolivinoides draco miliaris* and *Brotzenella taylorensis* local zones, the later with the *Pseudouvigerina cristata* Subzone, is defined in the East European platform. The other succession is characteristic of northwestern Germany, where the *Heterostomella gracilis* Zone is succeeded by the *Bolivina incrassata/Bolivinoides draco miliaris, Osangularia navarroana/Pseudouvigerina cristata* zones and the Campanian Stage is crowned by the *Bolivinoides peterssoni/Globorotalites hiltermanni* Zone (Schönfeld, 1990). In the scale of Hardenbol and his colleagues, the appearance of all index species (*Globorotalites hiltermanni, Bolivinoides draco miliaris, Bolivina incrassate*, and *Pseudouvigerina cristata*) is designated as concurrent at the level of 77.65 Ma. In such a situation, we had to date the Ardym Formation interval in the Vishnevoe section based solely on the nannoplankton zonation substantiated by Burnett (1998).

Accumulation of the Ardym Formation lower part that bears ammonites of the *Hoplitoplacenticeras coesfeldiense* local zone and foraminifers of the *Brotzenella monterelensis* local zone in the Mezino-Lapshinovka section plus belemnites *Belemnitella mucronata mucronata* and *B. mucronata senior* in the Vishnevoe section commenced 80.61 Ma ago and terminated after 0.10 m.y. approximately. Disappearance of nannoplankton species *Marthasterites furcatus* from marls of the higher Bed 9 marks the base of Zone CC19, and the respective level at 80.69 Ma corresponds to the early–middle Campanian boundary in the Tethyan belt. This is inconsistent, however, with occurrence of the upper Campanian ammonites and foraminifers in underlying deposits. In stratigraphic interval of the Mezino-Lapshinovka section correlative with Bed 11 of the Vishnevoe section, we established the first occurrence of *Calculites ovalis* (Stradn.) Prins et Siss. characteristic of Zone CC19 and found *Ceratholitoides* cf. *aculeus* (Prins et Siss.) Stradn., the index species of Zone CC20, along with *Prediscosphaera stoveri* (Perch-Nielsen)

Fig. 6. Chronostratigraphic chart of the Cenomanian–Santonian in the northwestern Saratov region: (1) sand; (2) sandstone; (3) clay; (4) cherty clay; (5) marl; (6) sandy marl; (7) siliceous marl; (8) chalk; (9) tripoli, opoka; (10) cherty sandstone; (11) calcareous rock; (12) silty rock; (13) phosphorite pebbles and gravel; (14) hardground; (15) ammonites; (16) belemnites; (17) levels with other organic remains; (BFUC) Benthic Foraminifera Upper Cretaceous.

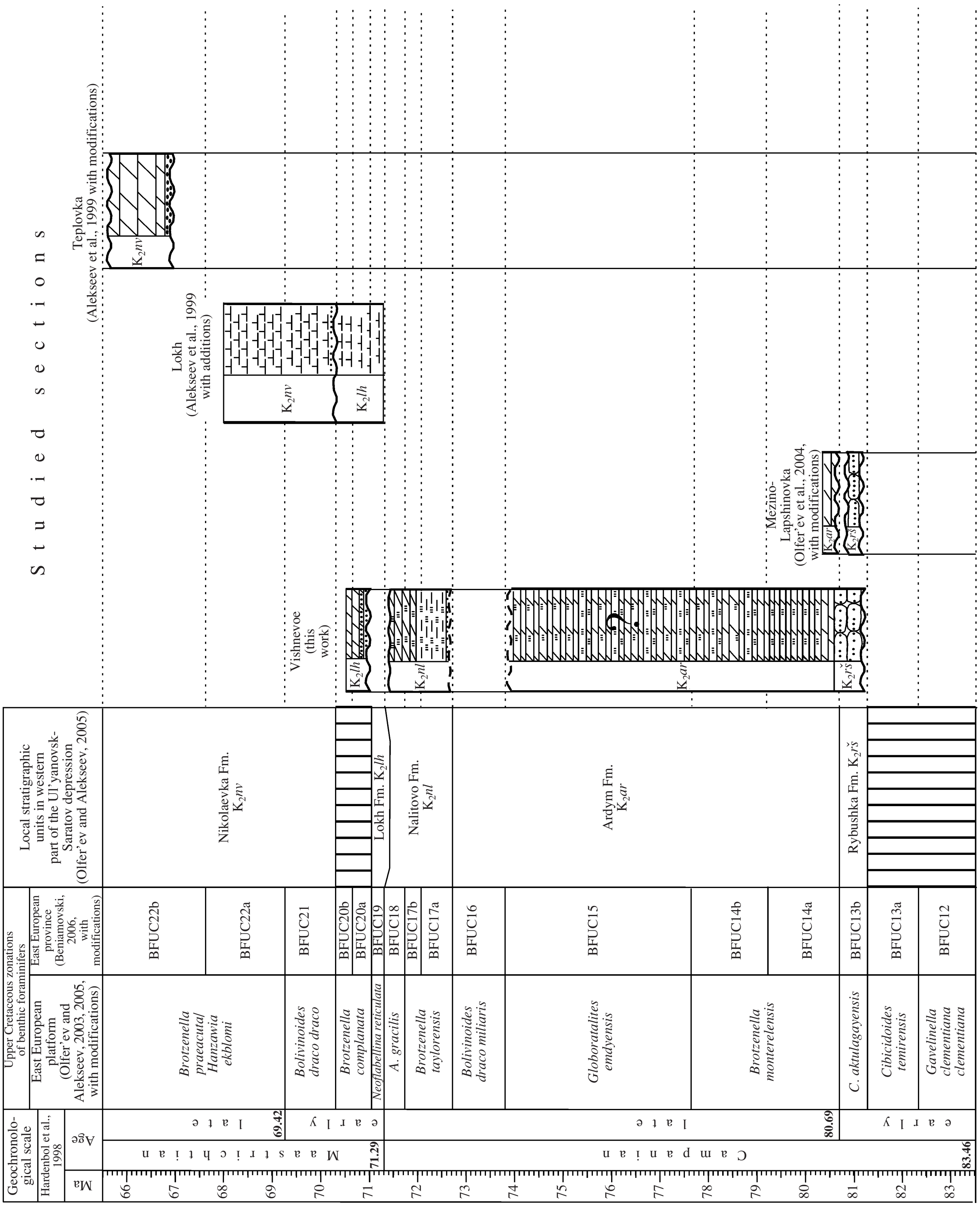


Fig. 7. Chronostratigraphic chart of the Campanian–Maastrichtian in the northwestern Saratov region (symbols for lithology as in Fig. 6).

Shafik et Stradn. in Bed 12 (analog of Bed 10 in the Vishnevoe section). According to Burnett, the last taxon appears a bit later than *Reinhardtites laevis* determining boundary between subzones CC22b and CC22c. Burnett correlated both biotic events with the middle of the *Belemnitella minor* phase (approximately 74.50 Ma). Above the marl with *Baculites* forms (interval 21.0–21.5 m in the Vishnevoe section), *Orastrum campaniensis* disappears from nannoplankton assemblage almost concurrently to appearance of rostra *Belemnitella langei langei* in the rocks. This level corresponds to the date of 74.10 Ma, and terminal part of the Ardym Formation to the interval of 72.70–74.10 Ma. Consequently, accumulation of the Ardym Formation lasted from 72.70 to 80.61 Ma. In the Vishnevoe section however, terminal part of this formation correlative with the *Bolivinoides draco miliaris* local zone about 1.00 m.y. long is missing, and interval of 72.70–73.70 Ma corresponds here to hiatus between the Ardym and Nalitovo formations.

Accumulation of the Nalitovo Formation lasted 1.41 m.y. within the time span of 71.29–72.70 Ma. Its commencement is marked by first occurrence of *Belemnitella langei najdini* in basal sandstones. A little higher in cherty clays, *Reinhardtites anthophorus* disappears from nannoplankton assemblage, and the relevant level determines upper boundary of Subzone CC22c. In the scale by Hardenbol et al., this biotic event is correlated with the middle of the *Belemnitella langei langei* Zone (73.60 Ma). Incorrectness of this correlation is obvious. The viewpoint of Burnett appears to be more correct. She determined the event under consideration in basal portion of the Campanian *Micraster grimmensis/Cardiaster granulosus* Zone, which is correlative in our opinion with the *Belemnella licharewi* local zone and the *Nostoceras hyatti* Zone.

The Maastrichtian sediments of the Lokh Formation corresponding in the stratotype to the *Belemnella lanceolata* and *Neoflabellina reticulata* accumulated since 71.29 Ma. Their accumulation terminated in lower part of the *Belemnella sumensis* local zone judging from its index species found in the formation upper part in the Vishnevoe section. In the stratotype, this part seems to be eroded. In the Lokh and Klyuchi sections, the formation top coincides with the base (70.17 Ma) of the *Bolivinoides draco draco* local zone, and consequently this subdivision spans chronological interval of 71.29–70.17 Ma. The Lokh Formation contains nannoplankton of CC23 and CC24 zones. In the scale of Hardenbol et al., Zone CC24 is considerably younger, spanning the interval of 69.89–68.89 Ma.

The Nikolaev Formation terminating the Cretaceous System is distinguished in the Lokh, Klyuchi, and Volsk sections (Alekseev et al., 1999), being absent in the Vishnevoe section. It corresponds in range to joint interval of nannoplankton zones CC25 and CC26. Its lower age limit (70.17 Ma) is defined by the base of the *Bolivinoides draco draco* local zone, while the upper one (65.0 Ma) is at the apparent top of zone CC26.

The dates considered above show that summary interval of sedimentation in the Turonian–Maastrichtian time was about 23.5 m.y. long (91.5–65.0 Ma), whereas breaks in sedimentation were only 3.0 m.y. long in sum, although the assessments may be corrected. The first occurrence level of index species not always corresponds to its appearance time. Besides, all the formations are separated by hiatuses of uncertain duration, as they are records of pertinent biotic events. According to indirect evidence, for instance to occurrence of redeposited rostra *Belemnitella langei langei* in basal sandstone of the Nalitovo Formation, it is possible to assume that accumulation of this stratigraphic unit commenced later than 72.70 Ma. The Upper Cretaceous succession of the Volga River basin may include as well the cryptic hiatuses. The summary time span of breaks in sedimentation must be longer therefore than the estimated value.

LATE CRETACEOUS PALEOGEOGRAPHY, SEA-LEVEL FLUCTUATIONS AND GEOLOGIC HISTORY OF THE STUDY REGION

The Upper Cretaceous sections have been studied in western part of the Ul'yanovsk–Saratov meridional depression (*Stratigraphic Chart*..., 2004). In terms of tectonics, they are in junction zone of this and the Ryazan–Saratov sublatitudinal depression not far away from the Peri-Caspian depression on the northwest (Fig. 8).

The Ryazan–Saratov depression is superimposed on the Riphean Pachelma aulacogen, being regenerated over the latter during two stages at least of the Mesozoic geologic evolution. The first stage was responsible for transgression of the late Bajocian–? early Bathonian epicontinental sea far to the west, up to the present-day Oka–Tsna swell (Olfer'ev et al., 1993). At the second Aptian–Albian stage, the Aptian marine sediments with ammonites characteristic of the Ul'yanovsk region near the Volga River became widespread up to the Orekhovo-Zuevo meridian (Olfer'ev, 1999). The Albian succession of the Ryazan–Saratov depression is of elevates thickness and apparently most complete, as it is evident from occurrence of Vraconian ammonites in terminal beds of this stage (Dobrov, 1915; Sazonova and Sazonov, 1967; Baraboshkin, 1996).

The Ul'yanovsk–Saratov depression is over 850 km long, extending from Kozmodem'yansk on the north to Volgograd on the south. Crustal downwarping in its northern part was active at the early Kimmerian folding phase of the Alpine orogeny in the Middle Jurassic, and final development of the depression structure terminated here prior to the Neogene. The southern part has originated over the Devonian Don–Medveditsa rift (Nikishin et al., 1999) and represents now transitional

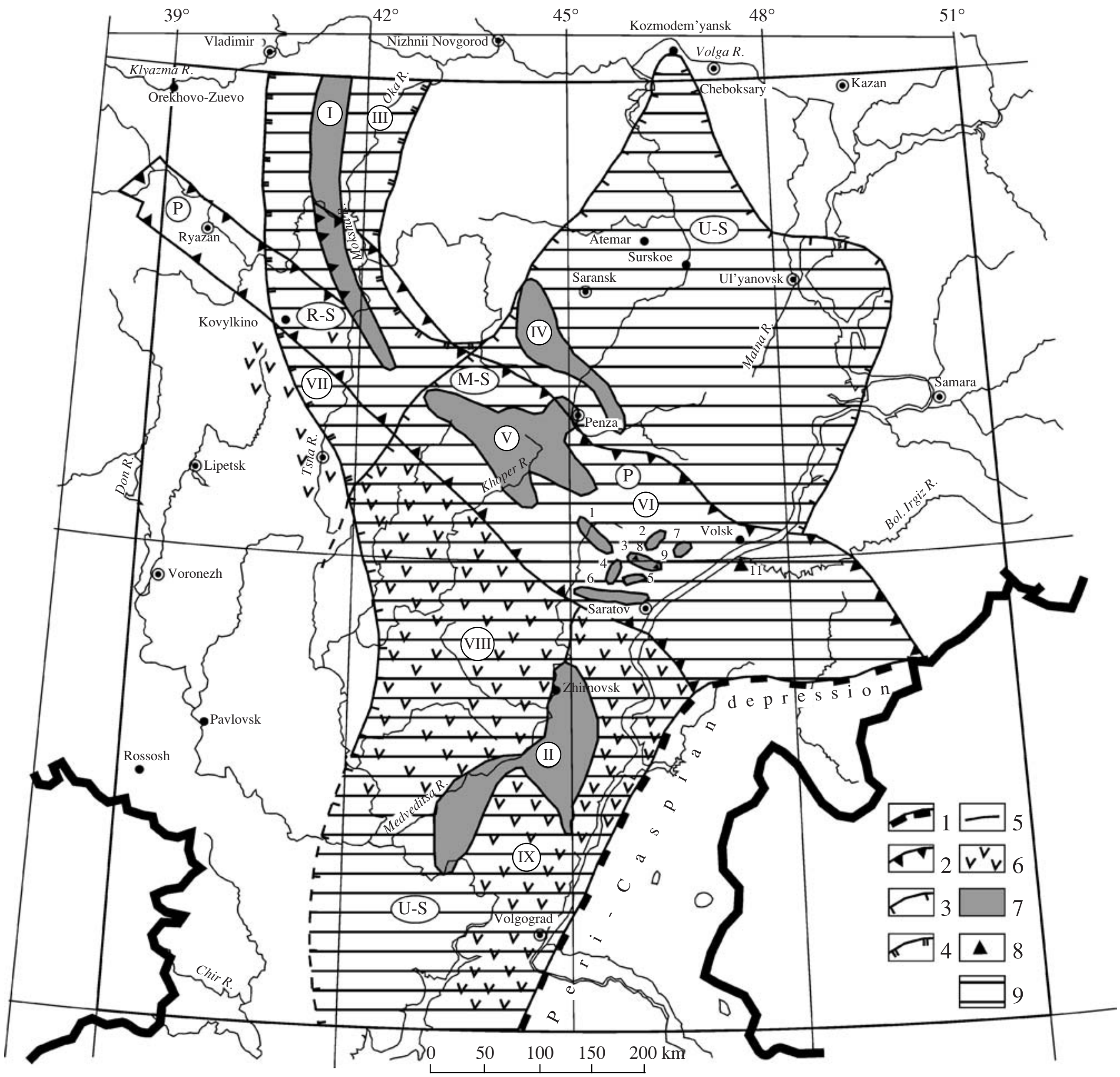


Fig. 8. Tectonic scheme of the Middle Volga region; boundaries of super-order structures: (1) Peri-Caspian depression, (2) buried Pachelma aulacogen, (3) Ul'yanovsk–Saratov and (4) Ryazan–Saratov depressions; (5) boundaries of first- and second-order structures; (6) monoclines; (7) swells and uplifts; (8) dome apex; (9) depressions. Encircled letters in the figure denote: (P) Pachelma aulacogen; (M-S) Murom–Serdoba zone of linear structures; (U-S) Ul'yanovsk–Saratov and (R-S) Ryazan–Saratov depressions. First-order structures designated by encircled Roman numbers: (I) Oka–Tsna swell; (II) Don–Medveditsa swell; (III) Murom–Penza trough; (IV) Sura–Moksha, (V) Kerensk–Chemba and (VI) Saratov structural systems; (VII) Tambov, (VIII) Khoper and (IX) Privolzh'e monoclines. Second-order structures marked by Arabic numbers: (1) Petrovsk, (2) Gusikha–Kikino, (3) Orkino–Irinovka, (4) Sleptsovo–Ogarevo, (5) Khlebnovo–Radishchevo, (6) Elshan–Sergiev and (7) Karabulak swells; (8) Orkino and (9) Teplovka–Irinovka uplifts; (10) Uras–Tri Mara and (11) Murom–Lomov depressions.

step between the Voronezh anteclise and Peri-Caspian depression.

Tectonic compression of the Late Cretaceous epoch gave birth to numerous compressional structures in the Ryazan–Saratov depression so that separate stages (Turonian, Coniacian, Santonian) or their combinations became eliminated in sedimentary sections. This was likely a result of situation, when active growth of these structures exceeded the amplitude of eustatic sea-level oscillations. Their rising led to either a break in sedimentation, or sediment erosion in apical areas of the uplifts. Besides the Surskoe–Moksha and Kerensk–Chemba dislocation zones, a bright example of compressional structures is the Teplovka–Irinovka uplift of the Orkino–Irinovka swell in the Saratov dislocation zone. In apical area of this uplift, the upper Albian is overlain by the upper Maastrichtian (Alekseev et al., 1999). The Vishnevoe section is localized on northern flank of the Orkino uplift.

In southern part of the Ul'yanovsk–Saratov depression, geodynamic environment of compression at the time of Alpine orogeny resulted in formation of the Don–Medveditsa swell and deformation of Paleozoic rocks into a system of linear submeridional folds conformable to the margin of the Peri-Caspian depression. Beginning since the late Bajocian and until the Neogene, waters of epicontinental sea periodically flooded the Late Triassic–Early Jurassic denudation surface of that swell and Privolzh'e monocline located eastward. During subsequent regeneration of the Don–Medveditsa swell, the Mesozoic and Cenozoic deposits have been eroded partially or completely so that the Late Cretaceous development history of this tectonic structure cannot be reconstructed at present.

Lithofacies maps for separate stages of the Late Cretaceous (Sobolevskaya, 1951; Flerova and Gurova, 1958; Derviz, 1959; Vinogradov, 1968) have been used as a basis for paleogeographic regionalization. In addition, paleogeographic and lithofacies maps for the late Cenomanian, early Campanian and late Maastrichtian have been compiled and analyzed by Alekseev et al. (2005b) in order to get insight into most intriguing and important events of the Late Cretaceous geological history.

On the west, the Cenomanian deposits are preserved from erosion within the Murom–Serdoba dislocation zone (Dashevskii, 1999). Eastern boundary of their distribution area is traceable along the line Sasovo–Nizhnii Lomov–Petrovsk and further eastward to Ozinki–Ural'sk, and Sol-Iletsk. In southern and southwestern areas, deposits of the Cenomanian Stage are widespread. On the northwest of Saratov region, deposits of this stage correspond to the Melovatka Formation of three-member structure, when lower and upper subformations are composed of sands, and the middle one of clay and aleurite like everywhere in the middle and lower reaches of the Volga River (Zozyrev, 2006). On the south and in peripheral zone of their distribution area, deposits of the Melovatka Formation are represented by nearly identical facies, and it is very likely that the Cenomanian basin of shallow-water terrigenous sedimentation extended far to the north. The subsequent erosion of the Melovatka Formation over spacious areas of the study region is the only plausible explanation to the fact that a remnant of Cenomanian marine sediments is observable at the Surskoe site remote for 250 km from the main southern distribution area of concurrent deposits. Long ago, Arkhangelsky (1926, p. 346) reported that the Cenomanian ammonites of the genus *Schloenbachia* were found in phosphorite pebbles at the Turonian base in the Khvalynsk–Volsk area. In the Sengilei section, Sobolevskaya (1951, p. 79) also found the redeposited Cenomanian fauna at the Turonian base. We explain transition from sandy to clay-aleuritic sedimentation across the boundary between the lower (Medveditsa) and middle (Krasnoyar) Melovatka subformations by the eustatic sea-level rise in the middle of the Cenomanian Age. In the Upper Cretaceous stratigraphic chart of the East European platform, this event is correlated with boundary between the *Turrilites costatus* and *T. acutus* subzones of the middle Cenomanian and can be dated at 95.23 Ma. However Hancock (2004), who analyzed sections of the Anglo-Parisian and Münster basins in Europe and of Interior basin in North America argued for the eustatic low at the *Turrilites costatus*–initial *T. acutus* time (95.10–95.84 Ma). According to this inference, the base of middle (Krasnoyar) Melovatka Subformation should be dated at 95.10 Ma (Fig. 9).

It is more difficult to reconstruct regional paleogeography of the Turonian Age because of hiatuses (pre-Santonian first of all) in the relevant sections, which are schematically described besides. In lower and middle reaches of the Volga River, the Turonian and Coniacian stages commonly correspond to undivided sequence of chalks and white chalk-like marls intercalated with greenish gray marls. On the west of the Ul'yanovsk region (borehole 3, Tagai site) and in Mordovia (information from N.A. Sviridov), stratigraphic interval attributed to the Turonian without serious paleontological substantiation is composed of gray silicified zeolitic marls, the possible analogs of the Turonian Chernevo Formation of the Klin–Dmitrov Ridge in the Moscow syneclise. This formation is very different in lithology from the Turonian Tuskar Formation of the Voronezh anteclise, as the latter is composed of chalks, being traceable northward up to the Kaluga latitude. The Chernevo Formation contains foraminifers, the peculiar West Siberian taxa inclusive, and radiolarians, which are close in composition to the Turonian radiolarian assemblage from the Kuznetsovo Formation of West Siberia. The analogous radiolarian assemblage was identified by Kazintsova (2000, 2004) in the Atemar section of Mordovia. These data may evidence that the Turonian seas of the study region and West Siberia were interconnected either via the Arctic basin, or directly across the Urals that was subsided at that time (Olfer'ev et al., 2000).

In most sections of the study region, the Bannovka Formation spans the middle–upper Turonian interval, although Kharitonov et al. (2001, 2003) suggested the early Turonian age for sandy marls with phosphorites (0.7–1.0 m) occurring at the formation base. It seems more correct to think that rostra of the lower Turonian belemnites *Praeactinocamax plenus triangulus* Najd. and associated phosphatic casts and shells of the Cenomanian bivalve mollusks have been redeposited at this level at the commencement of the middle Turonian transgression. Structural rearrangement that antedated the transgression changed the basin boundaries and was responsible for partial or complete erosion of formerly

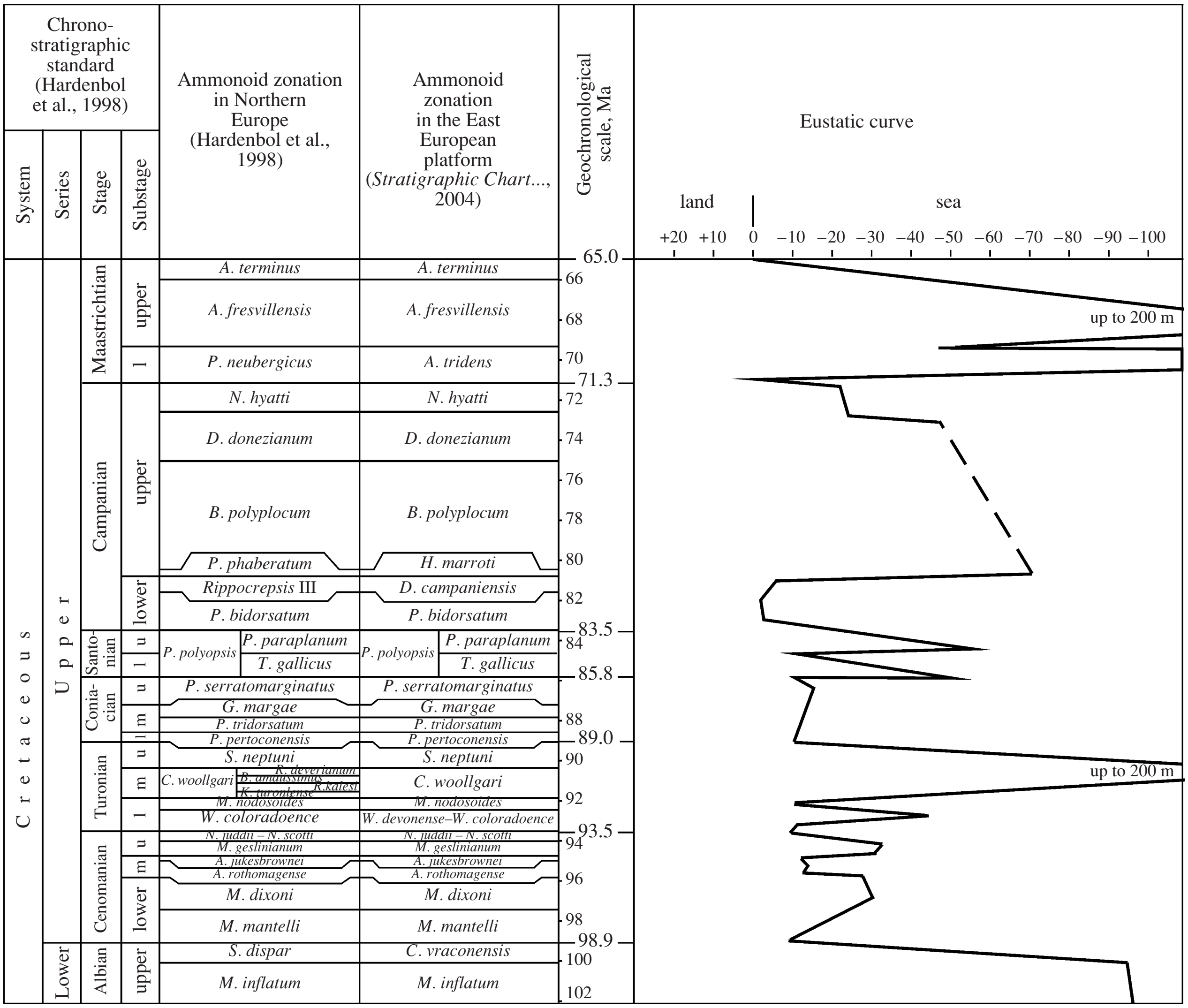


Fig. 9. Eustatic sea-level fluctuations of the Late Cretaceous time in the northwestern Saratov region; abbreviations: (l) lower, (m) middle, (u) upper.

accumulated sediments. As a result, the lower Turonian deposits were eliminated in most northern sections of the Saratov region, being retained at single isolated sites only, in particular near the Lokh village according to our observations. Deposition of the Bannovka chalks and marls is indicative of a sharp deepening of the South Russian sea basin at the early–middle Turonian boundary time in response to the eustatic sea-level rise postdating the short-term eustatic low.

Reconstruction of paleogeographic environments in the Coniacian Age is more problematic. The Volsk marl-chalk deposits preserved from the pre-Santonian erosion are more enriched in siliceous components than similar rocks of the Bannovka Formation. The short-term sea-level drop at the Turonian–Coniacian boundary time is evident from partial or even complete erosion of Turonian deposits beneath the Borisoglebsk Sequence within the Tambov monocline of the Voronezh anteclise (Olfer'ev, 1999) and in the Vishnevoe section. In the Ryazan–Saratov depression, the Surskoe Sequence of the Coniacian overlies the Turonian marls or upper Albian clays, having phosphorite accumulations and even conglomerates at the base (Ulanov, 2000).

Indications of tectonic activity at the Coniacian–Santonian boundary time are obvious. On the east of the platform, sediments of the Santonian overlie deposits of different age, the Aptian strata inclusive. The Lower Cretaceous rocks are observable below the Santonian sediments in apical part of uplifts. In the Saratov dislocation zone, the Mozzhevelovyi Ovrag Formation rests on the Cenomanian strata in central part but on the Bannovka Formation in flanks. In the Medveditsa River basin downstream of Zhirnovsk, the pre-Santonian erosion was less intense, and the Turonian chalks are up to 28 m thick here (Zozyrev, 2006).

Tectonic deformations of the time under consideration were concurrent to perceptible sea-level drop that resulted in erosion of older sediments over spacious areas. These events gave rise to deposition at the Santonian base of the regional Sponge Horizon that extends far to the west in the Voronezh anticline, being observable near Pavlovsk and Rossosh. Despite the partial restoration of sea level after the sharp eustatic low, the sea basin of the Santonian time was shallower than in the Turonian Age and accumulated accordingly the clayey-siliceous deposits. Siliceous sedimentation of the Santonian Age can be explained by penetration of cold waters from Arctic seas into the basin of the study region. This ingression reached the region at the accumulation time of the Banded Group of the Mozzhevelovyi Ovrag Formation. Existence of seaways, which connected basins of the Russian plate and Subpolar Urals during the Santonian, is evident from similarity of faunas from the study region and Usa River sections (Marinov et al., 2002). The belt of shallow-water, predominantly sandy deposits in the Murom–Lomov depression, which rim the Santonian siliceous sediments on the west, is indirect evidence in favor of existence of submeridional strait on the east of the platform.

The short-term sea-level drop at the early–late Santonian boundary time was responsible for erosion of the lower Santonian top and deposition of sand bed at the base of the Mezino-Lapshinovka Formation. Connections with the Arctic seas, which became ameliorated in the late Santonian, favored migration of bivalve mollusks *Oxytoma tenuicostata* from high latitudes into the study region, where they penetrated westward to northern areas of the Moscow region and Desna River basin. The Arctic seas could be also connected with the Moscow syneclise basin, as one can judge from occurrence of *Oxytoma* shells in glacial outliers near Yaroslavl (Kashlachev, 1947). The glacial exaration affected most likely the upper Santonian deposits of the Kostroma region on the other side of the Volga River, as we suspect their presence in that region within the anomalously thick sections of the Lower Cretaceous and misleading identification with the Albian clays by geological survey. Andrukhovich et al. (2005) suggested widening at that time of the hypothetical, early Santonian Yaroslavl strait, via which the cold northern waters penetrated into the Ryazan–Saratov depression and reached the Karpinsky swell.

In the study region, the early Campanian corresponds to the break in sedimentation. Sedimentation resumed at the very end of the early Campanian time, in the *Belemnellocamax mammillatus* phase. The early Campanian regression comprised entirely the study region. The sea-level drop that provoked the regression was concurrent to vertical tectonic movements in the region, as it is evident from the fact that the upper Campanian deposits rest discordantly on the Albian in the Kovylkino, Issa, and Penza areas. The Santonian is eliminated also beneath the Campanian chalks in quarries nearby Volsk, where influence of tectonic factor is doubtless: the hiatus is established in the quarry sections only, whereas in adjacent areas sedimentation continuously progressed under conditions of gradual sea-level lowering and sudden eustatic sea-level rise at the very end of the early Campanian. Consequences of tectonic compression are recognizable as well in the Surskoe–Moksha dislocation zone, where the Rybushka sandstones containing rostra *Belemnellocamax mammillatus* overlie the Aptian or Albian clays (Flerova and Gurova, 1958).

Our research did not confirm existence in the early Campanian of the hypothetical Proto-Don avandelta that drained apical part of the Voronezh anteclise and was localized to the northwest of the present-day Don valley (Alekseev et al., 2005b). Instead this, the lower Campanian white chalk containing *Belemnitella mucronata* (Schloth.) and foraminifers of the *Cibicidoides aktulagayensis* local zone is exposed here in the Taly, Boguchar (Naidin et al., 1980), Kolbinskoe, and Podgornoe sections, being recovered also by boreholes 16 (Ivanovka site) and 614 (Rovenki site).

In general, the facies distribution at the early–late Campanian boundary time was comparable with that of the Santonian Age, although the basin contracted somewhat in size. Along the western periphery of the present-day distribution field of the Campanian deposits, there is a belt of sandy deposits of the Rybushka Formation. On the northeast, these deposits are replaced for sandy marls of the Pudovkino Formation and then for the Sengilei marls and white chalks. This successive facies transition points to remoteness from shoreline in the SW–NE direction. The content of clastic material decreasing upward in the section is indicative of the basin deepening with time. The sea level became stabilized in the Ardym time.

The next short-time pulse of sea-level drop is recorded across the boundary between the Ardym and Nalitovo formations. As a result, terminal part of the Ardym deposits was eroded to give place for deposition of basal sandstones of the Nalitovo Formation, which are widespread and recognizable from northern sites of the Saratov region to southern sites near Rostov-on-Don. That pulse likely antedated the subsequent ingression of boreal waters and respective transition from carbonate to clay-siliceous sedimentation. Siliceous clays grade to the west into clayey chalk.

Cessation of the boreal ingression in the Campanian–Maastrichtian boundary time gave an impetus to restoration of carbonate sedimentation. Results of compressive tectonic stress responsible for the seaway closure are most spectacular in the Ryazan–Saratov depression and adjacent areas. Beyond the Teplovka–Irinovka uplift, the discordant contact between the Albian and Maastrichtian deposits is established here for many positive structure, the Uras and Tri Mara uplifts on the Volga left side inclusive (Rozhdestvenskii, 1951; Morozov et al., 1967; Pervushov et al., 2004). The hiatus between the Maastrichtian and underlying deposits could be even greater. For instance, the Santonian, Albian and even Callovian redeposited taxa were identified in the Maastrichtian foraminiferal assemblage from the base of the Lokh Formation that overlies the upper Albian clay of the Paramonovo Formation in section of Borehole 22 drilled near the Sumarokovo village at the Kerenka River, the Penza region (Olfer’ev and Alekseev, 2005). The Maastrichtian sea basin was fairly cold (Ovechkina and Alekseev, 2004) and became more heated in the late Maastrichtian second half (at 67.7 Ma).

The Maastrichtian paleogeography was similar to that of the Campanian Age, although shoreline migrated further to the northeast on the west of sedimentation basin. The facies transition from shallow-water sands to clay-carbonate sediments and then to chalks is observable in the same direction. Simultaneously, the basin expanded far to the east, where the Maastrichtian sediments are established in the Ural–Kinel interfluve and the Belaya River basin (Sobolevskaya, 1951; Derviz, 1959; Ulanov, 2000). The configuration of the Maastrichtian sedimentation basin is inconsistent with speculations about the Mesozoic age of the Ul’yanovsk–Saratov depression, as development of this structure ceased in the pre-Neogene time according to our understanding. This is evident from truncation of Jurassic and Cretaceous rocks risen under the current Volga valley by the deeply incised Neogene valley of Pra-Volga. Mesozoic rocks of the wedging zone do not reveal therewith the facies changes, which are very characteristic of western periphery of the Ul’yanovsk–Saratov depression.

Discordant contact between the Maastrichtian and underlying deposits is marked by the sand bed with phosphorites deposited during the short-term sea-level drop. The other eustatic pulse is recorded across boundary between the Lokh and Nikolaev formations. This event resulted in deposition of the condensed clay bed at the Nikolaev Formation base in the Klyuchi section and in rewashing of the Lokh Formation top in the synonymous section, where the erosion surface is overlain by basal sandy marl of the Nikolaev Formation (Alekseev et al., 1999). Hardground in the Volsk section corresponds most likely to the same level. It is most reasonable to correlate the event under consideration with boundary between the Korsun and Radishchevo formations. G.A. Zhukova (see in Olfer’ev and Alekseev, 2005) regarded this level as concurrent to boundary separating the *Bolivinoides draco draco* and *Brotzenella praeacuta* zones of the lower and upper Maastrichtian. A thin clay layer persistent along the strike is known at the same level in the Tereshka River basin and Klyuchi section.

Tectonic dislocations of the Cretaceous–Paleogene boundary time and subsequent rising of the platform resulted in erosion of the Maastrichtian terminal beds. Consequently, reconstruction of paleogeographic environment in the conclusive phase of the Late Cretaceous epoch remains problematic.

CONCLUSIONS

Summarizing the results of our research, we managed to compile the Vishnevoe reference section and to obtain its paleontological characterization within the Turonian–Maastrichtian interval. Taking into account the breaks in sedimentation at different stratigraphic levels, we used by compilation the results obtained earlier for the other sections in order to get a deeper insight into structure of the Upper Cretaceous deposits in the study region.

(1) As is suggested, the Bannovka Formation spans the Turonian Stage in its whole range. The middle–upper Coniacian Borisoglebsk Sequence known before only in the Tambov monocline of the Voronezh anteclise is first distinguished in the section. The Mezino-Lapshinovka Formation range is defined more precisely, and stratigraphic intervals of the Ardym and Lokh formations are shown to be greater than in the scale accepted for the East European platform.

(2) Paleontological characterization of all local stratigraphic subdivisions is described.

(3) Six biostratigraphic units ranked as beds with fauna are distinguished based on successive radiolarian assemblages. The established distribution ranges of several radiolarian taxa are shown to be greater than in the Mediterranean and Pacific radiolarian zonations.

(4) Ostracodes formerly unknown from the Santonian deposits are discovered in the Mezino-Lapshinovka Formation.

(5) Age determinations of lithostratigraphic units based on the nannoplankton scale not always coincide with dates inferable from distribution of other fossil groups. Parallel nannoplankton zonations substantiated for the Mediterranean and West European regions cannot be used directly for biostratigraphic subdivision of the Upper Cretaceous on the East European platform. Consequently, this group of microfossils needs to be studied better.

(6) We suggest that the molluscan *Sphenoceramus pinniformis* and foraminiferal *Stensioeina incondita* local zones of the upper Santonian should find their place at the substage base in regional biostratigraphic zonations accepted in the Upper Cretaceous stratigraphic chart for the East European platform.

(7) Age ranges of formations established in the region and of hiatuses separating them are determined. The Late Cretaceous geological history of the Volga River basin is elucidated.

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