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Foraminiferal Zones of the Boreal Berriasian, Valanginian, and Lower Hauterivian in Northern Siberia (Relatively Deep Sea Facies)

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Abstract—The analysis of stratigraphic distribution of foraminifers in the type section of the boreal Berriasian, Valanginian, and lower Hauterivian in the Nordvik Peninsula (the northern part of East Siberia) allowed recognition of the following succession of beds with foraminifers: *Trochamminoides emeljanzevi–Recurvoides praeobskiensis, Recurvoides romanovae, Recurvoides obskiensis, Evolutinella grandis, Recurvoides tigjanikus*, and *Cribrostomoides concavoides*, four of which (beds with *R. romanovae, R. obskiensis, E. grandis, R. tigjanikus*) are distinguished for the first time. Fragments of this succession are studied in the lower Neocomian sections in northern localities of East Siberia: the Tigyan-Yuryakh River, eastern coast of the Anabar Bay, and Bol'shoi Begichev Island. The complete succession of these beds is characteristic of the Surgut area in West Siberia. The age of beds with foraminifers is established on the basis of ammonite and buchia zones. Taking into consideration the consistent boundaries of recognized beds and steadiness of their stratigraphic ranges throughout the large region, the beds are ranked as foraminiferal zones. The foraminiferal zones of northern Siberia are correlated with beds bearing foraminifers in the northern Caspian region, Pechora basin, and Barents Sea plate. Based on characteristic morphological types of foraminiferal tests and species diversity, five successive groupings are established in the considered time interval, which are interpreted to represent paleoecological foraminiferal assemblages. The latter are named after the dominant taxon. Stratigraphic intervals enclosing these assemblages (stratoecotones) are considered as correlative units of sequences composed of different facies. The new species *Cribrostomoides praevolubilis, Recurvoides tigjanikus*, and *R. nordvikensis* are described.

Key words: benthic foraminifers, biostratigraphic zone, boreal Berriasian, Valanginian, Hauterivian, Lower Cretaceous, Siberia.

INTRODUCTION

Elaboration of zonal scales based on different fossil groups represents one of the urgent problems of the boreal Mesozoic biostratigraphy (Zakharov *et al.*, 1997). Foraminifers, along with other microfossils, always played a leading role in solving the stratigraphic problems, particularly when studying unexposed sections. It is quite natural therefore that the significance of foraminifers for the stratigraphy of Lower Cretaceous marine deposits in Siberia was first understood when studying the core material of deep drilling (Zaspelova, 1948; Balakhmatova *et al.*, 1960; Gerke, 1961; Subbotina *et al.*, 1964). Nonetheless, detailed stratigraphic works in connection with oil and gas prospecting required a more accurate dating of beds with foraminifers. The dating could be refined only on the basis of ammonites, belemnites, and bivalves occurring in the same beds. The success of foraminifer-based stratigraphic studies in the 1960s had its origin precisely in the fact that they were closely connected with elaboration on zonal molluscan scales based on the materials from natural exposures of the boreal Berriasian (BB), Valanginian, and Hauterivian in the northern part of Siberia (Sharovskaya, 1966; Basov, 1967, 1968; Saks, 1972; Basov *et al.*, 1983, 1989; Bulynnikova *et al.*, 1981; and others). Recognition of the assemblages, beds with foraminifers, and foraminiferal zones was performed at that time in the best sections of the Lower Neocomian, which served as the basis for elaboration of molluscan zonal scales.

The section of the boreal Berriasian located in the Nordvik (formerly, Paksa) Peninsula is one of such sections (Fig. 1). The section is most complete, with regard to stratigraphy and lithology, in the area of the boreal-type deposits and is recommended as the BB stratotype. (Zakharov and Bogomolov, 1997). At this site, a single exposure reveals a succession of ammonite- and buchia-based zones most complete in the northern regions of Eurasia and North America in the stratigraphic interval from the uppermost middle Volgian Stage to the basal Hauterivian, except for the upper Valanginian, which is either unexposed or truncated by the fault (Zakharov *et al.*, 1983; Bogomolov, 1989). Taking into consideration the aforesaid, as well the fact that

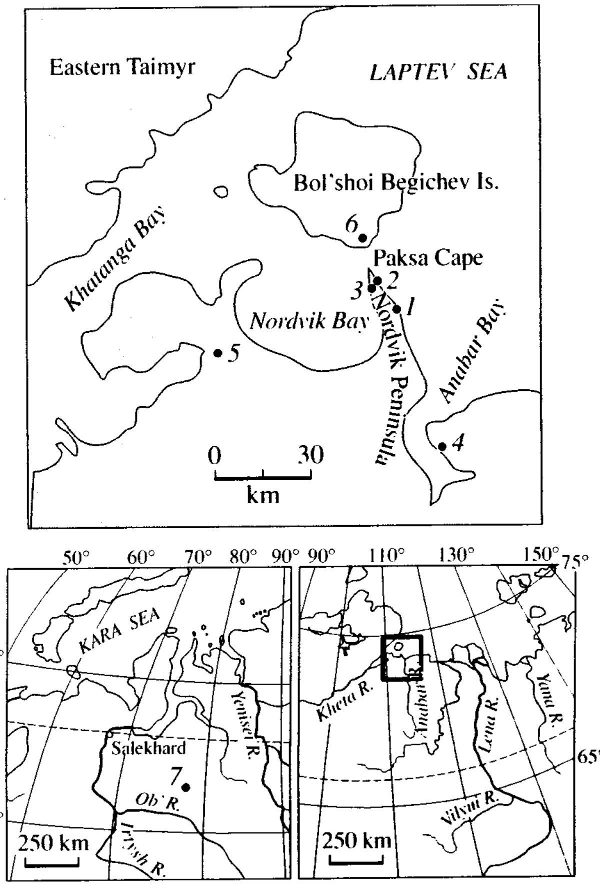


Fig. 1. Localities of considered sections of the boreal Berriasian, Valanginian, and Hauterivian deposits in the northern East Siberia: (*1*) Exposure 33, (*2*) Exposure 35, and (*3*) Exposure 36 in the Nordvik Peninsula; (*4*) the eastern coast of the Anabar Bay, Exposure 1A; (*5*) the Tigyan-Yuryakh River, Exposures 1 and 2; (*6*) Bol'shoi Begichev Is.; (*7*) West Siberia, boreholes in the Surgut area (rectangle shows the general geographic position of the upper map).

constituent rocks (clay and silty clay) accumulated in a central relatively deep part of the paleobasin (Zakharov and Yudovnyi, 1974), this section is most suitable for elaboration of autonomous biostratigraphic scales based on microfossils for the relatively deep-sea facies of the boreal Berriasian.

The first data on foraminifers were reported by Sharovskaya and Basov (1961) and Sharovskaya (1966), who used the collection by Emel'yantsev and Ershov (1953) from the Upper Jurassic–Lower Neocomian section of the Nordvik Peninsula. When describing the same section after the field works of 1967, Basov and Ivanova (Basov *et al.*, 1970) published the list of foraminifers for every member. Later these authors revised the taxonomic composition of foraminifers and stratigraphic interpretation of their assemblages. As a result, they distinguished four stratigraphic units in the rank of beds with foraminifers within the upper Volgian Substage, boreal Berriasian, and lower Valanginian. Every of th[illegible]s i[illegible]d b[illegible] a peculiar foraminiferal assemblage (Basov and Ivanova, 1972, Table 24). Later, Bulynnikova (1981) proposed another variant of subdivision of the section in question. The latter variant was officially accepted (*Resheniya...*, 1981). Ten years later, Bokova and Ivanova (1991) proposed to subdivide the upper part of the boreal Berriasian and boreal lower Valanginian of northern Siberia into three units (beds with fauna): *Gaudryina gerkei* (corresponding to the *Surites analogus* Zone), *Pseudolamarkina tatarica* (interval of *Bojarkia mesezhnikovi* and *Temnoptychites syzranicus* zones), and *Globulina* spp. (interval from the base of the *Polyptichites michalskii* and higher). Taking into consideration the aforesaid, we use here the nomenclature of beds suggested by Basov and Bulynnikova with indication of the assumed stratigraphic range in members described by Zakharov *et al.* (1983) (Table 1).

Beds with *Haplophragmoides fimbriatus* (=*Trochamminoides emeljanzevi*)–*Trochammina rosaceaformis* were distinguished by Basov and Ivanova (1972) within the upper Volgian Substage and basal Berriasian (Members VIII–IX; hereinafter numbers of members are given after Zakharov *et al.*, 1983). Bulynnikova (1981) united probably the same members into Beds with *Schleiferella volosatovi* (=*Trochamminoides emeljanzevi*)–*Trochammina septentrionalis* and Beds with *Schleiferella volosatovi*–*Ammodscus veteranus* (Table 1). The species *Trochammina rosaceaformis* Rom., [illegible] *septentr[illegible]ona[illegible]s* [illegible]c[illegible]ar., an[illegible] *[illegible]mmodiscus veteranus* Kos. are recorded in the lower part of the boreal Berriasian as single specimens. The characteristic feature of these units is an extreme abundance of representatives of the genus *Trochamminoides*.

Beds with *Gaudryina gerkei* (=*Gaudryinopsis gerkei* (Vas.))–*Trochammina parviloculata* (Basov and Ivanova, 1972) as well as Beds with *Recurvoides obskiensis* (Bulynnikova, 1981) correspond to the middle portion of the boreal Berriasian section (Members X–XII) (Table 1). The species *Trochammina parviloculata* Gerke episodically occurs in the boreal Berriasian section beginning from its base. The lower boundary corresponds to the level, where Assemblage I is replaced by Assemblage II, and where abundant representatives of the genus *Gaudryinopsis* appear.

The lower boundary of Beds with *Ammobaculites* spp.–*Gaudryina gerkei*–*Trochammina parviloculata* (Basov and Ivanova, 1972) or Beds with *Ammobaculites gerkei*–*Lenticulina gudinae* (Bulynnikova, 1981) coincides with the base of Member XIII (Table 1). Like all foraminiferal forms with calcareous tests, *Lenticulina gudinae* E. Ivanova is an accessory species episodically occurring in the boreal Berriasian and Valanginian deposits. Therefore, the lower boundary of this unit is drawn based on the increased proportion of genera *Gaudryinopsis* and *Ammobaculites* representatives, i.e., at the replacement level of foraminiferal Assemblage II by Assemblage III.

Table 1. Lithostratigraphic scheme of the boreal lower Neocomian sections in the Nordvik Peninsula (the Anabar Bay of the Laptev Sea) into beds with foraminifers (symbols for lithology as in Fig. 3)

Stage	Substage	Ammonite zones and beds (Zakharov *et al.*, 1997)	Buchia-based zones (Zakharov *et al.*, 1997)	Lithology	Member	Thickness, m	Beds with foraminifer: Basov and Ivanova, 1972	Beds with foraminifer: Bulynnikova, 1981	Beds with foraminifer: Proposed scheme
Hauterivian	lower		*Buchia crassicollis*		XXIV	4.0	Not defined	Not defined	Foraminifers are missing
					XXIII	27.0			*Cribrostomoides concavoides*
					XXII	10.0			*Recurvoides tigjanikus*
Valanginian	lower	Beani	*Buchia sublaevis*		XXI	7.0		*Pseudolamarkina tatarica Glomospirella intrita*	
		Ramulicosta			XX	12.0			
		Astieriptychus	*Buchia keyserlingi*		XIX	20.0			
		Quadrifidus			XVIII	20.8	*Reinholdella tatarica Harlophragmoides* ex gr. *latidorsatus*		*Evolutinella grandis*
		Klimovskiensis	*Buchia inflata*		XXII	17.5			
Berriasian		Tolli			XVI	17.4		*Ammobaculitas gerkei Lenticulina gudinae*	*Recurvoides obskiensis*
			Buchia tolmatschowi; *Buchia volgensis*		XV	10.7			*Recurvoides romanovae*
		Mesezhnikowi			XIV	7.8	*Ammobaculites* spp. *Gaudryina gerkei Trochammina parviloculata*		
		Analogus	*B. jasikovi*		XIII	4.7			
		Kochi	*Buchia okensis*		XII	2.7	*Gaudryina gerkei Trochammina parviloculata*	*Schleiferella volossatovi Ammodiscus veteranus*; *Recurvoides obskiensis G. gerkei*	
					XI	3.6			
					X	3.4			
		Sibiricus	*Buchia unschensis*		IX	4.0	*Haplophragmoides fimbriatus Trochammina rosaceaformis*	*S. volossatovi Trochammina septentrionalis*	*T. emeljanzevi R. praeobskiensis*
J_3v	u.	Chetae			VIII	1.2			
		Taimyrensis			VII				

Beds with *Reinholdella tatarica* (=*Valanginella tatarica* (Rom))–*Haplophragmoides* ex gr. *latidorsatus* (=*Cribrostomoides* spp.)) (Basov and Ivanova, 1972) comprise Members XIV–XVIII corresponding to two upper ammonite zones of the boreal Berriasian (*Bojarkia mesezhnikovi* and *Tollia tolli*) and two lower zones of the lower Valanginian (*Neotollia klimovskiensis* and *Propolyptychites quadrifidus*) (Table 1). The index species *Valanginella tatarica* occurs in the boreal Berriasian and Valanginian as single specimens and recognition of the unit is substantiated by abundant representatives of the genus *Cribrostomoides*.

Bulynnikova (1981) defined, in upper part of the boreal Berriasian, the Beds with *Ammobaculites gerkei* and *Lenticulina gudinae* corresponding to the interval of *Surites analogus–Tollia tolli* ammonite zones (Members XIII–XVI) and Beds with *Pseudolamarkina tatarica* (=*Valanginella tatarica*)–*Glomospirella intrita* (Members XVII–XX of the lower Valanginian) (Table 1). The lower boundary corresponds to the appearance level of representatives of the genus *Glomospirella* at the base of Member XVII, where this event accompanies the replacement of Assemblage III by Assemblage IV.

As will be shown below, beds with foraminifers defined by Basov and Ivanova, as well as the scale of Bulynnikova proposed for the boreal Berriasian and lower Valanginian in the Nordvik Peninsula are based on the succession of foraminiferal assemblages, which are facies-dependent to a significant extent. Similar foraminiferal assemblages are registered in the Valanginian sections of the Anabar and Tigyan rivers and in Bol'shoi Begichev Island, because they are located close to the area in question and correspond to a single facies zone (Fig. 1); nonetheless, the intra- and interfacies correlation potential of these assemblage is low.

MATERIALS AND METHODS

The collection sampled by V.A. Marinov in the bed-by-bed manner from the section of the Nordvik Peninsula in 1989 served as a basis for this study. The additional comparative materials from the boreal Berriasian and Valanginian sections of the Tigyan River, Anabar River, and Bol'shoi Begichev Is. were donated by K.V. Zverev, Yu.I. Bogomolov, and M.A. Levchuk, respectively. A.V. Yadrenkin donated samples of drill cores from the Surgut area of West Siberia. Numbers of beds and members, as well as subdivision of sections into formations and zones, are given in accord with a series of publications (Saks *et al.*, 1972; *Resheniya 3-go...*, 1981; Zakharov *et al.*, 1983; Bogomolov, 1989).

Describing the structure of complexes, we used, according to the accepted regulations (Bigon *et al.*, 1989, pp. 117–118), indices of the taxonomic diversity (Simpson index D) and distribution evenness (E).

$D = 1/\Sigma p_i^2$, $E = D/S$ where p_i is the occurrence frequency of the i-species, S is species diversity (the number of species in the assemblage).

Classification of taxons higher in rank than species is given after Podobina (1978).

FORAMINIFERAL COMPLEXES AND ASSEMBLAGES

As is noted above, the section in the Nordvik Peninsula was selected for elaboration of the foraminiferal zonal scale of the boreal Berriasian and Valanginian. First, the stratigraphic distribution of every species through the section was established, and then, stratigraphically isolated groups of species that are referred to as the complexes were defined. In total, six such complexes were distinguished. Every of them correspond to different stratigraphic intervals and are characterized by the peculiar species composition and proportions of constituent species. Our complexes, as well as those defined by our forerunners, likely reflect the taxonomic composition of biocoenotic assemblages. This assumption is based on previous reconstructions and facies analysis (Zakharov and Yudovnyi, 1974). According to the results of this study, the black-shale, locally highly carbonaceous sequence in the Nordvik Peninsula accumulated in the central part of the relatively deep sea basin under the oxygen deficiency in the bottom water layer during the late Volgian and early Barremian time. Tanathocoenoses that were established using the taphonomic analysis of oryctocoenoses are considered in most cases as autochthonous, or displaced only slightly. It was shown that macrobenthic communities occupied flattened bottom areas and were characterized by the laterally stable structure. Clayey and clayey–silty rocks enclosing fossils reveal only thin horizontal parallel lamination without signs of hiatuses (Zakharov and Yudovnyi, 1974). Thus, these results of taphonomic and sedimentological studies imply the autochthonous burial of foraminiferal shells. Consequently, it can be assumed with a fair degree of confidence that succession of complexes in the section reveals the replacement of foraminiferal assemblages with time. The replacement of assemblages was accompanied by changes in the composition and structure of foraminiferal communities that was caused by both the environmental changes and the evolutionary transformations of the species composition. The composition of dominant species represents one of the main characteristics of the assemblage.

The preponderance of particular taxons is most commonly thought to be related to environmental changes. Changes in composition of the dominant group of taxons occur at certain stratigraphic levels. Precisely these changes are considered to represent the most important biostratigraphic events (Krassilov *et al.*, 1985, p. 45). On the basis of this parameter, stratigraphic intervals with the most frequent occurrence of the species (epiboles) are defined in the section. Epiboles are of a great stratigraphic importance, therefore it seems reasonable to consider the hierarchy of taxa dominance in assemblages.

Taxons demonstrating the highest occurrence frequency are suggested to be referred to as the dominants of the complex. The dominant group unites taxons typical of the complex. They are characterized by the high occurrence frequency (as a rule, 5–10% and more) and usually represent no less than 50% of the total number of taxons and at least 90% of the total test abundance. The accessory group includes taxons with the low occurrence frequency (2% and less). This group includes more than a half of taxons, but less than 10% of the total taxa number (Fig. 2).

The composition of the dominant group represents a main characteristic of the complex. The complexes, or taxocoenoses according to Saidova (1976), have a certain hierarchy depending on the rank of taxons used for their description: they can be defined as orderocoenoses or subordinate familecoenoses and genocoenoses. The complexes (and assemblages) are named after dominant taxons. As a rule, there are more than one dominant species in the complexes, and names of two and more taxons usually constitute the complex name.

To characterize ecological and ethological peculiarities of species, we used the morphological–functional classification of foraminiferal tests described by Korsun *et al.* (1994).

Morphological group I includes species with flat-convex tests, which are referred to the epifauna populating the compact substrate. By the feeding mode, they are sestonophages extracting food particles from bottom waters or collecting them from the sediment surface.

Morphological group II comprises species with flattened, lenticular test, which represent dwellers of the flocculated layer enriched in organic matter.

Morphological group III consists of species with high conical (fusiform, drop-like, according to Korsun) elongated tests probably belonging to vagile representatives of the infauna, i.e., to detritophages dwelling within the soft sediment enriched in organic matter.

Morphological group IV is composed of species with nonspecialized ellipsoidal tests belonging to slightly mobile dwellers of the subsurface sedimentary layer and bottom vegetation.

Based on peculiarities of the taxonomic composition, six foraminiferal complexes named after the dominant taxons are established to successively replace each other throughout the section.

The Early Neocomian succession of foraminiferal assemblages characterized by the gradual increase in the taxonomic diversity can probably be explained by intensification of bottom hydrodynamics related to the general Berriasian–Hauterivian sea regression in the northern areas of East and West Siberia.

SUCCESSION OF FORAMINIFERAL COMPLEXES IN THE LOWER NEOCOMIAN SECTION OF THE NORDVIK PENINSULA

As a result of study on foraminifers from the Neocomian deposits of the Nordvik Peninsula, six their complexes were discriminated and their stratigraphic ranges were established (Fig. 3).

The replacement of one foraminiferal complex by another does not take place at some noticeable surface in the section, but usually occurs within a certain stratigraphic interval of recurrent alternation of the preceding and succeeding complexes. In terms of paleoecology, this interval should be considered as a stratoecoton and here is the main difference between foraminiferal complexes and beds with foraminifers. As will be shown below, the lower boundary of beds with foraminifers is determined by a particular level in the section coinciding with the first appearance of certain biostratigraphic feature, e.g., with the first occurrence of species or with its epibole (the "golden spike" principle).

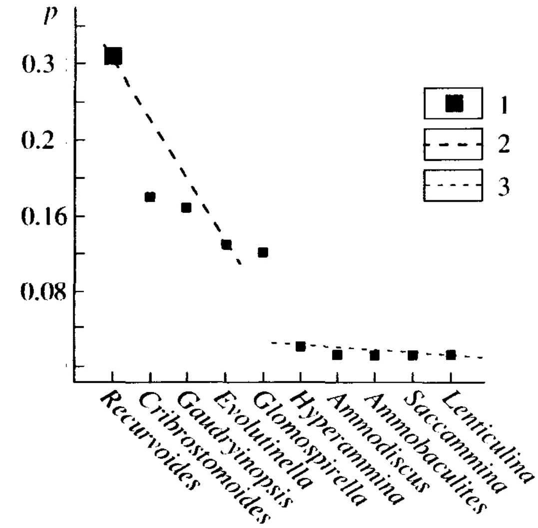


Fig. 2. The structure of foraminiferal assemblages from Sample 29-32-89 (Nordvik Peninsula, Exposure 33, Member XVII, *Neotollia klimovskiensis* Zone): (1) dominant taxon of the assemblage; (2) dominant group of the assemblage; (3) accessory group of the assemblage; (*p*) occurrence frequency.

The stratigraphic interval in question (Berriasian–Hauterivian) is characterized by the stable composition of defined complexes at the generic level. The only exception could be the disappearance of the genus *Trochamminoides* from the group of dominant taxons of the haplophragmoidid complex in the lower part of the boreal Berriasian (the ammonite *Analogus* Zone). However, data on other Neocomian sections did not confirm this fact so far. It is not inconceivable that the assemblage with *Trochamminoides* represents a specific facies variety of the haplophragmoidid complex.

Complex I (haplophragmoidid; Members VIII–IX)

Assemblage with *Trochamminoides*

Preponderant are representatives of the family Haplophragmoididae. Only one species of the genus *Trochamminoides*, namely *T. emeljanzevi* (Schl.), represents 50–90% of all specimens in the complex. The dominant group also includes genera *Evolutinella* (5–17%) and *Recurvoides* (4–10%). Representatives of genera *Orientalia(?)* (1–3, sometimes 17%) and *Saccammina* (1–2, sometimes 15%) are accessory, but episodically they are rather abundant. The accessory group includes species of genera *Hyperammina, Cribrostomoides, Gaudryinoides*, and *Trochammina* (1–3%).

The taxonomic diversity of the complex is low, D = 1.2–2.5, and the distribution evenness E = 0.23–0.25.

The assemblage includes only forms with tests of the nonspecialized morphological type (morphological group IV).

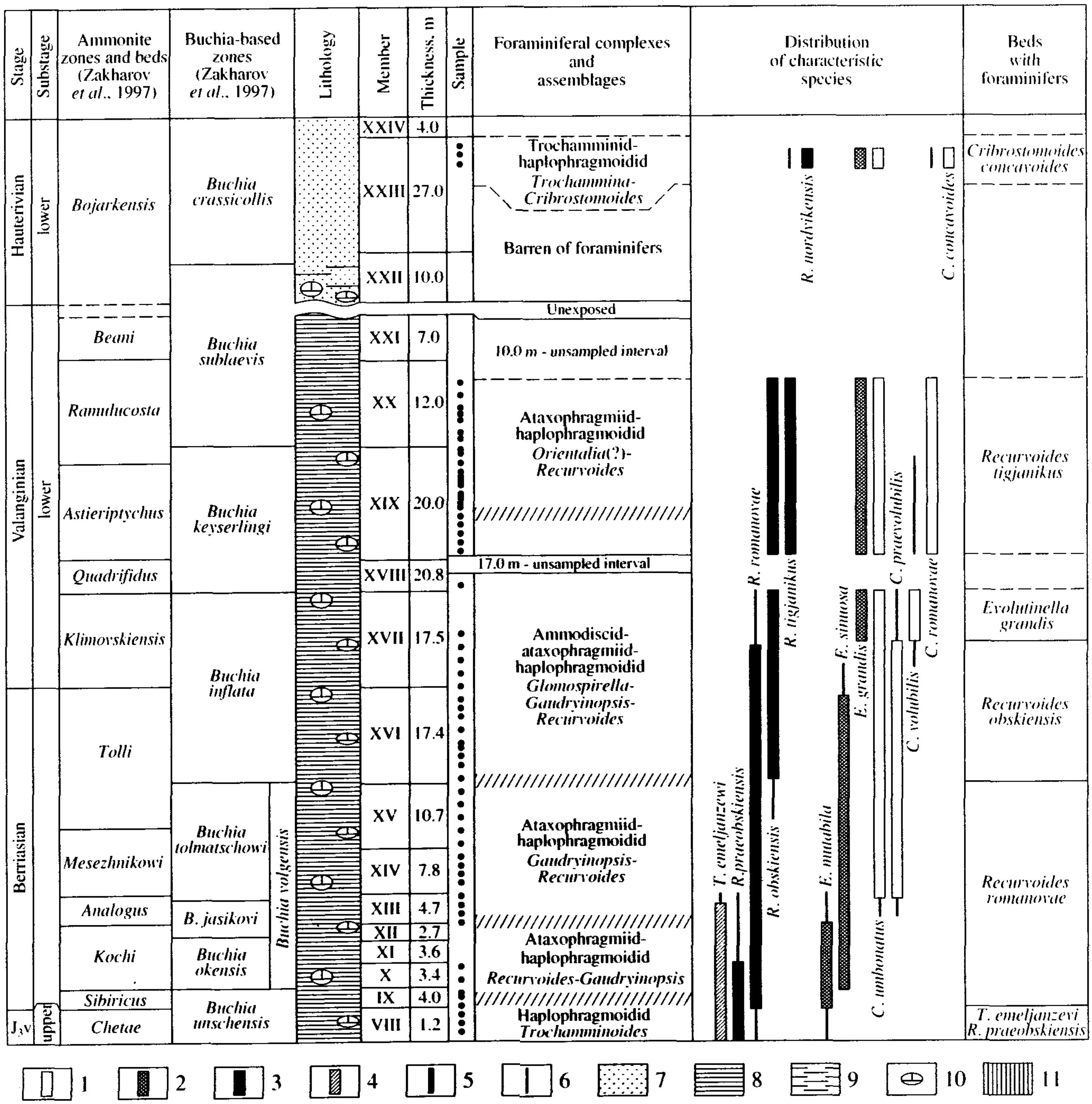


Fig. 3. Stratigraphic distribution of characteristic foraminiferal species, foraminiferal complexes, and beds with foraminifers in the section of the boreal Berriasian, lower Valanginian, and lower Hauterivian in the Nordvik Peninsula (northern East Siberia): (1) genus *Cribrostomoides*, (2) genus *Evolutinella*, (3) genus *Recurvoides*, (4) genus *Trochamminoides*, and (5) other taxons of the dominant group; (6) accessory taxons; (7) siltstone, sandstone; (8) argillite-like clay; (9) clayey siltstone; (10) carbonate concretions; (11) hiatus. Oblique hatchure designates stratoecotone.

The high occurrence frequency of the dominant species *Trochamminoides emeljanzevi* is most likely related to the oxygen deficiency in the bottom water layer of the early Berriasian Khatanga sea. It is not inconceivable that the subsurface sediments were contaminated with H_2S, because most of the tests are pyritized (Zakharov and Yudovnyi, 1874).

Complex II (ataxophragmiid–haplophragmoidid; Members X–XII)

Assemblage with *Gaudryinopsis–Recurvoides*

Dominant are representatives of the family Haplophragmoididae (85%). The dominant group includes genera *Recurvoides* (18–52%), *Evolutinella* (10–45%), *Trochamminoides* (5–15%), *Kutsevella* (to 7%) (family

Haplophragmoididae); *Gaudryinopsis* (6%) (family Ataxophragmiidae). The accessory group consists of species representing genera *Saccammina*, *Trochammina*, *Lenticulina*, and *Astacolus*.

The taxonomic diversity of the complex D = 3.5–3.8; the distribution evenness E = 0.38–0.42.

Characteristic morphological types of tests: nonspecialized (morphological group IV; 85%) and elongated, torpedo-like (subcylindrical) (morphological group III; 6%). The characteristic forms of the complex are infaunal detritophages (*Gaudryinopsis*).

Complex III (ataxophragmiid–haplophragmoidid; Members XIII–XV)

Assemblage with *Gaudryinopsis–Recurvoides*

Dominant are representatives of the family Haplophragmoididae (80%). The dominant group consists of genera *Recurvoides* (35–50%), *Evolutinella* (5–14%), *Cribrostomoides* (10–20%) (family Haplophragmoididae), and *Gudryinopsis* (6–8%) (family Ataxophragmiidae). Sometimes, they coexist with representatives of genera *Glomospirella* (9%) and *Lenticulina* (10%). The accessory group includes species of genera *Saccammina*, *Ammobaculites*, *Astacolus*, *Pseudonodosaria*, *Marginulina*, *Geinitzinita*, and *Valanginella*.

The taxonomic diversity of the complex D = 5.0–5.5; the distribution evenness E = 0.35–0.50.

Characteristic morphological types of tests: nonspecialized (morphological group IV; 80%) and elongated, torpedo-like (morphological group III; 10%). In contrast to Complex II, this one shows a higher proportion of representatives of the vagile infauna with elongated torpedo-like test (genus *Gaudryinopsis*). The dominant group of species includes representatives of the genus *Cribrostomoides* with the compact involute test characterized by a low number of chambers in the last whorl (7–9).

Complex IV (ammodiscid–ataxophragmiid–haplophragmoidid; Member XVI–lower part of Member XIX)

Assemblage with *Glomospirella–Gaudryinopsis–Recurvoides*

Dominant are representatives of the family Haplophragmoididae (60–70%). The dominant group consists of genera *Recurvoides* (34–40, sometimes 70%), *Cribrostomoides* (13–24%), *Evolutinella* (12–27%) (family Haplophragmoididae), *Gudryinopsis* (18%) (family Ataxophragmiidae), and *Glomospirella* (10–15%) (family Ammodiscidae). The accessory group includes species of genera *Saccammina*, *Ammobaculites*, *Lenticulina*, *Astacolus*, *Dentalina*, *Marginulina*, *Frondicularia*, *Valanginella*, and *Epistomina*.

The taxonomic diversity of the complex D = 6.0–9.0; the distribution evenness E = 0.60–0.75.

Characteristic morphological types of tests: nonspecialized (morphological group IV; 70%), elongated, torpedo-like (morphological group III; 20%), and flattened lenticular (morphological group II; 10–15%). Unlike Complex III, this one is characterized by the enhanced role of vagile representatives of the infauna dwelling on the soft clayey substrate (genus *Gaudryinopsis*). Also present are flattened lenticular tests of detritophages dwelling in the upper liquid sediment layer (genus *Glomospirella*).

Complex V (ataxophragmiid–haplophragmoidid; Members XIX–XX)

Assemblage with *Orientalia(?)–Recurvoides*

Dominant are representatives of the family Haplophragmoididae (75%). The dominant group consists of genera *Recurvoides* (24–42%), *Cribrostomoides* (7–10%), *Evolutinella* (9–20%) (family Haplophragmoididae), and *Orientalia(?)* (15-20%) (family Ataxophragmiidae). Sometimes, they associate with representatives of genera *Gaudryinopsis* (to 14%). The accessory group includes species of genera *Bathysiphon*, *Glomospirella*, *Trochammina*, *Lenticulina*, *Astacolus*, *Pseudonodosaria*, *Marginulina*, *Geinitzinita*, *Valanginella*, and *Epistomina*.

The taxonomic diversity of the complex D = 5.2–7.5; the distribution evenness E = 0.50–0.53.

Characteristic morphological types of tests: nonspecialized (morphological group IV; 75%), flat–convex (morphological group I; 10–15%), and elongated torpedo-like (morphological group III; 10%). As compared with Complex IV, the considered complex is characterized by the lower share of forms dwelling on the soft substrate (genus *Gaudryinopsis*). Present are flat–convex cap-shaped tests of epifaunal species dwelling on the compact substrate: genus *Orientalia(?)*. The dominant group lacks dwellers of the liquid surface sediment layer: genus *Glomospirella*.

Complex VI (trochamminid–haplophragmoidid; Members XIX–XX)

Assemblage with *Trochammina–Cribrostomoides*

Dominant are representatives of the family Haplophragmoididae (75%). The dominant group consists of genera *Cribrostomoides* (41%), *Recurvoides* (24%), *Evolutinella*, *Kutsevella* (6%) (family Haplophragmoididae), and *Trochammina* (7%) (family Trochamminidae). The accessory group includes species of genera *Lenticulina*, *Astacolus*, *Marginulina*, and *Geinitzinita*.

The taxonomic diversity of the complex D = 6.7; the distribution evenness: E = 0.44.

Characteristic morphological types of tests: nonspecialized (morphological group IV; 85%), flat–convex (morphological group I; 7%), and elongated torpedo-like (morphological group III; 7%).

Unlike the previous complex, the considered one lacks dwellers of the liquid surface sediment layer (genus *Glomospirella*). The dominant group also lacks species dwelling on the soft substrate, whereas epifaunal forms dwelling on the compact substrate are represented by the genus *Trochammina.*

Thus, the Neocomian section of the Nordvik Peninsula encloses a succession of foraminiferal assemblages reflecting the regressive replacement of facies. The stratigraphic intervals (stratoecotones) sandwiched between complexes (assemblages) can be useful for correlation of members within the distribution range of monofacies sequences.

BEDS WITH FORAMINIFERS IN THE BOREAL BERRIASIAN, VALANGINIAN, AND BOREAL HAUTERIVIAN OF THE NORDVIK PENINSULA

In our opinion, one of the main tasks, when elaborating the zonal scale based on foraminifers, is analysis of composition and structure of assemblages in order to discriminate their taxons representing the same phylogenetic lineage. As in case of orthostratigraphic groups, foraminiferal taxons selected for the scale construction should be facies-independent and characterized by a high radiation rate, clear diagnostic features, wide geographic distribution, and high abundance in the sections. The first stage of such a study, i.e., the establishment of a succession of biostratigraphic units in a particular section or area, is usually accompanied by discrimination of beds with fauna (*Stratigraficheskii kodeks...*, 1992).

In our study, beds with foraminifers were distinguished using stratigraphic complexes defined in the boreal Berriasian, Valanginian, and boreal Hauterivian of the Nordvik Peninsula and composed of representatives of genera *Recurvoides, Cribrostomoides*, and *Evolutinella.* It is assumed that north Siberian successions of species belonging to the above-mentioned genera characterize continuous phylogenetic lineages. Species of precisely these genera meet requirements of orthostratigraphic groups. They show sufficiently high rates of morphogenesis and are dominants or constituents of dominant groups in most assemblages (Fig. 3).

The distinguished biostratigraphic units corresponds partly to acme-zones of characteristic species. The lower boundaries of zones are substantiated by a complex of features. The latter include, as a rule, levels of the first species occurrence in the dominant group, levels of species transition from the accessory group into the dominant one, and vice versa.

Beds with Trochamminoides emeljanzevi–Recurvoides praeobskiensis

Member VIII. The thickness is 1.2 m.

Gerke (1957) was first to propose Beds with *Haplophragmoides emeljanzevi* (=*Trochamminoides emeljanzevi*) in northern Siberia as a unit corresponding to "the upper part of the Upper Jurassic (Kimmeridgian–upper Volgian)". Sharovskaya and Basov (1961) specified the position of their lower boundary in the section of the Urdyuk-Khaya Cape as lying "directly above beds with *Craspedites okensis*". Basov (1968) changed the rank of the beds correlating them with the entire upper Volgian Substage and widened their nomenclature (*H. emeljanzevi, Trochammina rosacea, T. septentrionalis*). Later, Basov and Ivanova (1972) correlated the beds only with two zones of the upper Volgian Substage (*Craspedites taimyrensis* and *Chetaites chetae*) coupled with the lower zone of the boreal Berriasian (*Ch. sibiricus*); they renamed the unit as Beds with *Trochammina rosaceaformis–Haplophragmoides fimbriatus*). We propose to change the nomenclature once again and to term the unit as Beds with *Trochamminoides emeljanzevi–Recurvoides praeobskiensis*, inasmuch as both index species are constituents of the dominant group, whereas *Trochammina rosaceaformis* Rom. is an accessory form. Species *T. fimbriatus* (Schar.), characterized by the same stratigraphic range as *T. emeljanzevi*, represents, in our opinion, a microspheric form of the latter.

Beds with *Trochamminoides emeljanzevi–Recurvoides praeobskiensis* are of monotonous lithologically being composed of thin-platty laminated dark gray clay with brown shading, which yields foraminiferal complex of uniform structure and composition sharply dominated by one species *T. emeljanzevi* (Schl.). The genus *Evolutinella* is represented by species *E. mutabila* and *E. schleiferi* (Schar.) occurring approximately in equal abundances. The genus *Recurvoides* includes species *R. praeobskiensis* (Plate, Figs. 1–3) and *R. romanovae* (Plate, Figs. 4 and 5). Species *Orientalia(?) baccula* Schleifer and *Saccammina* sp. occur episodically. Species *Hyperammina* sp., *Cribrostomoides* sp. indet., *Gaudryinopsis gerkei* (Vassilenko), and *Trochammina* cf. *parviloculata* Gerke et Scharovskaja are recorded as single specimens. Calcareous tests are absent.

Beds with Recurvoides romanovae

Members IX–XV (lower part). The thickness is 36.9 m.

The unit is proposed for the first time. Beds are composed of bluish gray argillite-like clays displaying angular jointing and alternating with thin-platty brownish gray clays, which exhibit horizons of limy concretions and pyrite nodules. The lower boundary of the unit corresponds to the base of the acme-zone of the index species. Slightly higher (the lower part of Member X), species *Evolutinella sinuosa* (Bulynn.) becomes dominant. At the base of Member XIII, species *Evolutinella mutabila* (Bulynn.) and *Recurvoides praeobskiensis* Dain et Bulynn. loss their dominant role turning into accessory forms. Beds correlate with the boreal Berriasian, the *Tollia tolli* Zone excluded.

Beds with Recurvoides obskiensis

Members XV (upper part) and XVII (lower part). The thickness is 27 m.

The unit is proposed for the first time as an equivalent of *Tollia tolli* and *Neotollia klimovskiensis* ammonite zones. The beds are composed of argillite-like dark gray clay with horizons of concretions of clayey limestone. The lower boundary of the unit corresponds to the level, where the index species is dominant.

Characteristic species: *Evolutinella sinuosa* (Bulynn.), *Cribrostomoides praevolubilis* Marinov, sp. nov. (Plate, Figs. 9, 10), and *Recurvoides obskiensis* Rom. (Plate I, Fig. 6).

Note to the nomenclature. The species name *Recurvoides obskiensis* was used by Bulynnikova (1981) to designate Beds with *Recurvoides obskiensis–Gaudryina gerkei* in the basal part of the boreal Berriasian of the Nordvik Peninsula, and later by Basov *et al.* (1989), when they subdivided the boreal Berriasian section in the southern Barents Sea basin. In our opinion, they all mistook the megaspheric forms of another species *R. romanovae* for *R. obskiensis.*

Beds with Evolutinella grandis

Members XVII (upper part)–XVIII. The thickness is 10.5 m.

The unit is proposed for the first time. The beds are composed of dark gray argillite-like silty clay and clayey siltstone with large concretions of clayey limestone.

The lower boundary is drawn slightly above the base of the *Neotollia klimovskiensis* Zone at the level, where the index species becomes dominant. In Member XVII, the accessory species is *Cribrostomoides volubilis* (Rom.) (Plate, Fig. 12), whereas *Cribrostomoides praevolubilis* and *Evolutinella sinuosa* become extinct. Characteristic species: *Evolutinella grandis* (Bulynn.), *Cribrostomoides volubilis*, and *Recurvoides obskiensis* (Rom.).

Beds with Recurvoides tigjanikus

Members XIX–XX. The thickness is 32 m.

The unit is proposed for the first time. The base of the unit has not been observed (the section interval of about 17 m was covered by ice and, thus, was not sampled).

The beds are composed of gray to dark gray silty clay alternating with clayey silt bearing large concretions of clayey limestone. The lower boundary corresponds with the level, where the index species is dominant. The dominant group of the complex includes *Recurvoides tigjanikus* Marinov, sp. nov. (Plate, Fig. 7), *Cribrostomoides romanovae* (Bulynn.) (Plate, Fig. 13), and *Evolutinella grandis*. The accessory group includes *Cribrostomoides volubilis.*

Beds with Cribrostomoides concavoides

Member XXIII. The thickness is 27 m.

The unit was first proposed by Bulynnikova (1971) as beds with mass accumulations of the index species. The beds are composed of gray medium- to fine-grained sands with parallel bedding and thin clayey lentils. The lower boundary is arbitrarily drawn at the base of Member XXIII because no foraminifers were registered in underlying sediments.

The dominant group of the complex includes index species (Plate, Fig. 11), *Recurvoides nordvikensis* Marinov, sp. nov. (Plate, Fig. 8), and *Evolutinella grandis*. The accessory group includes *Recurvoides tigjanikus* and *Cribrostomoides romanovae.*

CORRELATION POTENTIAL OF BEDS WITH FORAMINIFERS AND THEIR STATUS

The section of the boreal Berriasian, lower Valanginian, and lower Hauterivian in the Nordvik Peninsula comprises six beds with foraminifers named after the following dominant species: *Trochamminoides emeljanzevi–Recurvoides praeobskiensis, Recurvoides romanovae, Recurvoides obskiensis, Evolutinella grandis, Recurvoides tigjanikus, Cribrostomoides concavoides*. Four of these units are distinguished for the first time. Beds with *Trochamminoides emeljanzevi* were first established by Basov (1972) as a unit corresponding to the boreal Jurassic–Cretaceous boundary interval. Beds with *Cribrostomoides concavoides* were defined by Bulynnikova (1971) in the Hauterivian of West Siberia (*Speetoniceras versicolor* Zone).

To estimate the correlation potential (lateral consistency) of beds with foraminifers distinguished in the Lower Neocomian of the Nordvik Peninsula, we studied distribution of foraminiferal species within the same stratigraphic interval in the sections of neighboring areas of East and West Siberia, and other regions, where deposits of the boreal and subboreal types are exposed.

In the northern areas of East Siberia, the nearest sections are located along the Tigyan-Yuryakh River, the eastern coast of the Anabar Bay, and in the Bol'shoi Begichev Island (Fig. 1). Unfortunately, the boreal Berriasian is missing from these sections, whereas the lower Valanginian and the lower (*Bojarkensis*) zone of the lower Hauterivian are well represented. The section along the Tigyan-Yuryakh River located 50 km west of the Nordvik Peninsula exhibits the boreal Berriasian–Valanginian boundary layers, all the molluscan zones of the lower Valanginian, and, probably, the upper Valanginian–boreal Hauterivian boundary strata. The section is composed of uniform dark gray to gray silty clay with horizons of carbonate and clayey-carbonate concretions. The integral thickness of the section is about 206 m (Bogomolov *et al.*, 1985). The analysis of foraminiferal distribution revealed four successive complexes and three units in the rank of beds with foramin-

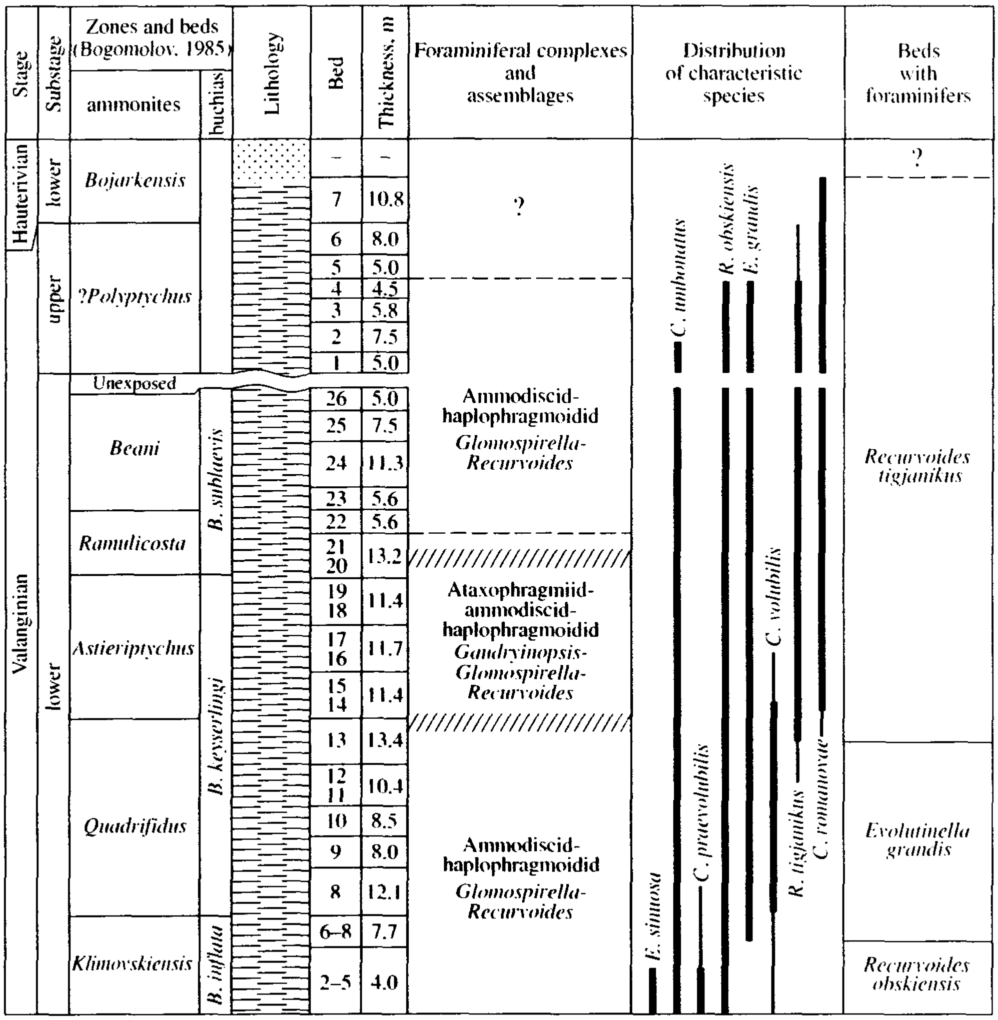


Fig. 4. Stratigraphic distribution of characteristic foraminiferal species, foraminiferal complexes, and beds with foraminifers in the section of the Valanginian and boreal lower Hauterivian along the Tigyan-Yuryakh River, northern East Siberia (symbols as in Fig. 3).

ifers analogous to *Recurvoides obskiensis, Evolutinella grandis,* and *Recurvoides tigjanikus* beds in the Valanginian of the Nordvik Peninsula (Fig. 4). The continuous exposure of the section made it possible to define, more precisely than in the Nordvik Peninsula, the boundaries of Beds with *Recurvoides tigjanikus* (Fig. 4): its lower boundary is close to the boundary between the *Quadrifidus* and *Astieriptychus* zones and the upper one is close to the Valanginian–Hauterivian boundary. The stratigraphic range of the Beds with *Evolutinella grandis* was also determined.

One of the best and well-studied lower Valanginian sections is located in the eastern coast of the Anabar Bay, 60 km southeast of the Nordvik Peninsula section (Fig. 1). Coastal scarps in this area are composed of dark gray silty clay with thin (0.3–0.4 m) interbeds of clayey limestone (the *Klimovskiensis, Quadrifidus,* and *Astieriptychus* ammonite zones) and with siltstone (the *Ramulicosta* Zone) and sandstone (the *Beani* Zone) members in the upper part. This stratigraphic interval corresponds to the *Buchia Inflata, B. keyserlingi,* and *B. sublaevis* zones. The total thickness of the considered section is less than 150 m (Bogomolov *et al.,* 1983). The section comprises three complexes and three units in the rank of beds with foraminifers (*Recurvoides obskiensis, Evolutinella grandis, Recurvoides tigjanikus*), the succession of which is approximately similar to that established in the Tigyan-Yuryakh section (Fig. 5).

The section on the Bol'shoi Begichev Island (Medvezhii Cape) is located several dozens of kilometers north of the Nordvik Peninsula section (Fig. 1) and, like in the latter, it is composed of the Valanginian dark gray silty clay (about 50 m thick) and boreal Hauterivian (the lower, *Bojarkensis* Zone) sandstone with rare clayey interbeds. The apparent thickness of the section is about 120 m. Foraminifers occur almost throughout the entire section, except for two intervals (Fig. 6). In this section, it was establish that the *Recurvoides tigjanikus* Beds correlate with the *Bojarkensis* Zone of the boreal Hauterivian and, consequently, the lower bound-

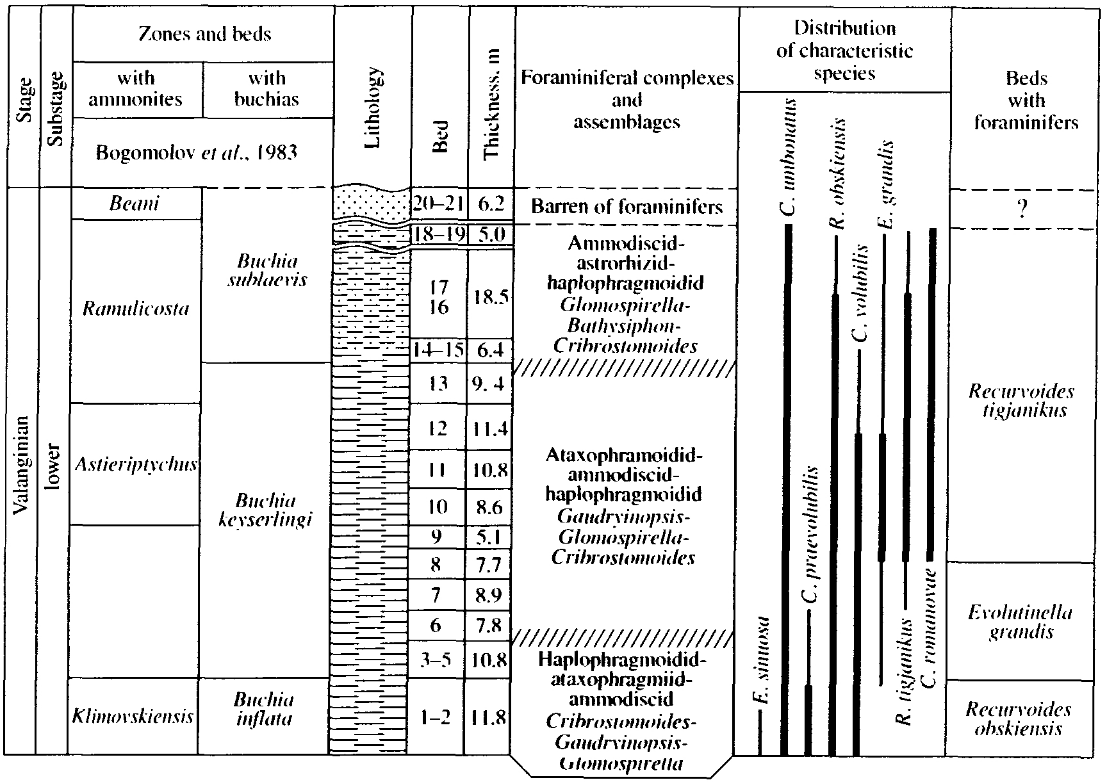


Fig. 5. Stratigraphic distribution of characteristic foraminiferal species, foraminiferal complexes, and beds with foraminifers in the lower Valanginian section in the eastern coast of the Anabar Bay, northern East Siberia (symbols as in Fig. 3).

ary of the Beds with *Cribrostomoides concavoides*, whose position in the Nordvik Peninsula section remains unclear, is located within the boreal lower Hauterivian (Fig. 6). According to data of Burdykina (1981), the section near the Medvezhii Cape (Bol'shoi Begichev Is.) includes only the upper Valanginian. She published one list of the late Valanginian mollusks collected from the lower clayey sequence more than 20 m thick. When describing ammonites, she used the letter designation of beds mentioning them as Beds C, E, and F. Unfortunately, neither stratigraphic position of beds nor their thickness are indicated in the paper. Inasmuch as we established the lower Valanginian Beds with *Recurvoides obskiensis* and Beds with *Evolutinella grandis* in the same interval of the section, it can be assumed that they correspond to the basal part of the section, i.e., to the Beds A and B not mentioned in the paper. In addition, according to data of M.A. Levchuk (field materials of 1973), the thickness of the clayey member approaches 50 m.

Correlation of beds with foraminifers in spatially close and lithologically similar sections of the Valanginian and boreal lower Hauterivian in the northern areas of East Siberia (the Nordvik Peninsula, eastern coast of the Anabar Bay, Tigyan-Yuryakh River, Bol'shoi Begichev Is.) showed that they form everywhere the same succession (Table 2). The Beds with *Recurvoides obskiensis, Evolutinella grandis, Recurvoides tigjanikus*, and *Cribrostomoides concavoides* are well traced. The succession of ammonite (Saks, 1972; Bogomolov, 1989) and buchia (Zakharov, 1981) zones established in the same sections allows an assumption that these beds have a stable stratigraphic position. The Beds with *Evolutinella grandis* in northern East Siberia closely correlate with the *Quadrifidus* ammonite zone. In two sections, they show contiguous patterns of the boundaries with underlying and overlying strata and, thus, can be considered as representing a foraminiferal zone.

To estimate the interregional correlation potential of beds with foraminifers established in the northern part of East Siberia, we studied the Lower Neocomian section in the Surgut area of West Siberia located almost 2000 km west–southwest of the Nordvik Peninsula (Fig. 1, point 6) using the core material from several boreholes (Malopyakutinskaya-543, Nasel'sk-563, Romanovo-140, Sugmut-423, Umsei-5, Yampino-8, Southern Pykuta-15 and 17, Nyudeyakha-300). It is noteworthy that foraminiferal complexes registered in these sections differ from those in northern Siberia. The peculiar composition of West Siberian complexes was repeatedly noted by previous researchers (Bulynnikova, 1973; Rodionova, 1976; Alekseeva *et al.*, 1982). Despite some shortages of the core material (spot sampling of the section and poor preservation), the West Siberion sections show the succession of beds with foraminifers identical to that in the northern areas of East

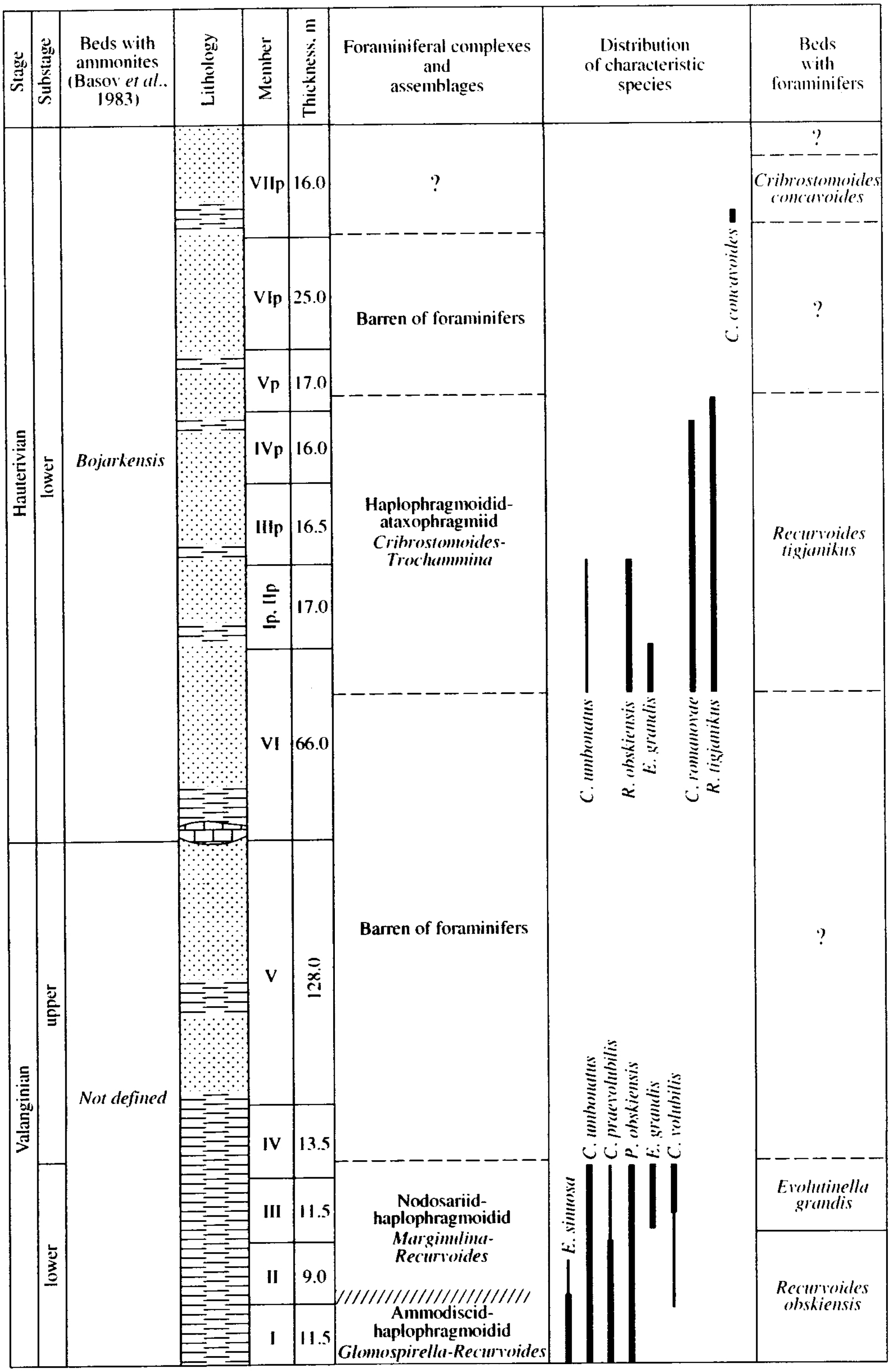


Fig. 6. Stratigraphic distribution of characteristic foraminiferal species, foraminiferal complexes, and beds with foraminifers in the lower Valanginian and boreal lower Hauterivian section on the Bol'shoi Begichev Island, northern East Siberia (symbols as in Fig. 3).

Table 2. Correlation scheme of beds with foraminifers in sections of the boreal lower Neocomian in northern East Siberia

Stage	Substage	Ammonite zones	Beds with foraminifers in particular sections of northern East Siberia: Nordvik Peninsula	Anabar River	Tigyan-Yuryakh River	Bol'shoi Begichev Is.	Foraminiferal zones and beds with foraminifers (standard)
Hauterivian	lower	*Bojarkensis*	*Concavoides* Foraminifers are missing	Unsampled	Unsampled	*Concavoides* Foraminifers are missing *Tigjanikus*	*Concavoides*
Valanginian	upper	*Kotschetkovi*	Unexposed		*Tigjanikus*	Foraminifers are missing	*Tigjanikus*
		Bidichotomoides					
		Triplodiptychus					
	lower	*Beani*	*Tigjanikus*	*Tigjanikus*			
		Ramulicosta					
		Asteriptychus					
		Quadrifidus	? *Grandis*	*Grandis*	*Grandis*	*Grandis*	*Grandis*
		Klimovskiensis	*Obskiensis*	*Obskiensis*	*Obskiensis*	*Obskiensis*	*Obskiensis*
Berriasian		*Tolli*		Unexposed	Unexposed	(hiatus)	
		Mesezhnikowi	*Romanovae*				*Romanovae*
		Analogus					
		Kochi					
		Sibiricus					
Volgian	upper	*Chetae*	*Trochamminoides emeljanzevi*				*Trochamminoides emeljanzevi*
		Taimyrensis	*Recurvoides praeobskiensis*				*Recurvoides praeobskiensis*

Siberia, i.e., the succession of *Recurvoides romanovae*, *Recurvoides obskiensis*, *Evolutinella grandis*, *Recurvoides tigjanikus*, and *Cribrostomoides concavoides* beds (Fig. 7). The boreal Berriasian and early Valanginian ammonites coexisting with foraminifers in deposits of the above-mentioned boreholes allow them to be considered as stratigraphic analogues of synonymous beds in northern Siberia. Thus, the Beds with *Recurvoides romanovae*, *Recurvoides obskiensis*, *Evolutinella grandis*, *Recurvoides tigjanikus*, and *Cribrostomoides concavoides* can be considered as representing regional zones.

The correlation potential of the proposed zonal scale is probably not limited by East and West Siberia. One can assume that some zones or their reliably substantiated stratigraphic analogues can also be recorded beyond the Siberian region in areas of the boreal and subboreal deposits. Basov was first to perform interregional correlation of beds with foraminifers for the boreal Berriasian (Basov, 1968), Valanginian and Hauterivian (Basov *et al.*, 1989). Already in his earlier work, he noted "an extreme uniformity of the late Volgian complex of agglutinated foraminifers (*Ammodiscus veteranus* and *Evolutinella emeljanzevi* beds), which is sustained throughout the vast region of northern Siberia... and comparable only with the uniformity of modern complexes in the deep areas of the World Ocean" (Basov, 1968, p. 109). The beds with foraminifers in the lower part of the boreal Berriasian are correlative through the northern Siberia, Pechora plate, and southern Barents Sea basin: (*Trochammina rosaceaformis* and *Gaudryina gerkei*, *Kutsevella praegoodlandensis* and *Lenticulina sossipatrovae*, *Recurvoides obskiensis* and *Orientalia(?) baccula* beds). Based on foraminiferal complexes, the lower Valanginian and Hauterivian deposits were traced through these regions (Basov *et al.*, 1989; scheme).

Our data confirm the possibility of interregional correlation of the Lower Neocomian relatively deep marine deposits at the stage and substage level (Table 3). They

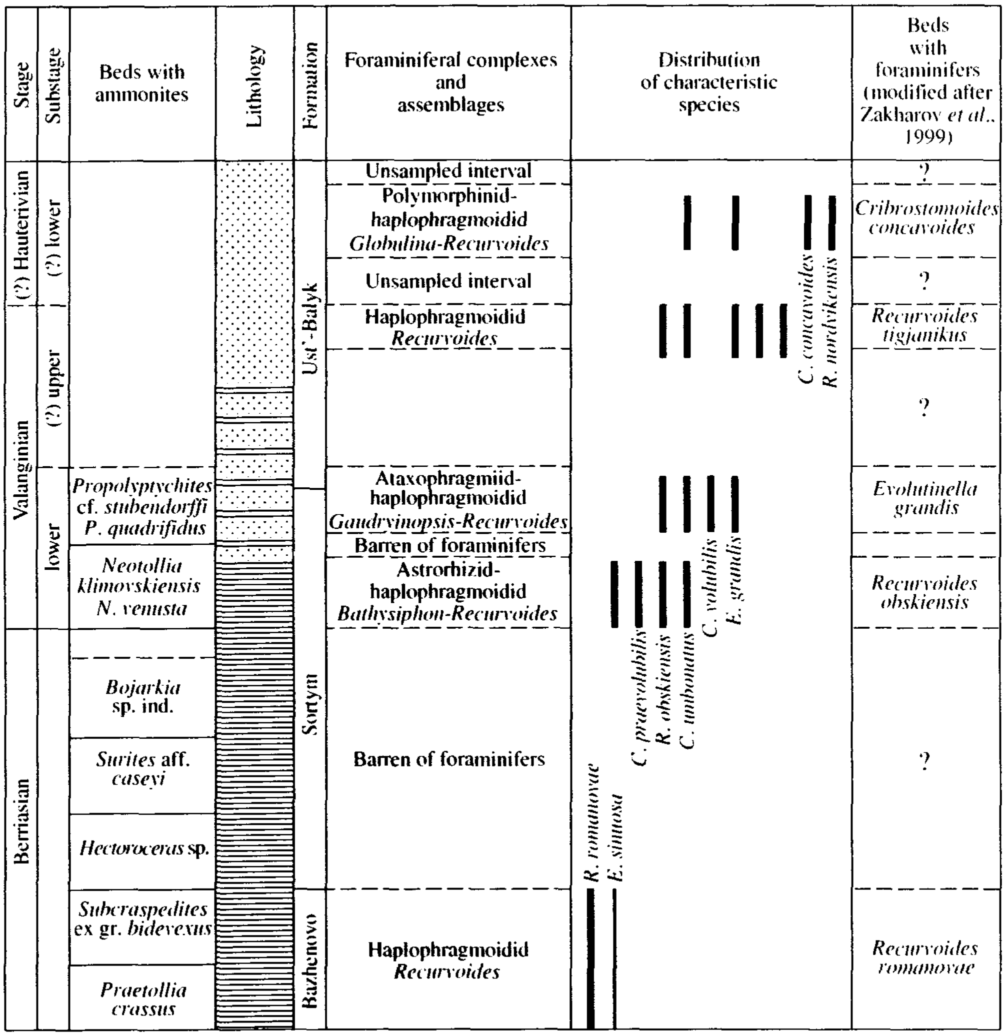


Fig. 7. Stratigraphic distribution of characteristic foraminiferal species, foraminiferal complexes, and beds with foraminifers in the integral section of the Neocomian in the Surgut area of West Siberia (symbols as in Fig. 3).

also support the reliable correlation of beds with foraminifers at the top of the upper Volgian Substage throughout the entire northern part of Siberia, as it was previously noted by Basov. The *Recurvoides romanovae* Zone is traced at the base of the boreal Berriasian of the Barents Sea plate and in Spitsbergen (Basov *et al.*, 1989; Nagy *et al.*, 1990). *Kutsevella praegoodlandensis*, one of the characteristic forms of this north Siberian zone is a dominant species of the synonymous beds in the lower part of the boreal Berriasian in the Pechora plate (Azbel' and Grigelis, 1991).

The change in composition of the dominant haplophragmoidid and nodosariid group in the lower Valanginian, namely the extinction of *Cribrostomoides volubilis* (Rom.), *Lenticulina lideri* (Rom.), and *L. variabilis* Rom. with simultaneous appearance of *L. neocomiana* (Rom.), correlates the lower boundary of the north Siberian *Recurvoides tigjanikus* Zone with the lower boundary of the *"Kutsevella" pseudogoodlandensis–Lenticulina subcrassa* Zone of the Pechora plate. We correlate the Beds with *Cribrostomoides concavoides* (lower Hauterivian) with the *Reophax torus–Globulina praelacrima–Astacolus assurgensis* Zone in the North Caspian depression based on the presence of *C. concavoides* in the latter (Plate III). The potential of foraminifers for interregional correlation is not exhausted by the above-mentioned stratigraphic intervals. The Nordvik Peninsula section contains *Lenticulina* ex gr. *macrodisca* (Reuss) and *Epistomina* ex gr. *caracolla* (Roem), the species characteristic of the lower Valanginian in the Boreal-Atlantic zoochore and assuming possibility to distinguish other reference levels. It is also important that taxons from different regions of the boreal realm are identified by the same researcher.

It should be emphasized once again that the proposed foraminifer-based zonal scale is effective first of all for correlation of marine clayey and silty–clayey Lower Neocomian deposits of the boreal type. Simultaneously, it is not so effective for correlation of other

Table 3. Foraminifer-based correlation of the Neocomian in the boreal areas

Stage	Substage	Ammonite zones	East Siberia proposed scheme	West Siberia, Surgut area (Zakharov *et al.*, 1999 modified)	North Caspian depression (Azbel' and Grigelis, 1991)	Pechora plate (Azbel' and Grigelis, 1991)	South Barents Sea plate (Basov *et al.*, 1989)	Spitsbergen Is. (Nagy *et al.*, 1990)
							This work	
Hauterivian	lower	*Bojarkensis*	*Cribrostomoides concavoides*	*Cribrostomoides concavoides*	*Reophax torus – Globulina praelacrima obessa – A. assurgensis*	*Kutsevella pseudogomensis – Hoeglundina caracolla nordensis*	*Lenticulina macrodisca – Trocholina* sp.	
Valanginian	upper	*Kotschetkovi*	*Recurvoides tigjanikus*	*Recurvoides tigjanikus*	*Ammobaculites prosper – Globulina fusina*			
		Bidichotomoides						
		Triplodiptychus						
	lower	*Beani*			"*Kutsevella*" *pseudogoodlandensis* *Lenticulina subcrassa*	*Reophax minutissima – Lenticulina eichenbergi*		*Glomospira* spp. *Glomospirella* spp.
		Ramulicosta						
		Asteriptychus						
		Quadrifidus	*Evolutinella grandis*	*Evolutinella grandis*	*Recurvoides excellens – L. lideri*	*Recurvoides excellens – Kutsevella pseudogoodlandensis*		
		Klimovskiensis	*Recurvoides obskiensis*	*Recurvoides obskiensis*				
Berriasian		*Tolli*			*A. granulum – L. andromedovae – L. dzhamyschensis*			*Gaudryina* aff. *milleri*
		Mesezhnikowi	*Recurvoides romanovae*	*Recurvoides romanovae*				
		Analogus			*Recurvoides valanginicus – R. embensis*	*Kutsevella pseudogoodlandensis – Lenticulina* gr. *sossipatrovae*	*Recurvoides romanovae – Orientalia* (?) *baccula*	
		Kochi						*Recurvoides romanovae*
		Sibiricus						
Volgian	upper	*Chetae*	*Trochamminoides emeljanzevi – Recurvoides praeobskiensis*	?		*Bullopora vivejae – Ammobaculites diligens*	*Ammodiscus veteranus – Trochamminoides emeljanzevi*	*Trochammina* aff. *abrupta*
		Taimyrensis						

facies. For instance, the Lower Neocomian coastal shallow-water deposits are subdivided using the succession of the secretory foraminiferal groups in the section (Basov and Ivanova, 1972; Bulynnikova, 1981; Fedorova, 1993). This zonation has none of zones in common with our scale proposed for the deposits of the Nordvik Peninsula (Anabar Bay) accumulated in relatively deep sea settings. Thus, parallel scales should be elaborated for correlation of different-facies sections.

CONCLUSION

The performed micropaleontological study of most complete boreal-type sections of the Berriasian, Valanginian, and Hauterivian in the Anabar Bay (Laptev Sea) revealed the diverse complexes mainly consisting of agglutinated foraminifers. They are dominated (75–100%) by representatives of the family Haplophragmoididae Maync, 1952 (genera *Recurvoides, Evolutinella, Cribrostomoides*, and *Trochamminoides*). The comprehensive study of foraminifers from these genera allowed the volume of species and their stratigraphic intervals to be specified. Evolutionary–morphological transformations of species belonging to three first genera served as the basis for elaboration of the foraminiferal zonal scale based on the Lower Neocomian sections of East Siberia. The complete succession of six units in the rank of beds with foraminifers is established in the most appropriate section of the Nordvik Peninsula. Fragments of this succession are registered in spatially close (within 100 km) and lithologically similar sections in the Tigyan-Yuryakh River, Anabar Bay eastern coast, and Bol'shoi Begichev Is. The same succession of all beds with foraminifers established in the Lower Neocomian of northern East Siberia are recorded in several sections drilled by boreholes in the Surgut area of West Siberia located about 2000 km west-southwest of the Nordvik Peninsula. This is a good basis for ranking these units as foraminiferal zones. The concurrent ammonites and buchias in section of both East and West Siberia allowed the stratigraphic range and geological age of these units to be determined. The foraminiferal scale ranging from the upper part of the upper Volgian Substage to the base of the boreal lower Hauterivian and including *Trochamminoides emeljanzevi–Recurvoides praeobskiensis, Recurvoides romanovae, Recurvoides obskiensis, Evolutinella grandis, Recurvoides tigjanikus*, and *Cribrostomoides concavoides* zones is proposed as a standard for the relatively deep-water deposits of the boreal type. The complexes include species reported from areas beyond Siberia, e.g., from the Pechora and Barents Sea plates, as well as from the North Caspian depression, that is favorable for interregional correlation at the stage and substage level.

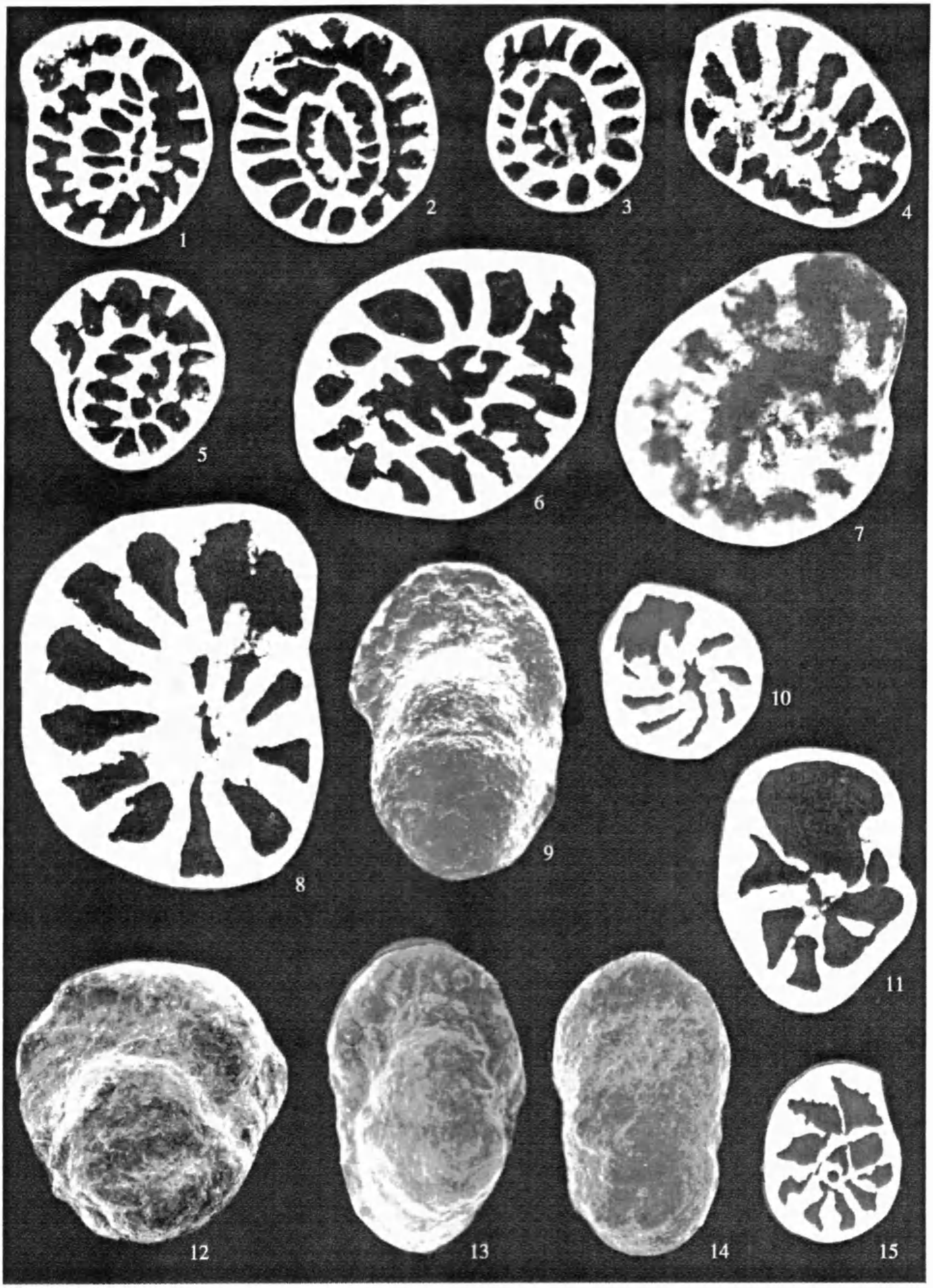
Based on peculiarities of composition and distribution of foraminifers, the relatively autonomous groupings of taxons (foraminiferal complexes) are discriminated. The stratigraphic interval from the Jurassic–Cretaceous boundary layers to the boreal lower Hauterivian comprises six successive complexes. In our opinion, these complexes reflect the life-time transformations of taxa assemblages, whose compositional and structural changes were controlled by the integral environmental changes related, in particular, to the general shoaling of the basin and phylogenetic radiation.

Foraminifers from the Lower Cretaceous (Berriasian, Valanginian, Hauterivian) of northern East Siberia.

All pictured specimens are stored at the Central Siberian Geological–Mineralogical Museum (CSGM), collection 1072.

Microphotographs 1–8, 10, 11, 15 are shot in the immersion liquid, and 9, 12–14, under the scanning electron microscope.

(1–3) *Recurvoides praeobskiensis* Dain et Bulynnikova, 1986. (1) specimen 1072/283, side view, ×56; northern East Siberia, Nordvik Peninsula, Exposure 33, Member X, Sample 4-32; Lower Cretaceous, Berriasian, *Chetaites sibiricus* Zone, Paksa Formation; (2) specimen 1072/285, side view, ×56; (3) specimen 1072/284, side view, ×56; locality of specimens in Figs. 2 and 3 the same as for specimen 1072/283. (4, 5) *Recurvoides romanovae* Putrja, 1967. (4) specimen 1072/286, side view, ×60; northern East Siberia, Nordvik Peninsula, Exposure 32, Member XII, Sample 15-33; Lower Cretaceous, Berriasian, *Hectoroceras kochi* Zone, Paksa Formation; (5) specimen 1072/287, side view, ×51; the same locality. (6) *Recurvoides obskiensis* Romanova, 1960. Specimen 1072/290, side view, ×60; northern East Siberia, Nordvik Peninsula, Exposure 33, Member XVII, Sample 29-32; Lower Cretaceous, lower Valanginian, *Neotollia klimovskiensis* Zone, Paksa Formation. (7) *Recurvoides tigjanikus* Marinov, s. nov. Specimen 1072/270, holotype, side view, ×58; northern East Siberia, Nordvik Peninsula, Exposure 35, Member XIX, Sample 35-35-1; Lower Cretaceous, lower Valanginian, *Euryptychites astieriptychus* Zone, Paksa Formation. (8) *Recurvoides nordvikensis* Marinov, sp. nov. Specimen 1072/295, holotype, side view, ×57; northern East Siberia, Nordvik Peninsula, Exposure 36, Member XXIII, Sample 2-36-89; Lower Cretaceous, lower Hauterivian, *Homolsomites bojarkensis* Zone, Tigyan Formation. (9, 10) *Cribrostomoides praevolubilis* Marinov, sp. nov. (9) holotype, specimen 1072/308, apertural view, ×50; northern East Siberia, Anabar River, Exposure 1A, Bed 1, Sample 0-1-1, 1.5 m above the base; Lower Cretaceous, lower Valanginian, *Neotollia klimovskiensis* Zone, Paksa Formation; (10) specimen 1072/312, side view, ×38; the same locality. (11) *Cribrostomoides concavoides* Bulynnikova. Specimen 1072/399, side view, ×40; northern East Siberia, Nordvik Peninsula, Exposure 36, Member XXII, Sample 2-36-89, 3.6 m above the base; Lower Cretaceous, lower Hauterivian, *Homolsomites bojarkensis* Zone, Tigyan Formation. (12) *Cribrostomoides volubilis* (Romanova), 1960. Specimen 1072/324, apertural view, ×44; northern East Siberia, Anabar River, Exposure 1A, Bed 1, Sample 0-1-4, 7.5 m above the base; Lower Cretaceouś, lower Valanginian, *Neotollia klimovskiensis* Zone, Paksa Formation. (13) *Cribrostomoides romanovae* Bulynnikova, 1971. Specimen 1072/382, apertural view, ×50; northern East Siberia, Anabar River, Exposure 1A, Bed 14, Sample 0-24-37, 0.5 m above the base; Lower Cretaceous, lower Valanginian, *Sibirites ramulicosta* Zone, Paksa Formation. (14, 15) *Cribrostomoides umbonatus* (Romanova), 1955. (14) specimen 1072/411, apertural view, ×52; West Siberia, Surgut area, Borehole Yuzhnopyakutinskaya-17, depth of 2737 m, Sample 17-13; Lower Cretaceous, lower Valanginian, *Neotollia klimovskiensis* Zone, Sortym Formation; (15) specimen 1072/400, side view, ×60; northern East Siberia, Anabar River, Exposure 1A, Bed 8, Sample 0-14-18, 5.5 m above the base; Lower Cretaceous, lower Valanginian, *Propolyptychites quadrifidus* Zone, Paksa Formation.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Transitions between complexes (assemblages) correspond to certain stratigraphic intervals (stratoecotones). The complexes (assemblages and stratoecotones) are characterized by the stable composition and structure in the case of lateral facies stability and can serve as an additional proxy for correlation of monofacies sections. Nonetheless, successions of the complexes, as well as the stratigraphic position of the boundary intervals (stratoecotons), differ even in spatially close sections.

TAXONOMIC DESCRIPTION

Order LITUOLIDA Blainville, 1825

Family Haplophragmoididae Maync, 1952

Subfamily Haplophragmoidinae Maync, 1952

Genus *Cribrostomoides* Cushman, 1910

Cribrostomoides praevolubilis Marinov, sp. nov.

Plate, Figs. 9, 10.

Holotype: Specimen 1072-308, CSGM; northern East Siberia, Anabar River, Lower Cretaceous, lower Valanginian, *Neotollia klimovskiensis* Zone, Exposure 1A, Bed 1, Sample 0-1-1, Paksa Formation, Plate, Fig. 9.

Diagnosis. The test is involute, with 7 chambers in the first whorl and 8 chambers in the second whorl. An umbo is narrow and deep. The aperture surface is low; its height is by a factor of 2.5–3 less than the width. The latter regularly increases in ontogeny; the test diameter (D) of 0.60, 0.70, 0.80, and 1.00 mm corresponds to the width of the apertural surface (H) of 0.43–0.45, 0.50–0.55, 0.55–0.60, and 0.70–0.75 mm, respectively.

Material: About 200 specimens of different preservation.

Dimensions, mm, the Anabar River, Bed 1, Sample 0-1-2.

Specimen	D	H	n	N	dp	D_1
Holotype	1.13	0.77	8			
1072-309	1.00	0.73				
1073-310	1.00	0.67				
1072-312	0.86		7	12		
1072-319	0.80	0.55				
1072-313	0.79		8	11	0.12	0.57
1072-315	0.70		7	10	0.10	0.60
1072-334	0.55	0.40				

Hereinafter: (D) the large diameter of the test; (d) the small diameter of the test; (H) the width of the apertural surface; (dp) the diameter of the primary chamber; (n) designates the number of chambers in the last whorl; (N) the total number of chambers; (n_1) the number of chambers in the first whorl; (n_2) the number of chambers in the second whorl; (n_3) the number of chambers in the third whorl; (D_1) the diameter of the first whorl.

Variability: see diagnosis and dimensions.

Comparison. The considered species differs from morphologically similar *Cribrostomoides romanovae* Bulynnikova in the greater width of the apertural surface when tests are equal in diameter. The *C. praevolubilis* test diameter (D) of 0.60, 0.70, 0.80, and 1.00 mm corresponds to the apertural surface height of 0.43–0.45, 0.50–0.55, 0.55–0.60, and 0.70–0.75 mm, respectively (the apertural surface height of the *C. romanovae* test is equal to 0.37–0.40, 0.44–0.48, 0.52–0.55, and 0.65–0.70 mm, respectively).

The height of the apertural surface in the same ontogenetic stage of *Cribrostomoides praevolubilis* and *Cribrostomoides concavoides* Bulynnikova from the Hauterivian of Siberia (Bulynnikova, 1971) is equal. The former differs from the latter in a greater number of chambers in the first and second whorls (7 and 8 versus 6 and 7, respectively).

The considered species differs from *Cribrostomoides volubilis* Romanova in a lower rate of the dimension increase in the apertural surface during ontogeny (the width of the apertural surface of *C. praevolubilis* test is equal to 0.47–0.53, 0.55–0.60, 0.62–0.70, and 0.78–0.83 mm, respectively). It also has a deeper umbo (*C. volubilis* virtually lacks the umbilical deep and inner edges of chambers join in the center of the lateral side).

Distribution: Siberia, Lower Cretaceous, boreal Berriasian–lower Valanginian, *Surites analogus–Neotollia klimovskiensis* zones.

Localities: Northern East Siberia, Nordvik Peninsula, Exposures 32, 33, and 35, Members XIII–XVIII, Paksa Formation, 15 samples (more than 600 specimens); Tigyan-Yuryakh River, Exposure 1, Beds 1–3, Paksa Formation, 6 samples (more than 50 specimens); Anabar River, Exposure 1A, Beds 1–5, 8 samples (more than 80 specimens); Bol'shoi Begichev Is., Exposure 504, Members I–II, Paksa Formation, 9 samples (125 specimens); West Siberia, Surgut area, Sortym Formation, Borehole Nassel'sk-563, Interval of 2660–2667 m, Borehole Western Nadym-70, Interval of 2632–2645 m, Borehole Yuzhnopyakutinskaya-17, Interval of 2734–2738 m, 12 samples (more than 50 specimens).

Subfamily Recurvoidinae Alekseitchik, 1973

Genus *Recurvoides* Earland, 1934

Recurvoides tigjanikus Marinov, sp. nov.

Plate, Fig. 7

Recurvoides sinuosus: Myatluk, 1988, Plate 4, Fig. 10; Plate 5, Figs. 1, 2.

Recurvoides princeps: Myatluk, 1988 (partly), Plate 5, Figs. 3, 5.

Derivation of the name. The species is named after the Tigyan-Yuryakh River.

Holotype: Specimen 1072-270, CSGM; northern East Siberia, Nordvik Peninsula, Exposure 35, Member XIX, Sample 35-35-1; Lower Cretaceous, lower Valanginian, *Euryptychites astieriptychus* Zone, Paksa Formation, Plate, Fig. 7.

Diagnosis. The width of the first, second, and third whorls in the megaspheric generation is 0.40, 0.65–0.70, and 1.10–1.20 mm, respectively. Tests consisting of 10, 20, and 30 chambers are 0.40–0.45, 0.75–0.85, and 1.10–1.20 mm in diameter, respectively. Tests with 11 and 12 chambers in the last whorl are 0.85–0.90 and 0.90–1.00 mm in diameter, respectively (Plate, Fig. 12). In the test of megaspheric generation, the width of the second whorl is 0.50–0.60 mm. Tests with 10 and 20 chambers are to 0.35 and 0.60–0.65 mm in size, respectively, and those with 10 and 13 chambers in the last whorl are to 0.45–0.50 and 0.70–0.75 mm across.

Material. About 100 specimens of different preservation.

Dimensions, mm. Nordvik Peninsula, Exposure 35, Member XIX, Sample 35-35-1.

Megaspheric generation

Specimen	D	d	H	n	dp	N	n_1	n_2	n_3
1072-105	0.44	0.38	0.21	8	0.06	11	6		
1072-268	0.64	0.55	0.23	9					
1072-269	0.68	0.60	0.23	10	0.07	17	7	10	
1072-107	0.76	0.71	0.30	10.5	0.08	19	6	9	
Holotype	0.95	0.73	0.26	11	0.08	23	6	10	
1072-271	0.97	0.77	0.30	11	0.07	25	7	9	
1072-293	0.98			11					
1072-110	1.02	0.90	0.41	12	0.08				
1072-273	1.04	0.98	0.35	12					
1072-112	1.10	0.97	0.41	12.5	0.06	29	6	9	12

Microspheric generation

Specimen	D	d	H	n	dp	N	n_1	n_2
1072-294	0.46			9.5				
1072-115	0.48	0.47	0.17	10	0.06	15	6	
1072-116	0.54	0.50	0.17	11				
1072-118	0.60	0.54	0.18	12				
1072-120	0.75	0.65	0.28	12.5				
1072-122	0.86	0.70	0.29	14	0.07			

Variability. Ontogeny is characterized by the growing degree of test enveloping (from involute to semievolute), by increasing number of chambers in the last whorl, and by the apertural surface widening (see diagnosis and dimensions).

Comparison. The considered species differs from *Recurvoides obskiensis* Rom. in a higher rate of the whorl height increase. The diameter of the first, second, and third whorls in the megaspheric generation of *R. tigjanikus* is equal to 0.40, 0.65–0.70, and 1.10–1.20 mm, respectively (these parameters for *R. obskiensis* are equal to 0.65–0.70, 0.70–0.80, and 0.80–0.90 mm, respectively).

The diameter of the second whorl in tests of the microspheric generation is 0.50–0.60 mm. Tests with 10 and 13 chambers in the last whorl are 0.45–0.50 and 0.70–0.75 mm in diameter, respectively (similar parameters for *R. obskiensis* are 0.40–0.45 and 0.60–0.65 mm, respectively).

Distribution: Siberia, Lower Cretaceous, Valanginian–lower Hauterivian; North Caspian depression, Valanginian–lower Hauterivian.

Localities: Northern East Siberia, Nordvik Peninsula, Exposure 35, Members XIX and XX, Paksa Formation, 9 samples (more than 40 well-preserved specimens); Exposure 36, Member XXIII, Paksa Formation, Sample 2-36-89 (2 specimens); Bol'shoi Begichev Is., Exposure 502, Members VI, Ip–IVp, Tigyan Formation, 12 samples (40 specimens); West Siberia, Surgut area, Borehole Yampino-8, Sortym Formation, Interval of 2727–2780 m (30 specimens).

Recurvoides nordvikensis Marinov, sp. nov.

Plate, Fig. 8.

Recurvoides ex gr. *stschekuriensis*: Flower and Braun, 1993, pp. 30–31, Plate 4, Figs. 10–12.

Recurvoides ex gr. *canningensis*: Flower and Braun, 1993, pp. 30–31, Plate 4, Figs. 22–26.

Derivation of the name. The species is named after the Nordvik Peninsula.

Holotype: Specimen 1072/270, CSGM; northern East Siberia, Nordvik Peninsula, Exposure 36, Member XXIII, Sample 2-36-89; Lower Cretaceous, lower Hauterivian, *Homolsomites bojarkensis* Zone, Tigyan Formation, Plate, Fig. 8.

Diagnosis. The test has up to two complete whorls. The width of the first and second whorls in the test of the megaspheric generation is equal to 0.40–0.45 and 0.75–0.80 mm, respectively. Tests composed of 10, 20, and 25 chambers are 0.55, 0.90–95, and 1.20 mm in diameter, respectively; tests with 10, 11, and 12 chambers in the last whorl are 0.90–1.00, 1.00–1.10, and 1.20 mm in diameter, respectively.

The width of the second whorl in the microspheric generation is 0.70 mm. Tests composed of 10 and 20 chambers are 0.45 and 0.80 mm in diameter, respectively. The diameter of tests with 10 and 12 chambers in the last whorl is 0.70–0.80 mm and 0.90–1.00 mm, respectively.

Material: about 60 specimens of different preservation.

Dimensions, mm. Nordvik Peninsula, Exposure 36, Member XXIII, Sample 2-36-89.

Megaspheric generation

Specimen	D	d	H	n	dp	N	n_1	n_2
1072-228	0.40	0.38	0.17	7	0.09	8	7	
1072-229	0.47	0.43	0.19	6	0.07	9	6	
1072-231	0.55	0.50	0.22	7	0.07	10	6	
1072-233	0.57	0.50	0.23	8	0.07	11	7	
1072-236	0.61	0.58	0.27	8		13	6	
1072-237	0.76	0.70	0.35	9	0.07	16	7	9
1072-238	0.97	0.90	0.30	10.5	0.08	21	7	9
1072-240	1.05	0.96	0.36	11	0.085	22	7	9
1072-296	1.06			11				
1072-241	1.10	0.98	0.43	11.5		22	6	9
1072-243	1.20	1.03	0.52	11	0.10	24	7	9
Holotype	1.20			12				

Microspheric generation

Specimen	D	d	H	n	dp	N	n_1	n_2
1072-244	0.98	0.87	0.36	12.5		23		
1072-297	0.73			9				
1072-245	0.70	0.60	0.32	9	0.09	17	7	9
1072-247	0.48	0.40	0.16	8	0.054	12		
1072-249	0.40	0.36	0.25	6.5	0.08	9	6	

Variability. Ontogeny is characterized by growth in the degree of the test enveloping (test with a single complete whorl is involute, and that with two whorls is involute at one side and partly evolute at the other), in the number of last whorl chambers, and in the width of apertural surface (see diagnosis and dimensions).

Comparison. The considered species differs from *Recurvoides tigjanikus* sp. nov. in a significantly higher rate of the whorl diameter increase. In the tests of microspheric generation, the first and second whorls are 0.40–0.45 and 0.75–0.80 mm in diameter, respectively (analogous parameters of *R. tigjanicus* are 0.40 and 0.65–0.70 mm, respectively). Tests with 10, 11, and 12 chambers are 0.90–1.00, 1.00–1.10, and 1.20 mm in diameter, respectively (the same parameters for *R. tigjanikus* are equal to 075–0.80, 0.85–0.90, and 0.90–1.00 mm, respectively).

The width of the second whorl in tests of the microspheric generation is 0.70 mm (that in *R. tigjanikus* is 0.05–0.60 mm). Tests with 10 chambers in the last whorl are 0.70 mm in diameter, those with 12 chambers, 0.90–1.00 mm in diameter (in *R. tigjanikus*, 0.40–0.50 and 0.60–0.65 mm, respectively).

Distribution: Siberia, Lower Cretaceous, lower Hauterivian, *Homolsomites bojarkensis* Zone; Arctic Canada, Hauterivian–Barremian.

Localities: northern East Siberia, Nordvik Peninsula, Exposure 36, Member XXIII, Tigyan Formation, Sample 2-36-8, 3-36-89 (more than 40 specimens of different preservation); Borehole Umsei-5, Ust'-Balyk Formation, Interval of 2673–2680 m (12 specimens).

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