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# New Data on the Stratigraphy and Depositional Environment for Upper Jurassic and Lower Cretaceous Deposits of the Stolbovoi Island (New Siberian Islands)

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**Abstract**—The section of Mesozoic terrigenous deposits over 1200 m thick has been described, and a new geological map of the Stolbovoi Island southern half has been compiled. The inference has been made that the sedimentary sequence represents a single uniform turbidite complex, which is indivisible into lithological units and which does not show transition to shallow-marine facies either in the visible foot section or visible roof section. The complex accumulated in the foreland basin emerged on the margin of the Novosibirsk–Chukchi continental block during the Anyuian orogeny. The presence of upper Volgian deposits (Upper Jurassic) with a visible thickness of 640 m, Berriasian (Ryazanian) deposits about 100-m thick, and lower Valanginian deposits with a visible thickness of ~200 m has been established on the basis of identification of fossils represented by remains of bivalve mollusks (the genus *Buchia*). Finds of upper Volgian buchias in the southeastern part of the island are inconsistent with field geological observations of the sequence of deposits. Paleontological data acquired for the island southern part suggest the presence of a transverse thrust fault, along which upper Volgian rocks were thrust over lower Neocomian rocks. The possibility of another interpretation of the data has also been considered. The correlation of the *Buchia* Beds of the Stolbovoi Island, Nordvik Peninsula, the basin of the Anyui River, and northern California has been carried out. The inference about a close relationship between the biota of the Stolbovoi Island and the North Pacific paleobiogeographic realm has been drawn.

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*Key words*: Arctic, New Siberian Islands, Anyui orogeny, foreland basin, turbidites, *Buchia*, Upper Jurassic–Lower Cretaceous stratigraphy.

## INTRODUCTION

The Stolbovoi Island is located in the southwestern part of the New Siberian Islands (Fig. 1). It is incorporated into the group of the Lyakhov Islands that is mainly made of the Lower Jurassic–Upper Cretaceous flyschoid complex. The complex was interpreted as deposits of the Siberian Craton's passive margin (Drachev et al., 1998) or as deposits of the foreland basin generated in the front of the Anyui orogen (Kuzmichev et al., 2006).

Until the present time, Stolbovoi Island has been poorly studied. A.V. Voronkov has gained the most complete information about its geology. He compiled the first and only geological map of the island in 1956 and showed that it was entirely composed of a single complex of Mesozoic sandy–shaly deposits (Voronkov, 1958). Voronkov was the first to find fossil buchias (bivalve mollusks) in terrigenous deposits, on the bases of which the deposits were attributed to the Valanginian. He evaluated their total thickness as 1700–1900 m. Prior to his studies, the geology of the island was unknown. It was suggested that its southern part was made of granite and the northern part, of limestone (Spizharskii, 1947). Two groups of geologists simultaneously carried out geological investigations in the northern part of the island in 1973 (Ivanov et al., 1974; Vinogradov and Yavshits, 1975). V.V. Ivanov with colleagues (1974) inferred that the stratigraphic range of the deposits they had studied involved the Oxfordian, Kimmeridgian, and Volgian stages of the Upper Jurassic, as well as the Berriasian Stage of the Lower Cretaceous. V.A. Vinogradov and G.P. Yavshits attributed the same deposits to the Volgian–Berriasian (Vinogradov and Yavshits, 1975). The map compiled by Voronkov has served as the basis for the official geological map on a scale of 1 : 200000 published later (*State*…, 1982). The stratigraphy of the Mesozoic terrigenous complex is presented in this map on the basis of materials obtained in 1973 after the study of a small area in the northern part of the island. The undivided Upper Jurassic rocks 650–700-m thick and the Berriasian–Valang-

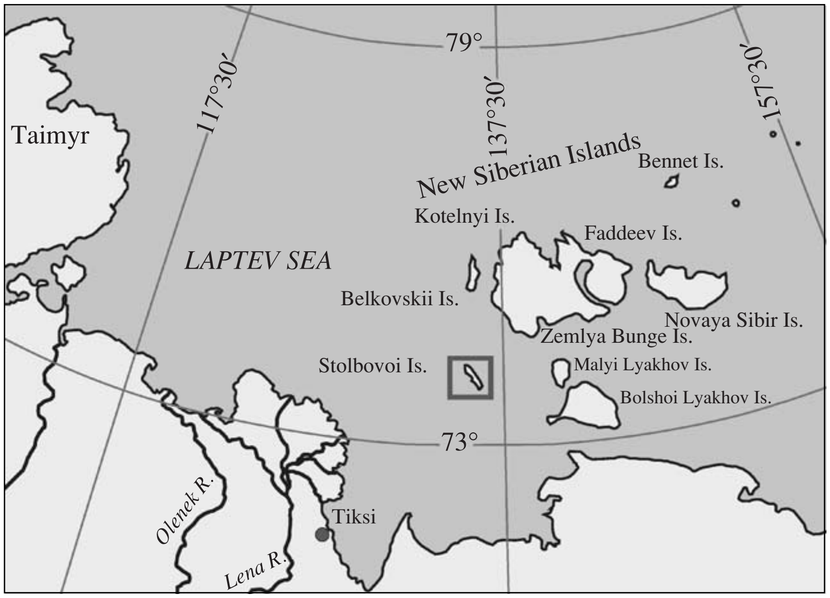



**Fig. 1.** Position of Stolbovoi Island (in the frame) in the New Siberian Islands.

inian beds 300–350-m thick are presented in the map. Information available to date on the geology and stratigraphy of the Stolbovoi Island is restricted to the publications listed above. In 2002, A.B. Kuzmichev carried out a short-term observation in the northern part of the island. Deposits were assigned to turbidites and correlated with the terrigenous complex of the Big Lyakhov island. It was inferred that the deposits accumulated in the late Volgian–early Neocomian in the synorogenic basin that extended from the Stolbovoi Island via the Big Lyakhov island to the northern Chukotka (Kuzmichev et al., 2006).

New data on the stratigraphy of the terrigenous complex that makes up the Stolbovoi Island are considered in this work. In 2007, Kuzmichev and M.K. Danukalova carried out detailed geological studies for 2.5 months in the southern part of the island. One of the tasks of these field studies was to refine the age and structure of the section of terrigenous deposits, which was necessary for characteristics of the Mesozoic tectonic history of the region, and to reveal the nature of the basin, in which sedimentary sequences accumulated. In particular, the Oxfordian–Kimmeridgian age of the section lower horizons, which was established by Ivanov with colleagues (Ivanov et al., 1974), was inconsistent with our ideas about the age and tectonic setting of the sedimentary basin. The authors (Ivanov et al., 1974) cast doubt on the inferences made by Voronkov that such a thick terrigenous sequence, which he had described, accumulated for a short period of time not falling outside the scope of the Valanginian. We, in turn, doubted the inferences made by Ivanov and his coauthors about the Oxfordian–Valanginian time interval of the accumulation of the terrigenous complex. Our doubts were caused by two reasons. First, deep-water turbidite complexes similar to those exposed on the Stolbovoi Island are formed very fast (Mutti, 1992). Second, the paleontological material, on the basis of which the rock age was inferred, is inadequate. The reasons are considered in detail below.

## GENERAL INFORMATION ON THE STOLBOVOI ISLAND'S GEOLOGY

The Stolbovoi Island extends northwestward for 46.5 km with a maximum width of about 10 km. Its maximum height is 220 m (Mount Podlog) (Fig. 2). This is one of the flat-topped terraced uplands that extend like a chain across the island and represent outliers of an old peneplane. The cliff surrounds most of the island. Higher and smoother cliffs 20–40 m high are found on the southwestern coast. Cliffs of the northeastern coast are usually lower and mostly weathered. The cliff is the only source of data on the succession of the terrigenous complex making up the island (Fig. 3). In places, the complex is also exposed as a rock debris on terraced slopes of uplands. The rocks do not differ in composition and texture from those that are exposed on the cliff, though, it is impossible to compile a section of them in the central part of the island due to poor exposure. It is these rock debris piled up on slopes that are shown in the map (Fig. 2) as exposures of Mesozoic bedrocks in the central part of the island. Sandstone and mudstone debris or individual blocks elevated above the Quaternary loam due to permafrost processes are also observed on the rest of the

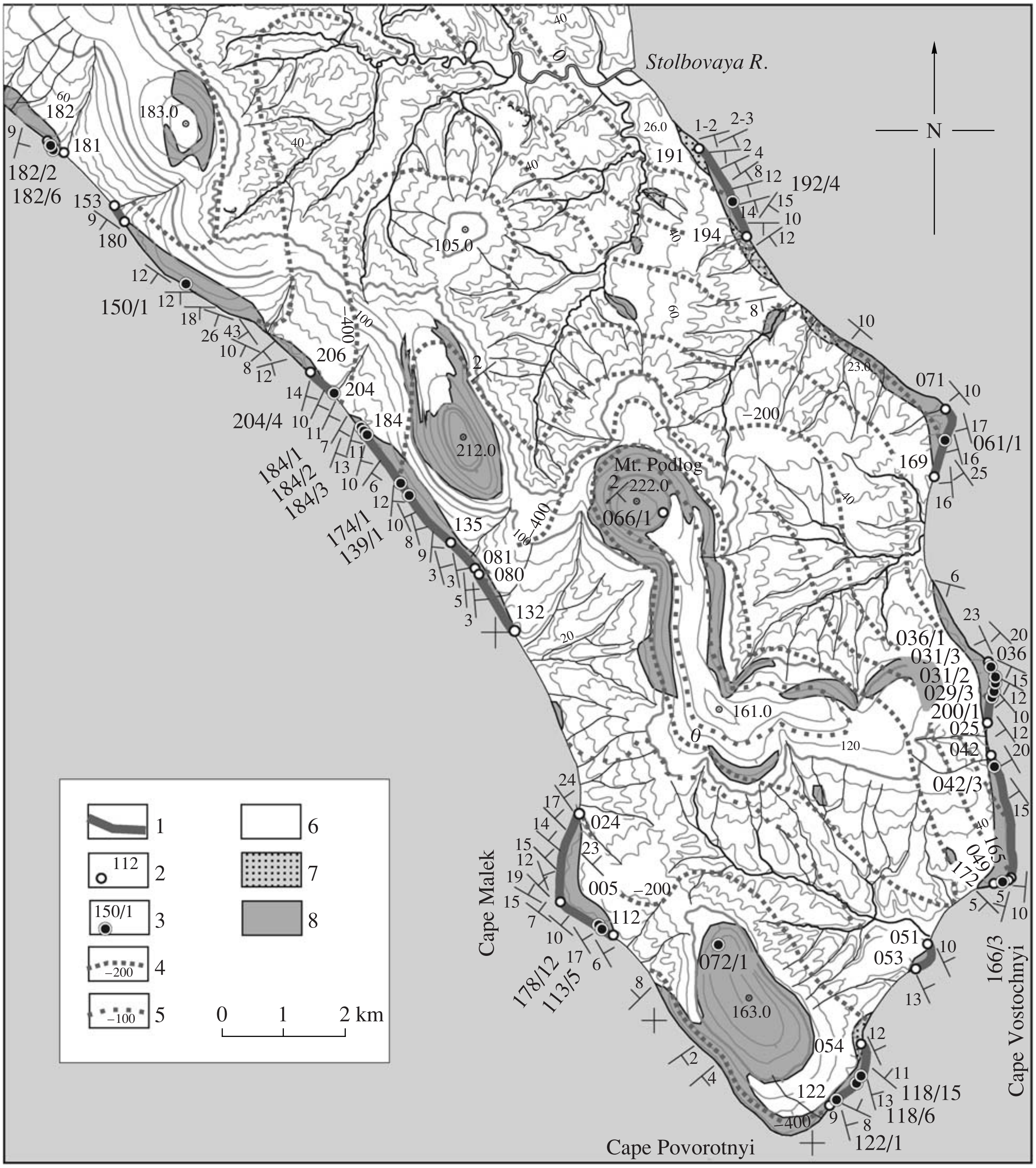



**Fig. 2.** Field geological map for the southern part of Stolbovoi Island compiled without regard for paleontological data.

(1) Measured section fragments; (2) numbers of initial and terminal observation points of measured section fragments; (3) localities of fauna finds and numbers of corresponding specimens; (4) structural lines of the Lower Cretaceous sequence and their numbers (in meters) are calculated downward in the section from a defined zero level in the syncline core on the southeastern coast and drawn in 200 m; (5) supplementary structural lines in 100 m; (6) Quaternary deposits (mainly Pleistocene ice complex); (7) Neogene lacustrine–boggy deposits (out of scale); (8) Lower Cretaceous (upper Volgian–lower Valanginian) turbidite complex (exposure width along cliffs is exaggerated).

territory. The observations leave no doubt that the whole territory of the island's southern half is composed of a single terrigenous material.

Judging from observations in the cliff, the rocks mostly dip gently, but their strike varies widely (Fig. 2). We interpret such strike variations as closings of

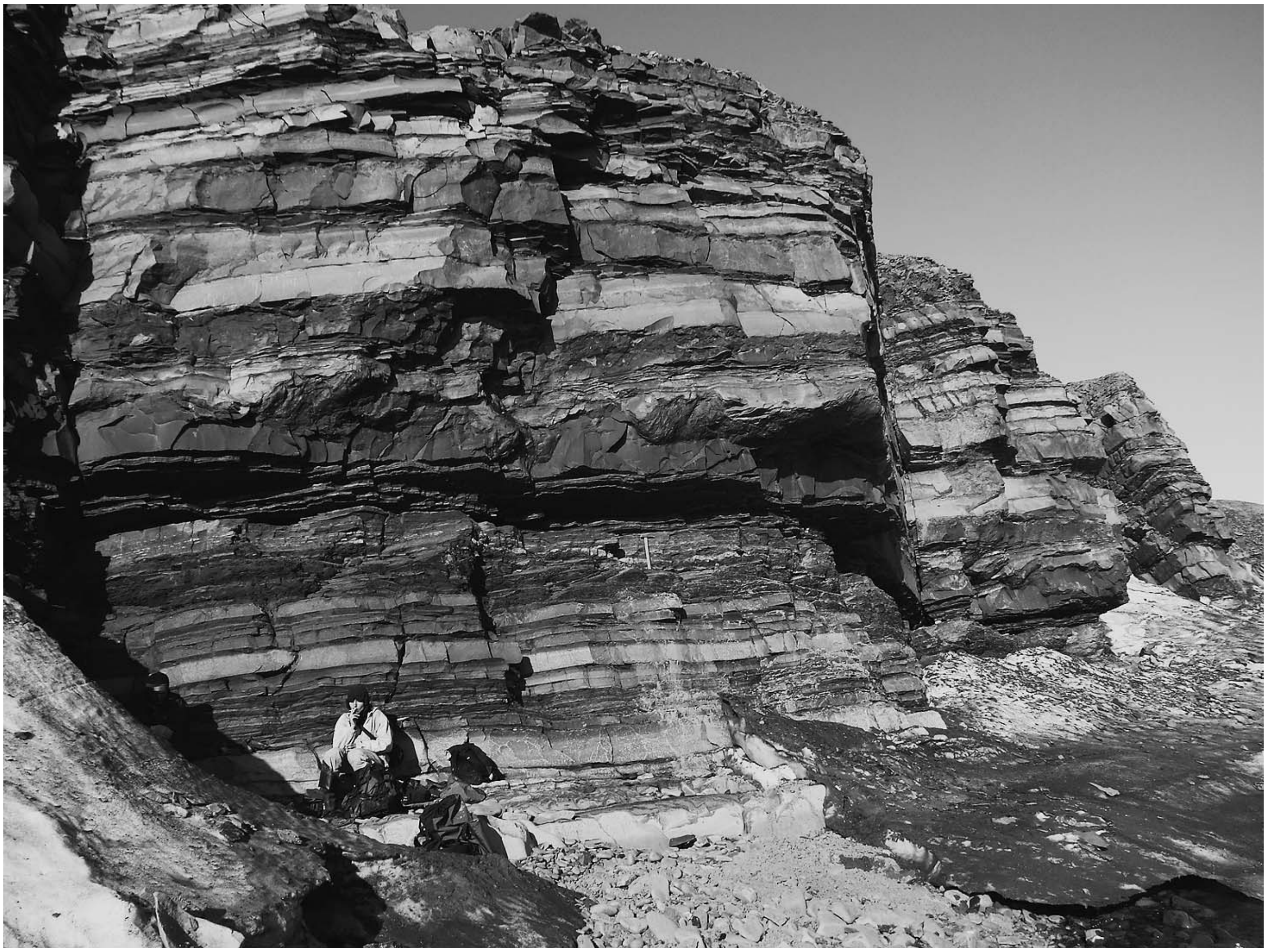


**Fig. 3.** A cliff near Cape Malek (see Fig. 2) made of a contrasting interbedding of light and dark turbiditic sandstones interlayered with siltstone and mudstone.
The person in the foreground is M.K. Danukalova.

brachyanticlines and brachysynclines. Figure 2 demonstrates the position of beds over the whole studied territory with due regard for topography. In general, structural lines trace out a gentle syncline extended nearly along the island's axis. The lower bend gently plunges southeastward. This main element of the structure is complicated by small brachysynclines and brachyanticlines.

The gentle folded structure is broken by numerous steep normal and reverse faults. In most cases, as observed in the cliffs, the amplitude of the faults is small and makes up centimeters or tens of centimeters, and rarely meters. Faults with the amplitude exceeding 10–30 m were revealed in some cases. In describing the cliffs, the correlation of the strata on fault walls was unambiguous with rare exceptions, and in general they did not preclude the compilation of a continuous section. In several cases, however, we were not sure of the validity of the correlation. In addition to subvertical faults, the section is broken in places by overthrusts (Fig. 2), whose amplitudes remained unknown. The cliff bounding the island is not continuous. One must not rule out the fact that gentle fragments of the coast, to which stream mouths are confined, can be related to high-amplitude dislocations substantially distorting the succession we have established.

All stratigraphic observations were carried out in the cliff. Beach scarps were studied on reconnaissance routes during the first half of the season, then for most of them, a layer-by-layer section was compiled with a complete measuring of their thicknesses by a rod. We failed to obtain some detailed section fragments as they were inaccessible after a complete thawing of the firns at their feet. The scarps have been irregularly studied. For a considerable part of them, the bed succession was formally described, the main rock varieties were distinguished, and their thicknesses were measured. Some section fragments were studied in greater detail with a comprehensive description of their sedimentologic peculiarities. Continuous panoramic photographing, which allowed us to refine the structure, the succession of beds and their thickness, as well as to trace their changes along the strike, covered part of the scarps. The quality of particular sections we have compiled and the extent of the reproducibility of the results in the course of possible repeat observations turned out to be unequal because of a series of objective and subjective reasons.

## LITHOSTRATIGRAPHY OF TERRIGENOUS DEPOSITS: ASSESSMENT OF THE POSSIBILITY OF SECTION CORRELATION BY LITHOLOGIC CHARACTERISTICS

The section of Mesozoic deposits of the Stolbovoi Island is made of distal turbidites with prevailing sandy facies. In general, the section is composed of three rock types which irregularly alternate: (1) thick (meters) beds of light uniform sandstone which are usually made of several amalgamated individual beds; (2) dark gray and black clay sandstone and diamictite making up beds as thick as decimeters or parts of decimeters; such beds usually compose rhythmic members up to several tens of meters thick; (3) dark gray to black mudstone constituting the upper parts of turbidite rhythms where their thickness is measured in centimeters. In some places, fine-clastic rocks make up members up to several meters thick. Predominating in them are mudstones with thin interlayers of siltstone or sandstone. For stratigraphic purposes, we have adopted this simplified classification as it was possible to show only the above-mentioned rock types and their combinations on all the columns drawn in the field on a scale of 1 : 200. The structure of individual beds and members varied in each section, thus reflecting the peculiarities of sedimentation. Despite the presence of characteristic beds and their successions, we failed to find any key horizon which could have been reliably identified (even in two separate sections).

We considered different criteria for lithologic correlation. In particular, we tried to use thick beds of light massive sandstones for these purposes. In places, such sandstones make up uniform beds over 10-m thick and represent the most conspicuous element of the section. Though, it was impossible to correlate sections on the basis of this criterion. The thickness of such beds was found to vary along the strike, and in places they fall into members separated by mudstones or dark sandstones. It is in the lowermost part of the section, near the observation point (o. p.) 180 on the western coast (Fig. 2) that a thick (about 40 m) member of massive amalgamated sandstone was revealed, which is missing from other sections.

Another conspicuous and recognizable element of the section is represented by rare and rather thick (exceeding 3–5 m) members with prevailing mudstones. This facies is the only one in the section to include its own basin deposits formed due to the settling of organic and inorganic suspension and the rewashing of it by submerged flows. Contrary to fast-settling turbidite sands, members made of fine clastics are likely to have accumulated for a long time and spread over vast areas in the basin abyssal parts. One or several members of such rocks were found in most of the particular continuous sections. It was established that the members cannot be regarded as key horizons as in some cases they were found to be "diluted" with sandstones at short distances. A member made of fine clastics was revealed only in the section's lower part on the eastern coast near observation point 192. No analogs of the member have been revealed in other sections. The member is mainly composed of mudstones with a total thickness of about 15 m.

Data on the direction of paleocurrents and the direction of turbidite flows' migration represent one more possible correlation criterion. Although the complete statistic processing of these observations has not yet been carried out, preliminary data show that only one interval at the section base near points 192–194 (Fig. 2) exhibits distinct variations in the orientation of initial sediment textures, which reflect changes in paleogeographic conditions of the basin.

The distinction and correlation of major sedimentation cycles could be one of the correlation criteria. Well-studied turbidite complexes are characterized by large-scale cyclicity, usually reflected in the thinning of turbidite rhythms upward the section; a contrary tendency was revealed more rarely (Mutti, 1992). We failed to reveal a distinct cyclicity in the section on the Stolbovoi Island that is likely to be related to the presence of two contrasting types of sandstones, which mainly make up the section. We believe that different processes were responsible for the generation of turbidite flows of two types. Each of the processes could be of a pulsational nature, but their overlapping could conceal cyclicity.

Voronkov (the only one who had studied the southern part of the island before us) subdivided the section into two unequal parts, the upper of which is mainly made of mudstones. The only exposure of the upper sequence shown by him on the territory we have studied is located in the southern part of the island between points 051 and 227 (Fig. 2). Our observations revealed no exposures of the black-shale sequence in this region. In the eastern part of the region, Mesozoic rocks are composed of massive sandstones that can be observed in a low beach scarp between points 51–53 (Fig. 2). No exposures or vysypkas (rock fragments scattered around) of Mesozoic rocks have been revealed in the southwestern part of the exposure shown by Voronkov. It is likely that based on structural considerations, Voronkov assumed the presence of the upper shale sequence there and placed it into the syncline core on the southern coast.

Having studied all the beach scarps, we came to the conclusion that the subdivision of the section into lithologically conspicuous and recognizable members is impossible. By sedimentologic and lithologic characteristics, some distinctions can be marked only for the lowermost part of the terrigenous complex section, which later can be distinguished as a sequence. The scheme for the correlation of measured section fragments, which we have adopted in the field, is shown in Fig. 4. The size of the publication in the journal gave us no way of depicting lithological peculiarities on the columns. The stratigraphic range of the studied fragments of the section was determined in accord with our ideas about the general structure of the complex (Fig. 2). The zero reference level, from which the thickness of beds is plotted downward, was placed into the syncline core of the southeastern coast of the island (Fig. 2). For unexposed areas of the coast, the inferred thickness of the beds was calculated graphically, with allowance for the strike and dip. The measured thickness was adopted for the scarps. The composite section compiled by these criteria is 1100 m thick. On Mount Podlog and the small mountains located south of it, the section is built up upward, for over 100 m from the zero reference level. The total thickness of the terrigenous complex slightly exceeds 1200 m in the studied part of the island.

## RESULTS OF PREVIOUS STRATIGRAPHIC STUDIES

Information about the age of Mesozoic rocks of the Stolbovoi Island is based on collections of buchias (bivalves) gained by previous investigators in two areas: in the northern part of the island, on the territory corresponding to the lower part of the section (Ivanov et al., 1974; Vinogradov and Yavshits, 1975), and in the southern part of the island corresponding to the section’s upper part (Voronkov, 1958).

Voronkov was the only one who worked in the island area we have studied. Amidst the collection of buchias that he gathered, only two specimens appeared to be good for identification. S.V. Cherkesova identified them in open nomenclature: *Aucella (=Buchia)* ex gr. *sublaevis* Keys., found on the watershed 2 km south of Mt. Podlog, and *A. (=B.)* cf. *concentrica* Fisch., on the western coast, 4.5 km west-northwestward of

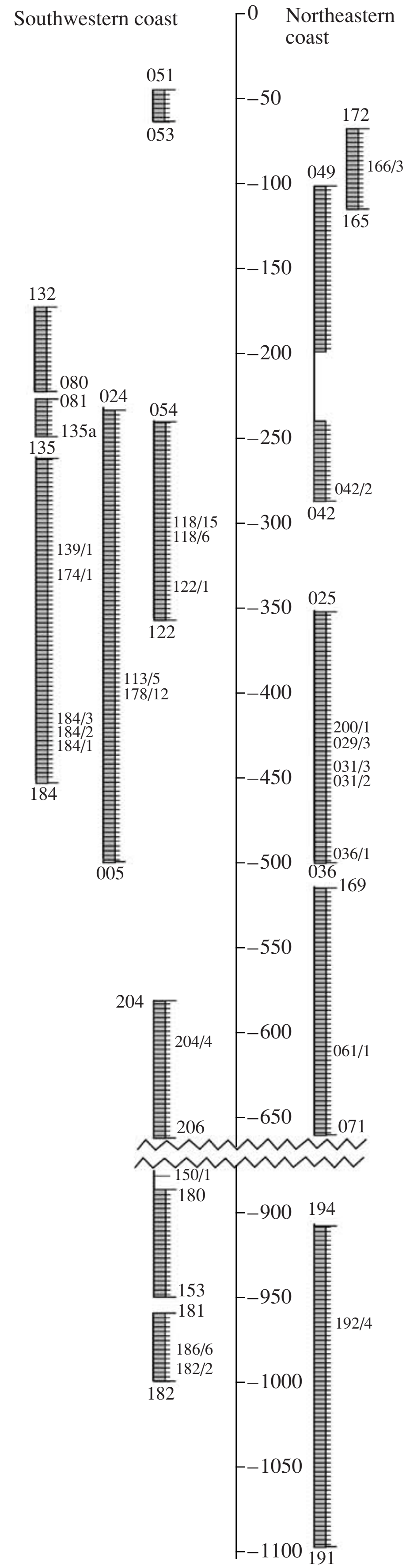



**Fig. 4.** Relative position of measured section fragments in the composite stratigraphic column in relation to the structure observed, without regard for paleontological data.

Numbers of initial and terminal points of particular columns correspond to Fig. 2. Numbers of fauna specimens are shown in small type to the right of the columns.

Mt. Podlog.[1] Based on these fossils, the deposits were attributed to the Valanginian. According to our plotting, the first of the found specimens corresponds to the section interval of +100 m. The second specimen corresponds to the level of about –200 m (Fig. 4). Approximately in the area where Voronkov found the second specimen, we collected numerous buchias which confirm the inference about the Valanginian age of the host rocks (see below). Hence, the buchias found by Voronkov characterize only the upper part of the section, whose thickness makes up about 300 m according to our plotting. Fossils were previously found only in the northern part of the island (Ivanov et al., 1974; Vinogradov and Yavshits, 1975).

Vinogradov, Ivanov, and their colleagues studied sections of the island's northern part in the early spring when most of the scarps were completely covered with firns. For this reason, they managed to describe only high scarps on the Cape Skalistii (the northern edge of the island) and those located three kilometers south of them. In addition to them, Vinogradov and Yavshits studied part of scarps near Cape Ozernyi (12 km south of Cape Skalistyi). Hence, these geologists have carried out rather a modest scope of observations on a small area and in an unfavorable season. Nevertheless, they spread the obtained results on the territory of the whole island that was embodied in the official geological map and the stratigraphic column supplemented to it (*State*…, 1982).

Ivanov and his colleagues distinguished five members in the section on Cape Skalistii (Ivanov et al., 1974). The two lower members comprise a substantial share of fine clastics, the third and fourth members represent a flyschoid alternation, and massive sandstones making up thick beds predominate in the fifth member. The three upper members comprise buchias. Identified in the third member were *A.* cf. *bronni* and *A.* ex gr. *bronni* (Oxfordian—Kimmeridgian, identified by V.P. Pokhialainen).[2] *A.* sp. resembling *A. gabbi*, *A.* sp.—"a fragment possibly belonging to one of the varieties of *A. mosquensis"* (Ivanov et al., 1974, p. 880), *A.* cf. *fischeriana* and *A.* ex gr. *okensis* were found in the fourth member. The latter is confined to the member top. Species *gabbi* and *fischeriana* indicate the Volgian–Berriasian interval for the greater part of the fourth member. Shells of four species: *A.* aff. *okensis, A.* ex gr. *okensis, A.* aff. *volgensis, A.* aff. *robusta*, and *A.* aff. *andersoni* were found in the fifth member. Pokhialainen thought that the stratigraphically most complex age occurred within the Berriasian–Valanginian. Hence, the lower part of the section was attributed to the Oxfordian and Kimmeridgian, whereas the upper part, to the Berriasian and Valanginian. As evident from the cited list of species, they all were identified in open nomenclature, which prevents the age of host rocks from being uniquely determined. Moreover, species representing key forms for the Valanginian are missing from the list. However, the first consideration is that only Latin names of species without images, which precludes judging the reliability of their identifications, are presented in publications.

Vinogradov and Yavshits subdivided the studied section into four sequences. The lower sequence comprises packets mainly made of mudstones. Exposed A 60-m interval (the upper 30 meters contains a member with a sharp prevalence of mudstones) is exposed and a 300-m interval is unexposed; the total thickness is 360 m. The third member is similar to the fifth member distinguished by Ivanov; its thickness is 106 m. The fourth member includes a fragment of a flyschoid alternation described for Cape Ozernii (200 m). The geologists collected 14 specimens of *Buchia* shells, most of which were identified as *Buchia* sp. Part of the shells retained the signs, on the basis of which, species such as—*B.* sp. (ex gr. *mosquensis* (Buch.)) (lowermost parts of the second sequence), *B.* ex gr. *fischeriana* (Orb.), *B.* sp. (? cf. *rugosa* (Fisch.)) (uppermost parts of the second sequence); *B.* sp. (ex gr. *okensis–spasskensis*) (lowermost parts of the third sequence); and *B. fischeriana* (Orb.), *B.* sp. (aff. *nuciformis* (Pavl.)), *B. lahuseni* (Pavl.) (the fourth sequence) (identifications by M.D. Burdykina with consultation by N.I. Shul'gina)—were identified in open nomenclature. Only two specimens from the fourth sequence were reliably diagnosed as *B. fischeriana* and *B. lahuseni*. In general, the authors inferred that the stratigraphic range of the terrigenous complex in the upper part of the Stolbovoi Island falls within the Volgian–Berriasian.

The review cited above shows that the *Buchia* collections were slightly representative, and most of the specimens had been satisfactorily preserved. This explains the fact that taxonomic identifications were made in open nomenclature. That is why the inference about the age of the host rocks should be regarded with caution. The reliable diagnostics of the *Buchia* species is possible only with representative collections at hand, which allow one to assess their age and individual and interpopulation morphologic variability. We happened to be in a more favorable situation when studying the geology and stratigraphy of the island compared to our predecessors and succeeded in gathering the *Buchia* collections in more than 20 sites (Fig. 2). Owing to mass finds of fossils in several key stratigraphic ranges, we managed to establish reliably the upper Volgian, Boreal Berriasian (Ryazanian) and lower Valanginian there. Remains of cephalopods were extremely rare and were represented only by a single find of a shell cast of the genus *Boreiophylloceras* sp. ind. from the order Phylloceratida (identified by M.A. Rogov) along with upper Volgian buchias.

[1] This species is included in the synonym of *B. sublaevis* (Keyserling) (Zakharov, 1981, p. 149).

[2] This species is a young synonym for *B. concentrica* (Sowerby) (Zakharov, 1981, p. 64).

## BIOSTRATIGRAPHY

### *Special Features of the Buchia Taphonomy*

The deep-water turbidite complex of the Stolbovoi Island is extremely poor in fossils. The majority of the material we have collected, like previous investigators, is satisfactorily or poorly preserved. This is because the shells are ill-prepared and the pelite sediments are highly compacted, which resulted in the shell flattening in the course of diagenesis. Nevertheless, up to several tens of specimens were collected) in some sites, and in cases, the material was well preserved. For the most part, the shells were found in situ or nearly in situ. According to their taphonomic features, all the finds can be subdivided into two types: (1) buried in situ or slightly transported in fine clayey deposits and (2) transported in sandstones.

**Burials in mudstones.** Remains of buchias are more often found in black mudstones. In most cases, the mudstone members of the Stolbovoi Island sections are not pelagic deposits in the strict sense. The prevailing volume of these rocks is of a rhythmic structure, which resulted from the pulsating mud settling caused by the convergence of turbidity flows. We stripped layer-by-layer thick clay members sporadically encountered in the section if exposure conditions allowed. Shells in such members were usually confined to the boundaries of the rhythms. The recurrence made up from 1 to 10 shells per square meter. Autochthonous burials of a few thin-walled shells were recovered in fine-grained rocks. This fact may reflect the unfavorable living conditions in deep-water silty grounds with a deficiency of oxygen (the host sediments comprise pyrite nodules at different levels). A group composed of several specimens buried in situ—micropaleopopulation (Plate I, Fig. 9) was found in one of the shale members. Similar in-situ burials consisting of small (about 5 mm) young specimens (Plate II, Fig. 4) were encountered as well. These cases can be explained by the fact that the buchias could have populated deep-water silty grounds in periods between descents of turbidity flows. Casts of different burrows of bottom mollusks are encountered in places in rhythmic members on surfaces of plates of siltstones overlying the clayey silt. These animals, like the *Buchia*, populated the substrate during time intervals between episodes of the accumulation of avalanches of the sediment.

**Burials in sandstones.** Shells are rarely encountered in sandstones. Solitary specimens transported by a turbidity flow were found in three cases. In one locality, a whole shell (core) was found on the lower surface of a sandstone bed. In three cases, shell clusters comprising tens and hundreds of specimens were encountered in sandstones. In two cases, such clusters were confined to the boundaries of amalgamated beds (both localities are within one thick bed). Shells from observation point 139/1 were attributed to this type. The shells are well preserved and arranged as a chain in a bed up to 15-cm thick directly above the boundary of the amalgamation. The boundary in the described cases was expressed as a thin (a few centimeters) interlayer of calcareous silt, light-colored on weathered surfaces. The shells were separated from the substrate by a bottom current and buried during the "freezing" of a grain flow. Whether the shells were transported from the shoal or washed-out and graded in the course of a marine erosion of the underlying fine sediment still remains unknown.

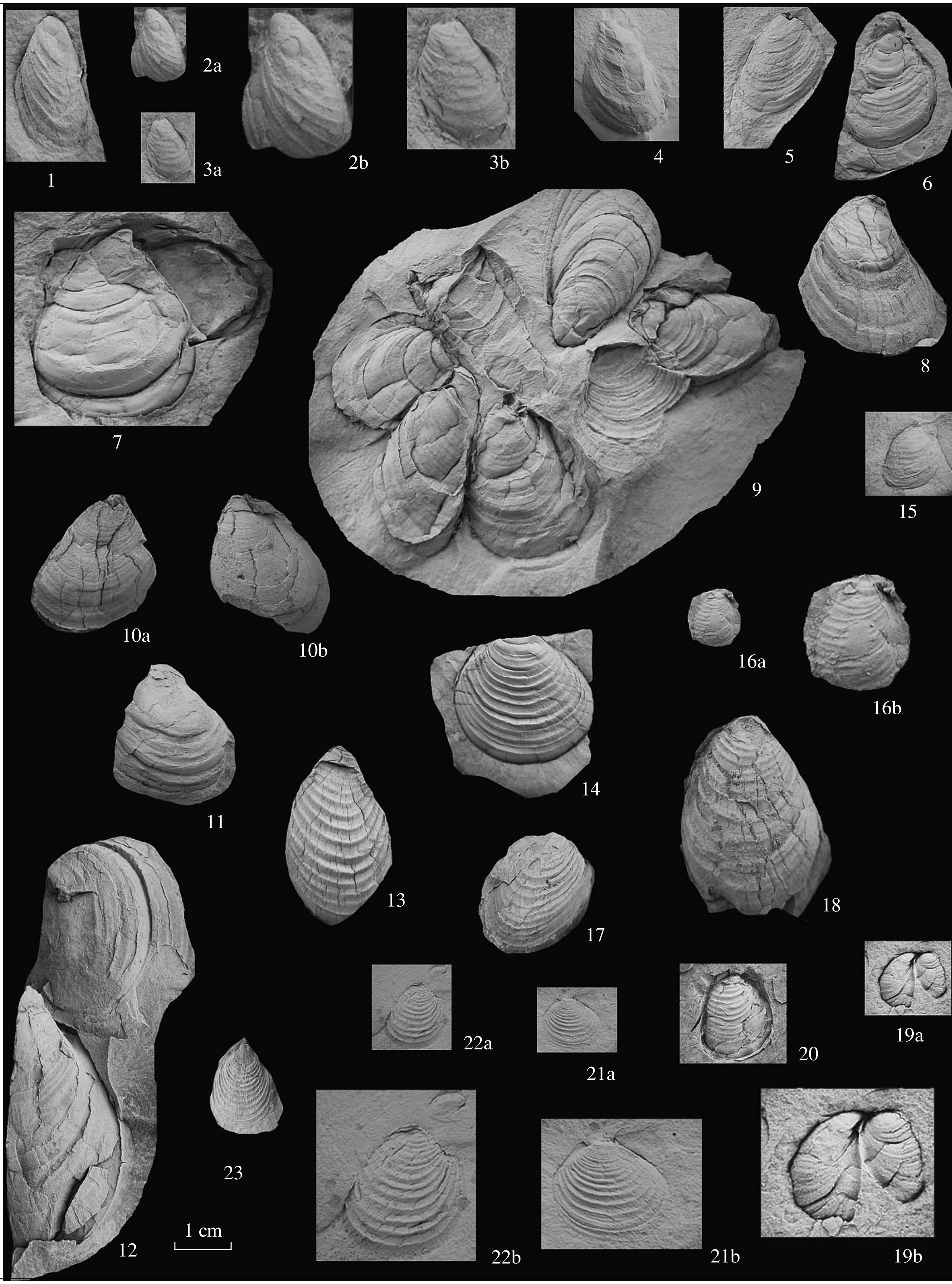
In the third case, the shells were confined to the floor of a thick bed made of massive light turbidite sandstone (point 174/1), *Buchia* mass burials being found in an erosion scour, in which sandstone comprised numerous mudstone and clayey sandstone clasts and blocks in sizes up to 1.3 m (rip-up). The buchias exhibit no regular orientation, individual valves and whole shells are arranged at random and are usually enclosed in a sandy matrix, but in places are "pressed" in mudstone. It is only in one case that a shell was completely enclosed in a clast of black clayey sandstone. Solitary shells are encountered in the sandstone foot beyond the erosion channel. The shells in this locality are not deformed and, in many cases, have both valves. The abundance of shells (hundreds of specimens) in a limited space is a unique phenomenon for the turbidites of Stolbovoi Island. The following versions seem to be possible. (1) The shells could be washed out from the underlying rocks. Though, no shells have been found in the underlying mudstones and black sandstones beyond the scour. This is not proof of their absence, but, at least, it shows that they were not in abundance there at all. (2) Buchias densely populated the bottom of a sink hole which later caused the eddy of a flow and the mixing of the material. (3) Shells were brought by the turbidite flow from a distance and loaded onto the area of the flow eddy.

It is Kuzmichev's opinion that the last version is the most realistic. This version is supported by the bioturbation nature of some rock debris, which is not typical of the Stolbovoi Formation, and may indicate that the debris was brought from shallow-water basin areas with more favorable conditions for life. In particular, large (up to 1 cm in diameter) round burrows filled with sand were revealed in one of the mudstone blocks. In one case, a straight burrow of a similar diameter was encountered in the sand cementing the debris. The burrow was not filled with any material and remained hollow.

### *The Age of Buchia Beds*

Three intervals with *Buchia* characteristic assemblages are distinguished in the described section: (1) *Buchia terebratuloides* (Lah.), *B. unschensis*; (2) B. ex gr. *unschensis, B.* cf. *fischeriana, B.* ex gr. *okensis, B. uncitoides, B.* cf. *volgensis*; (3) *B. inflata, B. keyserlingi* (Zakharov and Kuzmichev, 2008). The

Plate I


1
2a
3a
2b
3b
4
5
6
7
8
9
15
10a
10b
16a
16b
14
11
13
18
17
12
1 cm
23
22a
21a
20
19a
22b
21b
19b

section intervals, within which the mentioned assemblages were encountered, can be designated as biostratigraphic units of the rank of "beds with fauna" (*Stratigraphic…*, 2006). As fossils were encountered only within individual rather narrow stratigraphic ranges separated by substantial intervals (in places, by up to tens and even hundreds of meters, including exposure gaps) quite bare of fauna, there is no linkage between biostratigraphic units, and boundaries in the section (known as limitotypes) are designated arbitrarily. Nevertheless, the stratigraphic analysis of individual species and the biostratigraphic correlation with sections on adjacent territories allowed for the formation of the upper Volgian, Berriasian (Ryazanian), and lower Valanginian rocks in the southern part of the Stolbovoi Island (Tables 1, 2).

**Beds with *Buchia terebratuloides* (Lah.), *B. piochii* (Gabb), and *B. unschensis* (Pavl.)** can be attributed to the upper Volgian Substage of the Upper Jurassic on the basis of the co-occurrence of these species and the correlation with sections in the Northern Hemisphere. Although all the species constituting the complex cross the boundary between the Jurassic and Cretaceous, only the species *B. unschensis* predominates in the upper Volgian and lower Boreal Berriasian (including the base of the *Hectoroceras kochi* Zone) in many sections in the Arctic biogeographic realm: in the northern part of Eastern and Western Siberia (Zakharov, 1981; *Bazhenov…*, 1986), in the basin of the Pechora River (Mesezhnikov et al., 1979), in eastern Greenland (Surlyk and Zakharov, 1982), and in the Canadian Arctic Islands (Jeletzky, 1965, 1984). The species *B. terebratuloides* was reliably identified (Plate I, Figs. 4–12, 19). Judging from published data, the *B. terebratuloides* biozone spans the whole upper Volgian and Boreal Berriasian (Gerasimov, 1955; Ershova, 1983; Paraketsov and Paraketsova, 1989; *Atlas* …, 1990), but in the Berriasian of the Arctic Regions the species does not rise higher than the *Hectoroceras kochi* Zone (Zakharov, 1981; Jeletzky, 1984). Moreover, the epibole of the species in the hyperstratotype is limited by the *Craspedites subditus* and the *C. nodiger* zones (personal observations) on the Russian Plate (near the Village of Kashpir) and in the basin of the Pechora River and by their analogs—the *C. okensis* and *C. taimyrensis* zones, in the northern part of Eastern Siberia (Zakharov, 1981). We consider the species *B. piochii* in a wide range (Imlay, 1959). It is exceeded in abundance by two other species, but we do not doubt their identification (Plate I, Figs. 1–3). The *B. piochii* s. l. biozone extends from the upper part of the middle Volgian to the base of the Boreal Berriasian (but, probably, not higher than the *Praetollia maynci* Zone) with the epibole in the uppermost part of the upper Volgian. Hence, the age

**Plate I.** Buchias from the upper Volgian and Jurassic–Cretaceous boundary deposits of the Stolbovoi Island (New Siberian Islands). Collection of buchias is stored in the V.I. Vernadsky Museum, Russian Academy of Sciences, Moscow. Enclosed in parentheses are field numbers of specimens (see Figs. 2, 4, 6 and Table 2). All the images, except as specially noted, are given full sized (see the measuring rule).

(1–3) *Buchia piochii* (Gabb, 1864).

(1) Specimen no. GGM, BP-09616 (182/2), left valve view, western coast, exp. 181–182; (2, 3) *B. piochii* juv.: (2a, 2b) specimen no. GGM, BP-09617 (118/15), (2a) right valve view, (2b) the same, ×2; (3a, 3b) specimen no. GGM, BP-09618 (118/15), (3a) left valve vies, (3b) the same, ×2, Cape Povorotnyi, upper Volgian.

(4, 5) *Buchia* ex gr. *terebratuloides* (Lahusen, 1888).

(4) Specimen no. GGM, BP 09619 (118/15), left valve view, Cape Povorotnyi, (5) specimen no. GGM, BP-09620 (182/2), right valve view, western coast, exp. 181–182, upper Volgian.

(6–10, 19) *Buchia terebratuloides* (Lahusen, 1888).

(6) Specimen no. GGM, BP-09621 (182/2), right valve view, (9) specimen no. GGM, BP-09624 (182/2), cluster (in situ) of seven whole specimens, western coast, exp. 181–182; (7) specimen no. GGM, BP-09622 (150/1), right valve view, western coast, exp. 153–180; (10a, 10b) specimen no. GGM, BP-09625 (150/1), (10a) right valve view, (10b) left valve view, western coast, exp. 153–204, upper Volgian; (8) specimen no. GGM, BP-09623 (166/3), left valve view, Cape Vostochnyi, upper Volgian–basal Boreal Berriasian; (19a, 19b) specimen no. GGM, BP-09634 (200/1), (19a) back view, eastern coast, (19b) the same, ×2, exp. 117-036, middle Boreal Berriasian.

(11, 12) *Buchia* cf. *terebratuloides* (Lahusen, 1888).

(11) Specimen no. GGM, BP-09626 (036/1), left valve view, eastern coast, exp. 117–36, upper Volgian; (12) specimen no. GGM, BP-09627 (166/3), left valve fragment (in the image lower part), Cape Vostochnyi, upper Volgian–basal Boreal Berriasian.

(13, 14) *Buchia unschensis* (Pavlow, 1905).

(13) Specimen no. GGM, BP-09628 (122/1), left valve view; (14) specimen no. GGM, BP-09629 (122/1), right valve view, Cape Povorotnyi, upper Volgian–basal Boreal Berriasian.

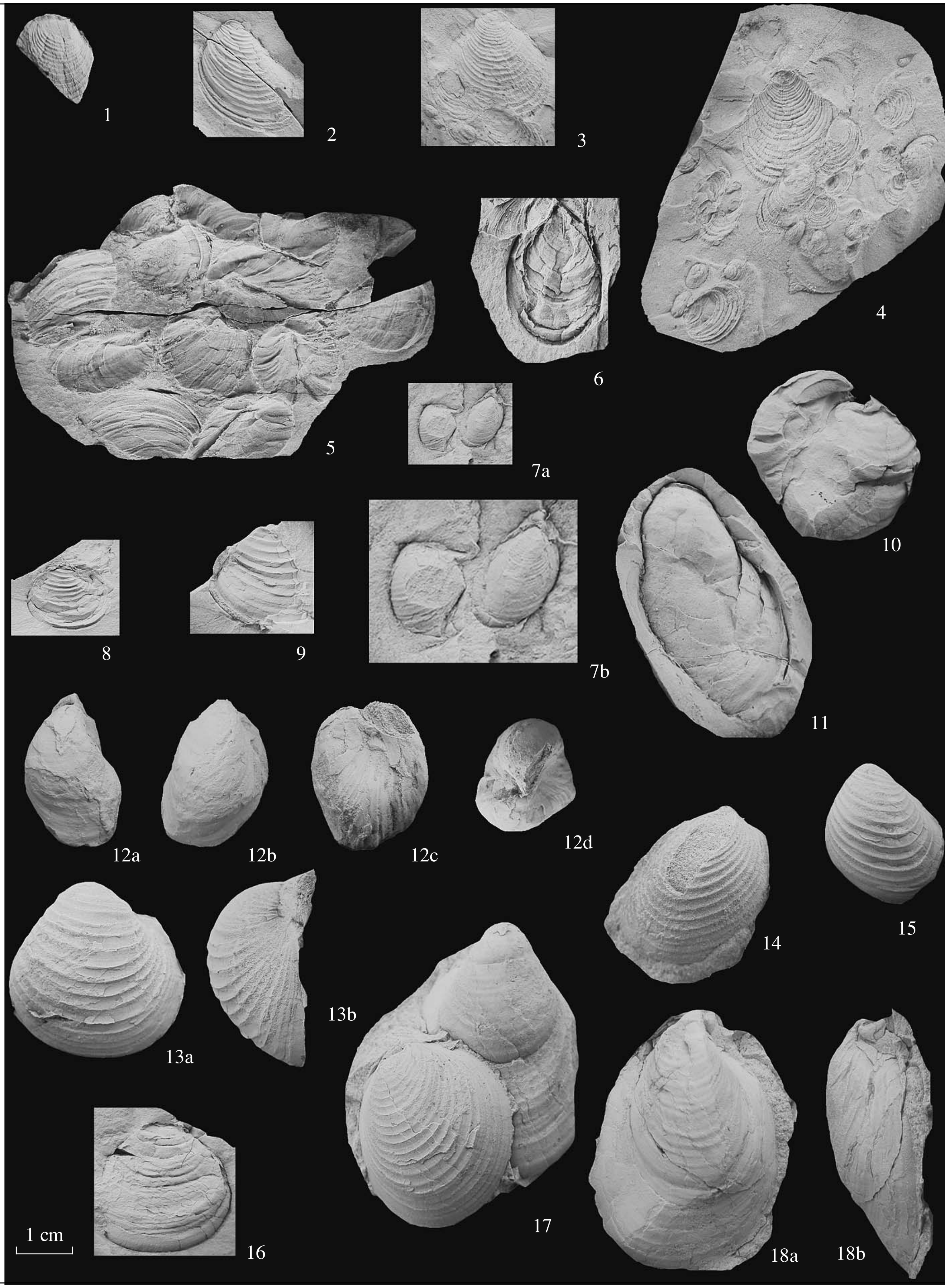
(15–18) *Buchia* cf. *unschensis* (Pavlow, 1905).

(15) Specimen no. GGM, BP-09630 (118/15), right valve view, (20) specimen no. GGM, BP-09635 (118/15), right valve view, Cape Povorotnyi, upper Volgian; (16a, 16b) specimen no. GGM, BP-09631 (042/3), (16 a) right valve view, (16b) the same, ×2, eastern coast, exp. 042–049; (17) specimen no. GGM, BP-09632 (166/3), right valve view, (18) specimen no. GGM, BP-09633 (166/3), left valve view, Cape Vostochnyi, upper Volgian–basal Boreal Berriasian.

(21, 22) *Buchia* sp. juv., cf. *okensis* (Pavlow, 1905).

(21a, 21b) Specimen no. GGM, BP-09636 (031/2), (21a) left valve view, (21b) the same, ×2; (22a, 22b) specimen no. GGM, BP-09637 (031/2), (22a) right valve view, (22b) the same, ×2, eastern coast, exp. 117036, basal Boreal Berriasian.

Plate II


1
2
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12a
12b
12c
12d
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14
15
16
17
18a
18b
1 cm

interval of beds with *Buchia terebratuloides, B. piochii,* and *B. unschensis* is likely to be slightly wider than the upper Volgian and formally corresponds to the *Buchia unschensis* Zone. However, taking into account the fact that *B. piochii* representatives are present in the assemblage and *B. terebratulodes* forms predominate in the lower part (lower 640 m of the section), we restricted the interval to the upper Volgian. The regional correlation was taken into consideration as well (see below).

**Beds with *B.* ex gr. *unschensis* (Pavl.), *B.* cf. *fischeriana* (d'Orb.), *B.* ex gr. *okensis* (Pavl.), *B. uncitoides* (Pavl.), and *B.* cf. *volgensis* (Lah.)** span only 60 m of the section (Figs. 2, 4). Though, their lower boundary is arbitrarily adopted, and it is quite possible that the thickness of the beds exceeds 100 m (Fig. 2). In this list only one *B. uncitoides* species (Plate II, Fig. 12), which implies the middle part of the Boreal Berriasian. The lower boundary of the beds is accepted by the appearance of *B.* cf. *volgensis* (Plate II, Figs. 10 and 11) in the section base (observation point 184), whereas the upper boundary, by the base of the bed with *B. keyserlingi* (o.p. 174). The species *B. okensis*, identified only in open nomenclature, is encountered throughout the whole interval (Plate I, Figs. 21, 22; Plate II, Figs. 1, 3, 4, 8, 9). The possible volume of the beds under consideration is discussed below.

**Beds with *B. inflate* (Lah.) and *B. keyserlingi* (Trtd.)** are more reliably dated as the mentioned species are represented by tens of well and satisfactorily preserved specimens (Plate II, Figs. 13–18). The *Buchia* assemblage unambiguously suggests the early Valanginian age of the beds. Their inferred total thickness makes up about 200 m (Fig. 2).

### *Intra- and Inter-Regional Correlation of Buchia Beds*

The succession of beds with buchias, which is most similar to that established in the studied region, is revealed in the territory of northeastern Asia (Paraketsov and Paraketsova, 1989). Based on the section structure (rock types, turbidite nature of beds, and the significant thickness of the section), Stolbovoi Island should be attributed to this region. Here, like in northeastern Asia, the boundary stages of the Jurassic and Cretaceous are similar in terms of the taxonomic composition of assemblages and successions of beds with buchias (Table 1). In schemes suggested by K.V. Paraketsov and G.V Paraketsova, the upper Volgian comprises beds with *B. terebratuloides* and *B. tenuicollis*.

**Plate II.** Buchias from Ryazanian and lower Valanginian deposits of Stolbovoi Island (New Siberian Islands). The collection of buchias is stored in the V.I. Vernadsky Museum, Russian Academy of Sciences, Moscow. Field numbers of specimens (see Figs. 2, 4, 6 and Table 2) are given in parentheses. All images, except as specially noted, are shown full sized (see the measuring rule).

(1) *Buchia* sp. juv., cf. *okensis* (Pavlow, 1905). Specimen no. GGM, BP-09638 (031/3), left valve view, eastern coast, exp. 117-036, middle Boreal Berriasian.

(2) *Buchia* cf. *fischeriana* (d'Orbigny, 1845). Specimen no. GGM, BP-09639 (031/2), left valve view, eastern coast, exp. 117-036, basal Boreal Berriasian.

(3, 4, 8, 9) *Buchia* cf. *okensis* (Pavlow, 1905).

(3) Specimen no. GGM, BP-09640 (031/3), left valve view; (4) specimen no. GGM, BP-09641 (031/3), cluster of valves after a moderate transportation (paraautochthonous fossil tanatocoenosis), eastern coast, exp. 117-036, middle Boreal Berriasian; (8) specimen no. GGM, BP-09645 (184/3), left valve, exterior view; (9) specimen no. GGM, BP-09646 (184/3), left valve, exterior view; western coast, exp. 135-184, middle Boreal Berriasian.

(5) *Buchia* ex gr. *okensis* (Pavlow, 1905). Specimen no. GGM, BP-09642 (200/1), cluster of valves after transportation (allochthonous fossil tanatocoenosis), eastern coast, exp. 117-036, middle Boreal Berriasian.

(6) *Buchia* ex gr. *uncitoides–terebratuloides* (Pavlow, 1905). Specimen no. GGM, BP-09643 (200/1), right valve cast, eastern coast, exp. 117-036, middle Boreal Berriasian.

(7) *Buchia* sp. juv. cf. *volgensis* (Lahusen, 1888).

(7a, 7b) Specimen no. GGM, BP-09644 (178/2), (7a, specimen on the right) right valve view, (7b) the same, ×2, Cape Malek, exp. 005-024, terminal upper Berriasian–lower Valanginian.

(10, 11) *Buchia* cf. *volgensis* (Lahusen, 1888).

(10) Specimen no. GGM, BP-09647 (184/1), front view; (11) specimen no. GGM, BP-09648 (184/1), left valve view, western coast, exp. 135-184, middle Boreal Berriasian.

(12) *Buchia uncitoides* (Pavlow, 1905).

(12a–12d) Specimen no. GGM, BP-09649 (184/2), (12a) right valve view, (12b) left valve view, (12 c) front view, (12d) apical view, western coast, exp. 135-184, middle Boreal Berriasian.

(13–15, 17) *Buchia inflata* (Lahusen, 1888).

(13a, 13b) Specimen no. GGM, BP-09650 (139/1), left valve, (13a) external view, (13b) back view; (14) specimen no. GGM, BP-09651 (139/1), right valve, external view, (15) specimen no. GGM, BP-09652 (139/1), left valve, external view, (17) specimen no. GGM, BP-09654 (139/1), right valve (in the image lower part, external view, western coast, exp. 135-184, lower Valanginian.

(16) *Buchia* cf. *inflata* (Lahusen, 1888), Specimen no. GGM, BP-09653 (113/5), right valve, external view, Cape Malek, exp. 005-024, terminal upper Berriasian–lower Valanginian.

(18) *Buchia keyserlingi* (Trautschold, 1968).

(18a, 18b) Specimen no. GGM, BP-09655 (174/1), right valve, (18a) external view, (18b) front view, western coast, exp. 135-184, lower Valanginian.

**Table 1.** Correlation of beds with buchias in the Arctic Region and the North Pacific rim

| Stage, substag | Northern Siberia (Zakharov, 1981) | Stolbovoi Island (New Siberian Islands) (this work) | NE Russia (Paraketsov and Paraketsova, 1989) | Northern California (Zakharov, 2004) |
|---|---|---|---|---|
| Lower Valanginian | *Keyserlingi* | No fossils | | *Keyserlingi* |
| | *Inflata* | *Inflata* | *Crassa*<br>*Inflata* | ?*Pacifica*<br>*Inflata* |
| Boreal Berriasian (Ryazanian) | *Tolmatschowi* | *Uncitoides*<br>*Okensis*<br>*Unschensis* | *Sibirica*<br>*Volgensis* | *Uncitoides* |
| | *Jasikovi* | | | |
| | *Okensis* | | *Okensis*<br>*Unschensis* | *Okensis*<br>?aff. *volgensis* |
| | *Unschensis* | | | |
| Upper Volgian | | *Terebratuloides*<br>*Piochii* | *Terebratuloides*<br>*Tenuicollis* | *Piochii* |
| | *Obliqua* | | | |
| Middle Volgian (part) | *Taimyrensis* | | *Fischeriana*<br>*Piochii* | *Elderensis* |

Note: The dotted line designates the boundary between the Jurassic and Cretaceous.

Attributing the second species to the volume of *B. piochii* (Zakharov, 1981), we come to recognize a close correspondence between the volume of the lower beds of the section on Stolbovoi Island and in northeastern Russia. The Boreal Berriasian in northeastern Russia is subdivided by buchias into two biostratigraphic units: beds with *unschensis–okensis* and beds with *volgensis–sibiricus*. In principle, the Berriasian on the Stolbovoi Island could also be subdivided into beds with *unschensis–okensis* (with the prevalence of the latter) and beds with *B. uncitoides*. The species *B. volgensis* (identified in open nomenclature) is encountered (as it is throughout the Arctic Regions) within the whole Berriasian. However, taking into account the reliable identification of only one species of the assemblage, namely, the *B. uncitoides*, the volume of beds with all five species was incorporated into the Berriasian. We correlate beds with *B. inflate* and *B. keyserlingi* with beds with *inflata–crassa* of northeastern Russia (Table 1). It should be noted that we always considered the species *B. crassa* in the volume of *B. inflate* (Zakharov, 1981). We assume with a high degree of confidence that beds with *B. inflata* and *B. keyserlingi* on Stolbovoi Island span only the *inflata* Zone of the lower Valanginian. The second species in this assemblage is sharply (by three times) exceeded in abundance by the index species of the *Buchia* zone.

A comparison of the succession of *Buchia* assemblages on Stolbovoi Island with the most complete (and closest in terms of territory) succession in northern East Siberia exhibits—in addition to many common features—a certain, and in places substantial, difference between them. For instance, the species *B. piochii* is lacking in the upper Volgian *Buchia* assemblages on the Nordvik Peninsula, whereas the species *B. unschensis* predominates in beds transitional from the Jurassic and Cretaceous. In the middle Berriasian on the Nordvik Peninsula, *B. uncitoides* forms have not been encountered, whereas *B. tolmatchowi* representatives have been found. The comparison of a succession of *Buchia* assemblages of Stolbovoi Island with a succession of northern California suggests considerable similarities (Zakharov, 2004). Hence, *Buchia* assemblages in the Jurassic–Cretaceous boundary beds on Stolbovoi Island are more similar to assemblages of the North Pacific (northeastern Asia and the US Pacific coast) (Zakharov, 1981, 2004; Paraketsov and Paraketsova, 1989) than northern Siberia and Atlantic Arctic areas (Greenland, Spitsbergen, Lofoten Islands) (Zakharov et al., 1981; Häkansson et al., 1981; Surlyk and Zakharov, 1982; Ershova, 1983).

## GEOLOGICAL INTERPRETATION OF PALEONTOLOGICAL DATA

The analysis of the spatial abundance and occurrence, in the section, of three described *Buchia* assemblages (Figs. 2, 4; Table 2) shows that field data on the succession of deposits are not corroborated by paleontological evidence. This means that (1) either the succession of deposits was incorrectly established, or (2) the stratigraphic range of some *Buchia* assemblages is

**Table 2.** Results of identifications of buchias

| Specimen no. | Taxon | Plate no./Fig. no. | Number of specimens | Stratigraphic units |
|---|---|---|---|---|
| 166/3 | *Buchia* cf. *unschensis* (Pavl.) | I/17–18 | 11 | Upper Volgian–base of Berriasian |
| | *B*. cf. *terebratuloides* (Lah.) | I/8, 12 | 3 | |
| | *B*. sp. juv. (ex gr. *unschensis*) | | 1 | |
| 042/3 | *Buchia* sp. ind. (cf. *unschensis*) | I/16 | 1 | ? |
| 118/15 | *B*. ex gr. *terebratuloides* | I/4 | 1 | Upper Volgian |
| | *B*. cf. *piochii* (Gabb) | I/2–3 | 4 | |
| | *B*. cf. *unschensis* | I/15, 20 | 2 | |
| 118/6 | *B*. sp. ind. (cf. *terebratuloides*) | | 1 | Upper Volgian |
| 122/1 | *B*. *unschensis* (Pavl.) | I/13–14 | 3 | Upper Volgian–lower Berriasian |
| | *B*. sp. ind. (cf. *terebratuloides*) | | 1 | |
| 139/1 | *Buchia inflata* (Lah.) | II/13–15, 17 | 20 | Lower Valanginian |
| 174/1 | *Buchia inflata* (Lah.) | | 60 | Lower Valanginian |
| | *B*. *keyserlingi* (Lah.) | II/18 | 31 | |
| 072/1 | *B*. sp. ind. (cf. *terebratuloides*) | | 2 | ?Upper Volgian–lower Berriasian |
| 066/1 | *B*. sp. ind. (cf. *terebratuloides*) | | 4 | ?Upper Volgian–lower Berriasian |
| 113/5 | *Buchia* sp. ind. (cf. *inflata*) | II/16 | 1 | ?Upper Berriasian–lower Valanginian |
| | *Buchia* sp. juv. (ind.) | | 4 | |
| 178/12 | *Buchia* sp. juv. (cf. *volgensis*) | II/7 | 1 | ?Berriasian |
| | *Buchia* sp. juv. (ind.) | | 4 | |
| 184/3 | *Buchia* ex gr. *okensis* (Pavl.) | II/8–9 | 7 | Middle Berriasian |
| 184/2 | *Buchia uncitoides* (Pavl.) | II/12 | 1 | Middle Berriasian |
| 184/1 | *B*. cf. *volgensis* (Lah.) | II/10–11 | 3 | Berriasian |
| | *B*. sp. ind. | | 3 | |
| | *B*. sp. ind. (cf. *okensis*) | | 3 | |
| 200/1 | *Buchia* ex gr. *okensis* | II/5 | 1 | Middle Berriasian |
| | *B*. ex gr. *uncitoides–terebratuloides* | I/19 | 1 | |
| | *B*. sp. ind. (cf. *unschensis–terebratuloides*) | | 10 | |
| 029/3 | *B*. cf. *fischeriana* (d'Orb.) | | 1 | ?Upper Volgian–lower Berriasian |
| 031/3 | *Buchia* ex gr. *okensis* | | 1 | ?Middle Berriasian |
| | *B*. sp. juv. (cf. *okensis*) | II/1, 3–4 | 10 | |
| 031/2 | *Buchia* sp. juv. (cf. *okensis*) | I/21–22 | 5 | ?Upper Volgian–lower Berriasian |
| | *B*. cf. *fischeriana* | II/2 | 1 | |
| 036/1 | *B*. cf. *terebratuloides* | I/11 | 2 | ?Upper Volgian |
| 204/4 | *Buchia terebratuloides* (Lah.) | | 2 | Upper Volgian |
| | *B*. sp. ind. (cf. *terebratuloides*) | | 1 | |
| 150/1 | ?*Boreiophylloceras* sp. ind. (1 specimen) | | 1 | Upper Volgian |
| | *Buchia terebratuloides* (Lah.) (1 specimen) | I/7, 10 | 1 | |
| | *B*. cf. *piochii* (Gabb) (1 specimen) | | 1 | |
| | *B*. sp. ind. (1 specimen) | | 1 | |
| 192/4 | *B*. ex gr. *unschensis* | | 1 | Upper Volgian–?Berriasian |
| | *B*. ex gr. *fischeriana* | | 1 | |
| 182/6 | *B*. ex gr. *unschensis–terebratuloides* | | 2 | Upper Volgian–?Berriasian |
| 182/2 | *Buchia terebratuloides* (Lah.) | I/6, 9 | 1 | Upper Volgian |
| | *B*. ex gr. *terebratuloides* | I/5 | 9 | |
| | *B*. cf. *piochii* (Gabb) | I/1 | 1 | |

Note: See Fig. 2 for specimen position on the island's territory and Figs. 4 and 6 for specimen position in the section.

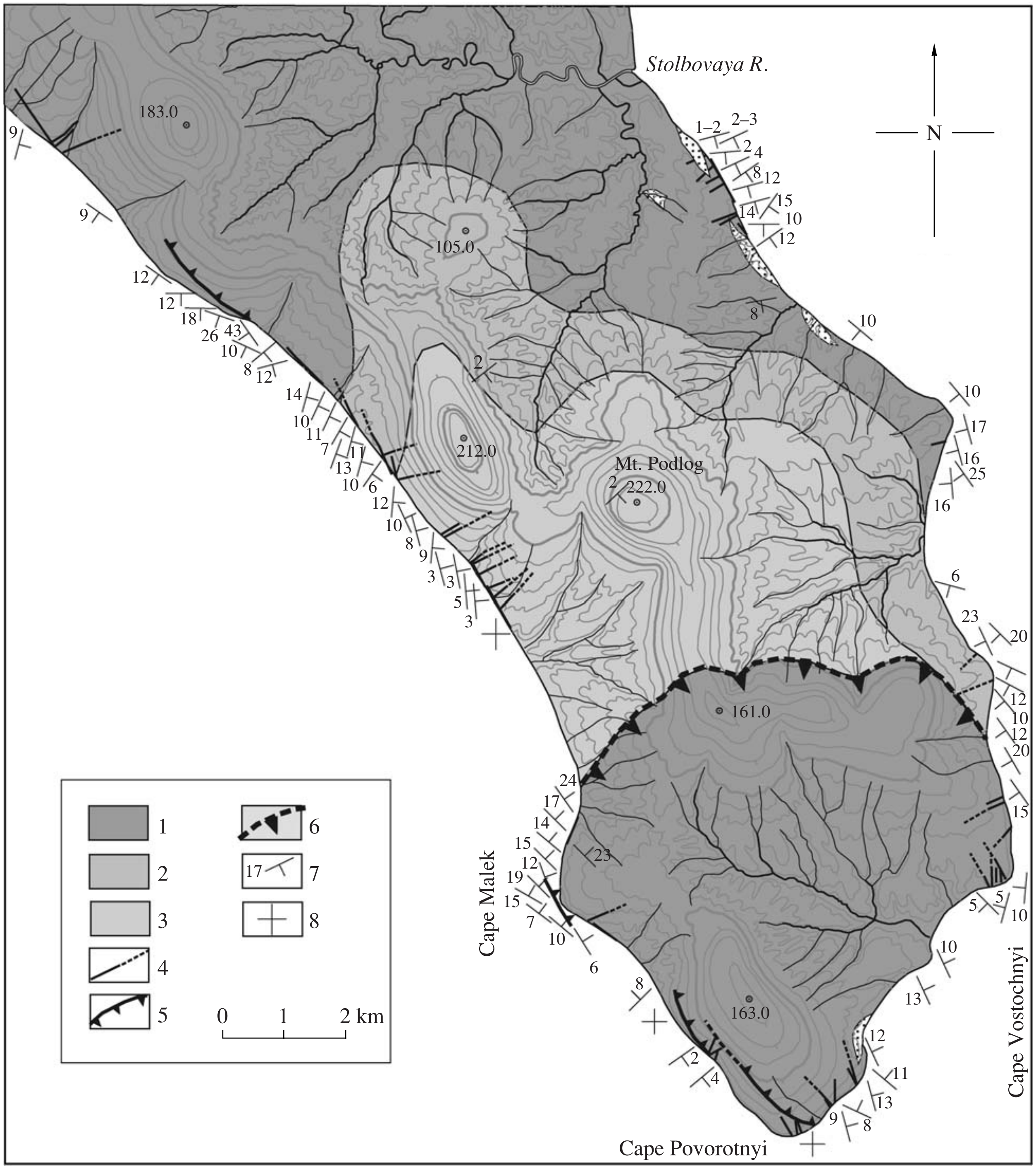


**Fig. 5.** Geological map for the southern part of Stolbovoi Island compiled with due regard for paleontological data.
Shown is a hypothetical overthrust, along which the upper Volgian rocks of the island's southeastern part are thrust over lower Neocomian strata. Quaternary deposits are removed.
(1–3) Upper Jurassic–Lower Cretaceous turbidite complex: (1) upper Volgian–lower Berriasian, (2) Berriasian, (3) lower Valanginian; (4) steep normal and reverse faults; (5) observed overthrusts; (6) hypothetical overthrust according to paleontological data; (7) bed elements (strike) and dip angle; (8) horizontal bedding.

wider then we adopted. Let us consider both alternatives.

(1) If we give priority to paleontological data in determining the age of a rock, it turns out that the part of the section, which we assumed to be the youngest and lying in the syncline core on the southeastern coast, is of the late Volgian age and that lower Valanginian beds structurally occur below it. Data on the geology of

Stolbovoi Island, which are at our disposal, do not rule out such a variant. The deposits are not completely exposed along the island coast, and when reconstructing successions of deposits we interpolated the orientation of beds through unexposed areas and inferred the continuous and monoclinal nature of the section. We cannot rule out the fact that high-amplitude faults may be confined to these areas. The only way to explain paleontological data about the rock age is to infer that the central part of the studied territory is broken by a transverse overthrust or a series of south–north-trending overthrusts, along which upper Volgian rocks are thrust over lower Neocomian rocks (Fig. 5). The possibility for such a zone of transverse dislocations to exist is confirmed by the geomorphological indicators. Just in the part of the island where the inferred overthrust could occur, a ridge oriented transversely to the general northwestern strike of the structures is located. It should be noted that such an overthrust does not allow us to explain the distribution of all found buchias over the area and in the section. In particular, field specimens 113/5 (*B.* cf. *inflata*) and 178/12 (*B.* sp. juv. cf. *volgensis*) collected on the Cape Malek (Fig. 2; Table 2) turn out to be on the southern part of this hypothetical overthrust and fall within the field of the upper Volgian rocks. The composite section of Mesozoic deposits compiled with regard to the inferred overthrust is presented in Fig. 6.

(2) Kuzmichev and Danukalova give preference to primary geological observations in establishing the succession of deposits and assume the possibility that the studied sedimentary complex accumulated in the initial Neocomian over a short period of time. The period of the formation of thick turbidite complexes in foreland basins, which are similar to rocks of the Stolbovoi Island, is known not to exceed several million years and often appears to be less than one million years (Mutti, 1992). This idea is corroborated by the example of the Mesozoic deep-water turbidite complex, which is similar to that on the Stolbovoi Island and was originally dated by the buchias as the Late Jurassic. However, the lower limit for the age of this complex was established by the U–Pb zircon method as the Early Cretaceous (Surpless et al., 2006). Kuzmichev and Donukalova's opinion is based on assumptions, and for purposes of this work we accept the inference (1) described above and illustrated by Figs. 5 and 6.

## STRATIGRAPHIC RANGE OF TURBIDITES OF STOLBOVOI ISLAND WITH RESPECT TO DATA ON THE ISLAND'S NORTHERN PART

The above-cited inferences about the late Volgian–early Valanginian age of the terrigenous complex on Stolbovoi Island are based on the results of studying its southern part. As evident from the map we have compiled (Fig. 2), the island structure represents a syncline, whose axis gently plunges southeastward. This may suggest that rocks exposed in the northern part of the island are older than those we have studied. Data on the presence of the Oxfordian–Kimmeridgian beds in the northern part of the island (Ivanov et al., 1974) confirm such a possibility. The possibility should be discussed before extending our inferences about its age over the territory of the whole island.

In 2002, we made a short journey to the northern part of Stolbovoi Island where we examined scarps within an interval of 4.3–6.3 km south of Cape Skalistii. It is likely that this fragment of the coast was completely or partially covered with snow in the spring of 1973 when Ivanov and his colleagues carried out their investigations. The cliff interval we studied involves the anticline core and southwestern limb opposite to that described by previous researchers. We did not measure the section but schematically described it within two sequences. The lower sequence, about 200-m thick, comprises a substantial share of mudstones and siltstones with interlayers of dark sandstones. A member with predominating mudstones about 40-m thick, which was mentioned by our predecessors, is recognized in the middle part of the section. This part corresponds to the lower sequence distinguished by Vinogradov and Yavshits and two lower sequences identified by Ivanov and his colleagues. The upper sequence, 250–300 m thick, is characterized by the prevalence of sandstones, including thick (several meters) beds of light massive rocks. It corresponds to the second sequence distinguished by Vinogradov and Yavshits and the third–fourth sequences established by Ivanov and his colleagues. According to these geologists, the whole interval of the section we examined corresponds to Upper Jurassic deposits; analogs of Cretaceous sequences distinguished by these geologists are not exposed within the studied cliff fragment. The lower sequence does differ in structure from the one that we observed in the southern half of the island, though, its absence on the territory we studied cannot be guaranteed. It is improbable that it is correlated with the lowermost part of the section exposed south of the Stolbovaya River (Figs. 2, 4) where the thickest clay member is truly exposed.

Two samples were taken from sandstones of the second sequence (according to our nomenclature) in the island's northern part to separate a heavy fraction: 51/1 (nearly from the base of the upper third of the lower sequence) and 53/3 (nearly from the middle part of the upper sequence). A.V. Soloviev dated the detrital zircons, separated from the samples, with the help of the SHRIMP RG mass spectrometer in Stanford. Twenty two crystals have been analyzed from sample 51/1. The youngest populations are represented by Jurassic zircons (186–149 ± 5 Ma, 7 grains) and one Late Cretaceous (135 ± 3 Ma) crystal. Seventeen grains have been analyzed from sample 53/1. Young populations are represented by Late Jurassic zircons (161–159 Ma,

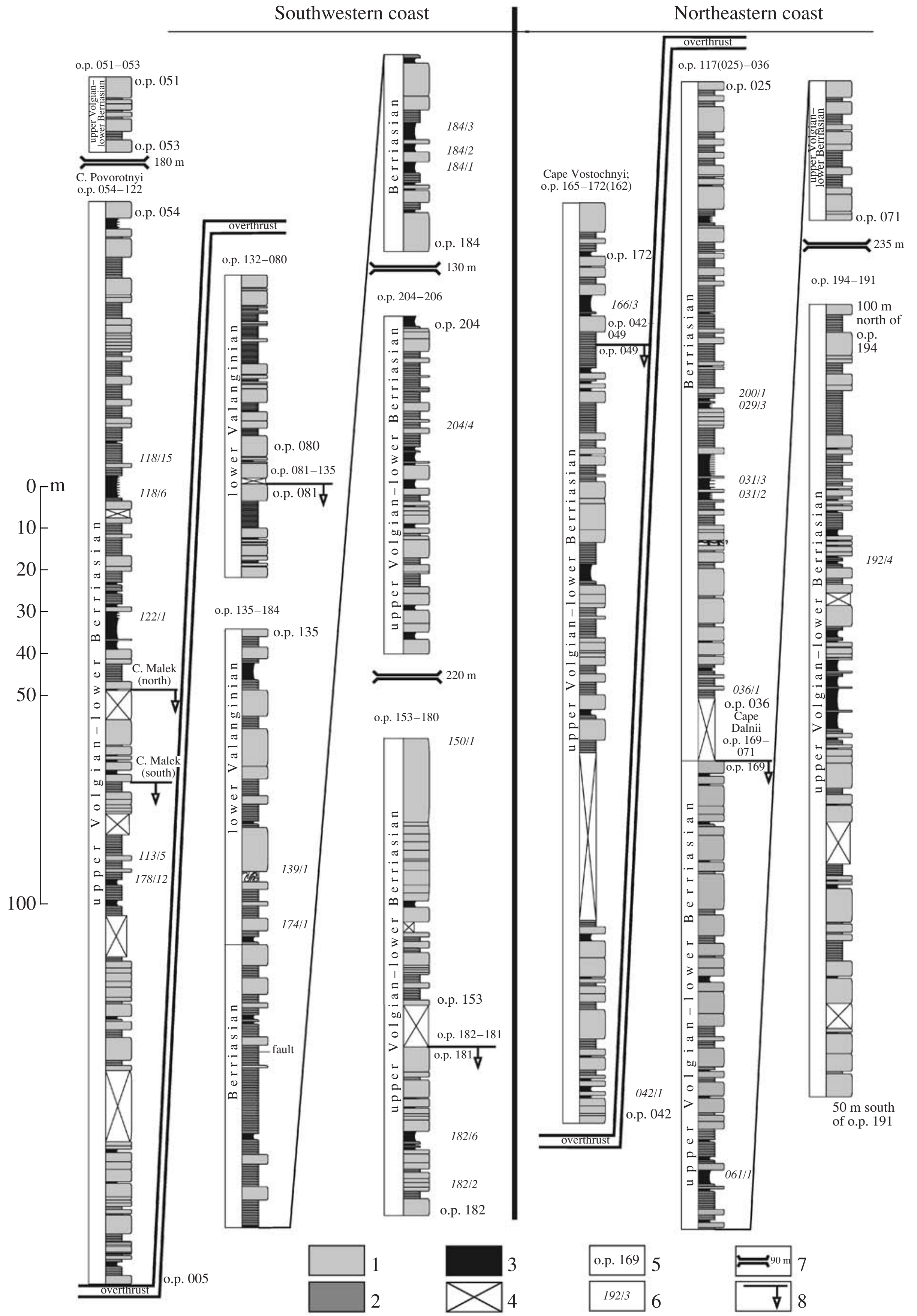
Southwestern coast
Northeastern coast
o.p. 051–053
o.p. 051
upper Volgian–lower Berriasian
o.p. 053
180 m
C. Povorotnyi
o.p. 054–122
o.p. 054
upper Volgian–lower Berriasian
118/15
118/6
122/1
C. Malek (north)
C. Malek (south)
113/5
178/12
o.p. 005
overthrust
0 m
10
20
30
40
50
100
overthrust
o.p. 132–080
lower Valanginian
o.p. 080
o.p. 081–135
o.p. 081
o.p. 135–184
o.p. 135
lower Valanginian
139/1
174/1
Berriasian
fault
Berriasian
184/3
184/2
184/1
o.p. 184
130 m
o.p. 204–206
o.p. 204
upper Volgian–lower Berriasian
204/4
220 m
o.p. 153–180
150/1
upper Volgian–lower Berriasian
o.p. 153
o.p. 182–181
o.p. 181
182/6
182/2
o.p. 182
Cape Vostochnyi;
o.p. 165–172(162)
o.p. 172
166/3
o.p. 042–049
o.p. 049
upper Volgian–lower Berriasian
042/1
o.p. 042
overthrust
overthrust
o.p. 117(025)–036
o.p. 025
Berriasian
200/1
029/3
031/3
031/2
036/1
o.p. 036
Cape Dalnii
o.p. 169–071
o.p. 169
upper Volgian–lower Berriasian
061/1
upper Volgian–lower Berriasian
o.p. 071
235 m
o.p. 194–191
100 m north of o.p. 194
192/4
upper Volgian–lower Berriasian
50 m south of o.p. 191
1
2
3
4
o.p. 169
5
192/3
6
90 m
7
8

**Fig. 6.** Generalized stratigraphic columns of the Upper Jurassic–Lower Cretaceous deposits for the northeastern and southwestern coasts of Stolbovoi Island plotted taking into account paleontological data and the hypothetical transverse overthrust, along which the upper Volgian rocks are thrust over the lower Neocomian rocks.

(1–3) rock varieties in the section of the Upper Jurassic–Lower Cretaceous turbidites: (1) amalgamated beds of sorted light-colored sandstone, (2) rhythmical bedding of dark gray clayey sandstone and diamictite, (3) mudstone; (4) unexposed section fragments; (5) initial and terminal section points and their numbers (see Fig. 2); (6) paleontological specimens and their numbers (see Table 2); (7) unmeasured section intervals; (8) roofs of particular sections.

3 grains) and one Early Cretaceous grain (142 ± 3 ma). Hence, out of 39 analyzed crystals, three crystals yielded an age which did not correspond to the interval established earlier by the buchias. These data call into question the Oxfordian–Kimmeridgian age of the sequence.

## CONCLUSIONS

The section of Stolbovoi Island is monotonous and cannot be subdivided into members based on lithological characteristics. According to the results of field observations, the thickness of the terrigenous complex exceeds 1200 m in the studied southern part of the island. The terrigenous sequence represents a single turbidite complex, which exhibits no trend to changing deep-water facies by shallow-water facies either in the visible base of the section or its visible top. In turbidites of the southern part of Stolbovoi Island, abundant *Buchia* shells were collected, which indicate the presence of upper Volgian, Berriasian (=Ryazanian), and lower Valanginian deposits on the island. It is likely that sequences, which are slightly older than in the region we have studied, are exposed in the island's northern part. The comparison of the succession of *Buchia* assemblages on Stolbovoi Island with the succession in the northern part of Eastern Siberia on the one hand and in northern California on the other hand (Zakharov, 2004) suggest a greater similarity of these associations with associations in the North Pacific (northeastern Asia and the US' Pacific coast) than in northern Siberia and Atlantic Arctic regions (eastern Greenland, Spitsbergen, Lofoten Islands).

Hence, judging from paleontological data, the stratigraphic range of the turbidite complex making up the southern part of the Stolbovoi Island does not go beyond the upper Volgian–lower Valanginian interval. Kuzmichev does not rule out the possibility that the interval of the turbidite complex accumulation on Stolbovoi Island may be still narrower and believes it is possible to extend this inference over the sequences making up the northern part of the island, as well as over the terrigenous complexes of the Bol'shoi Lyakhov and Malyi Lyakhov islands.

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