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The Volgidiscus Singularis Zone of the Terminal Horizons of the Volgian Stage of European Russia and Its Significance for Interregional Correlation and Paleogeography

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Abstract—It has been accepted until recently that a regionally developed gap corresponding to the boundary interval between the stages (equivalents of the Chetaites chetae and Volgidiscus lamplughi zones) exists between the upper Volgian Craspedites nodiger Zone and the Ryazanian Stage. Recently, the presence of this interval was established in Yaroslavl oblast. In this paper, we publish for the first time a detailed description of the sections of the terminal part of the upper Volgian Substage, the majority of which have not previously been published, as well as illustrations of characteristic mollusks (ammonites and bivalves) from these deposits. For this stratigraphic interval, the recognition of the Volgidiscus singularis Zone, including the V. pulcher and V. singularis biohorizons, is substantiated. In this zone, ammonites are mainly represented by the genus *Volgidiscus*, but the pulcher Biohorizon also contains very rare *Garniericeras*, whereas the glacial boulders together with *V.* cf. *pulcher* contained *Shulginites*. The Singularis Zone has a high correlative potential and, at an infrazonal level, directly correlates with the uppermost zones of the upper Volgian Substage of the Subpolar Urals, northern Siberia, England, and the North and Barents seas. It is most likely that the biostratigraphically confirmed gap between the upper Volgian Singularis Zone and Ryazanian stage is absent. In both the Subpolar Urals and in European Russia, the terminal part of the Volgian Stage and the lower part of the Ryazanian Stage both contain ammonites of the genus *Shulginites*. Bivalves are represented mainly by the genera *Anopaea*, *Camptonectes (Camptonectes)*, *Entolium (Entolium)*, and *Plagiostoma*. The studied sections lack *Buchia*, one of the most characteristic taxa of the Jurassic–Cretaceous boundary beds of the Panboreal Superrealm. It is proposed that the Volgian–Ryazanian boundary beds in the upper reaches of the Cheryomukha River (Rybinsk district, Yaroslavl oblast) are recognized as the Chudinovo Formation, the upper part of which contains numerous ammonites of the Singularis Zone.

Keywords: upper Volgian Substage, correlation, ammonites, *Volgidiscus*, bivalves
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INTRODUCTION

Over 40 years ago Casey (1973) established the Volgidiscus lamplughi Zone in the upper part of the upper Volgian Substage of East Anglia, containing ammonites belonging only to the genus *Volgidiscus*. This genus is considered to be a direct descendant of *Subcraspedites*, which is characteristic of the lower interval of the upper Volgian and partly middle Volgian substages. For a long time, occurrences of *Volgidiscus* were only known from northeastern Europe and the Subpolar Urals, whereas in other Boreal regions (including the Russian Platform), these ammonites were not found until recently. It was thought that a gap existed on the Russian Platform in all studied sections between the Nodiger and Rjasanensis zones. The recognition of this interval in Siberia is a debatable issue in correlations of the Central Russian and Siberian sections (Casey et al., 1977).

Later, the genus *Volgidiscus* was discovered in the Rybinsk district of Yaroslavl oblast, in deposits assigned to beds with Volgidiscus singularis (Kiselev, 2003). However, these beds were only established in one section and their relationships with the overlying and underlying beds remained unclear.

Observations in recent years have shown that the Volgidiscus Beds are more widespread than previously thought. For instance, in the Uglich district of Yaroslavl oblast, *Volgidiscus* were found in glacial boulders (Shkolin and Rogov, 2012). An occurrence of *Volgidiscus* is also known from Kostroma oblast (see below).

Recently, several sections discovered in the basin of the Cherromykha River in the Rybinsk district of

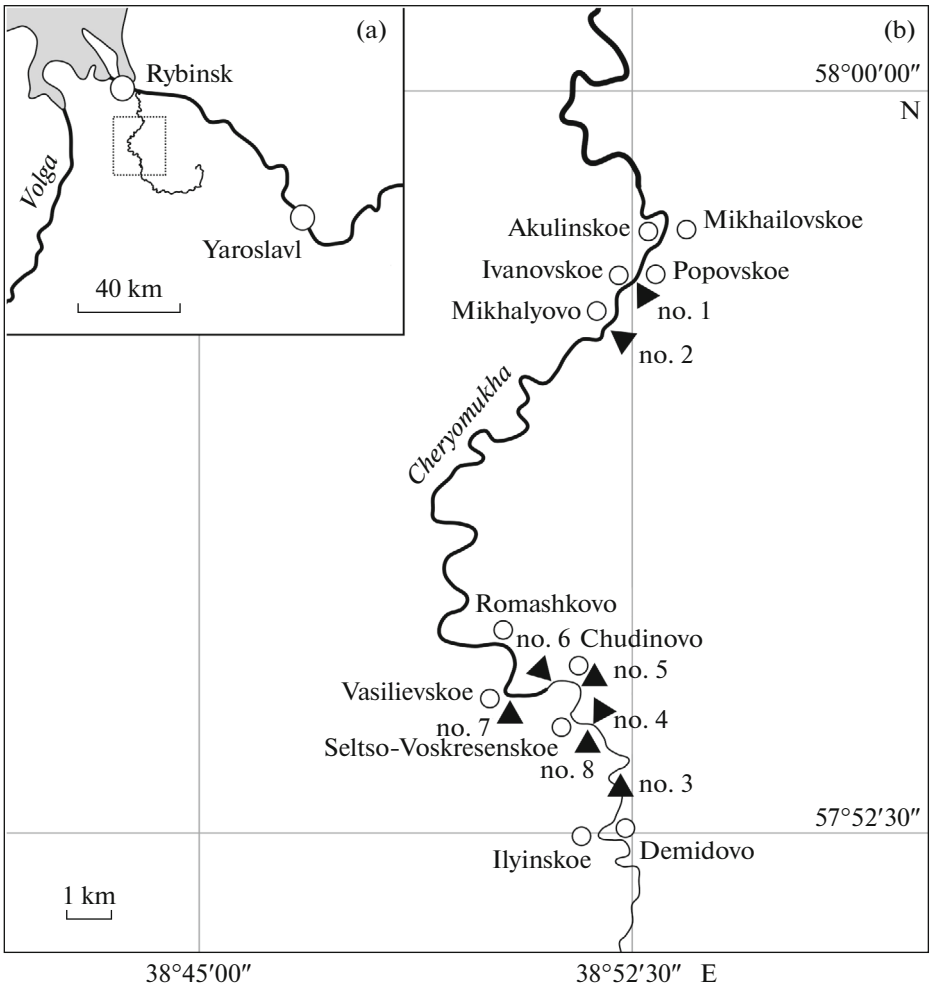


Fig. 1. Sections of the upper Volgian Substage in the basin of the Cheryomukha River. Black triangles with oriented corners show locations of the sections.

Yaroslavl oblast allow the refined and emended correlation of the Volgidiscus Beds with the underlying zones of the upper Volgian Substage (including the Nodiger Zone). These included a section with a slightly earlier association with *Volgidiscus*. Here, the sand and sandstone member contained an association of *Volgidiscus pulcher*, infrequent *Garniericeras*, the belemnites *Acroteuthis* (identified by A.P. Ippolitov), and bivalves (mainly *Anopaea* and *Camptonectes*).

This paper deals with the description and paleontological characterization of these beds and includes a discussion on the unresolved questions of the stratigraphy of the terminal part of the Volgian Substage and its correlation with the upper Portlandian.

LOCALITIES

In the basin of the Cheryomukha River (Rybinsk district), the upper Volgian Substage occurs in the middle (from the village of Ivanovskoe) and the upper reaches (from the villages of Demidovo and Ilyinskoe) (Figs. 1, 2). Each outcrop opens up only a small part of the upper Volgian succession. In recent years, about ten new sections have been discovered, which are compiled in a single section with an almost complete zonal and infrazonal succession from the Fulgens Zone to the Singularis Zone. Some of these (sections of the terminal part of the upper Volgian Substage) were previously described (Kiselev, 2003; Kiselev and Rogov, 2012b; Rogov et al., 2011). New data obtained in 2014–2016 allow the lower and the uppermost parts of the upper Volgian succession to be emended.

Below, we describe eight sections which compose a complete composite section of the upper Volgian Substage of the basin of the Cheryomukha River (Fig. 3). Beds of each section are designated by two numbers: bed number in an individual section and in the composite section (in brackets).

Section no. 1. The section is located on the left bank of the Cheryomukha River in several outcrops opposite the villages of Popovskoe and Ivanovskoe.

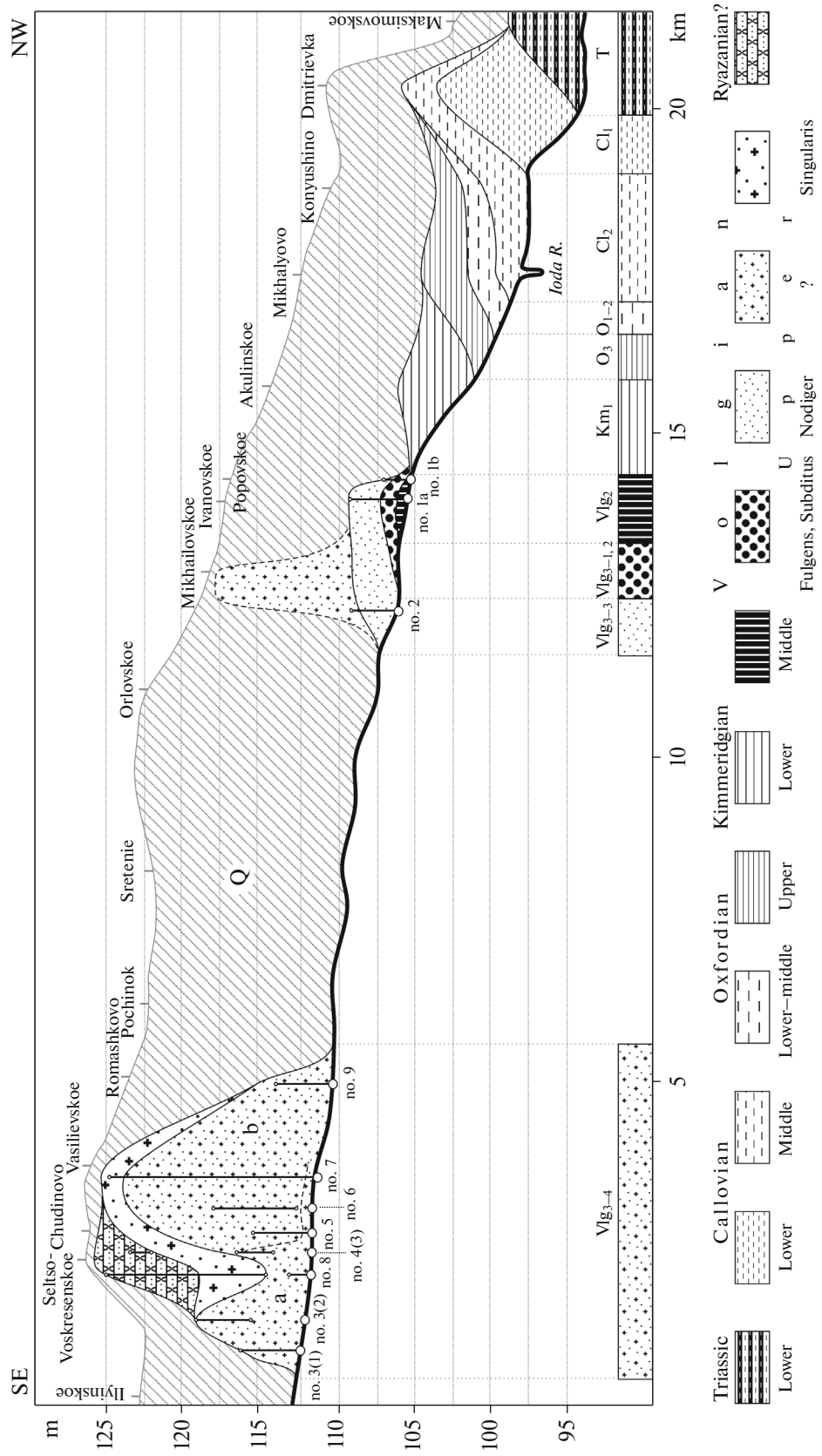


Fig. 2. Scheme of distribution of pre-Quaternary rocks and studied sections relative to the profile of the Cheryomukha River channel. The geological profile was exclusively based on the sections studied in outcrops near the channel of the Cheryomukha River (after Kiselev et al., 2003 and new data), without taking into consideration data from the mapping of quarries. The generalized gypsometric profile of the river channel (black line) and the natural bank (gray line) was constructed on the basis of the SRTM data using the Global Mapper software package. Oblique hatchings show Quaternary deposits.

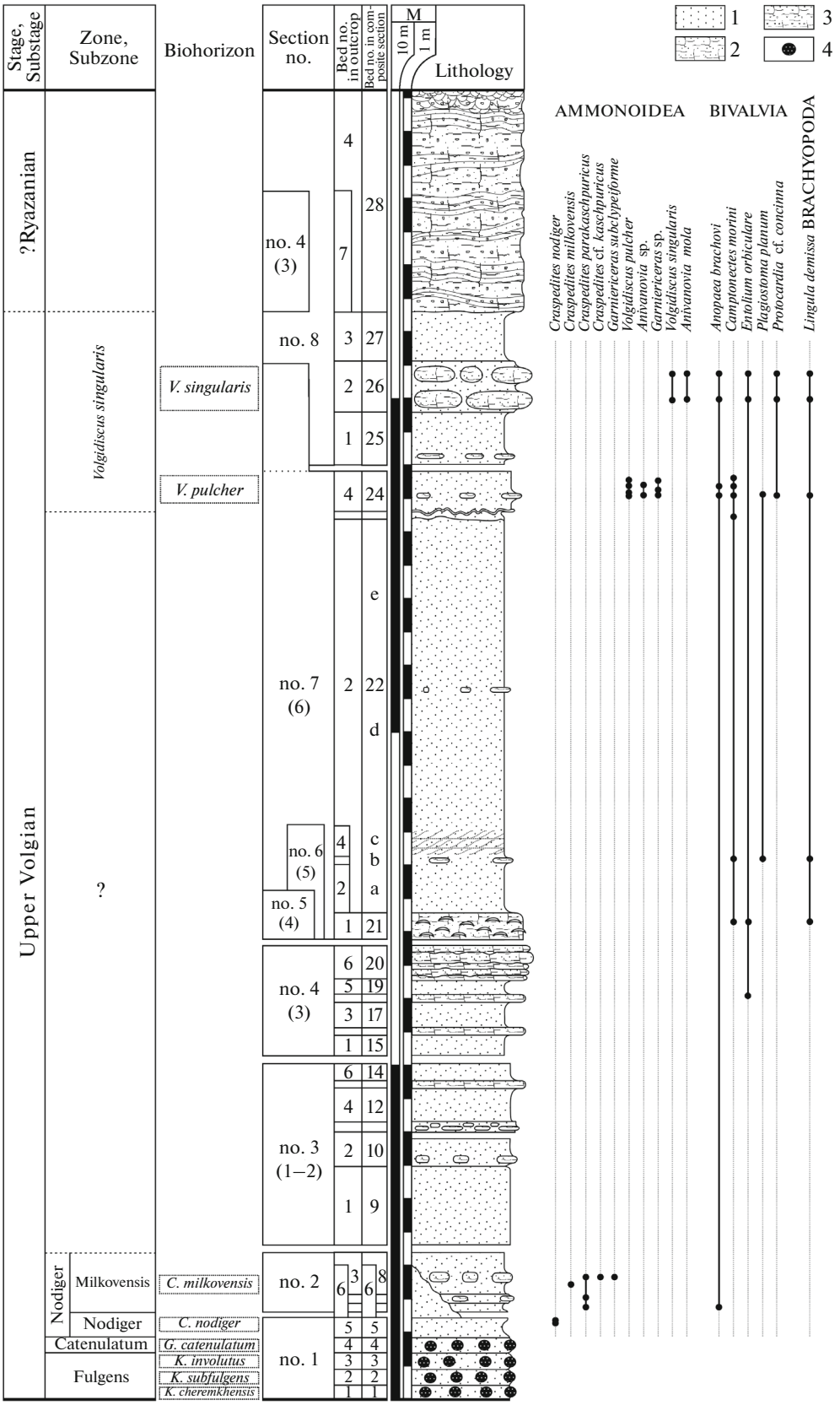


Fig. 3. Composite section of the upper Volgian Substage in the basin of the Cheryomukha River. For the Chudinovo Formation, the distribution of ammonites, bivalves, and brachiopods is shown. (1) Sand; (2) sandstone; (3) ferruginous sandstone; (4) concretions of phosphatized sandstone.

The description of the section in several cleared outcrops was produced by M.A. Rogov in 2014. The upper Volgian beds directly overlie lower Kimmeridgian black clays or phosphatized sandstones of the Virgatus Zone. The following succession is exposed here from bottom to top:

FULGENS ZONE

Cheremkhensis Biohorizon

Bed 1 (1). Sand medium-grained, with abundant concretions of phosphatized medium-grained black sandstone. The base of the bed is marked by a horizon of concretions which contains *Virgatites rarecostatus* Rogov and *Dorsoplanites* spp., characteristic of the *Virgatus* Zone. Above, concretions at the top of the bed contain *Kachpurites cheremkhensis* Mitta et al. (sometimes shells of *Kachpurites* occur in dense accumulations in the bed of phosphorites of the *Virgatus* Zone) and *Craspedites* spp. Thickness up to 0.15–0.2 m.

Subfulgens Biohorizon

Bed 2 (2). Sand argillaceous, bluish gray; in places, the upper part is cut by a moraine. The base is marked by a horizon of concretions of phosphatized sandstone mainly without fossils. The upper part contains ammonites, including *Kachpurites subfulgens* (Nik.), *Craspedites* (*C.*) *okensis* (Orb.), and *Craspedites* (*C.*) sp. Thickness 0.25–0.3 m.

Involutus Biohorizon

Bed 3 (3). Sand medium-grained, overfilled with concretions of black phosphatized sandstone with *Kachpurites involutus* Rogov, *Craspedites* (*C.*) *okensis* (d'Orb.), *C.* (*C.*) *subditus* (Trd.), and *C.* (*C.*) cf. *subditoides* (Nik.). Thickness 0.05–0.1 m.

CATENULATUM ZONE

Catenulatum Biohorizon

Bed 4 (4). Sand medium-grained, gray, with concretions of black phosphatized sandstone containing the ammonites *Garniericeras catenulatum* (Fisch.), *Craspedites* (*C.*) *okensis* (d'Orb.), *C.* (*C.*) *subditus* (Trd.), and *Craspedites* (*C.*) spp. Thickness up to 0.1 m. The bed is cut off from the moraine. The outcrop near the village of Ivanovskoe under this bed contained concretions of phosphatized sandstone with *Garniericeras interjectum* (Nik.) and macroconchs, characterized by a similar morphotype of the terminal body chamber, which suggests the presence of the basal biohorizon of the Catenulatum zone.

NODIGER ZONE AND SUBZONE

Nodiger Biohorizon

Bed 5 (5). Sand argillaceous, dark gray, at the top in the interval of 0.2 m intensely bioturbated, with orange stains and spots. The interval of 0.1–0.15 m below the top contained fragments of *Craspedites* (*Trautscholdiceras*) *nodiger* (Eichw.) and *C.* (*T.*) cf. *parakachpuricus* Geras. Thickness 0.7 m.

MILKOVENSIS SUBZONE

Milkovensis Biohorizon

Bed 6 (6). Sand orange. The upper part of the bed in the interval 0.2 m thick yielded fragments of *Craspedites* (*Trautscholdiceras*) *milkovensis* (Strem.). Visible thickness 1.5 m.

The section is laterally quite variable. The overlying moraine rests laterally on various beds or completely cuts the section. On the opposite, right, bank of the Cheryomukha River, concretions of phosphatized sandstone are redeposited from various beds, and this is best observed in the outcrop near the village of Ivanovskoe (Kiselev, 2003).

Despite the often observed condensed nature of concretion horizons, in the section in the interval of the Fulgens–Nodiger zones, there is an almost complete succession of zones, subzones, and biohorizons.[1] The infrazonal succession in the Fulgens Zone is represented by three upper biohorizons: cheremkhensis, subfulgens, and involutus. The lower biohorizons of the Fulgens Zone, evolutus and tenuicostatus (Rogov, 2017), in the sections of the Cheryomukha River are absent, and they are not known to occur in other sections of Yaroslavl oblast.

In the Catenulatum (=Subditus) Zone in the section near the village of Popovskoe, only one catenulatum Biohorizon is recognized, although the presence of another basal interjectum Biohorizon, the index species of which *Garniericeras interjectum* (Nik.), is often found among specimens of *Garniericeras* in the section near the village of Ivanovskoe. The presence of the upper part of the Catenulatum Zone, which typically shows co-occurrence of *Garniericeras subclypeiforme* (Milasch.) and *Craspedites* (*C.*) *okensis* (d'Orb.) (Rogov et al., 2015, p. 69; Rogov, 2017), has not been established in the basin of the Cheryomukha River, which suggests the presence of a small stratigraphic gap at the base of the Nodiger Zone.

The Nodiger Zone is represented by both subzones Nodiger and Milkovensis and apparently by an almost complete infrazonal succession, which include the eponymous biohorizons; so far, only ammonites of the lower biohorizon of the Nodiger Zone have not been found in Yaroslavl oblast.

[1] Here and below, a biohorizon is considered as an infrazonal subdivision. The definition and principles of recognition of biohorizons are considered in detail by Rogov et al. (2012).

Section no. 2. The section is located on the right bank of the Cheryomukha River downstream of the village of Mikhalyovo. It was provisionally described by Rogov et al. (2011).

The base of the section is covered by talus. The following succession of beds is exposed above the talus.

NODIGER ZONE

Milkovensis Subzone

Bed 1 (6). Sand greenish gray, with brown stains, medium-grained, argillaceous, indistinctly bedded, loosely cemented. The bed contains frequent accumulations of shell detritus with remains of nacre, which include poorly preserved *Craspedites* (*Trautscholdiceras*) ex gr. *parakaschpuricus* Geras. and *Anopaea* cf. *brachovi* (Rouillier). Measured thickness 0.2 m.

Bed 2 (7). Sand light grayish brownish, with stains of dark brownish argillaceous sand, medium-grained, indistinctly bedded, loosely cemented, with lenses of loosely cemented sandstone and compact sand, often overfilled by fragments of molluscan shells. Ammonites are poorly preserved *Craspedites* (*Trautscholdiceras*) cf. *milkovensis* (Strem.). Thickness 0.2 m.

Bed 3 (8). Sand greenish brown, medium-grained, with frequent stains of dark brown sand, the number of which increases toward the base, owing to which the bed acquires a dark color. At the top, the sand becomes orange-brown owing to secondary ferruginosity. Approximately 0.3 m above the base is a horizon of lenticular concretions of loosely cemented sandstone (up to 20 × 30 cm) with molds of *Craspedites* (*Trautscholdiceras*) cf. *kaschpuricus* (Trd.), *C.* (*T.*) *milkovensis* (Strem.), and *Garniericeras subclypeiforme* (Milasch.). Small concretions of sandstone with fragments of ammonites are found in the middle part of the bed. Thickness 1.2 m.

Quaternary fluvioglacial rocks lie above an eroded surface.

On the basis of the ammonite assemblage, all beds of the section are assigned to the upper Milkovensis Subzone of the Nodiger Zone and milkovensis Biohorizon.

Ivanov (Ivanov, 1950; Ivanov and Novskii, 1959) also noted the presence of "orange irregular sand... with fragments of *Aucella* and ammonites" in the vicinity of the village of Mikhalyovo above beds with greenish brown sand with *Craspedites nodiger* (Eichw.), whereas the total thickness of the upper Volgian Substage was determined as approximately 15 m. At present, these beds are not visible. If the thickness of the Nodiger Zone is determined according to the above description to be about 2 m, and together with the Fulgens Zone approximately 3–3.5 m, then the series of ferruginous sand will be about 11–12 m. It appears that the deposits recorded by A.N. Ivanov correspond to the part of the stratigraphic interval described below and designated here as the Chudinovo Formation.

Sections nos. 1 and 2 are located in the middle reaches of the Cheryomukha River. Sections in the upper reaches of the river between the villages of Vasilievskoe and Demidovo contain higher horizons of the upper Volgian Substage. Lithologically and facially, they are significantly different from the upper Volgian Beds in the Ivanovskoe–Mikhalyovo sections. They are mainly strongly ferruginous sands and sandstones. Outcrops of these beds in the sections of the upper reaches of the Cheryomukha River were discovered and briefly described by Ivanov (1950). He noted exposures of ferruginous sandstones near the villages of Vasilievskoe, Voskresenskoe, Chudinovo, and Penie. In his opinion, this series belongs to the Craspedites nodiger Zone. In the text, he indicated only fragments of *Craspedites nodiger* found in greenish brown sand cropping out opposite the village of Mikhalyovo (apparently, in a section similar to section no. 2 in the present study). Ivanov's collection also contains a single ammonite found in the vicinity of the village of Voskresenskoe. Unfortunately, Ivanov did not indicate the precise location of this find in the section; therefore, the precise position of this specimen is debatable. According to a relatively narrow cross section, shell size, and ornamentation, this ammonite is similar to the earliest *Craspedites* (*Trautscholdiceras*). According to the shell shape and ornamentation on the flanks, it is also similar to *C.* (*Taimyroceras*), but differs from this subgenus in the prominent ornamentation on the venter. Prominent primary ribs in this ammonite are also similar to those in *Subcraspedites*, but the suture in the specimen under discussion is not preserved. Considering that this specimen most likely come from a stratigraphically higher interval than section 2, it can be identified as *Craspedites (Taimyroceras?)* sp. Specimens of *Taimyroceras* with similar ornamentation on the flanks are found both in the uppermost Volgian Stage of northern Siberia and the lower part of the Ryazanian Stage (Zakharov and Rogov, 2008, text-fig. 3). Ammonites from A.N. Ivanov's collection are also similar to *Craspedites (Taimyroceras) ultimus* Mitta et Sha recently described from the lower part of the Ryazanian Stage (Mitta and Sha, 2011, p. 32, pl. IV, figs. 3–5).

The first confirmed finds of ammonites from this series were from a section near the village of Seltso-Voskresenskoe (Kiselev, 2003). The genus *Volgidiscus*, which in the English scale characterizes the upper zone of the upper Volgian Substage (Casey, 1973), was recognized for the first time in this ammonite assemblage. On this basis, the series of ferruginous sands and sandstones exposed by a quarry near the village of Seltso-Voskresenskoe was assigned to the beds with Volgidiscus singularis, which were later elevated to a zonal rank, rather than the Nodiger Zone (Rogov et al., 2015, p. 72).

The study of the series considered in 2014–2016 showed that the section near the village of Seltso-Voskresenskoe contains only the uppermost part of this series, whereas the underlying intervals of the series are exposed in other sections of the upper reaches of the Cheryomukha River characterized in this paper.

The sections were studied by D.N. Kiselev in 2014–2015; the section near the village of Vasilievskoe was additionally studied in 2016 by D.N. Kiselev, M.A. Rogov, I.S. Ukhov, and E.V. Shchepetova. The first (from the source of the Cheryomukha River) sections of the upper Volgian series of ferruginous sand and sandstone are located immediately on the border of the Rybinsk and Bolsheselsky districts of Yaroslavl oblast, between the villages of Ilyinskoe and Seltso-Voskresenskoe. Downstream, this series terminates near the village of Romashkovo and further up does not crop out in riverside outcrops. Apparently, it represents an erosional remnant about 3.5 km long in a straight line, beyond which the beds composing this series are destroyed by erosion. Structurally, these beds lie above the earlier beds, which in general corresponds to the succession of bedrock units of various ages in the basin in the Cheryomukha River (Fig. 2). The description of these outcrops follows the succession of the composite section starting from its base.

Section no. 3. The section is on the right and left banks of the Cheryomukha River half way between the villages of Ilyinskoe and Seltso-Voskresenskoe, in a segment of a meander about 300 m long. The following beds crop out here from bottom to top:

Bed 1 (9). Sand medium-grained, with rare gravel grains irregularly bedded, reddish brown, strongly ferruginous, in places transiting into thin layers of sandstone medium-grained, reddish brown. Thickness from the waterline approximately 2–2.4 m.

Bed 2 (10). Sand medium-grained, reddish brown or ochreous. In the lower half of the bed, there is a ferruginous horizon with loaf-shaped concretions (20 × 30 × 40 cm) of ferruginous, compact sandstone with concentrically layered texture (inside the color is jet black, and outside orangey ochreous). Measured thickness about 5–1.5 m.

Both beds are exposed in excavated clearings on the right bank. The overlying beds are better exposed on the left bank, 300 m below the first clearing. Beginning from the level 6–7 m above the water level, the following succession is exposed:

Bed 3 (11). Sand medium-grained, orange brown, not compact, with concretions of strongly ferruginous sandstone, which form two distinct horizons. The lower horizon is composed of loaf-shaped concretions about 10 × 15 cm in size and platy nodules 1–2 cm thick. The horizons are separated by an interval 1–7 cm. Thickness 0.15–0.2 m.

Bed 4 (12). Sand medium-grained, indistinctly bedded, not compact, with banded texture, formed by irregular alternation of orange and ochreous gray layers. The bed occasionally contains platy concretions of ferruginous sandstone 1–2 cm thick. Thickness 1 m.

Bed 5 (13). Sand medium-grained, with cellular-slaggy structure and mottled texture, formed by orange stains of inclusions in the dark brown sandstone. Thickness 0.1–0.2 m.

Bed 6 (14). Sand medium-grained, indistinctly bedded, not compact, with banded texture formed by irregular alternation of orange and ochreous gray sand. Thickness 0.5 m.

Section no. 4. The section is located on the right bank of the Cheryomukha River, opposite a holiday village in the southeastern vicinity of the village of Seltso-Voskresenskoe. The bedrock was cleared at a height of 4 m above the waterline. Here the following beds are exposed from bottom to top:

Bed 1 (15). Sand medium-grained, indistinctly bedded, not compact, with stratifications, with alternation of orange and ochreous gray sand. Thickness 0.2 m.

Bed 2 (16). Sandstone medium- and coarse-grained, platy, strongly ferruginous, orange-brown; forms a small ledge on the profile of the section. Thickness 0.1–0.15 m.

Bed 3 (17). Sand medium- and coarse-grained, ferruginous, bright orange. Thickness 0.4 m.

Bed 4 (18). Sandstone medium- and coarse-grained, platy, ferruginous, dark brown. The bed contained *Entolium orbiculare* (Sow.). Thickness 0.15 m.

Bed 5 (19). Sand medium- and coarse-grained, ferruginous, bright orange. Thickness 0.3 m.

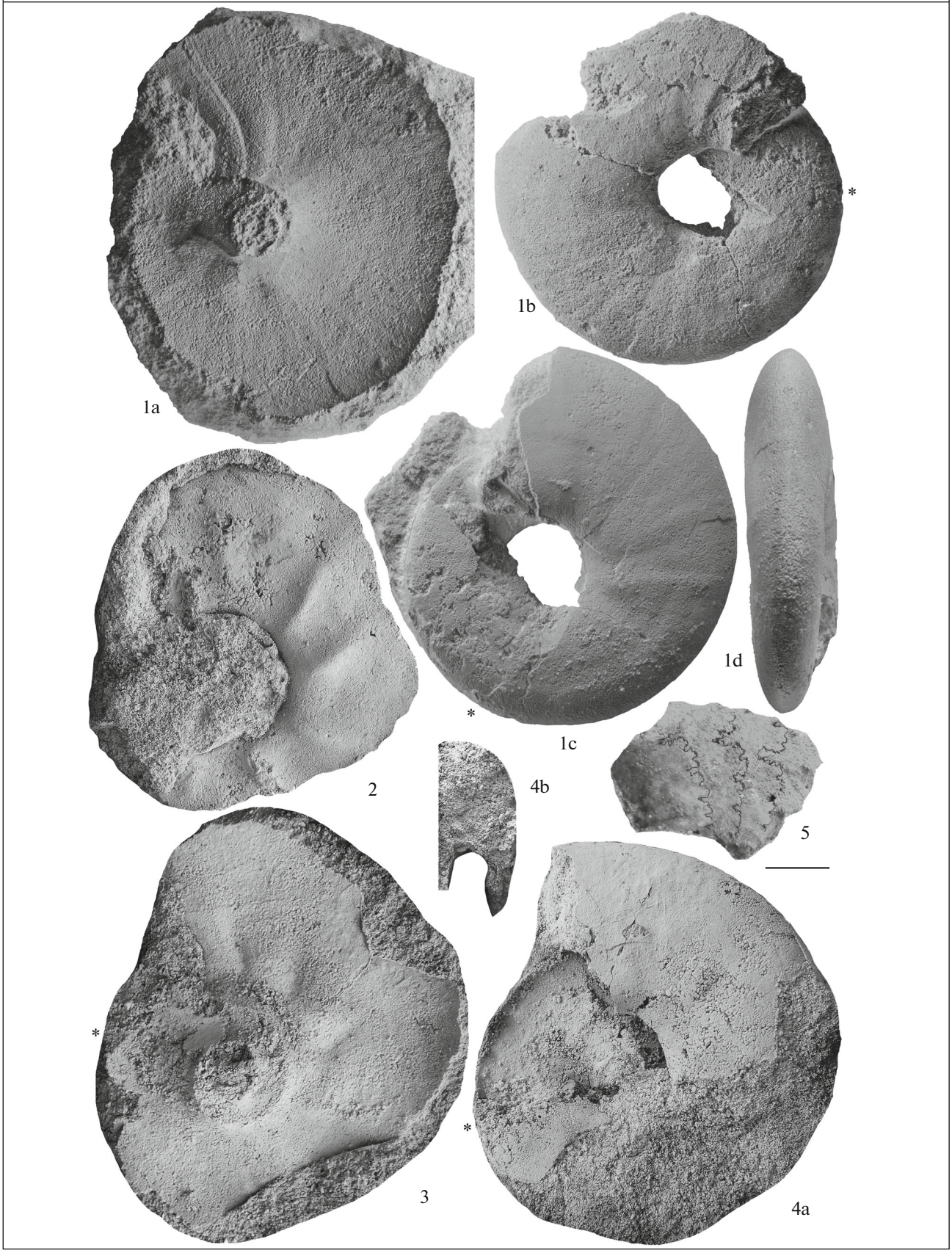
Bed 6 (20). Sandstone medium- and coarse-grained, platy, strongly ferruginous, orangey brown, very compact, with horizontal-blocky jointing. It forms a distinct ledge in the profile of the section. Thickness 0.8 m.

Above 4 m unexposed.

Bed 7 (approximately corresponds to Bed 28 of the compiled section). Sandstone coarse-grained, becom-

Plate I. (1–4) *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.), Rybinsk district, Vasilievskoe village, section no. 7 (6), Bed 4 (24), upper Volgian Substage, Volgidiscus singularis Zone, Volgidiscus pulcher Biohorizon: (1a–1d) specimen YarGPU Ch6-11, (1a) digital case from the imprint of the terminal body chamber, (1b, 1c) lateral view, (1d) ventral view; (2) specimen YarGPU MK7437; (3) specimen YarGPU MK7419; (4a, 4b) specimens YarGPU MK7421; (5) *Garniericeras* sp., specimen YarGPU Ch6-18, locality and age as in figs. 1–4. Here and in Plates II–VIII, scale bar 1 cm. Abbreviations: YarGPU—Geological Museum of Yaroslavl State Pedagogical University; VNIGRI—Museum of All-Russia Petroleum Research Exploration Institute; B.M.—Natural History Museum, London, UK; GSM—British Geological Survey Museum.

Plate I



ing gravelite, platy, strongly ferruginous, bright orange, not compact, easily breaking. Measured thickness about 2 m. Above that level, the beds are unexposed.

Section no. 5. Right bank of the Cheryomukha River next to the village of Chudinovo. The following beds are exposed above the waterline:

Bed 1 (21). Sandstone medium-grained, often horizontally bedded, orangey brown, in places cherry red, not compact, easily disintegrating when wet. This bed is usually overfilled with benthic fossils, mainly *Camptonectes morini* (de Loriol) and *Entolium orbiculare* (Sow.) and somewhat less commonly *Lingula demissa* Geras. Thickness 0.3–0.5 m.

Bed 2 (22). Sand medium-grained, loose, unbedded, orangey ochreous. Measured thickness about 1 m.

Bed 1 forms a marking horizon, also tracked in other outcrops.

Section no. 6. The section is located on the right bank of the Cheryomukha River, between the villages of Chudinovo (500 m downstream of the village) and Vasilievskoe (about 1 km above). The following beds crop out above the waterline:

Bed 1 (22a). Sand medium-grained, loose, horizontally bedded, orangey ochreous, with thin ferruginous beds. Measured thickness about 1 m.

Bed 2 (22b). Sand medium-grained, loose, unbedded, light grayish ochreous, with thin ferruginous layers. The bed contains a horizon of small pancake concretions of bedded or platy sandstone, overfilled with shells of *Lingula demissa* Geras. The bivalves *Camptonectes morini* (de Loriol) and *Plagiostoma planum* (Roemer) are less common. Thickness about 0.1 m.

Bed 3 (22c). Sand medium-grained, loose, orangey ochreous. The bedding is oblique, uniformly oriented, with parallel serial seams. The thickness of cross-bedded series is about 0.05–0.07 m. Measured thickness about 1 m.

A bed of horizontal-laminated ferruginous sandstone containing an assemblage of bivalves with predominating pectinids (Bed 21 of the composite section) is below the water level.

Section no. 7. One of the most important sections occurs on the left bank of the Cheryomukha River in a gully near the village of Vasilievskoe, in the right wall about 14 m high. The following beds are exposed here above the waterline to the top of the slope:

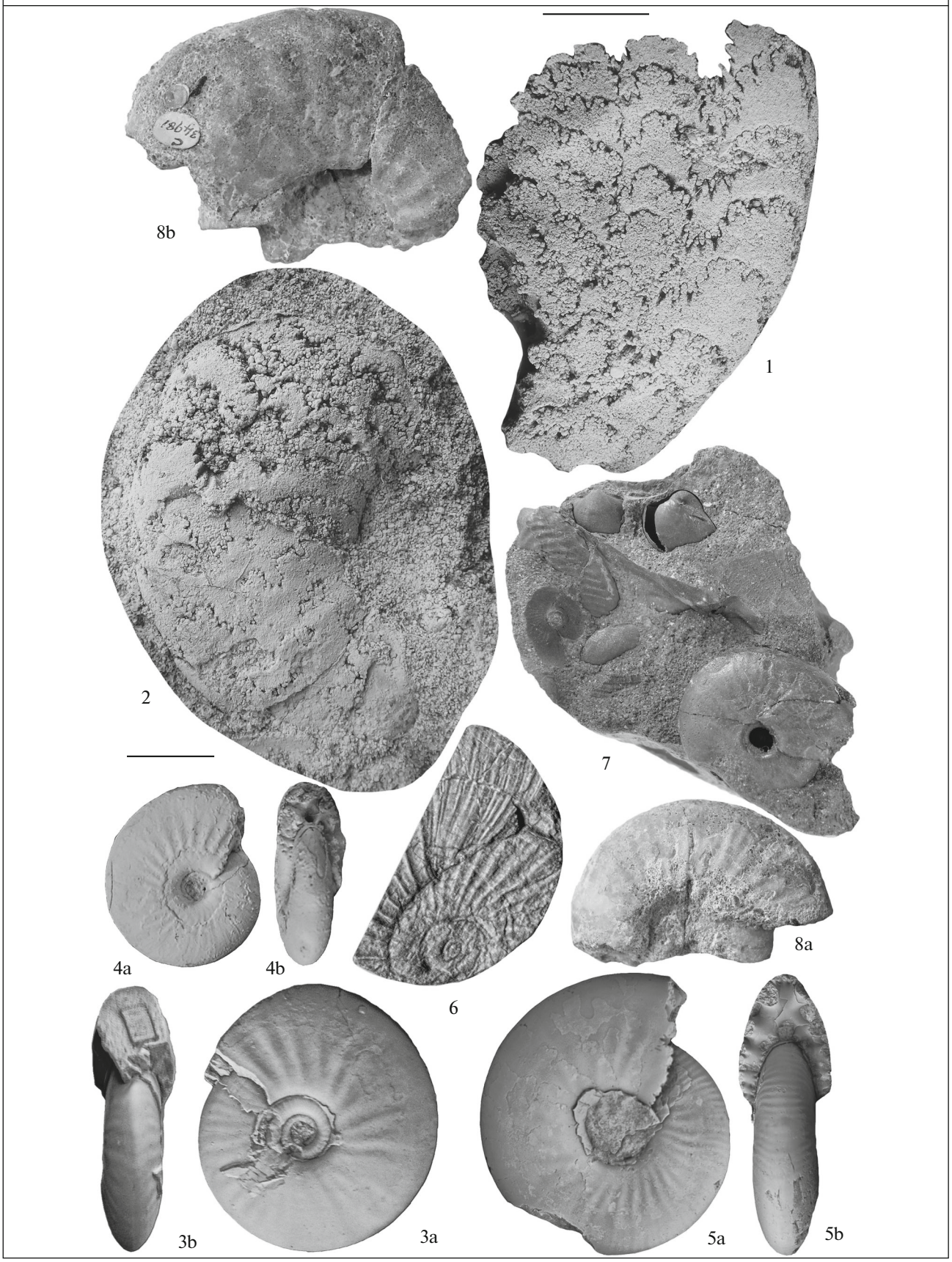
Bed 1 (21). Sandstone medium-grained, horizontally bedded, orange brown, loosely cemented. The bed contains frequent *Camptonectes morini* (de Loriol) and *Entolium orbiculare* (Sow.). The thickness above and below the waterline 0.5–0.6 m. This bed is equivalent to Bed 1 in the section near the village of Chudinovo.

Bed 2 (22, horizon a). Sand medium-grained, loose, unbedded near the base, and indistinct horizontally bedded in the upper part of the bed. In the lower part of the bed (in the interval 1 m above the base), the color is light grayish ochreous (horizon a). The rock becomes more strongly limonitized up the section, and the color changes to bright orange, most saturated at the top. Above 1 m from the base, the bed is covered by a landslide and solifluction material up to the level of 6.5–7 m. The lower part of the covered interval approximately corresponds to Beds 2–4 of section no. 6 (horizons b and c). Bed 2 is opened above the landslide by a clearing almost 12 m above the top of Bed 1. This part of the bed shows a change in the rock from bottom to top, allowing the recognition of two horizons. The lower horizon (d) is represented by medium-grained unbedded sand, with indistinctly and irregularly alternating reddish brown, orange ochreous and brown-gray sand. A horizon of pancake-like concretions of ferruginous sandstone 1–3 cm thick is at 7 m above the base. The upper horizon (e) begins at 8 m above the base. This is medium-grained sand, irregularly horizontally bedded, particularly in the lower part. The bedding is manifested by an alternation of bright orange or lemon yellow beds 5–10 cm thick with reddish brown lenses of sand of varying thicknesses. In the upper 1.5 m, the bedding is indistinct. The measured thickness of both horizons is about 4 m. The thickness of Bed 2 is about 12 m.

Bed 3 (23). Sand medium- to small-grained, loose, bright ochreous, almost orange in color, even more saturated than the color of Bed 2. The base and top of the bed is wavy. The top is marked by a thin, up to 5–10 mm, ferruginous horizon, where the bed becomes brownish black sandstone. It forms a wavy band with distinct boundaries. In places, concretional band forms beadlike inflations containing *Camptonectes morini* (de Loriol). Thickness 0.05–0.1 m.

Plate II. (1–4) *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.), upper Volgian Substage, Volgidiscus singularis Zone, Volgidiscus pulcher Biohorizon: (1) specimen YarGPU MK7442, Vasilievskoe village, Bed 4 (24); (2) specimen YarGPU MK7435, Rybinsk district, Vasilievskoe village, section no. 7 (6), Bed 4 (24); (3a, 3b) holotype, specimen VNIGRI 1857/634, eastern slope of the Subpolar Urals, Volya River basin, Borehole 255, depth 213.6 m; (4a, 4b) unnumbered specimen from A.V. Stupachenko's collection, Kostroma oblast, Ogarkovo village, condensed bed at the base of the Ryazanian Stage; (5a, 5b) *Volgidiscus* cf. *lamplughi* (Spath), middle whorls; TsNIGR 86/9565; adult whorls of the same specimen (*Opornyi*..., 1969, pl. XXXVIII, fig. 1, figured as *Garniericeras* aff. *tolijense*), Northern Siberia, Kheta River, Outcrop 20, Chetae Zone; (6) *Volgidiscus* sp., Barents Sea shelf, Borehole 6814/04-U02, depth 104.05 m, A. Wierzbowski's collection, Warsaw University; (7) *Volgidiscus* cf. *pulcher* (Casey, Mesezhn., Schulg.) (right) and fragment of *Shulginites* cf. *pseudokochi* Mesezhn. (left), A.A. Shkolin's collection from boulders, Vasilievskoe village, Uglich district, Yaroslavl oblast; (8a, 8b) *Volgidiscus lamplughi* (Spath), holotype, specimen B.M. C34981, England, Lincolnshire, Spilsby Sandstone, upper Volgian Substage, Lamplughi Zone.

Plate II



SINGULARIS ZONE

Pulcher Biohorizon

Bed 4 (24). Sand medium-grained, dense, dark orange-brown, rhythmically horizontally bedded, becoming weakly cemented sandstone. The middle part of the bed, at the level of 0.5 m above the base, contains a horizon of small potato-like concretions of dark brown sandstone. Concretions and surrounding rock contain crushed molds and imprints of ammonites and bivalves and also voids of dissolved belemnite rostra. Ammonites are represented by *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.), *Anivanovia* sp., and *Garniericeras* sp. Bivalves comprise *Anopaea brachovi* (Rouillier), *Camptonectes* (*Camptonectes*) *morini* (de Loriol), *Entolium orbiculare* (Sow.), and *Plagiostoma planum* (Roemer). The measured thickness of the bed is about 1.2 m.

The overlying beds covered by soil were not accessible for study, although it was possible to find fragments of the beds that had slid in the solifluction-landslide masses covering the middle part of Bed 2. These are fragments of sand bed, orange-brown, medium-grained, with two horizons of large loaf-shaped ferruginous, reddish brown sandstone concretions up to 0.5 m in size along the long axis. The inner part of the concretions is more solid, jet black or gray, often phosphatized. The outer layer of the concretions is loosely cemented, orange. The concretions were often overfilled by ferruginous molds of molluscan shells dominated by large *Camptonectes* (*C.*) *morini*, *Oxytoma* sp., and, less commonly, *Anopaea brachovi*. Ammonites are represented by rare fragments of *Volgidiscus* cf. *singularis* Kiselev.

Both concretionary horizons found in the landslide are equivalent to Bed 2, section no. 8 (Seltso-Voskresenskoe) and come from the singularis Biohorizon.

Section no. 8. A section of the terminal part of the upper Volgian Substage where for the first time the beds with Volgidiscus were established; it is known as the Seltso-Voskresenskoe (Kiselev, 2003) and is located in a quarry south of the village of Seltso-Voskresenskoe. The outcrop with the section is located 160 m west of the channel of the Cheryomukha River. At present, the lower bed containing ammonites is inaccessible for study; hence, the section is described according to the field observations of 2002 and Kiselev (2003), with small modifications.

SINGULARIS ZONE

Singularis Biohorizon

Bed 1 (25). Sand inequigranular, quartz, loose, greenish or yellowish gray. Nearer the top, the sand becomes more compact and orange-brown. At the base, at the groundwater table, there is a thin layer of ferruginous sandstone 0.05 m thick. Thickness 1.5–2 m. The underlying beds partly crop out outside the quarry on the bank of the Cheryomukha River, in section no. 3.

Bed 2 (26). Sand inequigranular, mainly coarse-grained, orange-brown, ferruginous, loose, indistinctly bedded, with a considerable admixture of cherty sand grains. The bed contains two horizons of concretions of ferruginous sandstone. The lower horizon is at the base and is formed by large elongated (1 × 0.2 m) concretions composed of loose ferruginous sandstone, within which there are one or several molds of compact brownish gray phosphatized sandstone. The concretions yielded numerous ammonites *Anivanovia mola* Kiselev, *Volgidiscus singularis* Kiselev, bivalves *Anopaea brachovi* (Rouillier), *Entolium* cf. *orbiculare* (Sow.), *Protocardia* cf. *concinna* (Buch.), and voids from belemnite rostra. The upper horizon of the concretions is 0.5 m above the previous horizons. It is composed of concretions of the same type, although smaller in size. They contain similar fossils. In addition, there are concretions with accumulations of the brachiopods *Lingula demissa* Geras. Thickness 1.2 m.

Bed 3 (27). Sand coarse-grained or gravel, loose, dark brownish gray, polymyctic, with cherty grains. Thickness 1.5 m.

?Ryazanian Stage

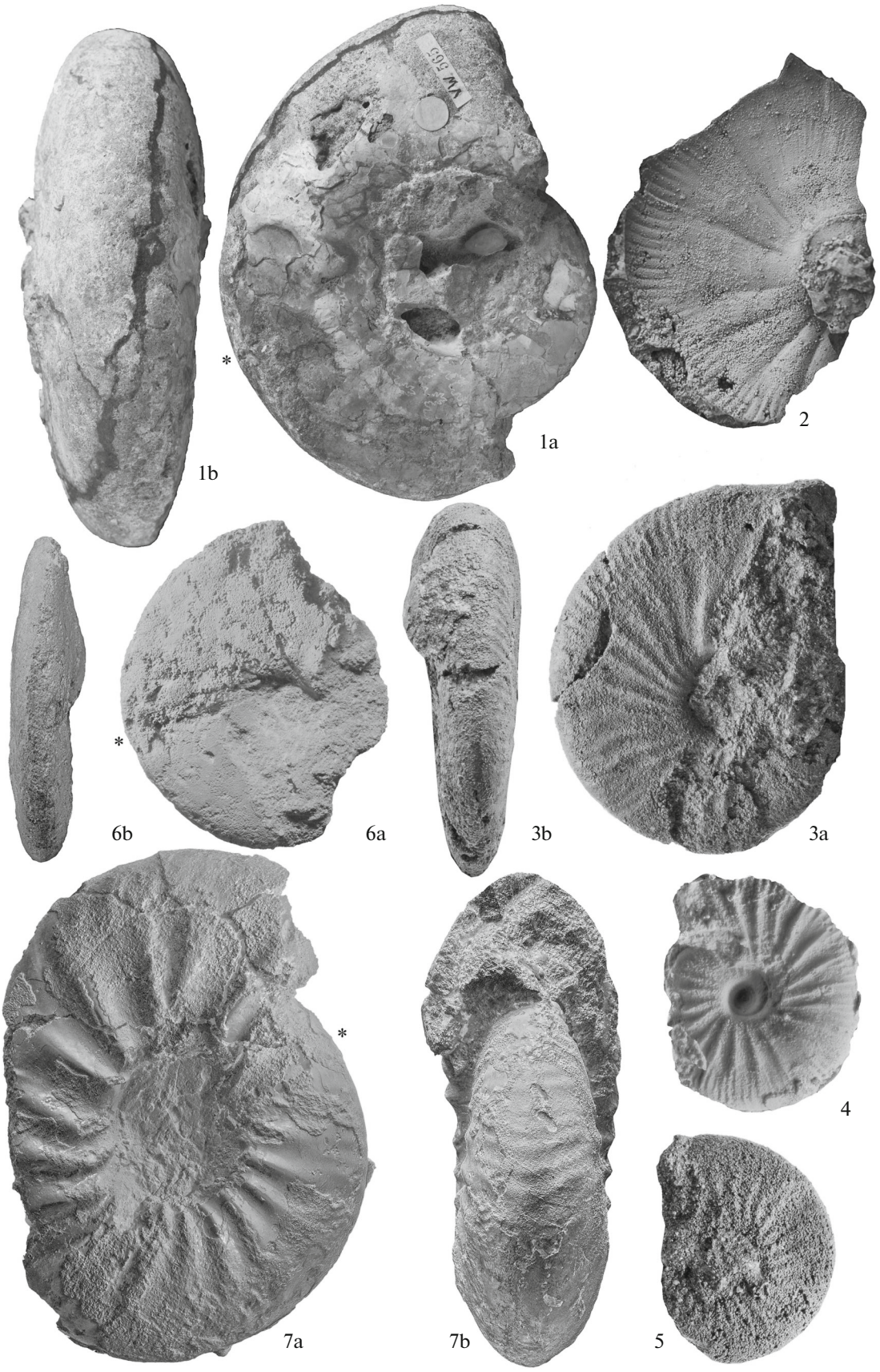
Bed 4 (28). Sandstone coarse-grained, in places gravelite, strongly ferruginous, reddish brown or orange-brown, compact, in places loose. The sandstone, with distinct stratifications, is horizontal to oblique, nearer the top becoming cellular with flaser texture. The bed forms a distinct ledge. Thickness up to 8 m.

LOCAL STRATIGRAPHY

The upper Volgian Substage in the upper reaches of the Cheryomukha River is lithologically different from the underlying Upper Volgian deposits: (1) coarse sand or gravel grains; (2) almost complete absence of clay and silty fractions; (3) strong ferruginous and

Plate III. (1, 6) *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.): (1a, 1b) paratype, specimen GSM VW565 (=*Subcraspedites (Volgidiscus)* sp. nov. in (Casey, 1973, p. 251, fig. 5i)), England, Lincolnshire, Caistor, Spilsby Sandstone, Volgidiscus lamplughi Zone; (6) specimen YarGPU Ch6-12, Rybinsk district, Vasilievskoe village, section no. 7 (6), Bed 4 (24), Volgidiscus singularis Zone, Volgidiscus pulcher Biohorizon; (2–5) *Volgidiscus singularis* Kiselev: (2) syntype, specimen YarGPU MK4618; (3a, 3b) paratype, specimen YarGPU Ch/B-1; (4) paratype, specimen YarGPU Ch/B-7, cast from imprint; (5) topotype, specimen YarGPU Ch/B-13; Rybinsk district, Seltso-Voskresenskoe village, section no. 8, Bed 2 (26), upper Volgian Substage, Volgidiscus singularis Zone and biohorizon; (7) *Craspedites (?Taimyroceras)* sp., specimen YarGPU CHI-1, Rybinsk district, upper reaches of the Cheryomukha River, upper Volgian Substage, coll. by A.N. Ivanov.

Plate III



hence yellow-orange or brown reddish strongly saturated color; (4) considerable thickness, about 35–40 m; (5) assembly of characters indicating a shallow-water, mainly littoral (in the lower part) and supralittoral (at the top) genesis of these deposits; (6) unusual faunal assemblage of both bivalves and ammonites. This series represents the upper part of a regressive system tract, most of which belongs to the Volgian Stage. It includes terminal upper Volgian beds and apparently the lower horizons of the Ryazanian Stage.

The distinctiveness of these beds allows them to be considered as an independent unit, which is designated here as the Chudinovo Formation. This formation is clearly subdivided into three parts, lower, middle, and upper:

Lower subformation—medium-grained sands and sandstones of Beds 9–23 of the composite section (Fig. 3). This formation is not completely exposed in any section of the Chudinovo Formation. It does not contain ammonites; hence, the local sections can only be correlated using lithostratigraphic characters. Bed 21 of the composite section, a slab of horizontal-stratified strongly ferruginous sandstone with numerous bivalves and brachiopods, is a marker horizon suitable for correlation. The lower subformation is distinctly subdivided into two members:

a. Lower member—Beds 9–21 of the composite section. It represents a rhythmical alternation of ferruginous sands and platy sandstones with total thickness of 10 m. The top of the section contains a marker horizon (Bed 21 of the composite section). The main part of the lower member is exposed in the southern part of the remnant fragment of the Chudinovo Formation (sections nos. 3–5); in the northern part of the fragment, these beds are below the waterline.

b. Upper member—Beds 22–23 of the composite section. These sands are often cross-bedded and do not contain beds of platy sandstones. This member is exposed mainly in the northern part of the upper Volgian remnant on the Cheryomukha River (sections nos. 6–9). Strong fluctuations in the thickness of the lower subformation and constituting members apparently resulted from glaciodislocations, which are widespread over the entire basin of the Cheryomukha River.

Middle subformation—medium- and coarse-grained ferruginous sand and sandstone, often with a small admixture of small gravel grains, Beds 24–27 of the composite section with the total thickness up to 6 m. The sandstone is represented by variously shaped concretions, from loaf-shaped to potato-shaped. The concretions contained ammonites of the Volgidiscus singularis Zone and characteristic assemblage of bivalvian mollusks (see below). The middle subformation is reliably found only in two sections, near the villages of Vasilievskoe (no. 7) and Seltso-Voskresenskoe (no. 8).

Upper subformation—sandstone coarse-grained or gravelite, strongly ferruginous, cross-bedded or vesicular-bedded; Bed 28 of the composite section. This subformation is only observed in sections near the village of Seltso-Voskresenskoe (nos. 4 and 8). This subformation is 8 m thick, apparently belonging to the supralittoral facies, and completes the regressive sequence. Supposedly, it is of Ryazanian age and corresponds to a regional gap at the base of the Ryazanian Stage, widespread on the Russian platform.

BIOSTRATIGRAPHIC SUBDIVISIONS AND CORRELATIONS

It is certain that the Chudinovo Formation corresponds to the terminal part of the upper Volgian Substage and is stratigraphically above the Craspedites nodiger Zone, although its lower part, lacking ammonites, can correspond to the upper part of this zone.

Ammonoids are found only in the middle subformation (Volgidiscus Beds), where the Volgidiscus singularis Zone includes two biohorizons: pulcher and singularis. The stratigraphic position of the overlying and underlying parts of the Chudinovo Formation is established indirectly, including by its position in the section.

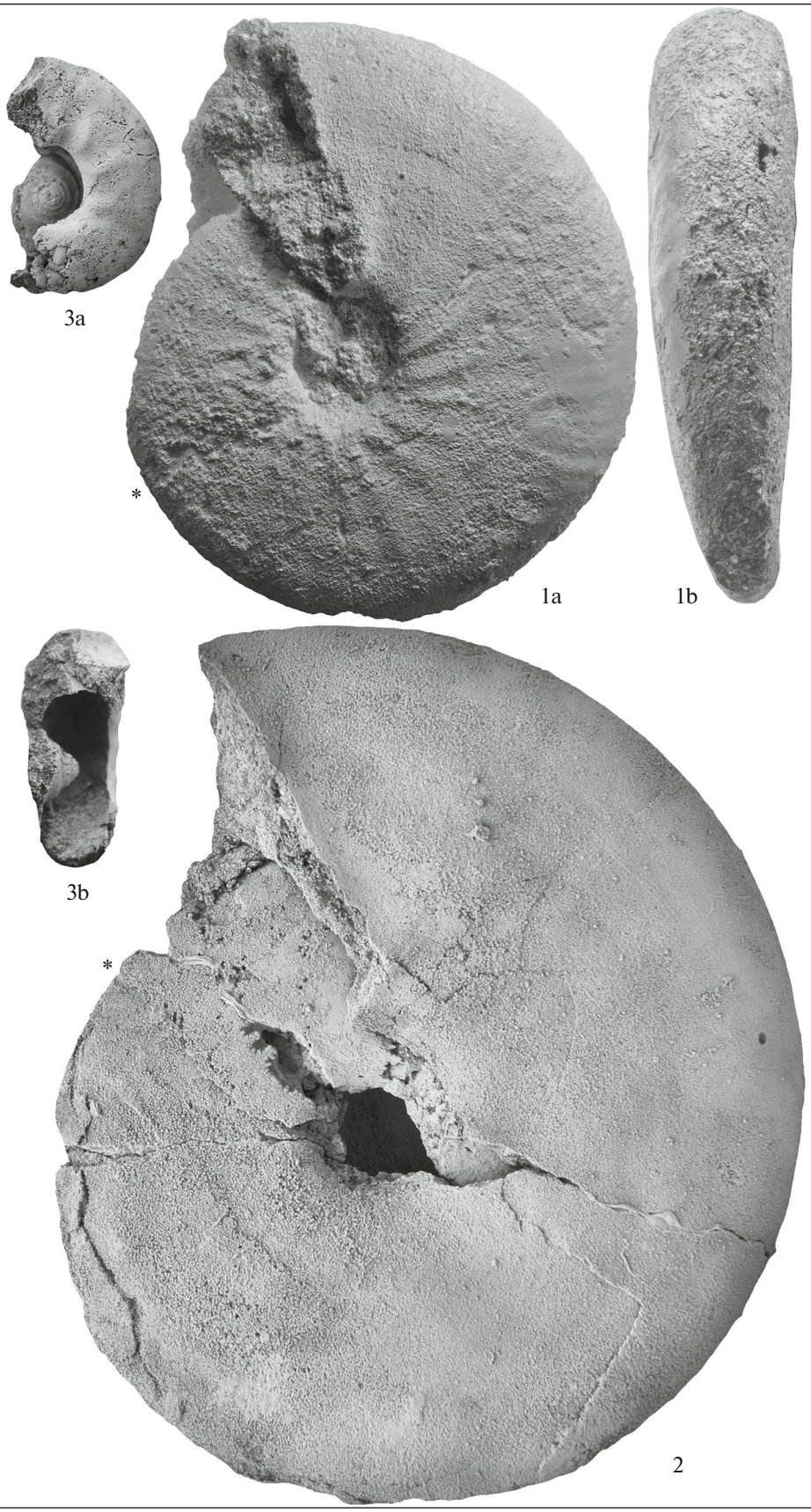
The age of the lower subformation is not resolved; it can equally belong to both the Singularis Zone and the Nodiger Zone. At present, there is only one specimen of an ammonite, which may come from the lower subformation. It was found near the village of Seltso-Voskresenskoe by A.N. Ivanov without an indication of precise stratigraphic position and was previously designated as *Craspedites* sp. nov. aff. *nodiger* (Kiselev and Rogov, 2012a, Fig. 33), and at present, it is redefined as *Craspedites (Taimyroceras?)* sp. The specimen is represented by a mold composed of strongly ferruginous compact sandstone with cellular texture. Most likely, it comes from the interval of Beds 15–20 of the composite section (Fig. 3). The middle subformation belongs entirely to the Volgidiscus singularis Zone.

All known localities of the genus *Volgidiscus* are recorded in the uppermost part of the upper Volgian Substage:

1. England, Lincolnshire, Volgidiscus lamplughi Zone (Casey, 1973; Casey et al., 1988), where apart from the index species *Volgidiscus lamplughi* (Casey) there is also *Volgidiscus pulcher* (Casey et al., 1977) and

Plate IV. (1, 2) *Anivanovia mola* Kiselev: (1a, 1b) holotype, specimen YarGPU Ch/B-8; (2) syntype, specimen YarGPU MK4612; Rybinsk district, Seltso-Voskresenskoe village, section no. 8, Bed 2 (26), upper substage of Volgian Stage, Volgidiscus singularis Zone and biohorizon; (3a, 3b) *Craspedites (Trautscholdiceras)* cf. *kaschpuricus* (Trd.), specimen YarGPU ChM-2, Rybinsk district, Popovskoe village, section no. 2, Bed 3, upper Volgian Substage, Craspedites nodiger Zone, Craspedites milkovensis Subzone.

Plate IV



also *V.* aff. *lamplughi* and representatives of the genus *Volgidiscus*, not identified to species (Casey, 1973). Later, Casey et al. (1988) suggested that a distinct level with *Subcraspedites claxbiensis* Spath is present above the Lamplughi Zone in East Anglia, but this hypothesis was only based on the fact that *S. claxbiensis* was found only in the redeposited state at the base of the Albian and was not found in outcrops.

2. North Sea shelf (Abbink et al., 2001), boreholes in the interval 2255–2251 m (Lamplughi Zone) containing an ammonite assemblage identified as *Subcraspedites* cf./aff. *lamplughi* or *Subcraspedites* sp. In our view, these ammonites (Abbink et al., 2001, textfigs. 5A–5I, ?5L, 6M) belong to the late representatives of the genus *Volgidiscus*, similar to *V. singularis*, but some of these possessing a wide umbilicus (Abbink et al., 2001, figs. 5J, 5K, 6N) could belong to later representatives of *Subcraspedites*, such as *S. turbinae* Klimova and *S. maurynijensis* Mesezhn. et Aleks. Hoedemaeker (in Hoedemaeker and Herngreen, 2003) suggested that the assemblage from the North Sea boreholes is younger than that of the Lamplughi Zone of England, but did not provide any argument in support of his hypothesis.

3. Eastern slope of the Subpolar Urals (Casey et al., 1988; Mesezhnikov and Braduchan, 1982), beds with *Subcraspedites maurynijensis* and *V. pulcher*, recognized in the basin of the Volya and Maurynya rivers, Chetaites chetae Zone on the Yany-Manya River. Ammonite assemblages in the terminal part of the Volgian Stage in different regions of the Subpolar Urals are significantly different, which was the reason for different authors using different index species to designate this stratigraphic interval. The Chetae Zone was established for the first time in the Subpolar Urals on the Yany-Manya (Golbert et al., 1972), where it is characterized by *Chetaites* cf. *chetae* Schulg., *Chetaites* sp. indet., *Craspedites* sp. (cf. *nodiger* (Eichw.)), *C.* (*Taimyroceras*) sp., and *Praechetaites* sp. (=*Virgatosphinctes* auct.). A completely different assemblage of ammonites was found above the Taimyrensis Zone in the section on the Maurynya River (Mesezhnikov and Braduchan, 1982; Mesezhnikov et al., 1983). These beds contained *Subcraspedites maurynijensis* Mesezhn. et Alekseev (Mesezhnikov et al., 1983, pl. VII, fig. 1), *Shulginites tolijense* (Nik.) (Mesezhnikov et al., 1983, pl. IV, figs. 1–5; pl. V, fig. 1), *S. pseudokochi* Mesezhn. (Mesezhnikov et al., 1983, pl. V, figs. 2, 4, 5; pl. VI, figs. 1–2). This assemblage Mesezhnikov and Braduchan (1982) proposed to assign to beds with *Subcraspedites maurynijensis* and *Volgidiscus pulcher*. However, the stratigraphic position of one index species proposed by Mesezhnikov and Braduchan (*Volgidiscus pulcher* (Casey et al.)), represented only by the holotype, which was found in a borehole drilled on the Volya River, is not clear, and for the Maurynya River, it seems more correct to recognize either beds with S. maurynijensis Mesezhn. et Alekseev (Dzyuba et al., 2013) or the maurynijensis Biohorizon, which can be considered in the Chetae Zone.

4. Western Siberia. Until recently, in the terminal part of the Volgian Stage of Western Siberia as in the Subpolar Urals, the " Shulginites Zone " (Mesezhnikov et al., 1984) or "beds with Subcraspedites maurynijensis and Volgidiscus pulcher" (*Reshenie*..., 2004; Shurygin et al., 2000) were recognized, although none of these species has ever been recorded in Western Siberia. Recently, Alifirov (2009) proposed instead to recognize here beds with *Shulginites* cf. *pseudokochi* Mesezhn. This proposal is also questionable because the species *S. pseudokochi* Mesezhn. is found both in the upper Volgian Substage and in the lower part of the Ryazanian Stage (Mesezhnikov et al., 1983); and in the opinion of the author of the proposed unit, in Western Siberia, only one record identified in open nomenclature could be assigned to this species (Alifirov, 2009). The analysis of published data on Western Siberia showed that beds above the Taimyrensis Zone contain a relatively diverse ammonite assemblage, which can be assigned to the Chetae Zone. The assemblage includes *Chetaites chetae* Schulg./cf. *chetae* Schulg., *Shulginites*, *Craspedites (Taimyroceras)* cf. *taimyrensis* (Bodyl.), and also representatives of the genus *Volgidiscus*, *V.* cf. *lamplughi* (Borehole Severo-Pokachevskaya 21, Borehole Solombalskaya 1; Vyachkileva et al., 1990, pl. 64, figs. 1–2). As in the Subpolar Urals, zonal assemblages from different boreholes contain essentially distinct ammonites, which suggest their dissimilar age rather than faunal differences within the basin.

5. Northern Siberia, basin of the Kheta River (*Opornyi*..., 1969), Chetaites chetae Zone, where apart from the characteristic zonal species assemblage *V.* cf. *lamplughi* is present.

The Volgidiscus singularis Zone from Yaroslavl oblast is characterized by ammonites, relatively similar to ammonites from the above localities, which allows the Singularis Zone to be correlated with the Lamplughi and Chetae zones.

Currently, the Singularis Zone is recognized only in the Cheryomukha River basin. Presumably, this zone can be present in the Uglich district of Yaroslavl oblast, where *Volgidiscus* comes from boulders (Shkolin and Rogov, 2012). Single findings of *Volgidiscus* are

Plate V. (1, 2) *Anivanovia mola* Kiselev: (1) topotype, specimen YarGPU Ch/B-14; (2) topotype, specimen YarGPU Ch/B-15; (3a, 3b) *Volgidiscus singularis* Kiselev, holotype, specimen YarGPU Ch/B-3; Rybinsk district, Seltso-Voskresenskoe village, section no. 8, Bed 2 (26), upper Volgian Substage, Volgidiscus singularis Zone and biohorizon; (4a, 4b) *Craspedites (Trautscholdiceras) milkovensis* (Strem.), specimen YarGPU ChM-1, Rybinsk district, Popovskoe village, section no. 2, Bed 3, upper Volgian Substage, Craspedites nodiger Zone, Craspedites milkovensis Subzone.

Plate V

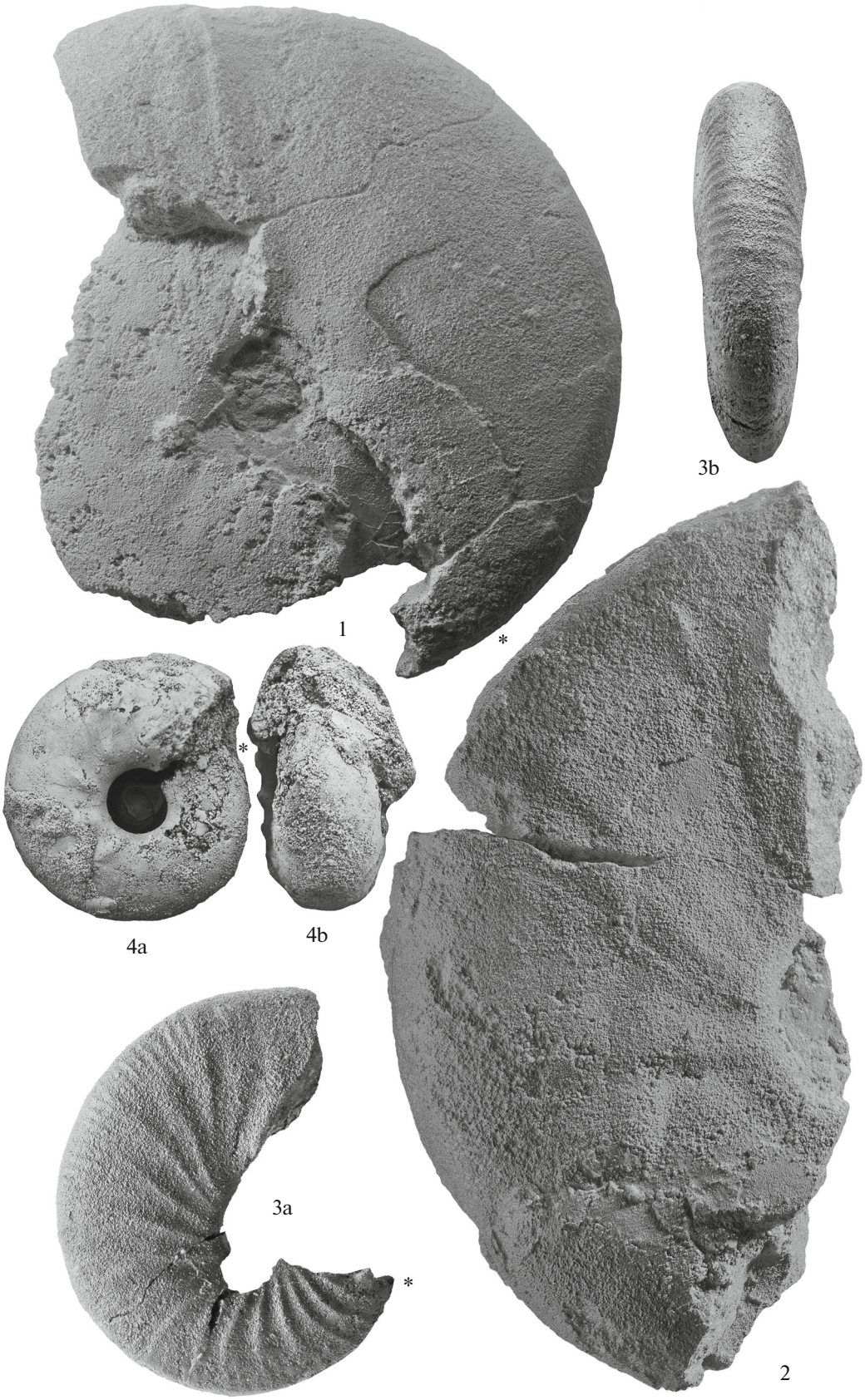


Table 1. Correlation of the upper Volgian beds of European Russia, England, North Sea, Subpolar Urals, Northern Siberia

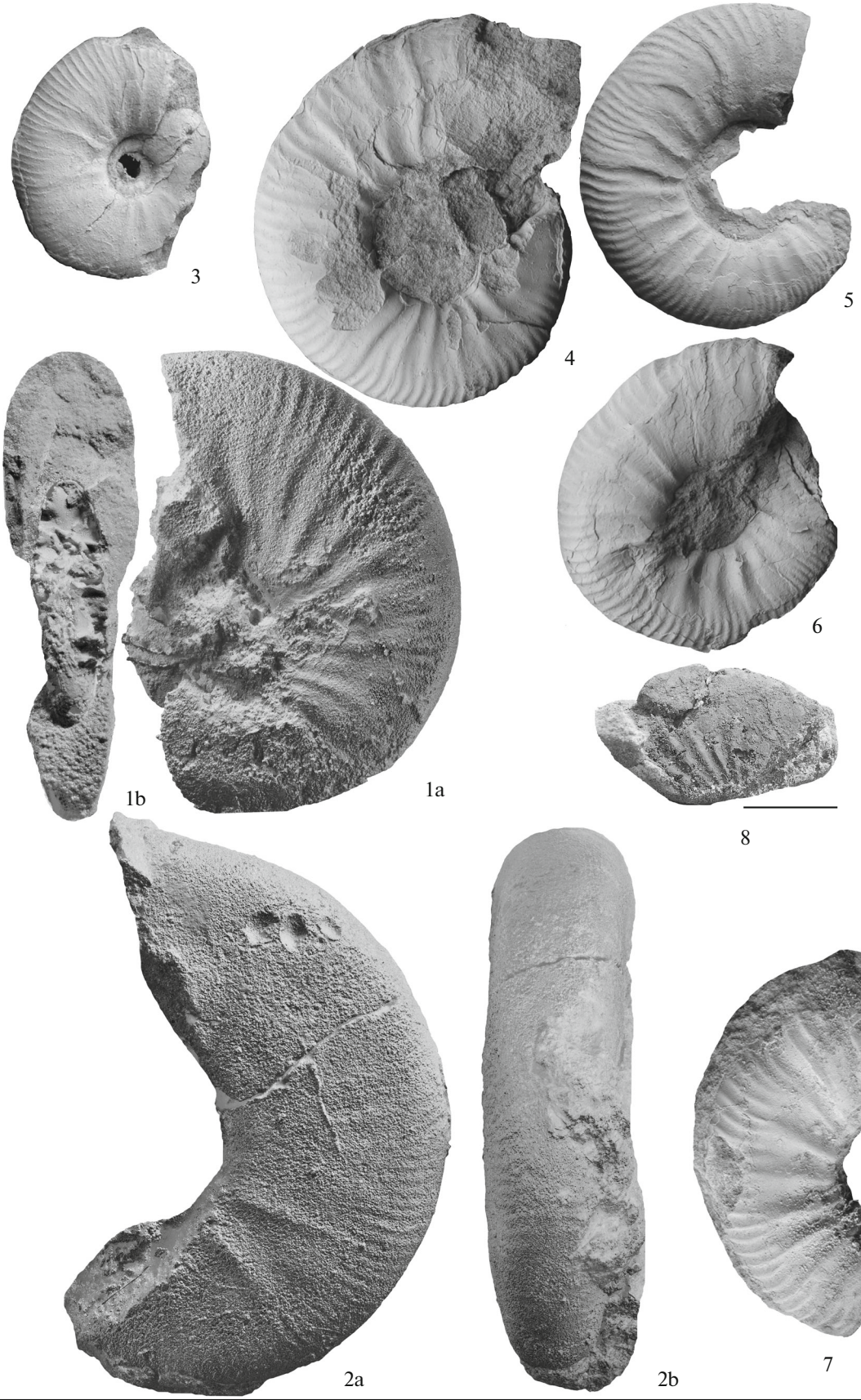
European Russia (Rogov, 2017; Rogov et al., 2015)			North Sea (Abbink et al., 2001)	England (Casey, 1973, Casey et al., 1988)	Subpolar Urals (Rogov and Zakharov, 2009)	Northern Siberia (Rogov and Zakharov, 2009)
Zone, subzone		Biohorizon	Zone, subzone, biohorizon			
Singularis		V. singularis	Lamplughi		Chetae	
		V. pulcher		V. pulcher		
Nodiger	C. sp. nov.		Preplicomphalus		Taimyrensis	
	Milkovensis	C. milkovensis				
	Nodiger	C. nodiger				
		C. transitionis				
Catenulatum		G. subclypeiforme			Subditus	Originalis
		G. catenulatum				
		G. interjectim				
Fulgens	Subfulgens	K. involutus			Fulgens	Okensis
		K. subfulgens				
		K. cheremkhensis				
	Fulgens	K. tenuicostatus				
		K. evolutus				

also known from the section near the village of Ogarkovo in Kostroma oblast, where they are found together with *Chetaites* cf. *chetae* Schulg. and *Craspedites* (Mitta, 2005).

The presence of two successive complexes with *Volgidiscus*, which are identified here as the pulcher and singularis biohorizons, provides the possibility of direct correlation with the sequences of other regions (Table 1). Although the highest part of the Volgian Stage on the supposed immigration path of these ammonites (Greenland-Norwegian Sea Route) is not well characterized by fossils, at least one ammonite from the core of Borehole 6814/04-U02 drilled in the Norwegian part of the Barents Sea can be attributed to *V. lamplughi*. *Volgidiscus pulcher*, known from East Anglia, European Russia, and the Subpolar Urals, is close to *V. lamplughi*, the index species of the terminal zone of Northwestern Europe. Thus, the findings of the *Volgidiscus* in European Russia, the Subpolar Urals, and Western and Northern Siberia apparently record the rapid immigration of ammonites of the genus *Volgidiscus* to the east at the beginning of the Lamplughi Chron, providing a good correlation level lying close to the base of the Chetaites chetae and slightly above the lower boundary of the Berriasian. It is surprising that, in the beds with the Volgidiscus both in England and in European Russia, there are no finds of typical Boreal bivalves of the genus *Buchia*. The bivalve assemblage from the beds with Volgidiscus singularis on the Russian Plate is similar to those from the interval from the top of the middle Volgian Substage to the middle part of the Ryazanian Stage. In the succession studied, the bipolar genus *Anopaea* is the most common, while the other bivalve mollusks (*Pla-*

Plate VI. (1, 2) *Anivanovia mola* Kiselev: (1a, 1b) topotype, specimen YarGPU Ch/B-9; (2) topotype, specimen YarGPU Ch/B-16; Rybinsk district, Seltso-Voskresenskoe village, section no. 8, Bed 2 (26), upper Volgian Substage, Volgidiscus singularis Zone and biohorizon; (3–7) *Subcraspedites turbinae* Klimova, eastern slope of the Subpolar Urals, Maurynya River, Outcrop 54a, M.S. Mesezhnikov's collections; (8) *Shulginites* cf. *tolijense* (Nikitin), specimen YarGPU MK7725, Ulyanovsk oblast, Maryevka village, lower part of Bed M24 (see section in Rogov et al., 2015).

Plate VI



giostoma) are rarer. Species close to *A. brachovi* are also found in the Taimyrensis Zone in the north of Eastern Siberia, but in this region, their records are relatively few, while *Buchia* prevails in the bivalvian assemblages. The discovery of the Singularius Zone suggests that there was no biostratigraphically significant gap between the Ryazanian and Volgian, since the Ryazanian Stage has taxa typical of the Sibiricus Zone, lower zone of this stage in Northern Siberia. Additional evidence in favor of this point of view comes from occurrence of ammonites of the genus *Shulginites*, both in the upper part of the upper Volgian Substage (together with *Volgidiscus*) and in the lower part of the Ryazanian Stage (in the Maryevka section). Above and below the boundary of the Volgian and Ryazanian stages, representatives of this genus are encountered also in the Subpolar Urals (Casey et al., 1988; Mesezhnikov et al., 1983).

Volgidiscus singularis Zone Kiselev, 2003

=Beds with Volgidiscus singularis Kiselev, 2003, p. 59.

=Singularis Zone: Rogov et al., 2015, p. 72.

Index species: *Volgidiscus singularis* Kiselev, 2003. Kiselev, 2003, pl. 26, figs. 4–5. Holotype—specimen YarGPU Ch/B-3 (Plate V, fig. 3).

Stratotype: village of Seltso-Voskresenskoe, section no. 8, Beds 1 (25)–3 (27).

Infrazonal division: two biohorizons—Volgidiscus pulcher and V. singularis.

Correlation. The zone is characterized by the greatest correlation potential at the infrazonal level among the remaining upper Volgian zones. In England, the Volgidiscus lamplughi Zone corresponds to the Singularis Zone. Besides the index species *Volgidiscus lamplughi* (Casey, 1973) (holotype, Plate II, fig. 8), *Volgidiscus pulcher* is present in the ammonite complex of the Lamplughi Zone. In the Singularis Zone, this species is prevalent only in the lower part, in the pulcher Biohorizon; therefore, it is not excluded that the Lamplughi Zone corresponds not to the entire Singularis Zone, but only to its lower part, but an insufficient degree of study of the zone in the type region does not make it possible to confirm this with confidence. At the same time, equivalents of the singularis Biohorizon are present in the Lamplughi Zone of the North Sea. In the Subpolar Urals, the Singularis Zone approximately correlates with the beds with Subcraspedites maurynijensis and the Chetaites chetae Zone, containing *Shulginites pseudokochi* Mesezhn. (Rogov and Zakharov, 2009)—a species co-occurring with *V. pulcher* in the Yaroslavl Povolzhye (Volga region) (Shkolin and Rogov, 2012, pl. 80, fig. 3). On the basis of the finds of *Volgidiscus*, the zone also corresponds to the Chetae Zone of Western and Northern Siberia.

Remarks. In its stratotype, the zone is represented only by the upper singularis Biohorizon and does not contain the basal pulcher Biohorizon. Although the overlying beds in the stratotype are not characterized by ammonites, we can use, as in the adjacent regions, the disappearance of the genus *Volgidiscus* as a good marker of the upper boundary. The lower boundary of the zone was not traced in the same section with the underlying beds and can only be marked in the composite section. We did not find evidence of the presence of the Lower Cretaceous taxa in the rocks overlying the beds with Volgidiscus singularis. However, the rule of "zone connection" is not as strict as formulated in the Stratigraphic Code of Russia (*Stratigraficheskii*..., 2006, p. 38), as it says, "Zonal assemblages of the adjacent biostratigraphic zones should usually follow the rule of connectivity or continuity in the composition of paleontological taxa or reflect a change in the ecological settings." The latter condition is observed in the studied sections: there is a continuity of taxa (all ammonites belong to the same subfamily, although the continuous succession of the phylozone cannot so far be confirmed, while a considerable change in ecological settings is clearly observed. We elevated the rank of the beds with Volgidiscus singularis to the zonal level on the basis of undoubted interregional correlation of this stratigraphic interval with remote sections in England, Subpolar Urals, and northern Eastern Siberia.

Mitta (2010) questioned identifications of ammonites from the Singularis Zone and accordingly the geochronological age of the middle part of the Chudinovo Formation. He concluded that two species of the specific assemblage of the zone, *Anivanovia mola* and *Volgidiscus singularis*, belong to the genera *Kachpurites* and *Craspedites*, whereas beds with V. singularis should be assigned to the lower part of the Subditus Zone (=Catenulatum according to Rogov et al., 2015; Rogov, 2017). A critical review of this opinion (Kiselev and Rogov, 2012b) showed that this view cannot be confirmed. The main parts of this discussion are as follows (Kiselev and Rogov, 2012b, pp. 129–130, slightly abbreviated):

1. *Anivanovia mola* Kiselev and *Volgidiscus singularis* Kiselev are distinctly different from *Kachpurites* in the presence of the well-developed ornamentation on the inner whorls, which in its type is similar to that of *Subcraspedites* and *Volgidiscus*. At the same time, the genus *Kachpurites* shows a gradual decrease in ornamentation in evolution. In the late representatives of the genus (*K. cheremkhensis*, *K. subfulgens*), it is usually present only on the terminal body chamber. Features of this ornamentation are also significantly different from those of *Volgidiscus*: in the late species of *Kachpurites*, the body chamber possesses thin, striated secondary ribbing and in many case large node-like primary ribs. Although *Volgidiscus* shows a high ribbing coefficient (see Abbink et al., 2001), primary ribs are not transformed into prominent nodes, and the secondaries do not become thin striations. The evolution of the genus *Kachpurites* clearly shows

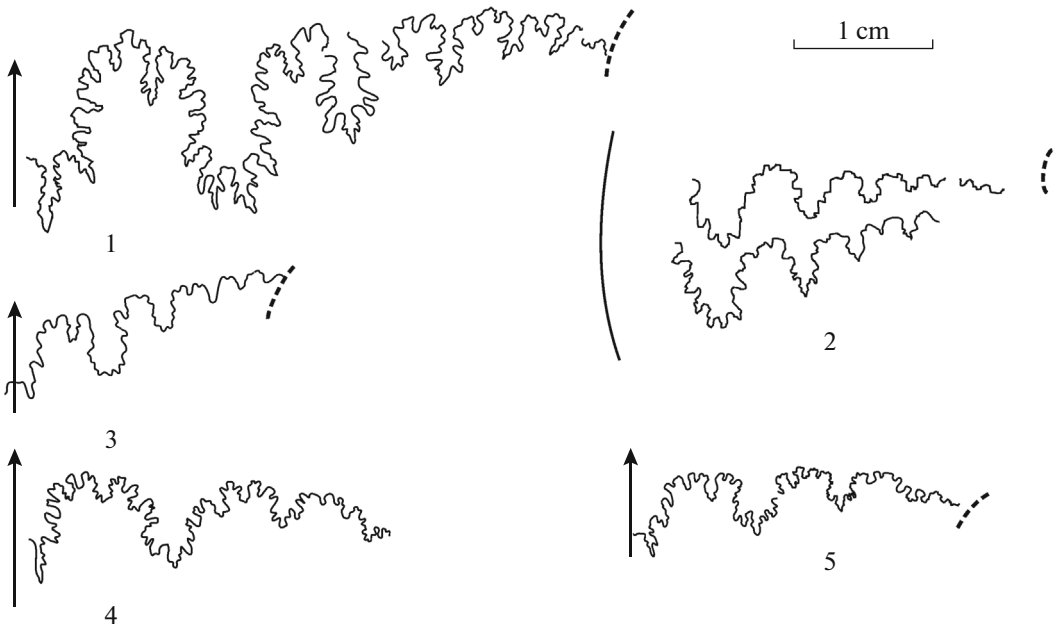


Fig. 4. Suture lines of some species of some craspeditids. (1) *Volgidiscus* cf. *lamplughi* (Spath) (=*Garniericeras* aff. *tolijense*, TsNIGR 86/9565, *Opornyi*..., 1969, pl. XXXVIII, figs. 1, Kheta River, 1961, Outcrop 20, upper Volgian Substage, Chetae Zone); (2) *Volgidiscus singularis* Kiselev, GIN MK4622, Seltso-Voskresenskoe, upper Volgian Substage, Volgidiscus singularis Zone and biohorizon; (3) *Volgidiscus* aff. *lamplughi* (Spath); (4) *Kachpurites* cf. *cheremkhensis* Mitta, I. Michailova et Sumin [M], GIN MK4274, Cheryomukha River, upper Volgian Substage, Fulgens Zone; (5) *Garniericeras catenulatum* (Fischer) [m], GIN MK4862, quarry near the village of Eganovo of Moscow oblast, upper Volgian Substage, Catenulatum Zone.

reduction in ornamentation, and we could rather expect descendants of this genus to be completely devoid of ribs, whereas *A. mola* and *V. singularis* show the presence of a plesiomorphic character (well-developed ornamentation in the inner and middle whorls), absent in the upper Volgian *Kachpurites*. Differences in the sutural outline of *Kachpurites* and *Volgidiscus* are as important (Fig. 4). The suture of *Kachpurites* is very similar to that of *Garniericeras* and is characterized by comparatively few wide lobes and relatively narrow and low saddles. At the same time, the suture of *Volgidiscus singularis*, as well as the suture of other representatives of the genus *Volgidiscus*, is distinguished by the presence of numerous lobes and saddles of approximately the same width. It remains unclear why Mitta assigned some paratypes of *V. singularis* to *Craspedites krylovi*, because the ornamentation of all figured *V. singularis* is sharply different from that of *C. krylovi*. While the latter species mainly has bipartite ribs slightly inclined toward the aperture, the ornamentation generally weakens in the middle part of the whorl, and the secondaries are as thick as the primaries, all specimens of *V. singularis* typically show a much higher ribbing coefficient and pronounced primaries, which are divided in the upper part of the flank into thinner secondaries slightly inclined toward the aperture. Ammonites of the genus *Volgidiscus* have that type of ornamentation

2. Specimens of *Kachpurites* from Prigorovsky's collection, in Mitta's opinion similar to *A. mola*, were found alongside numerous *Craspedites* and *Garniericeras*, whereas in the Seltso-Voskresenskoe sections no representatives of these genera have been found.

3. The similarity of the lithological composition of the Upper Volgian deposits in the Kamenik and Seltso-Voskresenskoe sections cannot be used for their correlation because such orange and brown sandstones are widespread in the middle and upper Volgian substages in Yaroslavl oblast.

4. The stratigraphic position of "beds with Kachpurites mola" in the lower part of the Subditus Zone, similar to Mitta's interpretation of the evolution of the genus *Kachpurites*, is not substantiated by the study of their distribution in the sections. The Catenulatum Zone indeed contains descendants of the genus *Kachpurites*, which show further development of the trends, which can be observed in the evolution of *Kachpurites* (gradual decrease in ornamentation, narrowing of the umbilicus, increase in the whorl height, and increase in the relative width of the sutural ornaments)—these are ammonites of the genus *Garniericeras*.

In addition to the above arguments, the following is noteworthy. The study of the upper Volgian deposits of the basin of the Cheryomukha River showed that the Chudinovo Formation, the middle part of which contains the Singularis Zone, is located stratigraphically not only above the Catenulatum Zone, to which in Mitta's opinion the Chudinovo Formation should be assigned, but also above the overlying Nodiger Zone. On one hand, the Chudinovo Formation is composed

of a rock complex of essentially different lithology and facies (thick series of ferruginous sands and sandstones) than the beds of the Fulgens and Catenulatum zones (thin series with phosphorite concretions). It is difficult to rationally explain such a profound change in the rock lithology and bed thickness within the basin of the Cheryomukha River by regular facies change. This would have required the existence in the middle region of the basin of the Cheryomukha River of different tectonic regimes in the Catenulatum phase. On the other hand, a record of *Craspedites (Taimyroceras?)* of considerably younger appearance than species of *Craspedites* from the Catenulatum Zone is known from the lower subformation of the Chudinovo Formation.

Finally, in the basin of the Cheryomukha River, outcrops of the Chudinovo Formation are exposed topographically and structurally substantially above the basal zones of the upper Volgian Substage. This agrees with the clear trend of change in the stratigraphically higher biostrata from the lower reaches of the Cheryomukha River to the upper reaches according to the river gradient (Fig. 2).

Volgidiscus pulcher Biohorizon nov.

Index species: *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.). Holotype: specimen VNIGRI 1857/634 (Plate II, fig. 3).

Stratotype: Village of Vasilievskoe (section no. 7 (6)), Bed 4 (24).

Ammonites: *Volgidiscus pulcher* (Casey, Mesezhn., Shulg.) (Plate I, figs. 1–4; Plate II, figs. 1–4, 9; Plate III, figs. 1, 6), *Anivanovia* sp., *Garniericeras* sp., (Plate I, fig. 5), *Shulginites* cf. *pseudokochi* Mesezhn. (Plate II, fig. 7).

Occurrence: Yaroslavl Povolzhye, middle part of the Chudinovo Formation in the Rybinsk District (upper reaches of the Cheryomukha River). This biohorizon can also be present in the Uglich District, where among the boulders near the villages of Altynovo and Vasilki concretions with the index species and *Shulginites pseudokochi* were found (Shkolin and Rogov, 2012); the redeposited finds of the index species are found in the Kostroma Region (village of Ogarkovo, Plate II, fig. 4); in the Subpolar Urals (Volya River); and in England, Lincolnshire, lower Spilsby Sandstone.

Correlation. The biohorizon is equivalent at least partly to the English Volgidiscus lamplughi Zone and the Chetae Zone of the Subpolar Urals and Western and Northern Siberia.

Remarks. The presence of the genus *Garniericeras* in such a high stratigraphic interval was quite unexpected. It was previously thought that the last species of *Garniericeras* are not found higher than the Nodiger Zone (species *Garniericeras subclypeiforme* (Milasch.); Rogov et al., 2015), and the milkovensis Biohorizon contains single finds of *Garniericeras* and they usually constitute 1–2% of the assemblage. In the pulcher Biohorizon, this genus is found in a single section near the village of Vasilievskoe. Presumably, these taxa should be assigned to a new species, but the preservation of specimens (fragments of molds) does not allow positive identification. The presence of *Garniericeras* in the pulcher Biohorizon indicates that there is not a significant gap between the Singularis and Nodiger zones.

Volgidiscus singularis Biohorizon Kiselev, 2003

Index species: as for the zone.

Stratotype: Seltso-Voskresenskoe village, section no. 8, Bed 2 (26).

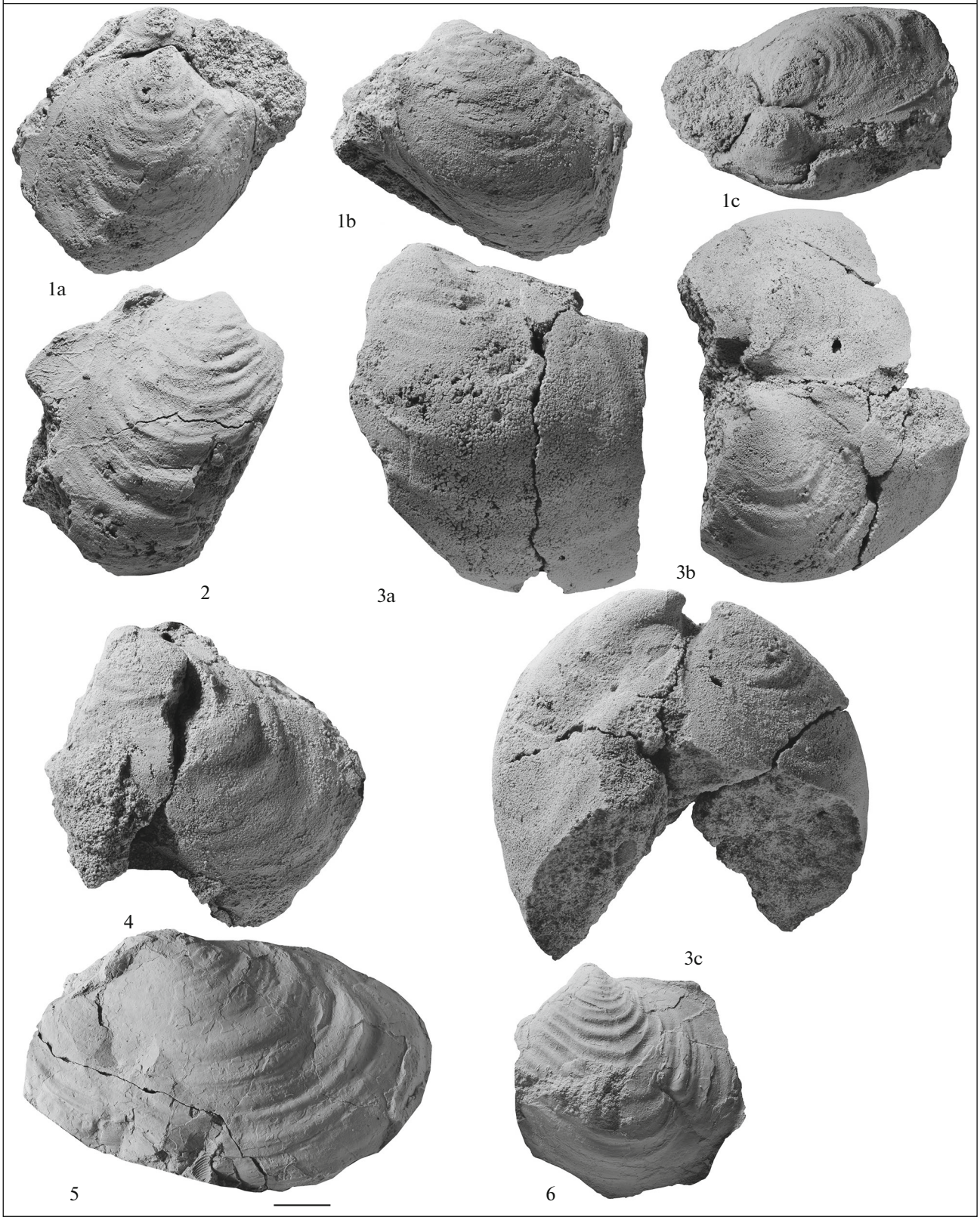
Ammonites: *Anivanovia mola* Kiselev (Plate IV, figs. 1, 2; Plate V, figs. 1, 2; Plate VI, figs. 1, 2), *Volgidiscus singularis* Kiselev (Plate III, figs. 2–5; Plate V, fig. 3).

Occurrence. At present, this biohorizon is known only in two sections of the Chudinovo Formation—in the stratotype (in situ) and near the village of Vasilievskoe (section no. 7(6)) in a landslide terrace. Outside the district, in the outcrops of the Chudinovo Formation, no occurrence of the biohorizon is found in Russia. Outside Russia, the biohorizon is apparently present on the North Sea shelf.

Correlation. The singularis Biohorizon is the upper biohorizon in the Singularis Zone. It is not clear whether or not its equivalents are present in England: it is possible that the singularis Biohorizon corresponds to a gap between the Lamplughi Zone and the basal Ryzanian Runctoni Zone (Casey et al., 1988). Representatives of *Volgidiscus* of the Lamplughi Zone from the Lincolnshire sections to a greater extent maintain the *Subcraspedites* morphotype than *V. singularis*. Characters of this species have runctoni-like aspect; hence, the combination of the ribbing characters in *V. singularis* can be considered as an apomorphy. Specimens from North Sea shelf (Abbink et al.,

Plate VII. (1–4) *Anopaea brachovi* (Rouillier): (1) specimen YarGPU no. Ch6-30, (1a) right valve view, (1b) left valve view, (1c) hingeline view; (2) specimen YarGPU no. Ch6-29, right valve view; (3) specimen YarGPU no. Ch6-7, (3a) left valve view, (3b) hingeline view; (3c) posterior end view; (4) specimen YarGPU no. Ch6-29, left valve view; Rybinsk district, Vasilievskoe village, upper Volgian Substage, Volgidiscus singularis Zone, V. pulcher Biohorizon; (5) *Anopaea* aff. *brachovi* (Rouillier), specimen YarGPU Br24-1, left valve view, upper Volgian Substage, Craspedites okensis Zone, Craspedites (Taimyroceras) originalis Subzone, basin of the Kheta River, Pravaya Boyarka River (Outcrop 24); (6) *Anopaea* aff. *sphenoides* Gerasimov, specimen YarGPU Ch18-1, left valve, upper Volgian Substage, Craspedites taimyrensis Zone, north Eastern Siberia, left bank of the Kheta River, Outcrop 18, 500 m above the mouth of Bukatyi Creek (*Opornyi*..., 1969, p. 61, Fig. 9).

Plate VII



2001, figs. 5A–5I, ?5L, 6M) can more likely be assigned to this species than to the English species of *Volgidiscus*. Accordingly, the singularis Biohorizon can be traced in the Lamplughi Zone of the North Sea shelf (Plate 1).

R e m a r k s. Species of *Volgidiscus* from the singularis Biohorizon possess more pronounced ornamentation than *Volgidiscus* from the underlying pulcher Biohorizon and are more similar to the representatives of the ancestral genus *Subcraspedites* (such as *S. turbinae* (Plate VI, figs. 3–7) or *S. maurynjensis*), which appears to contradict the observed succession of biohorizons. At the same time, the genus *Subcraspedites* and stratigraphic succession of its species are so far insufficiently studied. The data from European Russia show that relatively poorly ornamented species of *Subcraspedites* appeared there as early as the end of the middle Volgian.

BIVALVES OF THE *VOLGIDISCUS SINGULARIS* ZONE

Material

The bivalvian collection is represented by three samples from two sections in the Volgidiscus singularis Zone (nos. 7 (6) and 8). Only six species of bivalves are identified (four species are identified in the binary nomenclature), assigned to five genera: *Anopaea brachovi* (Rouillier) (Plate VII, figs. 1–4), *Camptonectes (Camptonectes) morini* (de Loriol) (Plate VIII, figs. 1–4), *Entolium (Entolium) orbiculare* (J. Sow.) (Plate VIII, figs. 6–7), *Plagiostoma planum* (Roemer) (Plate VIII, fig. 8), *Anopaea* aff. *brachovi* (Plate VII, fig. 5), and *Camptonectes* (*Camptonectes*) sp. ind. (Plate VIII, fig. 5) identified in open nomenclature. The description of two members also mentions *Protocardia* cf. *concinna* (Buch.). Almost all specimens are represented by either molds or imprints. The fossil assemblage also includes the inarticulate brachiopod *Lingula demissa* Geras., which is not represented in our collection.

Taphonomy of Oryctocoenoses and Benthic Community Habitats

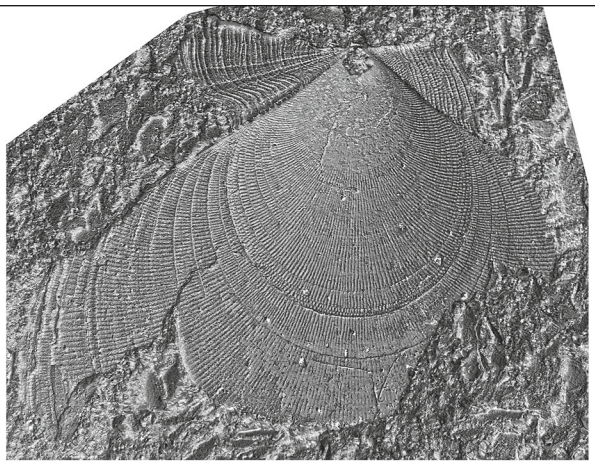
Two burial types are recognized in the sections: scattered isolated valves of *Anopaea* or cemented aggregates up to 100 mm in size composed of fragments of unidentified shells. There are also bivalved specimens of *Anopaea* with the valves open (Plate VII, figs. 1, 3). The sparsely scattered isolated pectinid valves frequently include large *Camptonectes* (up to 80 mm in diameter) with preserved contours (Plate VIII, figs. 3, 4). Small *Entolium* (20–30 mm in diameter) are preserved only as internal molds (Plate VIII, figs. 6, 7). The state of preservation of the complete valves scattered in the bed, infrequent complete specimens, and presence of accumulations of fragments suggest that the burial of hard parts of shells occurred in a high-energy wave environment, in extremely shallow settings with intense influx of siliciclastics from a nearby source area. The benthic communities were dominated by derived byssus suspension feeders: *Anopaea*, *Camptonectes* (*Camptonectes*), *Entolium* (*Entolium*), and *Plagiostoma*. Frequent occurrences of inarticulate brachiopods of the genus *Lingula*, inhabiting the tidal zone of Phanerozoic seas, also suggest an extremely shallow-water environment of accumulation of sedimentary sandy series, inhabited by benthic invertebrates.

Ranges and Paleobiogeography of Taxa

Although the relatively low taxonomic diversity of the benthic community inhabiting the late Volgian (Volgidiscus Chron) sea in the north of the Russian Plate indicates that this sea was connected to the basin of Northwestern Europe, because the studied association includes not only genera but also species of bivalves the same as in East Anglia. Some taxa were widespread in the Arctic. For instance, the range of *Entolium* (*Entolium*) *orbiculare* included almost all of the Northern Hemisphere, including Arctic territories of Siberia (species *E. demissum*; Zakharov, 1966). The pectinid subgenus *Camptonectes* (*Mclearnia*) is widespread in the boreal deposits of the Upper Jurassic and Lower Cretaceous (Zakharov, 1966) and was present in the Volgidiscus lamplughi Zone of England (Kelly, 1984). It could be expected in the Volgidiscus singularis Zone, but this zone in fact contains another subgenus *Camptonectes (Camptonectes)*. It is worth mentioning previously undescribed finds of *Anopaea* aff. *brachovi* (pl. VII, fig. 5) and *A*. aff. *sphenoides* (pl. VII, fig. 6) in the upper Volgian Substage in northern Eastern Siberia. This genus is recorded for the first time in the Arctic. The range of *Plagiostoma planum* is restricted to subboreal territories. This species is unknown in

Plate VIII. (1–4) *Camptonectes (Camptonectes) morini* (de Loriol), Cheryomukha River, Rybinsk district, Yaroslavl oblast, upper Volgian Substage, Chudinovo Fm: (1) specimen YarGPU Ch5-2, (1a) imprint of a right valve, (1b) reversed imprint of the same valve (×3); section no. 6 (5), Bed 1 (21), lower subformation; (2) specimen YarGPU Ch6-10, section no. 7 (6), Bed 1 (21), lower subformation; (3) specimen GIN MK 7428, mold left valve, section no. 7 (6), Bed 4 (24), middle subformation, Volgidiscus singularis Zone, V. pulcher Biohorizon; (4) specimen YarGPU Ch6-28, imprint of the right valve, section no. 7 (6), Bed 1 (21), lower subformation; (5) *Camptonectes (Camptonectes)* sp. ind., specimen YarGPU Ch6-34, mold of the right valve, the same geological age and locality as figs. 2, 4; (6, 7) *Entolium (Entolium) orbiculare* (J. Sowerby), Cheryomukha River, Rybinsk district, Yaroslavl oblast, upper Volgian Substage, Chudinovo Fm, lower subformation: (6) specimen YarGPU Ch5-3, mold of the right valve, section no. 6 (5), Bed 3 (22b); (7) specimen YarGPU no. Ch4-1, mold of an unidentifiable valve, section no. 5 (4), Bed 1 (21); (8) *Plagiostoma planum* (Roemer), specimen YarGPU Ch6-9, mold of the right valve, geological age and locality are the same as for fig. 3.

Plate VIII



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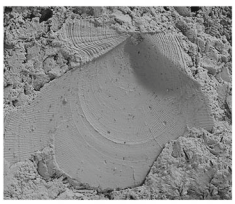

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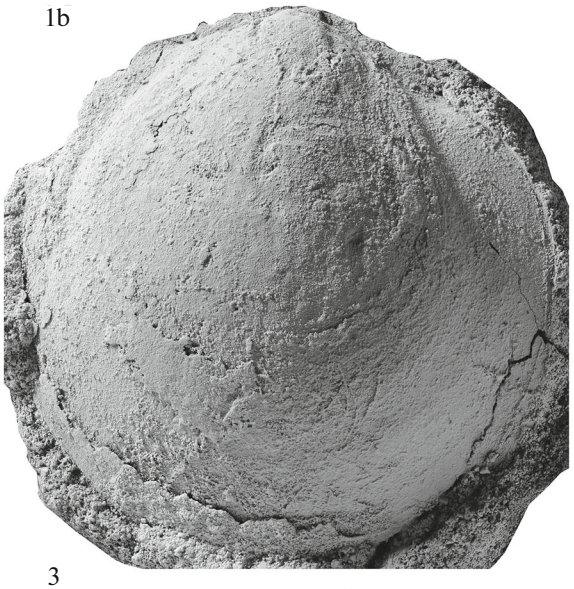

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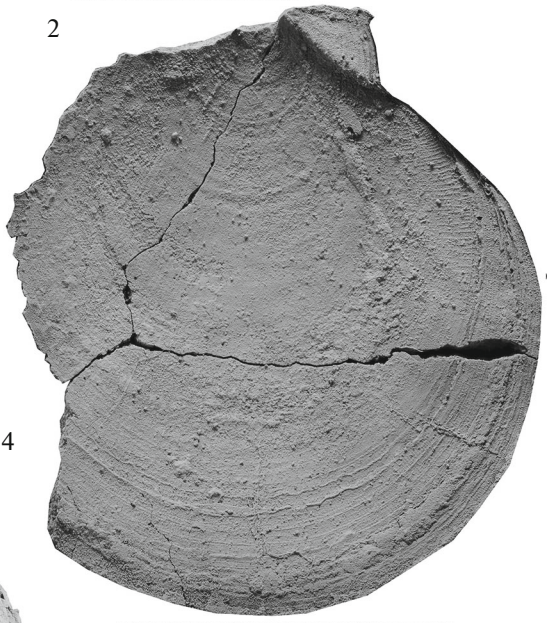

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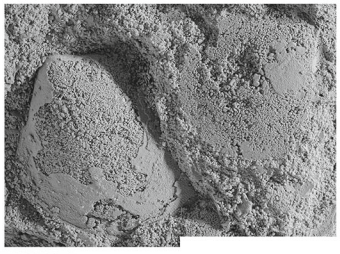

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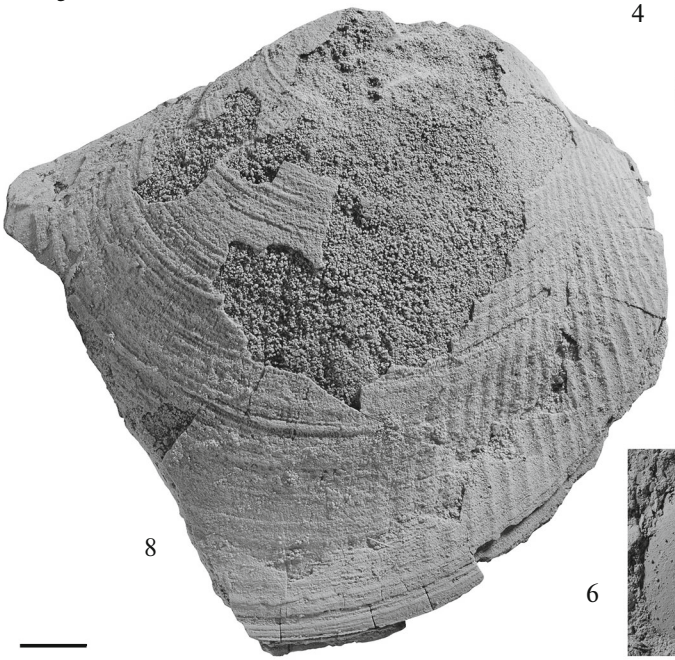

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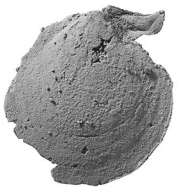

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Table 2. Distribution of bivalve mollusks in zones of the Volgian, Portlandian, Ryazanian stages

	England							European Russia (Cheryomukha)	Subpolar Urals		Northern Siberia (Kheta River basin)	
	Portlandian				Ryazanian							
	Oppressus	Primitivus	Preblicomphalus	Lamplughi	Runctoni	Kochi	Icenii	Singularis	middle Volgian	upper Volgian	Taimyrensis	Chetae
Anopaea sphenoidea Gerasimov, 1955				■								
Anopaea brachovi (Rouillier, 1849)			■	■		■		■			■	■
Parainoceramus golberti Zakharov & Turbina, 1979			■									
Grammatodon (*Grammatodon*) *spilsbiense* Kelly 1984			■									
Dicranodonta vagans (Keeping, 1883)			■									
Musculus (*Musculus*) *fischerianus* (d'Orbigny, 1845)			■									
Falcimytilus suprajurensis (Cox, 1937)			■									
Pinna (*Pinna*) *suprajurensis* (d'Orbigny, 1850)			■									
Pinna (*Pinna*) *subcuneata* Eichwald, 1865–1868			■									
Myophorella (*Myophorella*) *intermedia* (Fahrenkohl, 1844)			■									
Myophorella (*Pseudomyophorella*) *tealbyensis* Lycett, 1875			■									
Codakia crassa (Sowerby, 1827)			■									
Mesomiltha biscathorpensis Kelly, 1992			■									
Discoloripes fischerianus (d'Orbigny, 1845)		■	■	■								
Discoloripes septentrionalis Kelly, 1992				■								
Lyapinella asiatica (Zakharov, 1970)			■	■					■	■		
Pressastarte (*Pinguiastarte*) *pressula* Zakharov, 1970			■									
Nicaniella (*Trautscholdia*) *claxbiensis* (Woods, 1906)			■									
Plagiostoma planum (Roemer, 1839)	■	■					■	■				
Camptonectes (*Camptonectes*) *morini* (de Loriol, 1867)	■							■				
Entolium (*Entolium*) *orbiculare* (J. Sowerby, 1817)	■		■	■				■				
Protocardia cf. *concinna* (Buch, 1844)												

northern Eurasia (Arctic). The selective composition of the association studied is somewhat puzzling, as it lacks many taxa described from the Jurassic–Cretaceous boundary beds of East Anglia (Kelly, 1984, 1992; this paper, Table 2). Especially unusual is the absence in the Volgidiscus singularis Zone of the Boreal genus *Buchia*. However in East Anglia, this genus does not occur in the upper Volgian Substage and the lower part of the Ryazanian Stage, but appears only in its upper part (upper Spilsby member). *Buchia* are also absent in the upper part of the Volgian Stage on the Maurynya River (Subpolar Urals). This is clearly not a local event, as it appears to embrace the entire Boreal-Atlantic (Subboreal) region. It should be noted that the bivalvian association of the Volgidiscus singularis Chron lacks endemic taxa. All these genera and many species in the Volgian and before inhabited the Middle Russian Sea. The sea occupied large areas of the center of the Russian Plate and Timan-Pechora region. The basin was not isolated, so there was no environment facilitating the evolution of endemic taxa.

Stratigraphic Distribution of Bivalves of the Volgidiscus singularis Zone

Four taxa of bivalves are identified to species from two sections in the lower and middle parts of the Chudinovo Formation (nos. 5 and 7), in the upper reaches of the Cheryomukha River: *A. brachovi*, *C.* (*C.*) *morini*, *E.* (*E.*) *orbiculare*, and *P. planum*. Of these, *Anopaea brachovi*, *Camptonectes* (*Camptonectes*) *morini*, and *Plagiostoma planum* (Table 2) have the highest correlation potential. In East Anglia, these species occur in the interval from the Paracraspedites oppressus Zone of the upper part of the middle Volgian Substage to the Hectoroceras kochi and Lynnia icenii zones of the lower part of the Ryazanian Stage (Spilsby sandstone). Outside Europe, in northern Eastern Siberia, the Taimyrensis Zone of the upper Volgian Substage (*Opornyi*..., 1969) contains two species of *Anopaea*: *A.* aff. *brachovi* (Plate VII, fig. 5) and *A.* aff. *sphenoides* (Plate VII, fig. 6).

Considering the stratigraphic significance of the Volgidiscus singularis Zone, it is necessary to indicate two other invertebrate taxa not represented in the studied collection. These are the bivalve *Protocardia* cf. *concinna* (Buch) (Gerasimov, 1969, p. 78), found in the interval from the lower Callovian to the Riasanites rjasanensis Zone of the Ryazanian Stage in many regions of the central part of European Russia, but most commonly in the upper Volgian Substage and the Riasanites rjasanensis Zone, and the inarticulate brachiopod *Lingula demissa* (Geras.), very rare in the Epivirgatites nikitini Zone (topmost middle Volgian Substage) and Craspedites subditus Zone (=Garniericeras catenulatum Zone in this paper, upper Volgian Substage) of Moscow oblast (Gerasimov, 1969, p. 103).

CONCLUSIONS

The upper Volgian Substage of European Russia (similar to other subboreal regions) has a distinct regressive structure. After horizons of the Volgian Stage not confirmed in its type area were found in England, the Subpolar Urals, and Siberia, it became widely accepted that a gap between the Volgian and Ryazanian stages of one or two ammonite zones is present in European Russia. Recently, data have appeared that these deposits contain ammonites characteristic of both the uppermost part of the Volgian Stage and the lower part of the Ryazanian Stage of Siberia, such as *Chetaites*, *Shulginites*, *Craspedites* (*Taimyroceras*), and *Volgidiscus* (Kiselev, 2003; Mitta, 2005; Mitta and Sha, 2011), but most of these finds were redeposited or came from intervals of uncertain stratigraphic position.

Our study of the sections of the upper previously unknown part of the upper Volgian Substage in sections of the basin of the Cheryomukha River (Yaroslavl oblast) containing numerous ammonite and bivalvian occurrences showed that a new ammonite zone, Volgidiscus singularis, can be established here. The zone mainly contains occurrences of *Volgidiscus*, found in association with single *Garniericeras* and *Shulginites*. Two biohorizons can be recognized in this zone, which can be directly correlated with the upper horizon of the upper Volgian Substage of the Subpolar Urals, Northern Siberia, England, and the North and Barents seas. No ammonites were found between the Singularis Zone and Nodiger Zone, but apparently this interval contained an occurrence of *Craspedites* (*Taimyroceras*?) sp. from A.N. Ivanov's collection. It is shown that a biostratigraphically fixed gap between the upper Volgian Singularis Zone and the Ryazanian Stage is absent, which his supported by the correlation with the successions in other regions and the greater similarity of the ammonite fauna of the topmost upper Volgian Substage and lower Ryazanian Stage. The upper part of the upper Volgian Substage and the lower part of the Ryazanian Stage of European Russia are shown to contain *Shulginites*, *Chetaites*, and *Craspedites* (*Taimyroceras*). The assemblage of bivalvian mollusks of the Singularis Zone is very similar to the synchronous fauna of England. The bivalvian assemblage is dominated by *Anopaea*, while *Camptonectes (Camptonectes)*, *Entolium* (*Entolium*), and *Plagiostoma* are slightly less common. It is noteworthy that the Singularis Zone does not contain the bivalvian genus *Buchia*, like the upper Volgian deposits of England. The Volgian–Ryazanian boundary beds in the upper reaches of the Cheryomukha River (Rybinsk district, Yaroslavl oblast) are recognized in the Chudinovo Formation, which includes three subformations.

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REFERENCES

Abbink, O.A., Callomon, J.H., Riding, J.B., et al., Biostratigraphy of Jurassic–Cretaceous boundary strata in the Terschelling Basin, the Netherlands, *Proc. Yorksh. Geol. Soc.*, 2001, vol. 53, no. 4, pp. 275–302.

Alifirov, A.S., Ammonite scale for the Volgian of Western Siberia and its paleontological substantiation, *Stratigr. Geol. Correl.*, 2009, vol. 17, no. 6, pp. 632–644.

Atlas geologicheskikh pamyatnikov Yaroslavskoi oblasti (Atlas of Geological Monuments of the Yaroslavl Region), Kiselev D.N., Eds., Yaroslavl: Yaroslav. Gos. Ped. Univ., 2003 [in Russian].

Casey, R., The ammonites succession at the Jurassic–Cretaceous boundary in East England, *Geol. J.*, 1973, Spec. Iss., vol. 5, pp. 193–266.

Casey, R., Mesezhnikov, M.S., and Shul'gina, N.I., Correlation of the Jurassic-Cretaceous boundary deposits of England, Russian Platform, Subpolar Urals, and Siberia, *Izv. Akad. Nauk SSSR. Ser. Geol.*, 1977, no.7, pp. 14–33.

Casey, R., Mesezhnikov, M.S., and Shul'gina, N.I., Ammonite zones of Jurassic–Cretaceous boundary deposits of the Boreal Realm, *Izv. Akad. Nauk SSSR. Ser. Geol.*, 1988, no. 10, pp. 71–84.

Dzyuba, O.S., Izokh, O.P., and Shurygin, B.N., Carbon isotope excursions in Boreal Jurassic–Cretaceous boundary sections and their correlation potential, *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 2013, vols. 381–382, pp. 33–46.

Gerasimov, P.A., *Verkhnii pod"yarus volzhskogo yarusa tsentral'noi chasti Russkoi platformy* (The Upper Volgian Substage of the Central Part of the Russian Platform), Moscow: Nauka, 1969 [in Russian].

Gol'bert, A.V., Klimova, I.G., Saks, V.N., et al., New data on the Jurassic–Cretaceous boundary beds of the Western Siberia, *Geol. Geofiz.*, 1972, no. 5, pp. 11–17.

Hoedemaeker, P.J. and Herngreen, G.F.W., Correlation of Tethyan and Boreal Berriasian–Barremian strata with emphasis on strata in the subsurface of the Netherlands, *Cretaceous Res.*, 2003, vol. 24, pp. 253–275.

Ivanov, A.N., *Geologicheskie ekskursii po Yaroslavskoi oblasti (Geological Excursions in the Yaroslavl Region)*, Yaroslavl: Yaroslav. Obl. Gos. Izd., 1950 [in Russian].

Ivanov, A.N. and Novskii, V.A., Geological structure and mineral resources, in *Priroda Khoz-vo Yaroslav. Obl. Ch. I*, Yaroslavl: Yaroslav. Kn. Izd., 1959, pp. 38–141.

Kelly, S.R.A., Bivalvia of the Spilsby sandstone and Sandringham sands (Late Jurassic–Early Cretaceous) of Eastern England. Part 1, *Monogr., Palaeontogr. Soc.*, 1984, vol. 137, no. 566.

Kelly, S.R.A., Bivalvia of the Spilsby sandstone and Sandringham sands (Late Jurassic–Early Cretaceous) of Eastern England. Part 2, *Monogr., Palaeontogr. Soc*, 1992, vol. 146, no. 591, pp. 95–125.

Kiselev, D.N., Sel'tso-Voskresenskoe, in *Atlas geologicheskikh pamyatnikov Yaroslavskoi oblasti* (Atlas of Geological Monuments in the Yaroslavl Region), Kiselev, D.N., Eds., Yaroslavl: Yaroslav. Gos. Ped. Univ., 2003, pp. 58–62.

Kiselev, D.N. and Rogov, M.A., Ivanovskoe-Mikhalevo, in *Ob"ekty geologicheskogo naslediya Yaroslavskoi oblasti: stratigrafiya, paleontologiya i paleogeografiya* (Geosites of the Yaroslavl Region: Stratigraphy, Paleontology, and Paleogeography) Kiselev, D.N., Eds., Moscow" Izd. Dom Yustitsinform, 2012 a, pp. 121–125.

Mesezhnikov, M.S. and Braduchan, Yu.V., Detailed stratigraphy of the Jurassic–Cretaceous boundary deposits on the eastern slope of the Sub-Polar Urals, in *Stratigrafiya triasovykh i yurskikh otlozhenii neftegazonosnykh basseinov SSSR* (Stratigraphy of Triassic and Jurassic Deposits of the Oil- and Gas-Bearing Basins of the USSR), Lennigrad: Vseross. Neft. Hauchno-Issled. Geol. Inst., 1982, pp. 88–95.

Mesezhnikov, M.S., Alekseev, S.N., Klimova, I.G., et al., On the development of some Craspeditidae at the Jurassic-Creatceous boundary, in *Mezozoi sovetskoi Arktiki* (Mesozoic of the Soviet Arctic), Zakharov, V.A. and Nalnjaeva, T.I., Eds., *Tr. Inst. Geol. Geofiz. Sib. Otd. Akad. Nauk SSSR*, vol. 555, Novosibirsk: Nauka, 1983, pp. 103–124.

Mesezhnikov, M.S., Zakharov, V.A., Braduchan, Yu.V., et al., Zonal subdivision of the Upper Jurassic deposits of the Western Siberia, *Geol. Geofiz.*, 1984, no. 8, pp. 40–52.

Mitta, V.V., New data on age of the Ryazanian Stage base, *Stratigr. Geol. Korrel.*, 2005, vol. 13, no. 5, pp. 51–59.

Mitta, V.V., Late Volgian *Kachpurites* Spath (Craspeditidae, Ammonoidea) of the Russian platform, *Paleontol. J.*, 2010, vol. 44, no. 6, pp. 622–631.

Mitta, V.V. and Sha, J., Ammonite distribution across the Jurassic–Cretaceous boundary in Central Russia, *Paleontol. J.*, 2011, vol. 45, no. 4, pp. 379–389.

Opornyi razrez verkhneyurskikh otlozhenii basseina r. Khety (Khatangskaya vpadina) (Reference Section of Upper Jurassic Deposits of the Kheta River Basin (Khatanga Basin)), Leningrad: Nauka, 1969 [in Russian].

Reshenie 6-go Mezhvedomstvennogo stratigraficheskogo soveshchaniya po rassmotreniyu i prinyatiyu utochnennykh stratigraficheskikh skhem mezozoiskikh otlozhenii Zapadnoi Sibiri, Novosibirsk, 2003 g. (Resolution of the 6th Interdepart. Stratigr. Conf.on Consideration and Approval of Improved Stratigraphic Charts for the Mesozoic Deposits of West Siberia, Novosibirsk, 2003)), Novosibirsk: Sib. Nauchno-Izdat. Tsentr Ob"ed. Inst. Geol. Geofiz. Miner. Sib. Otd. Ross. Akad. Nauk, 2004 [in Russian].

Rogov, M. and Zakharov, V., Ammonite- and bivalve-based biostratigraphy and Panboreal correlation of the Volgian Stage, *Science in China. Ser. D. Earth Sci.*, 2009, vol. 52, no. 12, pp. 1890–1909.

Rogov, M.A., Kiselev, D.N., Gulyaev, D.B., New data on Craspedites nodiger Zone (Upper Volgian sub-Stage) of the Yaroslavl Region, *Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii. Chetvertoe Vserossiiskoe soveshchanie, 26-30 sentyabrya 2011 g., Sankt-Peterburg* (Jurassic of Russia: Problems of Stratigraphy and Paleogeography. Proc. Fourth All-Russ. Conf., St. Petersburg, September 26–30, 2011), Zakharov, V.A., Ed., St. Petersburg: OOO Izd. LEMA, 2011, pp. 183–185.

Rogov, M.A., Gulyaev, D.B., Kiselev, D.N., Biohorizons as infrazonal biostratigraphic units: An attempt to refine the Jurassic stratigraphy based on ammonites, *Stratigr. Geol. Correl.*, 2012, vol. 20, no. 2, pp. 211–229.

Rogov, M.A., Baraboshkin, E.Yu., Guzhikov, A.Yu., et al., *Granitsa yury i mela v Srednem Povolzh'e. Putevoditel' ekskursii "Mezhdunarodnaya nauchnaya konferentsiya po probleme granitsy yurskoi i melovoi sistem, 7-13 sentyabrya 2015 g., g. Samara (Rossiya)"* (Jurassic-Cretaceous Boundary in the Middle Volga Region. Guidebook of Excursion "International Scientific Conference on the Jurassic-Cretaceous Boundary, September 7–13, 2015 (Samara, Russia)), Samara: FGOBU VO Samar. Gos. Techn. Univ., 2015 [in Russian].

Rogov, M.A., Ammonites and infrazonal stratigraphy of the Kimmeridgian and Volgian Stages of southern part of the Moscow Syneclise, in *Tr. GIN* (Trans. Geol. Inst.), 2017, vol. 615, pp. 7–160.

Shkolin, A.A. and Rogov, M.A., Jurassic and Lower Cretaceous ammonites from glacial boulders of the Yaroslavl Volga area, in *Ob"ekty geologicheskogo naslediya Yaroslavskoi oblasti: stratigrafiya, paleontologiya i paleogeografiya* (Geosites of the Yaroslavl Region: Stratigraphy, Paleontology, and Paleogeography), Kiselev, D.N., et el., Ed., Moscow: ZAO Izd. Dom Yustitsinform, 2012, pp. 187–189.

Shurygin, B.N., Nikitenko, B.L., Devyatov, V.P., et al., *Stratigrafiya neftegazonosnykh basseinov Sibiri. Yurskaya sistema (Stratigraphy of Oil-and-Gas Basins of Siberia. Jurassic System)*, Novosibirsk: Izd. Sib. Otd. Ross. Akad. Nauk, Fil. GEO, 2000 [in Russian].

Stratigraficheskii kodeks Rossii. Izd. tret'e (Stratigraphic Code of Russia, the 3rd ed.), St. Petersburg: Vseross. Nauchno-Issled. Geol.Inst., 2006 [in Russian].

Vyachkileva, N.P., Klimova, I.G., Turbina, A.S., et al., *Atlas mollyuskov i foraminifer morskikh otlozhenii verkhnei yury i neokoma Zapadno-Sibirskoi neftegazonosnoi oblasti. Tom I. Stratigraficheskii ocherk. Mollyuski* (Atlas of Mollusks and Foraminifers from Marine Upper Jurassic and Neocomian Sediments of the West Siberian Petroliferous Region. Vol. I. Stratigraphic Review. Mollusks), Moscow: Nedra, 1990 [in Russian].

Zakharov, V.A., *Pozdneyurskie i rannemelovye dvustvorchatye mollyuski severa Sibiri i usloviya ikh sushchestvovaniya. Otryad Anisomyaria* (Late Jurassic and Early Cretaceous Bivalve Mollusks of Northern Siberia (Order Anisomyaria)), Moscow: Nauka, 1966 [in Russian].

Zakharov, V.A., and Rogov, M.A., The upper Volgian Substage in Northeast Siberia (Nordvik Peninsula) and its Panboreal correlation based on ammonites, *Stratigr. Geol. Correl.*, 2008, vol. 16, no. 4, pp. 423–436.

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