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Radiolarians from Upper Jurassic (Middle Oxfordian and Upper Kimmeridgian) Deposits of Yaroslavl Oblast

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Abstract—The middle Oxfordian and late Kimmeridgian radiolarian assemblages from Upper Jurassic deposits of Yaroslavl oblast are studied for the first time. The middle Oxfordian assemblage is dominated by stauraxonic morphotypes of genera *Paronaella* and *Pseudocrucella* occurring in association with discoid forms. Nassellarian radiolarians are very rare in this assemblage of extremely low taxonomic diversity, which is lacking spheroidal morphotypes. The late Kimmeridgian assemblage is more diverse in morphological and taxonomic aspects. It includes spheroidal forms, those of the family Pantanelliidae Pessagno inclusive, and more frequent nassellarian species, but stauraxonic radiolarians are less abundant in its composition. This assemblage is comparable to a considerable extent with the Kimmeridgian radiolarians from Moscow oblast, being of the South Boreal type according to its composition.

Keywords: radiolarians, Upper Jurassic, phosphorites, Oxfordian, Kimmeridgian

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INTRODUCTION

Gerasimov (1969) and Kozlova (1973) reported in their works the occurrence of radiolarians in Jurassic deposits of the Russian plate central part, but the found assemblages of these microfossils are described in detail only in a few works (e.g., Bragin, 1997). At the same time, the respective data are of great interest for stratigraphy and paleobiogeography of the Boreal Upper Jurassic. As a planktonic group of microfossils, radiolarians provide broad interregional correlations and can be used simultaneously as indicators of sedimentation environments. In the case of Boreal Jurassic deposits, however, we should study first of all the distribution trends of these microfossils in the Upper Jurassic reference sections based on well-preserved specimens characterizing taxonomic compositions of radiolarian assemblages as completely as possible. This work is dedicated to radiolarian assemblages first found in the Upper Jurassic reference sections of Yaroslavl oblast.

MATERIALS AND METHODS

We collected material for this work during the fieldwork of 2007 in Yaroslavl oblast, where the objects of prime importance to us were the Upper Jurassic successions of clay beds bearing phosphorite nodules. Radiolarians frequently occurring in Jurassic clays are poorly preserved as a rule and unsuitable for investigation therefore. On the other hand, radiolarians from phosphorite nodules are usually preserved much better, being suitable for examination even if their skeletons are replaced by secondary minerals (e.g., by pyrite, glauconite, and limonite sometimes). Precisely in nodules of this kind, the Jurassic radiolarians of the Russian plate were reliably identified for the first time (Khudyaev, 1931). Of course, not all the phosphorite nodules yield desirable microfossils. For instance, sandy phosphorite nodules abundant in sands of the Volgian Stage near the village of Glebovo are barren of radiolarians, and nodules of argillaceous phosphorite always promise greater success.

Taking the above preamble into account, we purposefully collected the argillaceous phosphorite nodules from the reference section of the Oxfordian stage and from basal conglomerate of the Volgian stage containing the redeposited Kimmeridgian phosphorite. In the laboratory, phosphorite samples were treated first in concentrated (20–30%) nitric acid for 20 min. The residual fractions after leaching were washed in water and subsequently dried and were studied under a LOMO MBS-9 optical microscope. Radiolarian specimens picked up by hand and mounted on slides were finally examined and photographed under a Tescan 2300

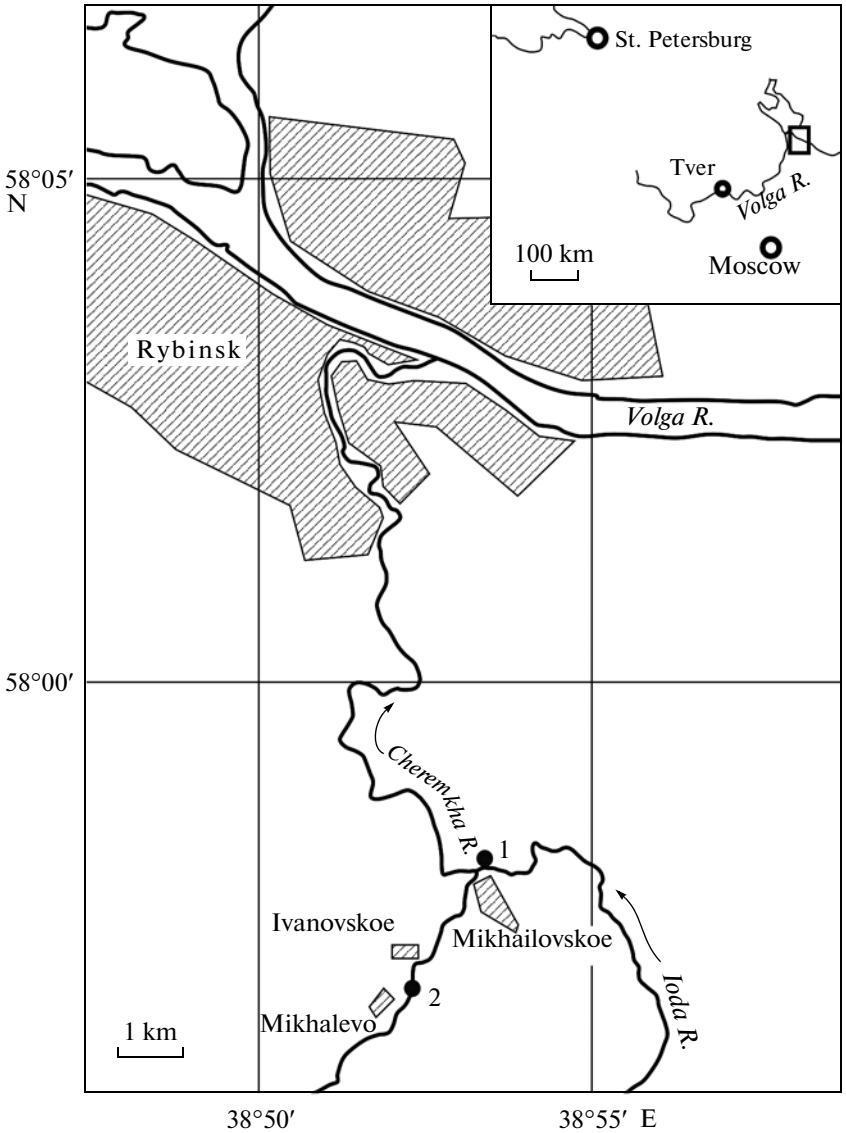

Fig. 1. Localities of the Jurassic reference sections studied in the Cheremkha River basin (Rybinsk district, Yaroslavl oblast): (1) section of the Callovian, Oxfordian, and Kimmeridgian deposits exposed along the Ioda River; (2) section of the Kimmeridgian and Volgian deposits exposed along the Cheremkha River between the villages of Ivanovskoe and Mikhalevo.

scanning electron microscope at the Geological Institute of the Russian Academy of Sciences, Moscow.

DESCRIPTION OF PLACES OF OCCURRENCE AND RADIOLARIAN ASSEMBLAGES

We identified radiolarians from two localities: from the Middle–Upper Jurassic (Callovian–Kimmeridgian) section of the Ioda River and from the Upper Jurassic (Kimmeridgian–Volgian) section of the Cheremkha River that was sampled between the villages of Ivanovskoe and Mikhalevo (Fig. 1). In the Ioda River section, radiolarians are confined to the middle Oxfordian deposits. In Yaroslavl oblast, this section is the reference one for Jurassic stratigraphy. Being situated in the Rybinsk district, the section is exposed on the right bank of the Ioda River 50 m downstream of the bridge on the Rybinsk–Mikhailovskoe highway crossing the river. The section structure (Fig. 2) is as follows (Kiselev et al., 2003):

CALLOVIAN STAGE

Middle Substage

Kosmoceras jason Zone

1. Clay, dark gray, compact, unlaminated, calcareous, containing pyrite and marcasite nodules that

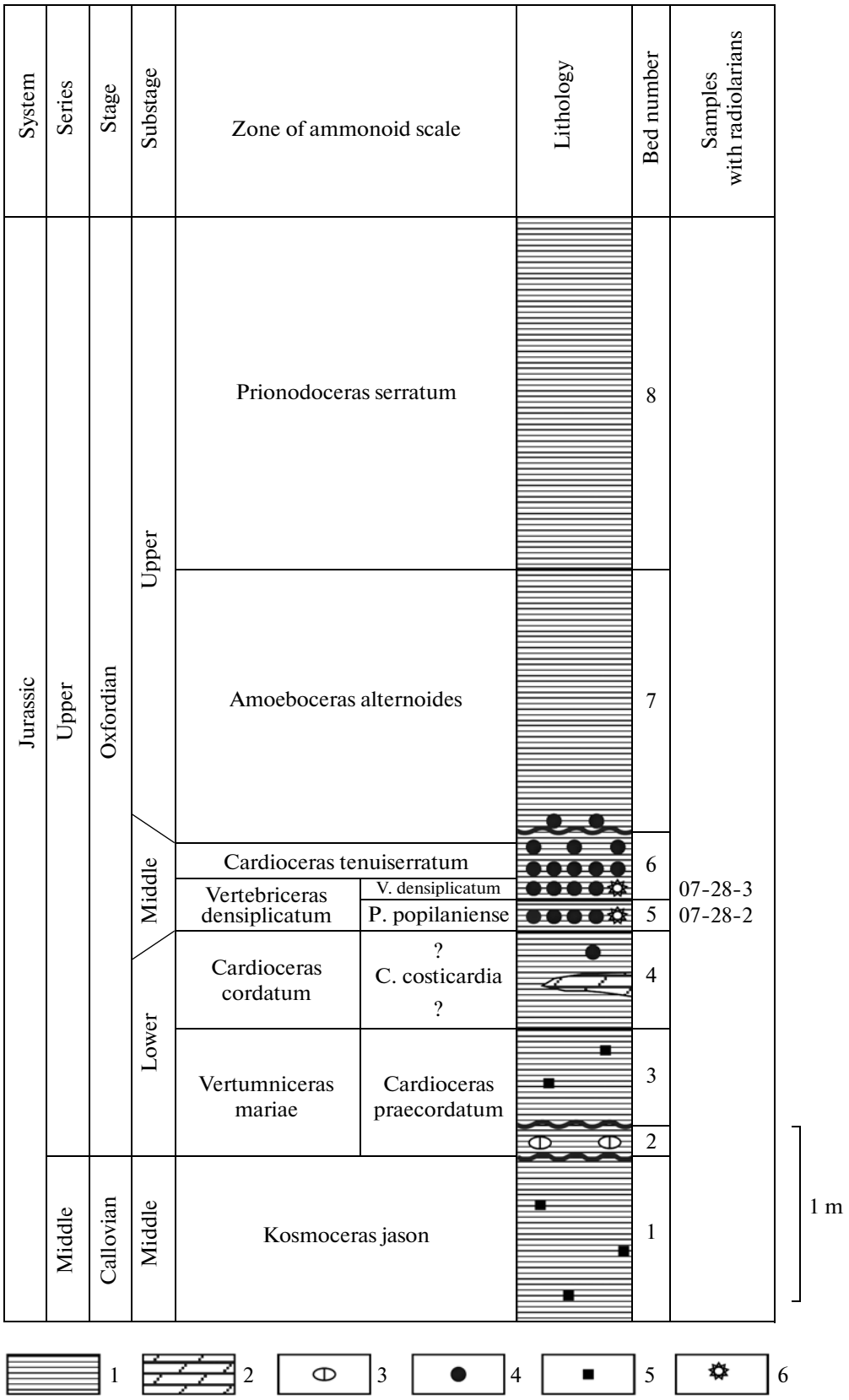

Fig. 2. Stratigraphic column of the Middle–Upper Jurassic deposits studied at the Ioda River and occurrence levels of samples bearing radiolarians: (1) clay; (2) argillaceous limestone; (3) marl nodules; (4) phosphorite nodules; (5) pyrite and marcasite nodules; (6) samples with radiolarians.

yield ammonites of the *Kosmoceras* (*Gulielmites*) *jason* (Rein.) assemblage; apparent thickness of the bed is less than 1.5–1.8 m.

OXFORDIAN STAGE

Lower Substage

Vertumniceras mariae Zone

Cardioceras praecordatum Subzone

2. Clay, dark gray, compact, unlaminated, containing ferruginated ooliths and small nut-shaped nodules of phosphatized oolitic marl, which yield ammonites *Kosmoceras* (*Lobokosmoceras*) cf. *kuklikum* Buckman; thickness of the bed is up to 0.2 m.

3. Clay, dark gray, compact, unlaminated, calcareous, containing pyrite and marcasite nodules and ammonites *Cardioceras* (*Scarburgiceras*) *praecordatum* Douv. and others; thickness of the bed is up to 0.6 m.

Cardioceras cordatum Zone

Cardioceras costicardia Subzone

4. Clay, yellowish to ochreous, with ash gray clay veinlets that are most abundant near the bed top. In the middle part of the bed, clay locally grades into yellowish, poorly cemented marl or argillaceous limestone. Rare and small nodules of clayey phosphorite contain ammonites *Cardioceras* cf. *cordatum* (Sow.), *C.* (*C.*) *costicardia* Buckman and others; the bed is 0.65 m thick.

Middle Substage

Vertebriceras densiplicatum Zone

Plasmatoceras popilaniense Subzone

5. Clay, light colored, ash gray to brownish, calcareous and micaceous, unlaminated, containing small abundant nodules of clayey phosphorite and ammonites *Vertebriceras vertebrale* (Sow.), *Plasmatoceras* spp., and others. Radiolarians occurring in phosphorite nodules are represented by the following taxa: *Paronaella* sp. aff. *P. broennimanni* Pessagno, *P.* sp. aff. *P. obesa* (Yang), *P.* sp., *Pseudocrucella ehrenbergii* Hull, *Homoeoparonaella* sp., Spongodiscoidea gen. et sp. indet., and *Praeparvicingula* sp. The bed is 0.2 m thick.

Middle Substage–Lower Part of the Upper Substage

Vertebriceras densiplicatum,
Cardioceras tenuiserratum,
and Amoeboceras alternoides zones

6. Clay, yellowish brown, silty, dolomitized, containing nodules of phosphatized and dolomitized marl frequently displaying the layered structure of stromatolitic type presumably. Small, pale-colored phosphorite nodules very abundant in the bed are often surrounded by concentric laminae of yellowish green glauconitic clay. Ammonites *Vertebriceras densiplicatum* (Boden) occur in the lower 0.05-m-thick interval of the bed. The higher interval 0.3 m thick yields ammonite species *Cardioceras* (*Miticardioceras*) *tenuiserratum* (Opp.), while specimens of *Amoeboceras glosense* (Young et Bird) are confined to the upper part that is 0.1 m thick. Radiolarian assemblage identical to that from the overlying bed was found in the lower part. Total thickness of the bed is 0.45 m.

Upper Substage

Amoeboceras alternoides Zone

7. Clay, black, micaceous, pyritized, thin-laminated, bioturbated, containing small phosphorite nodules at the bed base. The bed yields ammonites *Amoeboceras alternoides* (Nik.). Its thickness is 1.5 m.

Prionodoceras serratum Zone

8. Clay, black, micaceous, pyritized, thin-laminated, lacking bioturbation marks and bearing ammonites *Prionodoceras serratum* (Sow.) and others. Apparent thickness of the bed is up to 2 m.

The middle Oxfordian radiolarian assemblage from the Ioda River section (Plate I) is dominated by stauraxonic morphotypes of genera *Paronaella* and *Pseudocrucella* occurring in association with discoid forms. Nassellarians are very rare in this assemblage, which is of low taxonomic diversity in general and completely deprived of spheroidal morphotypes. Species representing the genus *Paronaella* are *Paronaella* sp. aff. *P. broennimanni* Pessagno, *P.* sp. aff. *P. obesa* (Yang), and *P.* sp. The first of these taxa is comparable with *Paronaella broennimanni* Pessagno described from the upper Kimmeridgian–Tithonian deposits of California (Pessagno, 1977). In the Tethyan Realm, the same species is widespread in the Bajocian–Kimmeridgian interval (Baumgartner et al., 1995). In contrast to typical Tethyan species, radiolarians discovered in the studied section have shorter and more massive arms. Species *P. obesa* (Yang) described from the Tithonian of Mexico (Yang, 1993) is also known from California (Hull, 1997). We should note that comparable massive morphotypes of the genus *Paronaella* are generally widespread in Jurassic deposits. For instance, the very close species *Paronaella corpulenta* De Wever is characteristic of the Lower Jurassic strata (De Wever, 1981; Gorican et al., 2006). One more species *Pseudocrucella ehrenbergii* Hull described from the middle Oxfordian of California (Hull, 1997) can be of interest for stratigraphic correlation after investigation in detail of its stratigraphic and paleogeographic distribution. The other forms identified in this

Plate I

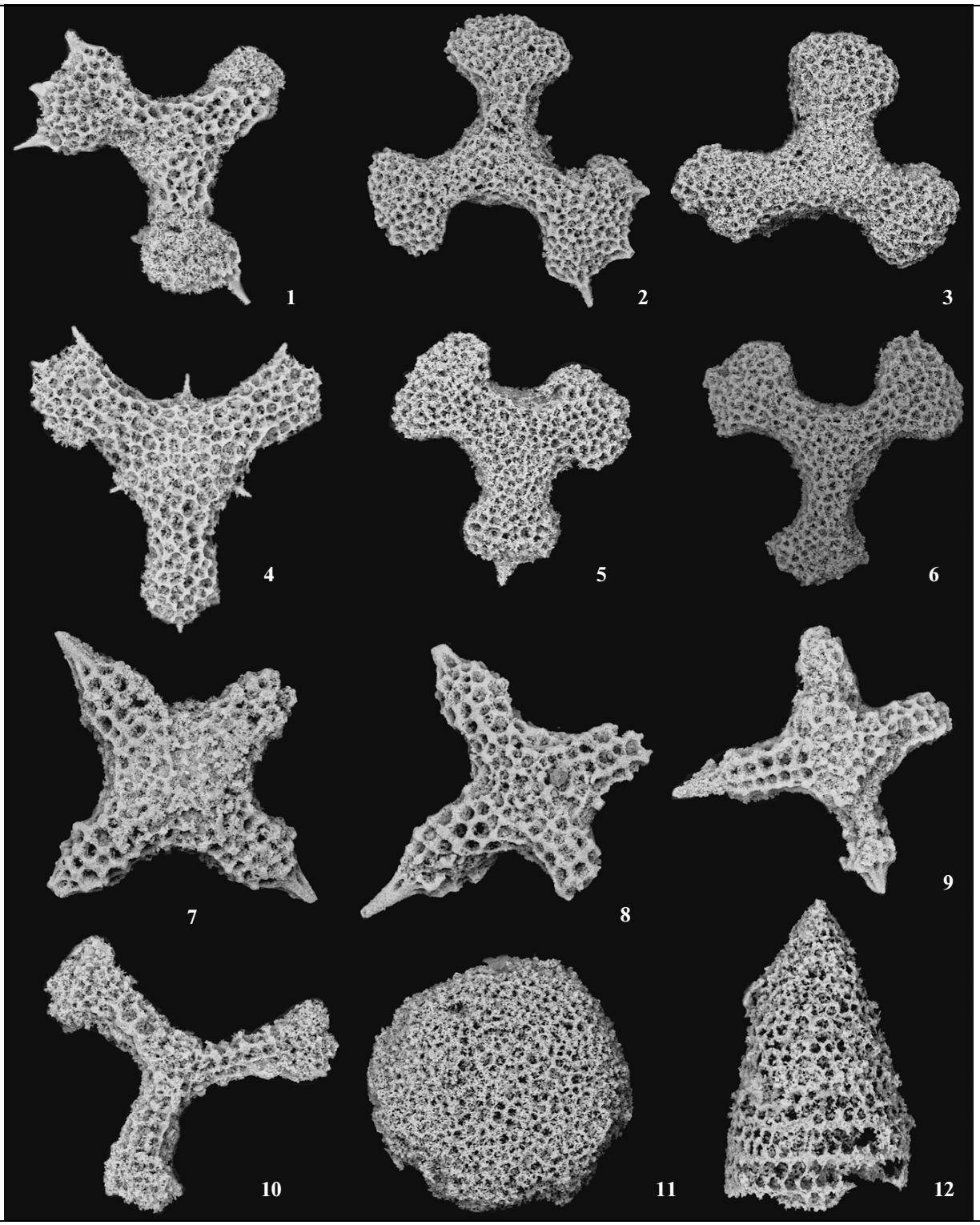

Plate I. Middle Oxfordian radiolarians sampled from the Ioda River section:
(1, 2) *Paronaella* sp. aff. *P. broennimanni* Pessagno, ×150 (both specimens); (3, 5, 6) *Paronaella* sp. aff. *P. obesa* (Yang), ×150 (all specimens); (4) *Paronaella* sp., ×180; (7–9) *Pseudocrucella ehrenbergii* Hull: (7, 8) ×170, (9) ×150; (10) *Homoeoparonaella* sp., ×150; (11) Spongodiscoidea gen. et sp. indet., ×200; (12) *Praeparvicingula* sp., ×275.

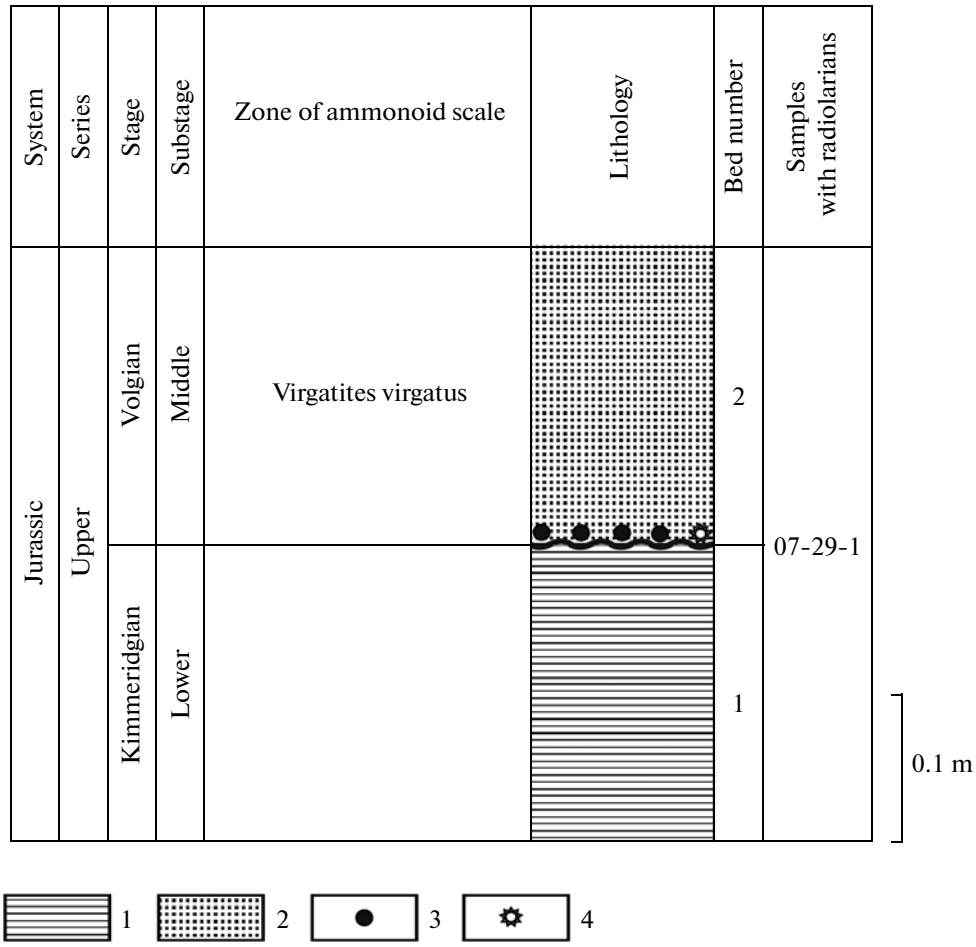

Fig. 3. Stratigraphic column of the Upper Jurassic deposits studied between the villages of Ivanovskoe and Mikhalevo at the Cheremkha River and occurrence levels of samples bearing radiolarians: (1) clay; (2) sand; (3) phosphorite nodules; (4) sample with radiolarians.

work at the generic or superfamily ranks are *Homoeoparonaella* sp., Spongodiscoidea gen. et sp. indet., and *Praeparvicingula* sp. The impoverished taxonomic composition of the assemblage most likely characterizes its boreal origin. It is remarkable that the Mesozoic radiolarian assemblages typical of the boreal regions include characteristic species and genera of the high-latitudinal, sometimes bipolar distribution (e.g., this is *Praeparvicingula* sp. from the assemblage under consideration) along with a certain amount of species of very wide paleogeographic distribution, which are known from both the Boreal and Tethyan realms and represent cosmopolitan taxa, as is suggested in (Bragin, 1997, 2011). It should be noted as well that the middle Oxfordian assemblage in question is even less diverse in taxonomic aspect than the other boreal assemblages of Jurassic radiolarians studied and described earlier. Seeking to explain this fact, we can assume that it exemplifies the earliest assemblage among the other radiolarian assemblages known from Jurassic deposits in central regions of the Russian plate. If colonization of the respective epicontinental basin by radiolarians commenced in the middle Oxfordian time, then it would be reasonable to regard the studied assemblage as representing a pioneer radiolarian community. Nevertheless, it is impossible for the time being to insist on this postulate, and we should seek and study additional materials characterizing the middle Oxfordian radiolarians from other regions of the Russian plate. It is necessary as well to analyze the possible connection between the appearance of radiolarians in the Jurassic epicontinental sea and global climatic warming of the middle Oxfordian time (Abbink et al., 2001; Brigaud et al., 2008; Gruszczynnski, 1998).

The section of the Upper Jurassic deposits exposed along the Cheremkha River between the villages of Ivanovskoe and Mikhalevo (Fig. 3) has the following structure (Kiselev et al., 2003):

KIMMERIDGIAN STAGE

Lower Substage

1. Clay, black, micaceous, with fine horizontal lamination, containing ammonites *Amoeboceras (Amoebites)* ex gr. *kitchini* (Salf.); apparent thickness of the bed is 0.2 m.

VOLGIAN STAGE

Middle Substage

Virgatites virgatus Zone

2. Sandstone, medium-grained, black, phosphatized, bearing ammonites *Virgatites virgatus* (Buch.). At the bed base, there is a horizon of small (up to 0.5 cm in diameter) redeposited phosphorite nodules colored black and sporadically containing casts and molds of the late Kimmeridgian ammonites. The radiolarian assemblage macerated from the nodules consists of the following taxa: *Thecosphaera* (?) sp. A., *Archaeocenosphaera* sp., *Pantanellium tierrablancaense* Pessagno et MacLeod, *P. meraceibaense* Pessagno et MacLeod, *Crucella* sp., Spongodiscoidea gen. et sp. indet., and *Praeparvicingula* sp. cf. *P. donnae* Bragin. The bed is up to 0.2 m thick.

The late Kimmeridgian radiolarian assemblage from the Cheremkha River section (Plate II) is slightly more diverse in terms of morphology and taxonomy of microfossils than the middle Oxfordian one. In composition of the late Kimmeridgian assemblage, we identified spheroidal morphotypes, the representatives of the family Pantanelliidae Pessagno inclusive, and more frequent nassellarians, but stauraxonic radiolarians are less abundant here. Several species of the assemblage are certainly of interest for stratigraphy. For instance, there is *Pantanellium meraceibaense* Pessagno et MacLeod described from the lower part of the upper Kimmeridgian in Mexico (Pessagno et al., 1987) and found later in concurrent strata of California (Hull, 1997) and Moscow oblast (Bragin, 1997). Species *Pantanellium tierrablancaense* Pessagno et MacLeod is known from the Tithonian of Mexico (Pessagno et al., 1987; Hull, 1997) and from the upper Kimmeridgian of Moscow oblast (Bragin, 1997). In addition, some radiolarians of the assemblage are morphologically close to *Praeparvicingula donnae* Bragin described from the upper Kimmeridgian of the latter region (Bragin, 1997). The other specimens are identifiable only at the generic or family ranks. In general, the assemblage is compositionally comparable with the Kimmeridgian radiolarian assemblage from Moscow oblast (Bragin, 1997), where it was similarly found in phosphorite pebbles from basal conglomerate of the Volgian Stage.

According to its composition, the described assemblage is of the so-called South Boreal type (Pessagno and Blome, 1986; Pessagno et al., 1987, 1993; Hull et al., 1997). As is shown in the cited works, the Late Jurassic radiolarians are known from the following paleobiochores: the Tethyan realm subdivided into the central, southern, and northern Tethyan provinces, the Boreal realm comprising the southern and northern Boreal provinces, and the Austral realm with the northern and southern Austral provinces. These paleobiochores were distinguished on the basis of the geographic distribution of radiolarian index taxa, in particular, of the family Pantanelliidae and genera *Parvicingula* and *Praeparvicingula*. As was substantiated in the works mentioned above, pantanelliids are widespread throughout the Tethyan realm and penetrate into the southern Boreal and northern Austral provinces, whereas genera *Parvicingula* and *Praeparvicingula* do not occur in the central Tethyan province. Later, Kiessling (1999), who studied the Late Jurassic radiolarians of the Antarctic Peninsula, established a wider distribution of pantanelliids in the Austral realm and argued for revision of the original scheme characterizing the paleobiogeographic distribution of Late Jurassic radiolarian communities. In the Northern Hemisphere however, the original scheme suggested by Pessagno et al. (1987) has been confirmed in recent work dedicated to radiolarians of the Volgian Stage from the Nordvik Peninsula (the north of Central Siberia), where parvicingulids are widespread, whereas pantanelliids are absent (Bragin, 2011). It should be noted in addition that, following the tradition of Russian publications (Zakharov et al., 2003; Zakharov, 2005), we prefer using the term "region" instead of "province," as it corresponds to paleobiochores of a higher rank.

Pantanelliids are certainly characteristic taxa of the studied assemblage, and the identified forms belong to the morphophylogenetic group *Pantanellium meraceibaense* that is characteristic, as has been shown, precisely of the southern Boreal region. Parvicingulids of the genus *Praeparvicingula* belong to the next group of identified radiolarians, which substantiates the South Boreal type of the Kimmeridgian radiolarian assemblage from the Cheremkha River section.

CONCLUSIONS

(1) Representative radiolarian assemblages of the middle Oxfordian and late Kimmeridgian are discovered for the first time in the Upper Jurassic reference sections of Yaroslavl oblast.

(2) The middle Oxfordian assemblage of low taxonomic diversity is dominated by radiolarians of genera *Paronaella* and *Pseudocrucella*. This assemblage of the Boreal type most likely can be regarded as characterizing the onset of colonization by radiolarians of the Jurassic epicontinental sea in the Russian plate.

(3) The late Kimmeridgian assemblage is distinctly of the South Boreal type, which is evident from joint occurrence of pantanelliids belonging to the morphophylogenetic group *Pantanellium meraceibaense* and parvicingulids of the genus *Praeparvicingula*. Species

Plate II

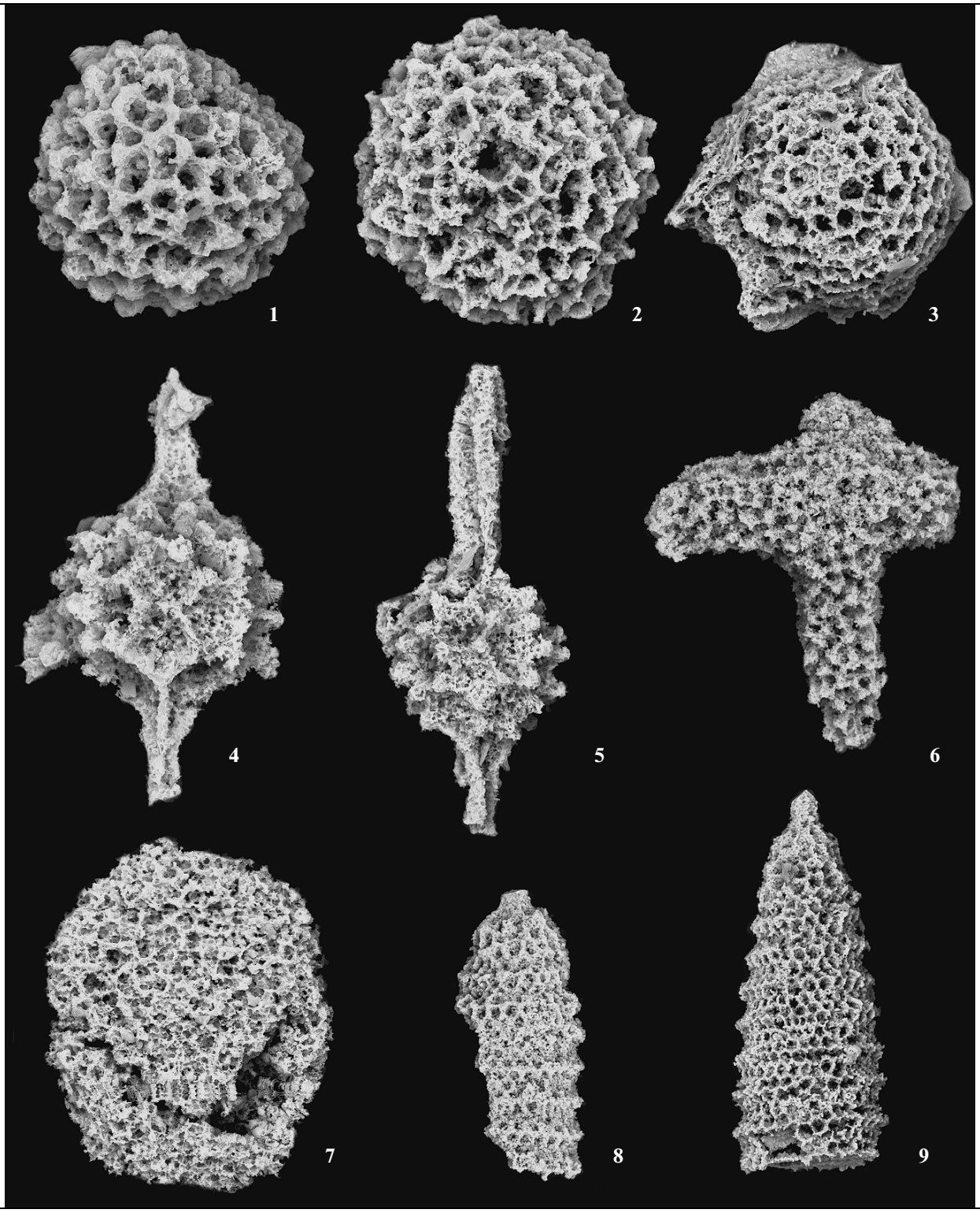

Plate II. Kimmeridgian radiolarians sampled from the Cheremkha River section between the villages of Ivanovskoe and Mikhalevo:
(1, 2) *Thecosphaera* (?) sp. A., ×320 (both specimens); (3) *Archaeocenosphaera* sp., ×250; (4) *Pantanellium tierrablancaense* Pessagno et MacLeod, ×340; (5) *Pantanellium meraceibaense* Pessagno et MacLeod, ×260; (6) *Crucella* sp., ×170; (7) Spongodiscoidea gen. et sp. indet., ×330; (8, 9) *Praeparvicingula* sp. cf. *P. donnae* Bragin, ×180 (both specimens).

P. meraceibaense present in the assemblage offers the possibility of correlating the upper Kimmeridgian strata in central regions of the Russian plate with concurrent deposits of Mexico and California.

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