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New Data on Biostratigraphy of the Volgian Stage Lectostratotype near the Gorodishche Village (Middle Volga Region)

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Abstract—A thorough revision of the lectostratotype of the Volgian Stage near the Gorodishche Village (Ul'yanovsk region) and neighboring section of the upper Kimmeridgian–lower Volgian (Dubki Village) revealed the radiolarian assemblage with *Parvicingula jonesi* corresponding to the *cymodoce* and *eudoxus* ammonite zones. The radiolarian assemblage from the lower Volgian *klimovi* ammonite zone is dominated by *Parvicingula blowi*. Representatives of the genus *Parvicingula* prevail also in the *sokolovi* and *pseudoscythica* zones. The uppermost middle Volgian *Zarajskites zarajskensis* Zone and the *Dorsoplanites panderi* Zone contain the diverse radiolarian assemblage with *Parvicingula haeckeli*. The late Volgian radiolarian assemblage from the *subditus* ammonite zone includes abundant *Stichocapsa devorata* and is close to that from coeval sediments of the North Sea. In contrast to Kimmeridgian–Tithonian radiolarian assemblages of the Caucasus, the studied assemblages are of the boreal type. The *Virgatites gerassimovi* Zone is established and the scope of the *Virgatites virgatus* and *Epivirgatites nikitini* zones of the middle Volgian Substage is specified. The upper Volgian *Kachpurites fulgens* Zone is subdivided into subzones. The thorough study of the phosphorite horizon at the boundary between Volgian and Hauterivian stages did not confirm the presence of the upper Berriasian and lower Valanginian fossils even in the redeposited state.

Key words: Kimmeridgian and Volgian stages, Volga region, zone, condensed section, ammonites, radiolarians.

INTRODUCTION

Recently, Volgian and Kimmeridgian bituminous beds of the Volga region attracted a special attention (*Tsentral'nye raiony*..., 1984; Bukina *et al.*, 1987; Kuleva *et al.*, 1992, 1996; Vishnevskaya, 1998; Baudin *et al.*, 1996; Sedaeva and Vishnevskaya, 1995; Hantzpergue *et al.*, 1998; Turov, 1998).

Similar bituminous Upper Jurassic rocks are well known along the Uralian margin of the Barents Sea–Pechora depression (combustible shales), in West Siberia, where they are main constituents of the Bazhenovo productive horizon (Braduchan *et al.*, 1986, 1989; Kozlova, 1971, 1994), and from the North Sea (Dyer and Copestake, 1989). Of a great interest is a problem of the origin of the Volgian shaly sequence, as well as a problem of stratigraphic correlation of the Boreal Volgian Stage with its counterparts in the Tethyan province.

Nikitin (1881) was first to distinguish the Volgian Stage, and lectostratotype of the stage was selected by Gerasimov and Mikhailov (1966). It was considered for a long time that the Volgian Stage corresponds in its scope to the Tithonian Stage of the Mediterranean region (*Zony*..., 1982). Nevertheless, many researchers tend to believe that the upper Volgian Substage (partly or completely) corresponds to the lower Berriasian (Casey, 1973; Casey *et al.*, 1977; Hoedemaeker, 1987; Sei and Kalacheva, 1997; Baraboshkin *et al.*, 1999; and others). Precisely this point of view is accepted by the Interdepartmental Stratigraphic Committee of Russia (Zhamoida and Prozorovskaya, 1997). In view of controversial opinions, a thorough revision of the lectostratotype section of the Volgian Stage is of a particular scientific interest.

The lectostratotype of the Volgian Stage is exposed along the right bank of the Volga River downstream of the Gorodishche Village and 25 km upstream of Ul'yanovsk. Detailed descriptions of the section can be found in a series of works (Pavlov, 1884; Milanovskii, 1940; Gerasimov and Mikhailov, 1966; *Svodnyi putevoditel'*..., 1984; Kuleva *et al.*, 1992). The last one substantiated the stratigraphic incompleteness of the Gorodishche section, and its authors proposed a new lectostratotype for the *Dorsoplanites panderi* Zone distinguished in the Borehole 559 of the Perelyubskii area (eastern Volga River basin).

In their appearance and formation conditions, the lower–middle Volgian rocks of the lectostratotype represent a continuation of the Kimmeridgian part of the

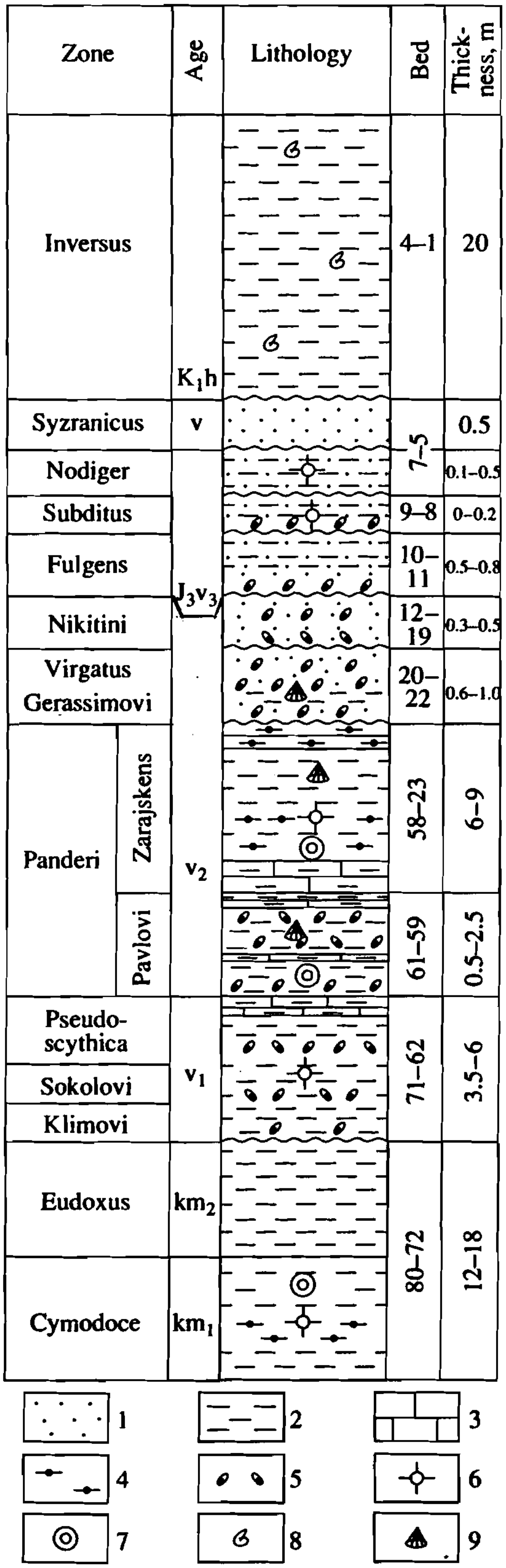

Fig. 1. The Gorodishche section and sampling sites of radiolarians: (1) sandstone; (2) clay; (3) limestone; (4) combustible shale; (5) pebble; (6) radiolarians; (7) nannoplankton; (8) ammonites; (9) buchias.

section, and they should be discussed in the context of general development of the basin. It is important that the Kimmeridgian sequence also encloses the high-bituminous horizon in the basal part of the section (Hantzpergue *et al.*, 1998) and bears Tethyan elements amid ammonite species (Gerasimov and Mikhailov, 1966; *Svodnyi putevoditel'...*, 1984; Baudin *et al.*, 1996; Hantzpergue *et al.*, 1998). The most complete upper Kimmeridgian section is exposed in the Dubki Village area, 9–10 km upstream of the Gorodishche section.

We studied sections exposed near the Gorodishche and Dubki villages during field works of 1995–1997 autonomously and in cooperation with researchers from the Geological Institute of the Russian Academy of Sciences, Scientific–Research Institute of the Saratov State University, and Simbirsk Geological–Prospecting Expedition of the Ministry of Mineral Resources of the Russian Federation.

DISTRIBUTION OF MACROFAUNA AND RADIOLARIANS

The Kimmeridgian sequence (Fig. 1) is composed of slightly calcareous light clays with rare members of dark-colored bituminous marls containing up to 15% of organic matter (Baudin *et al.*, 1996). The radiolarian assemblage is mainly represented by nasselarians, among which representatives of the genus *Parvicingula* are sharply dominant. The share of these forms amounts to 50–60% of total radiolarian abundance. Because fossils in the lower Kimmeridgian part of the section are poorly preserved, we were able to determine only *Parvicingula jonesi* Pessagno prevailing in the assemblage. A similar assemblage with preponderant *P. jonesi* Pessagno was previously registered in the lower Kimmeridgian *cymodoce* Zone of the North Sea (Dyer and Copestake, 1989).

In addition to radiolarians, the lower Kimmeridgian part of the section located 10 km north of the Gorodishche Village (the Mimei section after Hantzpergue *et al.*, 1998) yielded ammonites *Rasenia* cf. *cymodoce* (d'Orb.), *R.* (=*Zonovia*) cf. *uralensis* (d'Orb.), and others, as well as rare *Buchia concentrica* (Sow.) and other bivalves (Hantzpergue *et al.*, 1998). The faunal assemblage correlates this part of the section with the *Rasenia cymodoce* Zone of the uppermost lower Kimmeridgian.

The upper Kimmeridgian part of the section (Beds 80–72 corresponding to Beds 1–4 in the guidebook *Tsentral'nye raiony...*, 1984) was studied directly near the Dubki Sanatorium (6 km north of the Gorodishche Village) and also in the Gorodishche section proper. The section is largely composed of light gray calcareous clays with pyrite concretions, most of which developed after large ammonite shells. Concretions yield *Aulacostephanus eudoxus* (d'Orb.), *A. contejeani* (Thur.), *A.* cf. *yo* (d'Orb.), *Pararasenia hibridus* Ziegler, *Aspidoceras caletanum* (Opp.), *A.* ex gr. *quer-*

cynum (Hantz.), *A.* ex gr. *longispinum* (Sow.), and *Tolvericeras sevogodense* (Cont. et Hantz.) (Hantzpergue *et al.*, 1998). This part of the section corresponds to the upper Kimmeridgian *Aulacostephanus eudoxus* Zone.

Previously, ammonites *Aulacostephanus eudoxus, A. sublacertosus, Amoeboceras volgae*, and *A. subtilicostatum* were determined from clays of Bed 2 (according to the numeration system accepted in the excursion guidebook of the 27 IGC; *Tsentral'nye raiony* ..., 1984) in the Gorodishche lectostratotype. Because of poor preservation, only *Parvicingula* genus with species *R. jonesi* was determined amid radiolarians.

The overlying Kimmeridgian part of the section is composed of light gray calcareous clays and alternating dark and light gray clays. These rocks yield *Aulacostephanus autissiodorensis* (Cott.), *A. undorae* (Pavl.), *A. volgensis* (d'Orb.), and *Virgataxioceras fallax* (Ilov.) correlating host layers with the *Virgataxioceras fallax* Subzone of the *Aulacostephanus autissiodorensis* Zone.

The lower Volgian Substage is represented by alternating light and dark calcareous clays (Beds 71–62 or Beds 5–8 in *Tsentral'nye raiony...*, 1984) with phosphorites. Clays contain ammonites *Ilowaiskya klimovi* (Ilov. et Flor.), *I. sokolovi* (Ilov. et Flor.), *I. pseudoscythica* (Ilov. et Flor.), and *Haploceras* sp. characteristic of the *Ilowaiskya klimovi–Ilowaiskya pseudoscythica* zones of the lower Volgian. The radiolarian assemblage from the ammonite *klimovi* Zone of the Gorodishche section is dominated by the *Parvicingula* genus, in particular by *P. blowi* (Pessagno). This assemblage is most similar to that described from the upper Kimmeridgian–lower Volgian *eudoxus–elegans* ammonite zones of the North Sea (Dyer and Copestake, 1989). This is consistent with the standpoint of Hantzpergue *et al.* (1998) who correlate the lower Volgian Substage with the uppermost Kimmeridgian. Radiolarians are scarce in clays of the *eudoxus–elegans* zones, but phosphate concretions confined usually to erosional surfaces yield abundant representatives of the genus *Parvicingula*.

The analyzed distribution of ammonites in sediments of the middle Volgian *Dorsoplanites panderi* Zone revealed that the *Pavlovia pavlovi* (lower) and *Zarajskites zarajskensis* (upper) subzones defined by Gerasimov and Mikhailov (1966) are distinct owing to prevalence of one or another index species. In contrast, Mitta (1993) does not subdivide the *panderi* Zone into subzones. In the Volgian Stage sections located southerly (Kashpir, Saratov Volga region, North Caspian region), the situation is opposite: *Zarajskites* forms are sharply dominant. This phenomenon can be explained by climatic zoning of the Volgian time, and hence by the temperature control over ammonite distribution (Baraboshkin, 1999). We think it is reasonable therefore to retain subdivision of the *panderi* Zone into subzones (at least for the Middle–Upper Volga region).

The *pavlovi* Subzone (Beds 61–59 or Bed 9 in *Tsentral'nye raiony...*, 1984) is composed of clayey–calcareous rocks with thin layers of marcasite and small phosphate concretions confined to erosional surfaces. The rocks enclose following groups of fauna: ammonites *Pavlovia* sp., *Dorsoplanites* aff. *panderi* (d'Orb.), *D.* sp., *Zarajskites* cf. *tschernyschovi* (Mich.), *Z.* cf. *michalskii* Mitta, and *Z.* sp.; abundant rostra of belemnites *Lagonibelus (L.) parvula* Gust. concentrated usually along erosional surfaces; bivalves *Mesomiltha fischeriana* (d'Orb.), *Buchia russiensis* (Pavl.), *Oxytoma* sp., *Protocardia concinna* (Buch), and *Gresslya alduini* (Fish.); gastropods *Eucyclus* sp., and *Apporhais* sp.; brachiopods *Lingula* sp., *Russiella* sp., and *Rhynchonella loxiae* (Fisch.); and rare scaphopods *Laevidentalium* sp., and "*Serpula*" sp.

The *zarajskensis* Subzone (Beds 58–23 or Beds 10–11 in *Tsentral'nye raiony...*, 1984) encloses a more diverse fossil assemblage. It spans an interval composed of rhythmically alternating calcareous clays from the basal bed, showing dissolution and redeposition marks, to black bituminous shales at the top. The ammonite assemblage of *zarajskensis* Subzone includes species *Zarajskites* cf. *scythicus* (Vischn.), *Z. pilicensis* (Mich.), *Z. quenstedti* (Rouill. et Fahr.), *Z. stchukinensis, Dorsolplanites panderi* (d'Orb.), and *Pavlovia* sp. They associate with other faunal groups: belemnites *Lagonibelus* (L.) *magnifica* (d'Orb.), *L.* (*Holcobeloides*) *volgensis* (d'Orb.), and *L.* (*L.*) cf. *rosanovi* Gust.; bivalves *Astarte* sp, *Gresslya alduini* (Fisch.), *Buchia mosquensis* (Buch), *B. russiensis* (Pavl.), *Oxytoma* sp., *Mesomiltha fischeriana* (d'Orb.), *Nucula* sp., *Panopea* sp, *Limatula consobrina* (d'Orb.), and *Eucyclus* sp.; scaphopods *Laevidentalium* sp.; and brachiopods *Lingula* sp., *Rhynchonella rouillieri* Eichw., and others. Species *Berlieria maeotis* (Eichw.) is sharply prevalent in the upper part of the shaly section. It is accompanied by abundant young ammonite shells forming lens-like accumulations. The top of the shaly section is strongly eroded.

Among microfossils from the *Zarajskites zarajskensis* Subzone of the *Dorsoplanites panderi* Zone, there were discovered diverse radiolarians, abundant benthic foraminifers (Dain and Kuznetsova, 1976), and coccolithophorids (Nikiforova, 1986). The radiolarian assemblage includes *Orbiculiforma* ex gr. *mclaughlini* Pessagno, *Stichocapsa*? *devorata* (Rust), *Phormocampe favosa* Khudyaev, *Parvicingula hexagonata* (Heitzer), *P. cristata* Kozlova, *P. conica* (Khabakov), *P.* aff. *alata* Kozlova, *P. multipora* (Khudyaev), *P. haeckeli* (Pantanelli), *P.* aff. *spinosa* (Grill et Kozur), *Plathycryphalus? pumilus* Rust, and *Lithocampe* cf. *terniseriata* Rust. Like in the Kimmeridgian and early Volgian assemblages, sharply prevalent here are representatives of the genus *Parvicingula* that is characteristic of the Boreal province. Species of this genus constitute more than 50% of the assemblage (Plate).

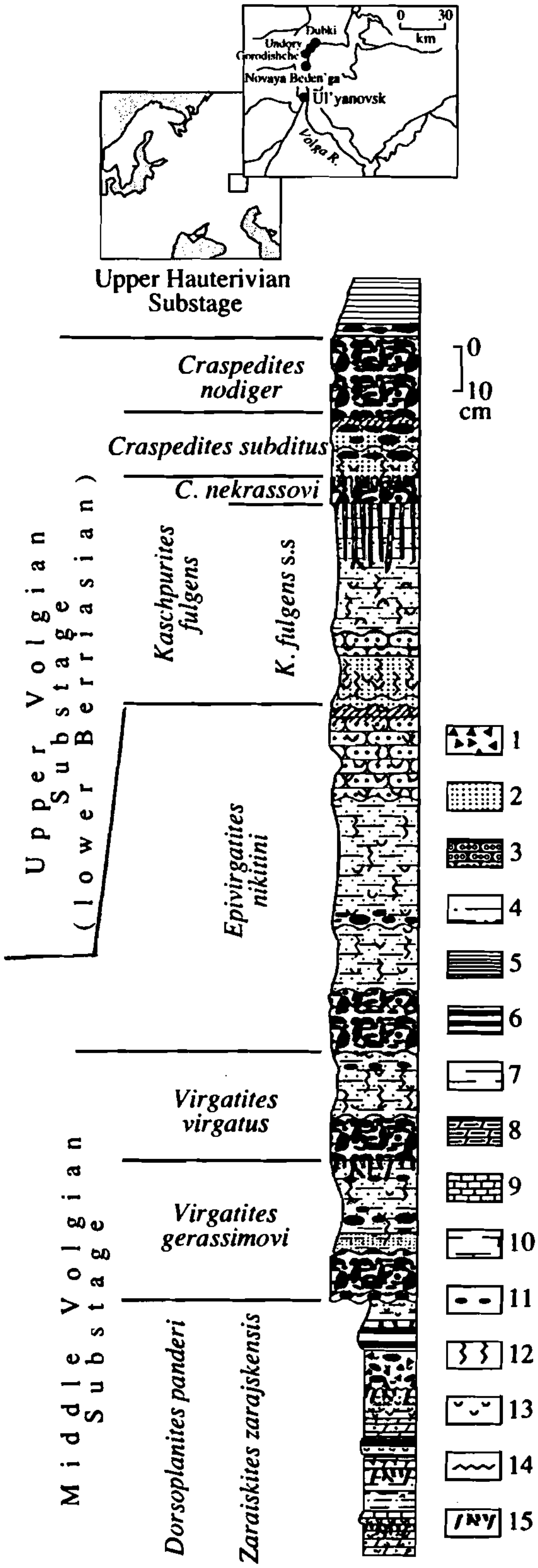

Fig. 2. Detailed section of the upper part of the Volgian Stage: (1) breccia; (2) sand; (3) sandstone; (4) siltstone; (5) clay; (6) combustible shale; (7) argillite-like clay; (8) marl, clayey marl; (9) limestone; (10) calcareous clay; (11) phosphorites; (12) bioturbation; (13) shelly detritus; (14) erosional surface; (15) "soft ground".

We refer the overlying interval (Beds 22–21 or Beds 12–13 in *Tsentral'nye raiony...*, 1984) to the *Virgatites gerassimovi* Zone that was previously ranked as subzone (Mitta, 1993). In our opinion, this unit lacking *Virgatites virgatus* s.s. is of a higher rank because of its sufficient distribution range (central areas of the Russian plain, Middle Volga and easterly regions). In the lectostratotype, this condensed zone corresponds to a member of loose quartz–glauconite sandstone with rounded phosphorite pebbles and "soft-ground" surface at the top. Basal phosphorite pebbles yield redeposited *Zarajskites* cf. *scythicus* (Vischn.) and *Pavlovia* sp., as well as abundant radiolarians occurring in clays of the underlying *zarajskensis* Subzone. Rounded and redeposited fragments of both zonal species *Virgatites gerassimovi* Mitta and *Virgatites virgatus* (Buch) were found, along with *Mesomiltha* sp. and rostra of *Lagonibelus* (H.) *volgensis* (d'Orb.), in phosphorite pebbles of several generations (Bed 20). Thus, the *gerassimovi* Zone is recognized based on its position in the section and on finds of redeposited index species at the base of the overlying zone. The thickness of the *gerassimovi* Zone is 0.35–0.45 m (Fig. 2).

As was mentioned, the *Virgatites virgatus* Zone (Beds 20–21 or Beds 13–14 in *Tsentral'nye raiony...*, 1984) begins with the phosphorite conglomerate member grading upward into greenish bioturbated quartz–glauconite sandstone with pyrite concretions. Sandstone is eroded at the top. The zone contains index species and is about 0.25–0.55 m thick (Fig. 2).

The *Epivirgatites nikitini* Zone (Beds 19–12 or Bed 15 in *Tsentral'nye raiony...*, 1984) is composed of gray bioturbated limy sandstone with the basal phosphorite conglomerate member containing redeposited *Virgatites virgatus* (Buch), *V. pusillus* (Mich.), and *V. pallasianus* (Mich.). One of several erosional surfaces distinguishable in the zone (the base of Bed 17) is marked by small-pebble phosphorite conglomerate. Remains of large to giant ammonites *Epivirgatites bipliciformis* (Nikitin) and *E. nikitini* (Mich.) occur at a higher level of the section. Radiolarians are missing from these sediments. The eroded roof is ocherous. The thickness of the zone is 0.3–0.5 m.

Higher in the section (Beds 11–10 or Beds 16–17 in *Tsentral'nye raiony...*, 1984), the erosional surface of the zone is overlain by the upper Volgian (lower Berriasian) clayey sandstones of the *Kachpurites fulgens* Zone. Sandstones enclose lenticular clayey interbeds, and abundant erosional surfaces are marked in this interval by accumulations of belemnite rostra. The upper part of the interval yields ammonites *Kachpurites fulgens* (Trautsch.) (Bed 11), *Craspedites nekrassovi* Prig., *C.* sp., bivalves *Buchia piochii* (Gabb.), belemnites *Acroteuthis* (A.) *russiensis* (d'Orb.) and *A.* (A.) *mosquensis* (Pavl.) (Bed. 10). By analogy with the Kashpir section (Gerasimov and Mikhailov, 1966; Gerasimov, 1969), one can assume that the *fulgens* Zone (Baraboshkin, 1999) consists of two *Kachpurites*

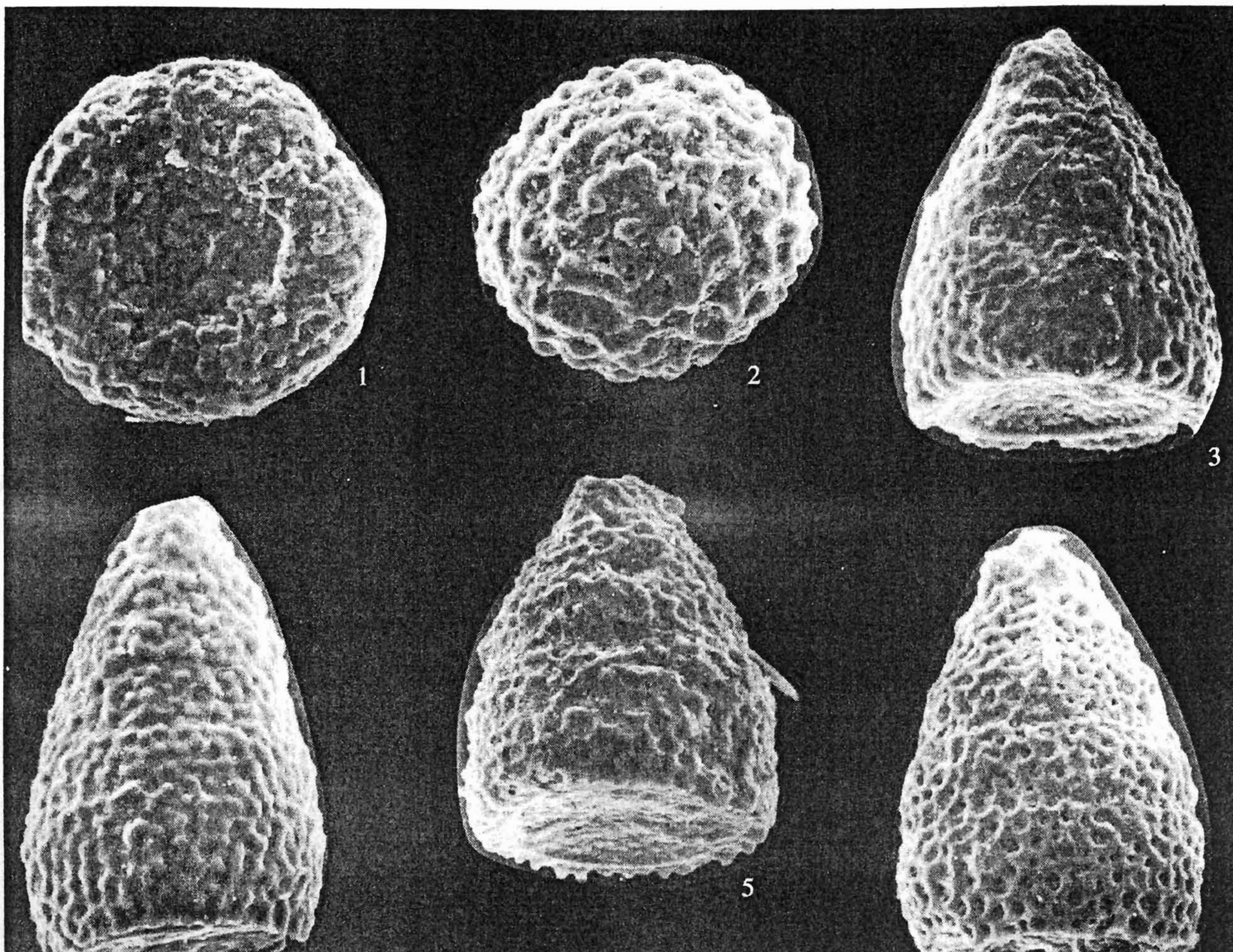

Plate. Radiolarians from the Volgian Stage of the Gorodishche section: (1) *Orbiculiforma* ex gr. *mclaughlini* Pessagno; (2) *Praeconocaryomma* sp.; (3) *Stichocapsa devorata* (Rust); (4) *Parvicingula hexagonata* (Heitzer); (5, 6) *P. cristata* Kozlova; (7–9) *P.* aff. *alata* Kozlova. Magnification for all specimens is 400. Distribution through the section: (1–7) upper Volgian Substage, (8, 9) middle Volgian Substage.

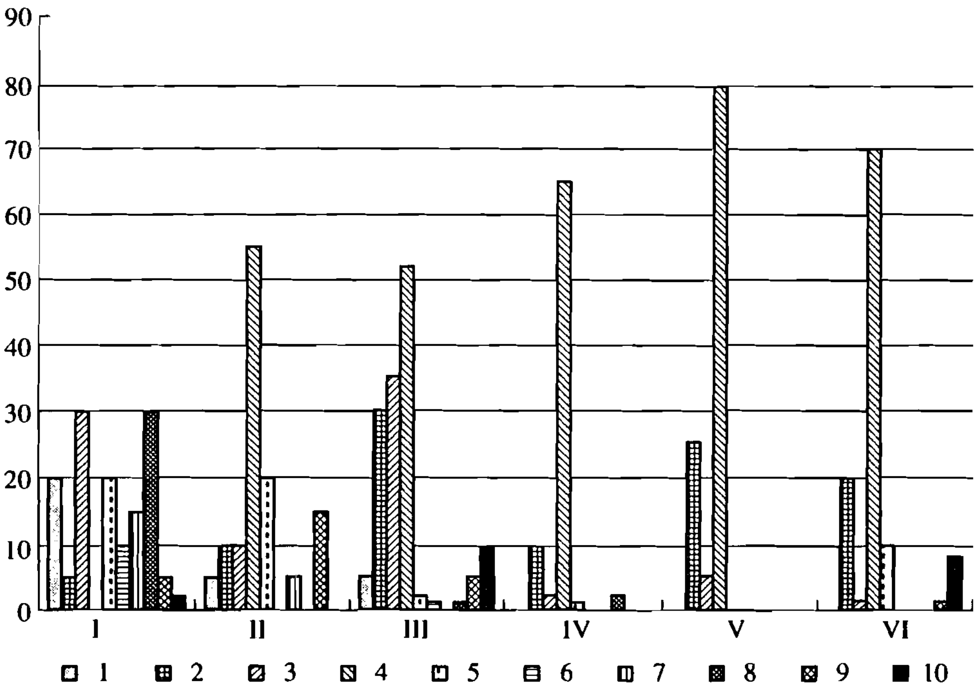

Fig. 3. Quantitative distribution of Kimmeridgian–Volgian and Kimmeridgian–Tithonian radiolarian high-rank taxa in different regions: (I) Alps, (II) California, (III) Antarctica, (IV) Volga region, (V) Barents Sea, (VI) Bering Sea. Radiolarian series: (1) Perispyridae, (2) Orbiculiformidae, (3) Pantanellidae, (4) *Parvicingula*, (5) Hsuidae, (6) Xitidae, (7) *Ristola*, (8) *Tethysetta*, (9) *Napora*, (10) *Amphipyndax*.

Histograms show maximum abundance rates of taxa. For instance, the content of genus *Ristola* in the Alps varies from 5 to15% and the histogram shows its maximum value, i.e., 15%.

fulgens s.s. (Bed 11) and *Craspedites nekrassovi* (Bed 10) subzones. The base and top of Bed 10 are marked by "soft-ground" surfaces with crustacean burrows penetrating down to a depth of 10–30 cm. The thickness of the *fulgens* Zone is 0.5–0.8 m (Figs. 1, 2).

Overlying quartz–glauconite sandstones (Bed 9–8 or Beds 17–18 in *Tsentral'nye raiony...*, 1984) rest also upon the erosional surface of the previous zone, and their basal part encloses rounded pebbles of phosphatic sandstone with redeposited coarsely ribbed *Kachpurites* sp. found in association with bivalves *Buchia piochii* (Gabb), *B.* sp., and *Entolium* sp. Bed 8 yields poorly rounded phosphatized fragments of ammonites *Craspedites* cf. *okensis* (d'Orb.). This form is most typical of the *Craspedites subditus* Zone, but can occur also in the upper part of the *fulgens* Zone (Gerasimov, 1969; Baraboshkin, 1999). No specimens of *Kachpurites* were found in this member that yields only abundant rostra of belemnites *Acroteuthis* (A.) *mosquensis* (Pavl.) and bivalves *Buchia piochii* (Gabb) and *B. tenuicollis* Pavl.). This part of the section should probably be referred to the *Craspedites subditus* Zone, because its zonal species was previously noted in corresponding sediments (Gerasimov and Mikhailov, 1966). The apparent thickness of the zone, the roof of the which is eroded, is up 0.2 m (Figs. 1, 2).

Calcareous clays from Bed 8 enclose the radiolarian assemblage of *Orbiculiforma* sp., *Praeconocaryomma* sp., *Parvicingula cristata* Kozlova, *P. alata* Kozlova, *P. blowi* (Pessagno), *Spinicingula* sp., and *Stichocapsa devorata* (Rust.). The latter species is particularly abundant. In the appearance, it is similar to the morphotype described from the North Sea (Dyer and Copestake, 1989). Like in the underlying sediments, the radiolarian assemblage is dominated by parvicingulids representing up to 50–60% of all specimens.

Beds 7–5 (or Beds 18–19 in *Tsentral'nye raiony...*, 1984) crowning sections of the Volgian Stage represent a succession of three phosphorite conglomerate layers separated by erosional surfaces. The lower conglomerate layer (0.12 m) encloses abundant rostra of belemnite *Acroteuthis* sp., bivalves *Buchia* sp., and *Pleuromya* sp. as well as redeposited phosphorite casts of ammonite *Craspedites* cf. *okensis* (d'Orb.). The middle conglomerate layer (0.1 m) that is softer forms a recess in the exposure surface. The upper conglomerate layer (0.1 m) is hardest consisting of large "hard-ground" fragments and black phosphorite crust. The fragments yield phosphatized remnants of *Craspedites parakaschpuricus* Geras. and *Buchia volgensis* (Lah.). The find of *Nikitinoceras* (=*Temnoptychites*) *mokschensis* (Bog.) frequently cited in publications (Gerasimov and Mikhailov, 1966; *Tsentral'nye raiony...*, 1984) originates most likely from the same layer. During our thor-

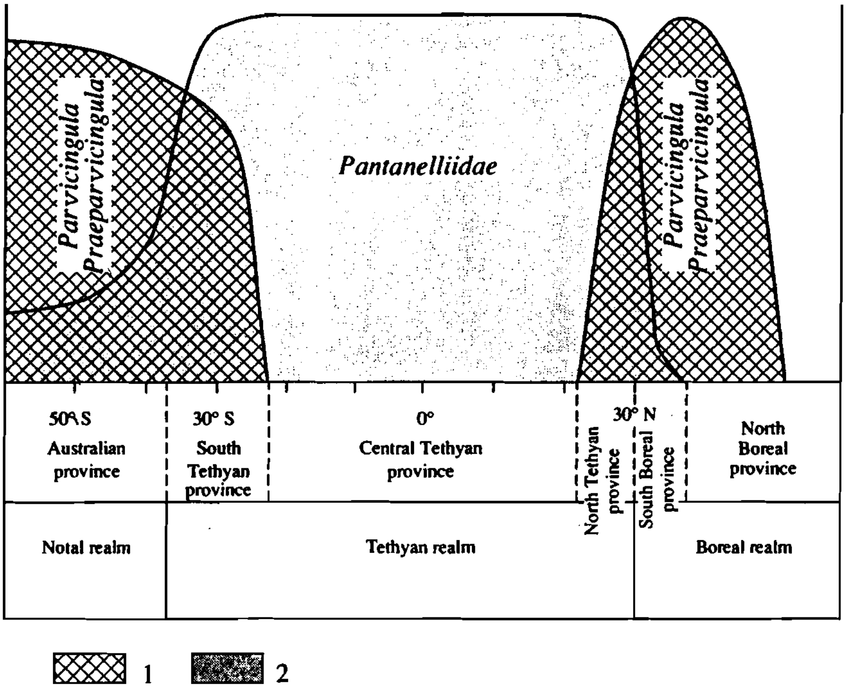

Fig. 4. Quantitative distribution of *Parvicingula* (1) and Pantanellidae (2) representatives in different provinces versus paleolatitudes (after Kiessling and Scasso, 1996).

ough search in the Gorodishche and Slantsevyi Rudnik (several kilometers downstream of the Volga River) sections, we failed to find either Berriasian or Valanginian ammonites. Therefore, we refer the considered sediments to the *Craspedites nodiger* Zone. Taking into consideration the abundant hiatuses and lenticular structure of this part of the section, we think that sediments referred to the *Temnoptychites syzranicus* Zone (lower Valanginian) could be preserved in the section studied by Gerasimov and Mikhailov (1966). Phosphorites yield radiolarians *Parvicingula boesii* (Parona), a species widespread in the Tithonian–Valanginian sequences of the Mediterranean belt. Previously (Vishnevskaya *et al.*, 1990), this species was also identified in the Tithonian deposits of the western Dagomys area (Greater Caucasus).

The section is crowned by black clays (Beds 4–1 or Bed 20 in *Tsentral'nye raiony...*, 1984) with siderite and limonite concretions enclosing large ammonites *Speetoniceras* (*S.*) *versicolor* (Trautsch.) and *S.* (*S.*) *subinversum* (M. Pavl.,) characteristic of the upper Hauterivian *Speetoniceras* (*S.*) *versicolor* Zone (Chernova, 1951) that was previously defined as the *Speetoniceras inversus* Zone.

CHARACTERISTIC OF THE RADIOLARIAN ASSEMBLAGE

At several stratigraphic intervals, fossils with calcareous skeletons coexist with abundant siliceous microfossils (radiolarians and sponge spicules). It is important that siliceous microplankton (radiolarians) in the *zarajskensis* Zone occurs together with calcareous plankton (coccolithophorids) and juvenile forms of benthic (*Mesomiltha, Berlieria*) and nektonic ammonites.

Notwithstanding the fact that radiolarians were previously recorded in the Kimmeridgian–Volgian interval of the Gorodishche section (Dain and Kuznetsova, 1976), but their assemblage was never studied in detail. Radiolarians were also noted in coeval sediments of the Pechora basin and in the Bazhenovo Formation of West Siberia, where they form considerable local accumulations (Kozlova, 1983, 1984).

Abundance of radiolarians throughout the Gorodishche section conflicts with the assumption that the Volgian basin was extremely shallow and insufficiently saline (Kuleva *et al.*, 1996). Our data favor better the standpoint of Strakhov (1936, 1937) who suggested the normal salinity and gas regime for the basin. To substantiate this assumption, he mentioned mass accumulations of various shelly organisms in combustible shales (Strakhov, 1937). He emphasized that virtually every sample contained organic remains, and that one square meter of the exposure demonstrates up to 160 imprints of *Orbiculoidea maeotis* Eichw. according to assessment of A.N. Rozanov.

Unlike the Kimmeridgian–Tithonian radiolarian assemblages of the Caucasus (Vishnevskaya *et al.*, 1990), those from the Gorodishche section show a great similarity with the Boreal–Atlantic assemblages of the North Sea (Dyer and Copestake, 1989), Barents Sea–

Pechora region (Kozlova, 1983, 1994; Vishnevskaya, 1998) and with Arctic–Boreal assemblages of northern Siberia (Vishnevskaya and Malinovskii, 1995). Thus, they are of the boreal type. Abundant representatives of the genus *Parvicingula* prevailing in the studied radiolarian assemblage indicate its origin in the Boreal province (Pessagno *et al.*, 1986; Hull, 1995; Kiessling and Scasso, 1996), thus casting doubts on the thermophilic affinity of the fauna from bituminous Volgian shales of the *panderi* Zone in the Middle Volga region (Kuleva *et al.*, 1996). Our materials are completely compatible with previous data on other faunal groups, first of all on ammonites (Gerasimov and Mikhailov, 1976; Dain and Kuznetsova, 1976; *Zony*..., 1982; Braduchan *et al.*, 1986, 1989; Hantzpergue *et al.*, 1998; Baraboshkin, 1999; and others). It is most likely that the Gorodishche section encloses boreal assemblages with single thermophilic elements, and this is an obstacle impeding correlation between the Volgian and Tithonian stages. As is known, thermophilic *Haploceras* forms of the Tithonian occur only in the uppermost *panderi* Zone of the North Caspian region. In the Middle Volga region, Tethyan ammonites disappear at the top of the *panderi* Zone and only single Kimmeridgian and early Tithonian ammonites of Tethyan affinity are registered in this area (Repin and Rashvan, 1995).

Parvicingulids permanently constituting up to 50–60% of radiolarian assemblages (Fig. 3) represent a good indicator of upwelling (Vishnevskaya, 1996) and boreal influence (Fig. 4). Figure 3 demonstrates that the abundance rate of the genus *Parvicingula* is 70–80% in the Barents and Bering seas and 50% or more in Antarctica and flysch deposits of California, whereas its share is below 1% in Alpine sections. Thus, histograms showing distribution of high-rank radiolarian taxons within low and high latitudes are substantially different. Similarity in distribution patterns of radiolarians is especially characteristic of northern Russia. Radiolarian assemblages from the North Atlantic province (Barents Sea, Volga region) show a greater similarity between each other than with their counterparts from the Pacific province (see histograms of radiolarian distribution in California, Antarctica, and Bering Sea). In the latter province, distribution patterns are characterized by their own peculiarities. They are bimodal in character and show prevalence of *Parvicingula* forms.

Paleotemperature estimated from occurrence of belemnites in association with radiolarians show that waters in the North, Pechora, and Volga (Gorodishche) seas were heated up to 14–17°C during the Kimmeridgian and Volgian times, whereas temperature in the North Caspian sea was about 20°C during the Volgian time (Riboulleau *et al.*, 1998).

Sponge spicules from the middle Volgian layers of the Gorodishche section are largely represented by short fragments of calcareous and siliceous–keratose forms, although present are also thin long transparent spicules of a strictly regular geometric form belonging to glassy sponges. Finds of the latter serve as an additional argument favoring the normal salinity of the basin.

CONCLUSION

New biostratigraphic data obtained for the Gorodishche section allow the following to be stated:

(1) The *Virgatites gerassimovi* Zone is proposed and the scope of the *Virgatites virgatus* and *Epivirgatites nikitini* zones of the middle Volgian Substage is specified. The upper Volgian (lower Berriasian) *Kachpurites fulgens* Zone is subdivided into subzones traceable also in the Kashpir section; the scope of this zone is specified as well. The presence of lower Valanginian strata in the Gorodishche section is not confirmed.

(2) The Jurassic–Cretaceous (middle–upper Volgian) boundary is marked by the change in dominant species of radiolarian assemblages: representatives of the genus *Parvicingula* prevail in the Jurassic part of the section and *Stichocapsa* forms, in the Cretaceous one. Radiolarian assemblages from the Ul'yanovsk Volga region show a high similarity with those from coeval successions of the Pacific province.

(3) The same *Parvicingula* species (*P. alata, P. conica, P. cristata, P. multipora*), occurring in the boreal Barents Sea–Pechora–West Siberia basin and subboreal Moscow–Middle Volga basin, and species *P. hexagonata, P. spinose*, and *Stichocapsa devorata*, which are known from boreal sections of West Europe (Hetzer, 1931; Dyer and Copestake, 1989) and from the Middle Volga region, suggest the boreal character of the Kimmeridgian–Volgian basin of the East European platform. This basin was under significant or even prevalent influence of the Arctic Ocean or cold Arctic currents during formation of Kimmeridgian and Volgian strata of the Gorodishche section.

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