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The Upper Bajocian–Lower Bathonian Boundary Section in the Outskirts of Saratov: Molluscan Characteristics and Biostratigraphy

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Abstract—The analysis of all available data on the structure of the Bajocian–Bathonian boundary section in the outskirts of Saratov (Sokur quarry) and the taxonomic composition of its ammonites, belemnites, and bivalves revealed a continuous succession of the *Pseudocosmoceras michalskii* (Upper Bajocian), *Oraniceras besnosovi*, and *Arcticoceras ishmae* (Lower Bathonian) zones. In connection with the critique by Meledina et al. (2009), correlation of Bajocian and Bathonian boundary strata of the Central Russia and Northern Siberia is discussed. The inconsistency of Siberian bivalve and belemnite assemblages with Central Russian ammonite zones is explained by heterochronous invasions of different molluscan groups.

Keywords: Saratov Volga region, ammonites, Bajocian, Bathonian, biostratigraphy, zones, Boreal–Tethyan correlation.

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INTRODUCTION

The Bajocian–Bathonian sequences of the Saratov–Volgograd Volga region containing rare ammonites of the family Parkinsoniidae have been studied for a century. Discovery of these Tethyan ammonites in the quarry near Saratov (Mitta and Sel'tser, 2002) together with Boreal Arctocephalitinae (family Cardioceratidae), which had previously been considered to be exclusively a high-latitude group, renewed interest in this region. Recent years have produced new data on the distribution of fossil remains in this section (Mitta et al., 2004; and others). In addition, a borehole, which recovered older Bajocian strata, has been drilled in this area. Recently, Meledina et al. (2009) published a paper with a critique of our views on the Boreal–Tethyan correlation of the Bajocian–Bathonian boundary beds. In this work, we discuss both earlier and recent data, and respond to our opponents. Voucher material discussed in this work is housed at the Borissiak Paleontological Institute (PIN) of the Russian Academy of Sciences and Vernadskii State Geological Museum (SGM) of the Russian Academy of Sciences.

HISTORICAL REVIEW

Until the end of the 19th century, the Callovian strata were considered to be the oldest Jurassic marine sediments in the Saratov–Volgograd region (Lower Volga River). A.V. Pavlov, a follower of Professor A.P. Pavlov, was the first to discover differences between the Jurassic deposits of the Saratov region and typical Central Russia Jurassic sections, revealing members of light gray clays with intercalations of clayey siderite in the Saratov province, the so-called "Upper Dogger with *Parkinsonia parkinsoni* Sow." (Pavlov, 1904a, 1904b). Rzhonsnitskii (1905) established the Dogger strata with *Parkinsonia* representatives below the Lower Callovian sediments with *Cadoceras elatmae* in the Chardym River basin (Saratov Volga region).

Arkhangelsky (1906) noted that in the Kamyshin district of the Saratov Region, dark clays with clayey siderite concretions containing abundant Lower Callovian ammonites such as "*Kepplerites* aff. *Gowerianum* Sow., *Cardioceras Chamussetti* d'Orb., *Cadoceras surense* Nik., *C. Elatmae* Nik., and *C. Frearsi* d'Orb." overlie pale sandy–micaceous platy clays with intercalations of thin-bedded micaceous sandstones containing rare poorly preserved *Pseudomonotis* remains attributed to undivided Bathonian–Callovian interval. They are underlain by Bathonian layers separated in two members:

(1) dark clays with gypsum and marcasite intercalated by beds and concretions of dark clayey siderites with *Parkinsonia* and abundant *Pseudomonotis*; the

lower clays enclose beds of ferruginous sandstone and pebble gravel consisting of rounded fragments of Carboniferous limestones and cherts;

(2) white calcareous sandstones, yellow quartz and gray micaceous–glauconite sands with beds of pebble gravel and separate large cherty blocks; the base of sands immediately above the Carboniferous limestones is represented by red ferruginous conglomerate.

Rzhonsnitskii's studies of 1904–1906 and 1914 made it possible to specify the structure of Jurassic sections in the outskirts of Saratov. Below, we cite his inferences concerning the lower part of the section:

"The oldest rocks constitute the Bathonian Stage, represented by gray and yellowish gray clays with intercalations of dark gray siderite. These rocks yielded ammonites belonging to the genus *Parkinsonia*, bivalves of the genera *Pseudomonotis, Pleuromya*, and others, belemnites, and wood fragments. The most abundant fossils are single *Pseudomonotis* species resembling *P. echinata* Sow., which literally oversaturate both clays and siderite beds. ... The Bathonian strata are immediately overlain by gray and yellowish gray sandy and micaceous clays with intercalations of thin-bedded dark gray fine-grained micaceous sandstones, which are readily separated into fine plates. These sediments are mostly barren of organic remains, while their upper part contains rare Lower Callovian *Cadoceras* forms, which allow the entire sequence to be attributed with a certain degree of confidence to the Lower Callovian. ... These strata are overlain by black gypsum-bearing clays with spheroid concretions and intercalations of dark gray siderite and intergrowth of ferrous pyrite. These clays contain abundant *Cadoceras modiolare* Sow., *Cadoceras Elatmae* Nik., *Cadoceras Frearsi* Nik., *Macrocephalites* sp., *Cardioceras Chamussetti* d'Orb., *Kepplerites Gowerianum* Sow., belemnites, Gryphaea, wood fragments, and others" (Rzhonsnitskii, 1914, p. 60).

In 1917, Jurassic sections in the Ilovlya River basin were visited by A.N. Mazarovich, who noted under "Neocomian sands" in the Kamyshin district, thin Oxfordian, "Callovian, problematic Bathonian, Bajocian," and underlying strata, which are divisible into two units: the Karaulinskaya Group and Gnilushki conglomerates and sands overlying the Carboniferous limestones" (Mazarovich, 1923, p. 31). Mazarovich reached the conclusion that clays with siderite concretions underlying "clayey sands, siderites, and pale clays of the problematic Bathonian" are older, and attributed them to the Bajocian. He assumed that the Bajocian Stage is represented by two zones: lower *Stephanoceras humphriesianum* and upper *Parkinsonia parkinsoni*. From the lower zone, he described a new loosely collected ammonite species *Sonninia mojarowskii*.

These and other ammonites from the collection by Mazarovich (from clays with intercalations of siderite concretions universally developed in the northern extremity of the Don–Medveditsa swell) were described slightly later by P.K. Murashkin, who provided the first image of "*Parkinsonia (?) mojarowskii* Masar." (holotype by monotypy). In addition, this author described *Parkinsonia subcompressa* sp. nov. (based on a single poorly preserved fragment) and defined the genus *Pseudocosmoceras* with the type species *Cosmoceras michalskii* Bor., that was first described by Borisyak (1908) from the Donets Jurassic (Lower Bathonian after Borisyak, 1917). This genus also included "varieties" of the type species (*Ps. michalskii* var. *minor* and var. *media* and *Ps. masarowici* nov. sp. (with var. *descendens*, var. *conjungens*, and var. *inclara*). Murashkin finishes his article with the words "...from my point of view it is not possible at present to estimate the exact age of beds with the above-mentioned ammonites. It is conceivable that beds with *Parkinsonia subcompressa* nov. sp., correspond to the zone with *Parkinsonia würtembergica* Opp. (? = *Parkinsonia compressa* Qu.) correlated with the Upper Dogger in the Jurassic section of northwestern Germany. One may confidently postulate synchronism of Kamyshin Middle Jurassic sediments containing the above-mentioned varieties of *Pseudocosmoceras michalskii* from the Donets Middle Jurassic beds containing *Pseudocosmoceras michalskii* Bor. var. *typica"* (Murashkin, 1930, p. 159). In his table of "assumed phylogenetic relationships between examined ammonites" this author indicates the "*Parkinsonia donezi-ana* Zone with hypothetical forms closely related to this species" and higher, beds with *Pseudocosmoceras michalskii* and *Ps. masarowici*, varieties included (Murashkin, 1930, p. 150).

In 1930, Murashkin conducted fieldwork in the Kurdyum and Chardym river basins (North of Saratov), where he noted "gray, locally, ferruginous sandy clays with lenticular beds of siderites containing *Parkinsonia compressa* var. close to var. *würtembergica* Opp. emend. Nicolesco" attributed to the Bathonian Stage (Murashkin, 1932, p. 74).

In the middle of the 20th century, a group of Saratov researchers headed by V.G. Kamysheva-Elpat'evskaya systemically investigated Jurassic fossils in the Saratov Volga region. In several guidebooks and atlases (Kamysheva-Elpat'evskaya and Ivanova, 1947; Kamysheva-Elpat'evskaya et al., 1956, 1959), these researchers described and illustrated (in most cases as Bajocian) some Bathonian Parkinsoniidae. They had limited material at their disposal (approximately 10 specimen), which prevented a comprehensive investigation of the taxonomic composition of the fossils. Clays with intercalations of siderite concretions were ambiguously dated: in the explanations of the plates *Parkonsonia* forms in the above-mentioned works were attributed to the Bajocian, while in their subsequent summarizing work, the authors referred the *Parkinsonia* to the Bajocian and *Pseudocosmoceras* and *Medvediceras*, to the Lower Bathonian (*Atlas...*, 1969).

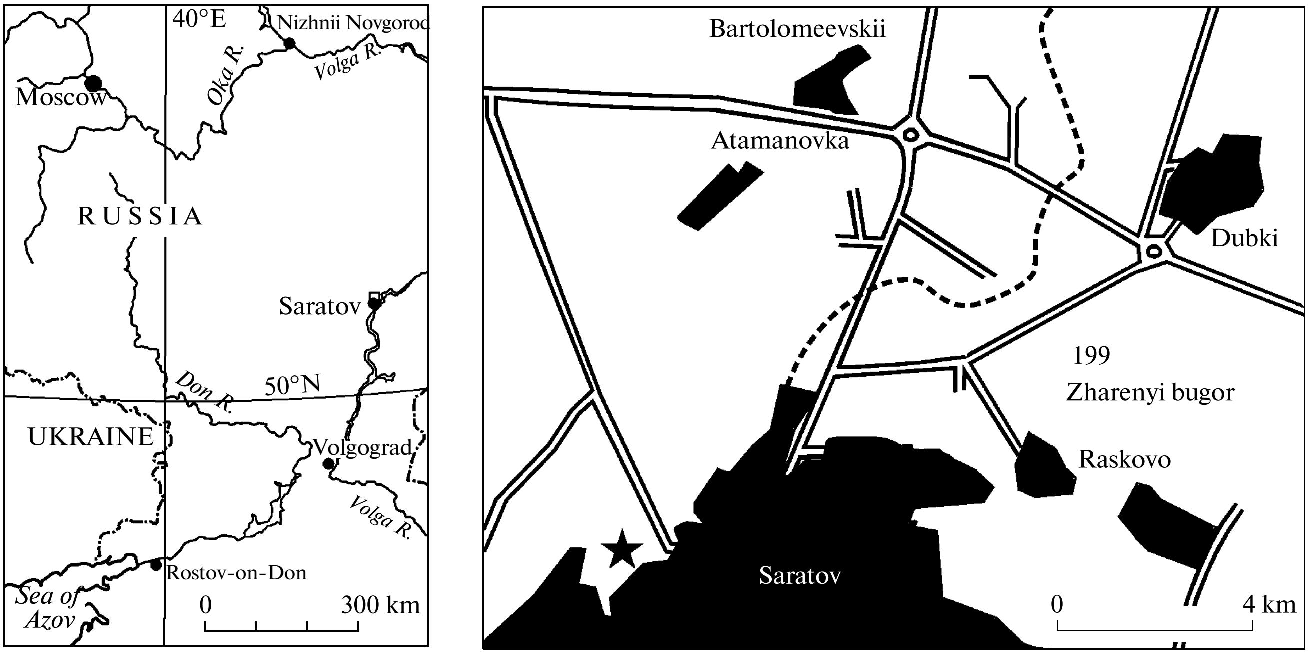

Fig. 1. Schematic map of the Lower Volga region. Star designates the position of the Sokur section in the northwestern Saratov outskirts.

Some images of Parkinsoniidae specimens from the area under consideration have been published in other works (Kamysheva-Elpat'evskaya, 1951; Sazonov, 1957; Sazonova and Sazonov, 1967). Using finds from the Ilovlya and Medveditsa river interfluve, Nikolaeva (1967) described the new genus *Medvediceras*[1] with the type species *Ps. masarowici* Murashkin.

It should be noted that most of the ammonites illustrated in the publications cited were either loosely collected or found in isolated outcrops, which prevented their succession in the section from being established. Numerous ammonites, which were determined in boreholes, were never illustrated and are missing from collections.

The recent phase in the study of Bajocian–Bathonian sections in the area under consideration is connected with the section recovered in the clay quarry in the northwestern outskirts of Saratov 0.4 km away from the Sokur Road; therefore, it is known among geologists as the Sokur or Sokur Road quarry (Fig. 1). The clays with siderite concretions yielded abundant Parkinsoniidae and single Macrocephalitidae. The subsequent detailed study of available collections and new finds revealed that *Arctocephalites* and *Arcticoceras* belonging to the subfamily Arctocephalitinae of the family Cardioceratidae were erroneously identified as Macrocephalitidae (Mitta and Sel'tser, 2002). These taxa, which are characteristic of high latitudes (Pechora River basin, North Siberia, Arctic Canada, and East Greenland), were first found in a single section together with Peri-Tethyan Parkinsoniidae. Subsequently, the results of complex biostratigraphic studies and data on the taxonomic composition of ammonites, belemnites, bivalves, gastropods, and palynological complexes were published (Mitta et al., 2004). Several recent works contain descriptions of some ammonites from the Volga region near Saratov with substantiation of Boreal–Tethyan correlation between Bajocian–Bathonian sections also using material from the Pechora River basin (Izhma River) (Mitta, 2004, 2007, 2009).

THE SOKUR SECTION

The Sokur section (Fig. 2) contains the following beds (from the quarry bottom upward) (Mitta and Sel'tser, 2002, 2009; Mitta et al., 2004):

Upper Bajocian

Pseudocosmoceras michalskii Zone

(1) Clay, light gray with the bluish tint, with insignificant silt admixture, separating into platy fragments. The apparent thickness is approximately 5 m. Sediments 2 m below the bed top and at the same level or slightly lower yielded *Pseudocosmoceras masarowici* Murashkin (Mitta and Sel'tser, 2002, Plate 6, fig. 2) and large (250 mm across) shell of *Parkinsonia* sp. (sp. nov. ?), respectively, while the upper part of the bed provided small-shelled *Parkinsonia* sp. juv. (Mitta

[1] According to Mitta (2009), *Medvediceras* Nikolaeva, 1967 is a junior subjective synonym of *Pseudocosmoceras* Murashkin, 1930.

et al., 2004, Plate 1, fig. 5; this work, Plate II, fig. 3). In addition, Belemnoidea indet. (juvenile rostrum with a part of phragmocone), shells of *Tancredia* sp., *Katosira?* sp., and Caenogastropoda gen. indet. were found in situ. The bed is attributed to the *Pseudocosmoceras masarowichi* faunal horizon.

Lower Bathonian

Oraniceras besnosovi Zone

(2) Clay, light gray, with intercalations of sideritic carbonate concretions at the base and top. The thickness is 0.8 m. At the base of the bed, concretions contain *Oraniceras* cf. *mojarowskii* (Masarowich); concretions from the upper part of the bed yielded *O.* cf. *besnosovi* Mitta et Seltzer, *Modiolus (Modiolus)* cf. *bipartitus* (Sowerby). The bed corresponds to the *Oraniceras mojarowskii* faunal horizon.

Oraniceras besnosovi and Arcticoceras ishmae Zones

(3) Clay, light gray to gray, with silt admixture increasing upward the section and sideritic carbonate concretions at the base and scattered through the section. The thickness is up to 3 m. The basal beds enclose *Oraniceras besnosovi* Mitta et Seltzer, *Oraniceras* sp. juv. (Plate II, fig. 5), *Mesosacella* ex gr. *morrisi* (Deshayes), *Thracia* (*Thracia*) *depressa* (J. de. C. Sowerby), *Th. (Thracia)* sp., *Modiolus (Modiolus)* cf. *bipartitus* (Sowerby), *Meleagrinella echinata* (Smith), *Oxytoma* (*Oxytoma*) *inaequivalve* (Sowerby), and *Protocardia* sp. Higher in the section, the following fossil assemblages were found in sediments: (1) *Parkinsonia* sp., *Retroceramus* sp. juv., *Parvulacteon sokurensis* Gründel, *Tricarilda* cf. *extenta* (Jamničenko), and *Levipleura* sp. 0.5–1.0 m above the base of the bed; (2) *Parkinsonia* sp., (Plate II, fig. 2), *Pachyteuthis* aff. *subrediviva* (Lemoine), *Camptonectes* cf. *rigidus* (Sowerby), *Liostrea* sp., *Protocardia* sp., *Parvulacteon sokurensis* Gründel, *Tricarilda* cf. *extenta* (Jamničenko), *Levipleura* sp. and *Serpula* sp. 1.5–2.0 m above the base; (3) *Oraniceras besnosovi* (Mitta et Seltzer, *Modiolus (Modiolus)* cf. *bipartitus* (Sowerby), *Liostrea multiformis* (Koch), *Thracia* (*Thracia*) *depressa* (J. de. C. Sowerby), *Pinna* sp., *Protocardia* sp., *Arctica*? sp., and *Pleuromya* cf. *uniformis* (Sowerby) 2.0–2.5 m above the base; (4) *Oraniceras* sp., *Arcticoceras harlandi* Rawson (Plate I, fig. 5), *Aequipecten* sp., *Myopholas* sp., and *Camptonectes (Camptonectes)* ex gr. *lamellosus* (Sowerby) 2.5–3.0 m above the base. The specimens of *Oraniceras besnosovi* Mitta et Seltzer illustrated in (Mitta and Sel'tser, 2002, Plate 5, fig. 1, Plate 6, fig. 3, Plate 7, figs. 2, 3; Mitta et al., 2004, Plate 1, fig. 1) and a single specimen of *Sokurella galaczi* Mitta found in situ (collection by S.A. Bratashova) also originate from this bed. The most lower part of the bed is attributed to the *Oraniceras besnosovi* faunal horizon, while the upper 0.5 m are referred to the *harlandi* faunal horizon of the *Arcticoceras ishmae* Zone based on the appearance of *Arcticoceras harlandi*.

Arcticoceras ishmae Zone

(4) Clay, gray, silty, with rare sideritic carbonate concretions. In the upper part of the bed, a thin lenticular layer of clayey material contains abundant rounded belemnite rostra and fragments of pyritized wood with attached bivalve shells (the so-called "belemnite level"). The thickness is 0.35 m. The bed yielded diverse fossils: *Nannobellus bellus* Barskov, *N. parabellus* Barskov, *Paramegateuthis* cf. *pressa* Nalnjaeva, *P.* cf. *manifesta* Nalnjaeva, *Pachyteuthis subrediviva* (Lemoine), *Modiolus (Modiolus)* cf. *bipartitus* (Sowerby), *Liostrea* (*Deltostrea*) *eduliformis* (Schlotheim), *Liostrea* (*Liostrea*) *multiformis* (Koch), *Quenstedtia* sp., *Protocardia* sp., *Goniomya* cf. *v-scripta* (Sowerby), *Pleuromya* ? sp., *Berenicea* sp. The basal part of the bed yielded *Arcticoceras harlandi* (Rawson) (Mitta and Sel'tser, 2002, Plate 1, fig. 1); *Arctocephalites freboldi* Spath (*Arctocephalites* sp. in Mitta and Sel'tser, 2002, Plate 4, fig. 2) probably originate from the same level. The "belemnite level" is characterized by *Acticoceras ishmae* (v. Keyserling) (Plate II, fig. 2) and single ichthyosaurus vertebra fragment (Arkhangel'skii and Pervushov, 2002). The bed is attributed to the *Arcticoceras harlandi* faunal horizon.

(5) Clay, reddish gray, silty, grading to brownish gray and yellow–brown thin-bedded clayey silt locally cemented into thin-platy siltstone. A lenticular layer 0.1–0.2 m above the base with rare sideritic concretions and scattered rounded belemnite rostra yielded *Arcticoceras ishmae* (v. Keyserling) (Mitta and Sel'tser, 2002, Plate 3, fig. 1) and impression of ammonite identified as *Parkinsonia* (s.l.) (Mitta and Sel'tser, 2002, Plate 5, fig. 3). The thickness is 1.1 m. The bed is attributed to the *Arcticocears ishmae* faunal horizon.

?Middle and Upper Bathonian

(6) Silt, yellowish gray, thin-bedded, cemented into either compact siltstone protruding from the quarry wall in form of a plate (at the base) or locally poorly consolidated siltstone (in the upper part). The thickness is approximately 6.5 m). No macrofossils are found in situ, although some plates of yellowish brown siltstone in talus are saturated with separated valves of *Oxytoma (Oxytoma)* ex gr. *inaequivalvis* (Sowerby).

?Lower Callovian

(7) Clayey brownish gray, becoming yellowish gray upward the section, silty, with small gypsum crystals and jarosite inclusions. The apparent thickness amounts to 3.2 m.

As follows from the description, beds 1–5 are sufficiently well characterized by fossil organic remains suitable for dating host sediments. It should be emphasized that recent mining operations in the quarry provided new information on lithology and structure of the section, which influence its stratigraphic interpretation. For example, it appeared that the so-called “belemnite level” of Bed 4 pinches out along the strike. Correspondingly, this interval of the section should be interpreted as a lens being of local distribution and characterizing a local brief erosion event. It should be noted that in our earlier works (Mitta and Sel’tser, 2002; Mitta et al., 2004) we noted in Bed 5 containing *Arcticoceras ishmae* a bed with rounded belemnite rostra and other fossils, which was named in field descriptions as an “upper belemnite level.” Its distinct lateral variability and discontinuity prevented from defining it as an autonomous layer. Similarly, according to observations by Sel’tser, the basal layer of siltstones, which was previously observable above Bed 5, pinches out in the southeastern part of the quarry. Such features are of importance primarily for the answer to the critique by (Meledina et al., 2009). In this connection, it should also be noted that new finds of fossils in beds 1–5 confirm or are consistent with previous data. For example, Sel’tser found a specimen of *Parkinsonia* sp. (sp. nov. ?) 250 mm in diameter approximately at the level of the *Medvediceras masarowici* find (probably, slightly below). Inner whorls of this ammonite are covered by relatively thin and densely spaced ribs typical of *Parkinsonia* forms from the West European *Parkinsonia parkinsoni* Zone. Until this find, all the *Parkinsonia* forms from this interval of the section were juvenile specimens. Ivanov found among his fossils sampled in the 1990s from the “belemnite level an ammonite specimen with the matrix and taphonomic features indicating its origin precisely from this interval of the section. This specimen (Plate II, fig. 1) is identified as *Arcticoceras ishmae* (v. Keyserlyng), an initial variety described by Callomon (1993) as morpha α. M.A. Grigor’ev donated us specimens of *A. harlandi* (Plate I, fig. 5) and *A. ishmae* found under and above the belemnite level,” respectively, as well as a well-preserved specimen of *Arctocephalites freboldi* Spath up to 160 mm in diameter. Unfortunately, the latter was collected loose, although it eliminated doubts about the validity of the identification of this species, which had previously been based on incomplete specimens. The last researcher also donated several *Oraniceras* specimens from the *Besnosovi* Zone. Figure 2 only shows taxa found in situ.

In 2003, A.V. Ivanov’s initiative was crowned by the drilling of an exploration borehole in the Sokur quarry, which recovered a sequence of gray clays approximately 55 m thick below Bed 1. Unfortunately, core material sampled by V.B. Sel’tser yielded only fragments or juvenile shells of ammonites (identifications by V.V. Mitta; hereinafter, sampling depth (m) is given in brackets): Parkinsoniidae gen. et. sp. indet. (2.5, 4.5, 27.8, 32.0, and 34.6), *Parkinsonia* sp. (4.0, 4.7 (Plate II, fig. 4), 5.2, 6.0, 6.2, 6.4, 6.9, 15.6), *Pseudocosmoceras* sp. cf. *masarowici* Murashkin (27.0, 29.45), *Pseudocosmoceras?* sp. (34.5) attributed to the *Pseudocosmoceras michalskii* Zone. Preservation of bivalves is slightly better; their assemblage includes the following taxa (identifications by V.A. Zakharov): *Meleagrinella echinata* (Smith) (16.40, 19.30, 24.30, 29.35, 49.90, 53.00), *Liostrea* (*Liostrea*) *mutiformis* (Koch) (42.10), *Liostrea* subgen. et sp. indet. (50.40), *Thracia* sp. indet. (50.40). Such a composition of fossil assemblages indicates only Middle Jurassic age of host strata. The detailed description of the borehole along with accompanying geophysical and micropaleontological data will be published later.

DISCUSSION

As has been mentioned, the recently obtained data on the Sokur quarry section neither confirm nor refutes our previous inferences. Based on the analysis of published data and their investigations of Bajocian–Bathonian sections in northern East Siberia, Meledina et al. (2009) arrived at the conclusion that our views on the zonation and correlation of Bajocian–Bathonian sediments in the Saratov outskirts are erroneous. They also question the correctness of stratigraphic levels of our ammonite occurrences, primarily high-boreal Arctocephalitinae forms, i.e., representatives of the *Arctocephalites* and *Arcticoceras* genera. In their opinion, these ammonites should be located in the section above the “belemnite level” or correspond to the latter. Moreover, beds 4 and 5 up to 1.5 m thick in total should correspond to the interval of the *Arctocephalites arcticus, Arctocephalites* aff. *greenlandicus*, *Arcticoceras harlandi*, and *Arcticoceras ishmae* zones in northern East Siberia. These researchers assume that beds 4 and 5 are strongly condensed, and that the “belemnite level” reflects reworking of the older *Arctocephalites arcticus–A. greenlandicus* zones” (Meledina et al., 2009, p. 68). No index species of the last two zones have, however, been found so far in the Saratov outskirts, and, of index species from other faunal horizons, only *A. freboldi* Spath, which characterizes the terminal faunal horizon of the *Greenlandicus* Zone, is found. However, their main arguments are based on the different molluscan assemblages characteristic of Siberia.

Our identifications of ammonites are not contested except for the imprint of an ammonite (Mitta and Sel’tser, 2002, Plate 5, fig. 2) from the *Ishmae* Zone determined as *Parkinsonia* s.l. Meledina et al., 2009 state that, in their opinion, this impression may equally belong to a member of Arctocephalitinae. Parkinsoniids became extinct in the middle part of the early Bathonian and their distribution above the *Besnosovi* Zone is inconsistent with our views on correlation of this zone with the *Convergens* and *Macrescens* subzones of the *Zigzag* Zone of the standard scale.

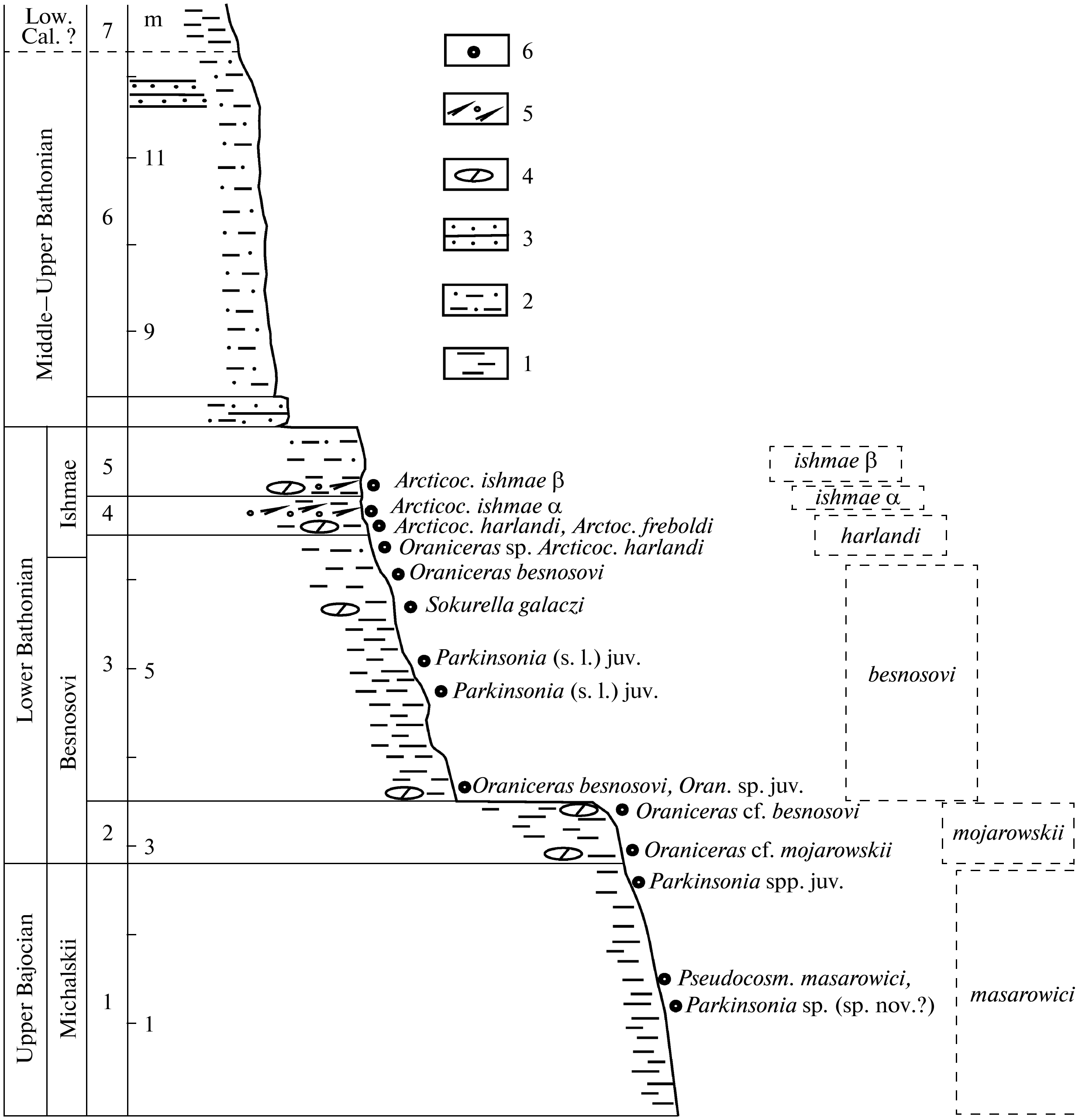

Fig. 2. The Bajocian–Bathonian Sokur quarry section, Saratov.

(1) clay; (2) silt; (3) siltstone; (4) sideritic concretions; (5) "belemnite level;" (6) in situ ammonite finds. Scale bar 1 m. Abbreviations: (low. Cal.) Lower Callovian, (*Arcticoc.*) *Arcticoceras*, (*Arctoc.*) *Arctocephalites,* (*Oran*) *Oraniceras*, (Pseudocosm.) *Pseudocosmoceras.* Faunal horizons are shown on the right.

Therefore, we agree that the imprint under consideration represents a member of Arctocephalitinae.

Other notes in relation to the Saratov ammonites concern the position of arctocephalitines in the section (Figure 2 presents all the in situ finds) and the consistency (or more accurately, the inconsistency) between assemblages of ammonites, belemnites, and bivalves (retrocerams) from the Saratov Volga region and from Middle Jurassic sections of North Siberia. It should be kept in mind that invasions of different molluscan groups could be heterochronous. This is particularly obvious in case of brief or rapid (geologically instantaneous) events. In addition, available recent information on the geographic and stratigraphic distribution of particular taxa is far from being complete and final. The certain share of subjectivism in identification of fossils cannot be ruled out as well.

The main source of doubts for our opponents is the fact that almost all the *Arctocephalites* specimens are found in situ, except for a single incomplete specimen

Plate I

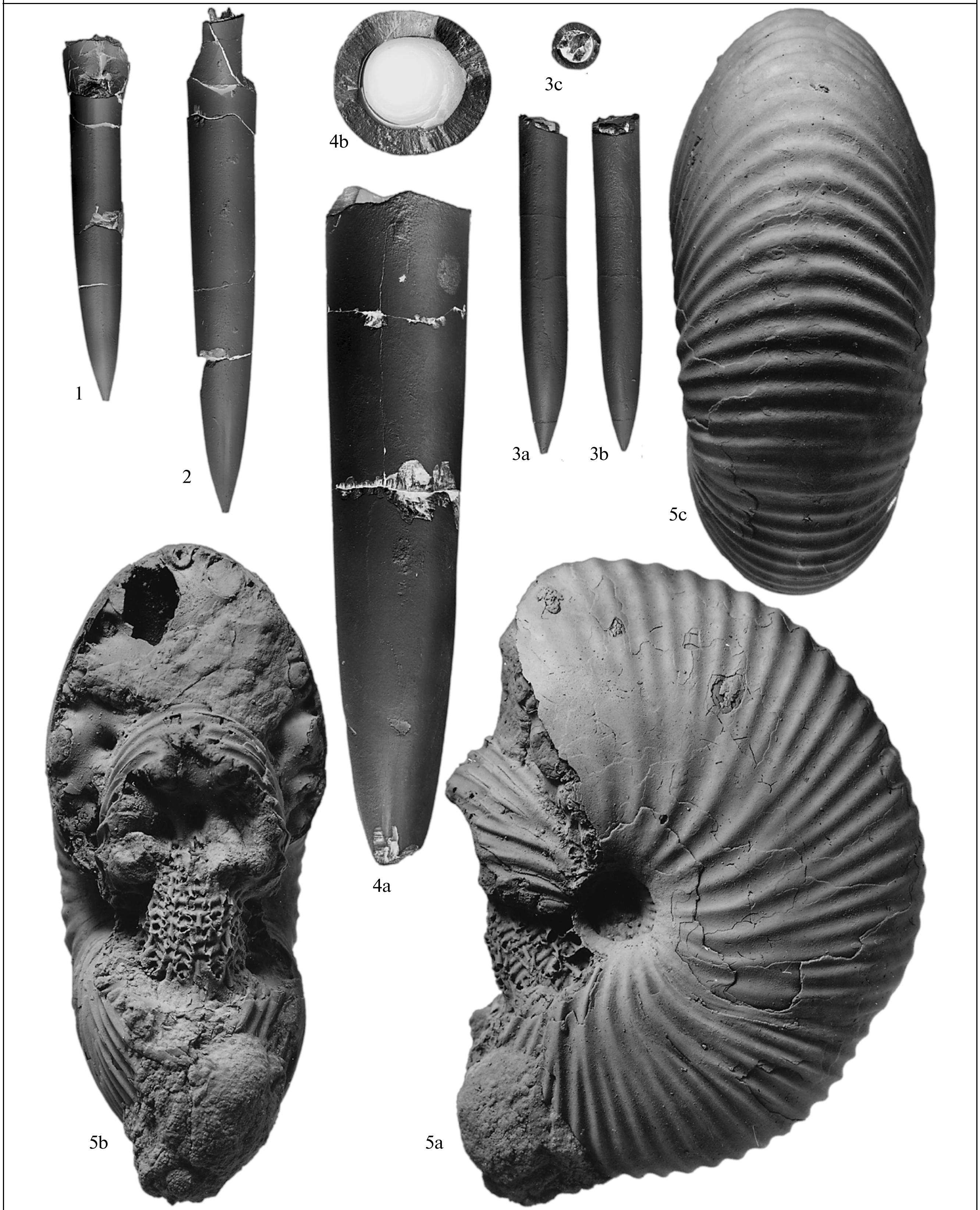

Plate I. Cephalopods from the Lower Bathonian Sokur Road section, Saratov. All images are given 0.9 of natural size.

(1–3) *Cylindroteuthis spathi* Sachs et Nalnjaeva: (1) Specimens SGM, no. CR-2884, (2) Specimen SGM, no. CR-2885, (3) Specimen SGM, no. CR-2886, all the specimens originate from beds 3–5 without more exact position; (4) *Pachyteuthis optima* Sachs et Nalnjaeva, Specimen SGM, no. CR-2887, from beds 3–5 without more exact position; (5) *Arcticoceras harlandi* Rawson, Specimen PIN, phragmocone no. 5029/088, 0.5 m below the "belemnite level," upper part of Bed 3 (*Arcticoceras ishmae* Zone, *Arcticoceras harlandi* faunal horizon). Collection by M.A. Grigor'ev.

from the *Ishmae* Zone. Taking into consideration that *Arctocephalites* forms are ancestral relative to *Arcticoceras*, their co-occurrence may serve as a basis for suspicion of their reworked state or condensed section. At the same time, the last *Arctocephalites* are also recorded in the *Ishmae* Zone of Greenland. When examining the collection by J. Callomon and T. Birkelund in the Geological Museum of the University of Copenhagen, V.V. Mitta was able to confirmed that. Moreover, Mitta suggested that Cadoceratinae evolved from *Arctocephalites* in the middle Bathonian, while *Arcticoceras* represents a dead end branch, which, like many other early cardioceratids terminated its evolution with an suboxyconic shell. Nevertheless, *Arctocephalites* representatives are relatively rare in the *Ishmae* Zone, and we assume that most specimens in our collection originate from the upper part of the *Besnosovi* Zone. The first elements of the high-boreal fauna (retrocerams, see below) appear in this zone, and it is logical to assume that high-boreal cephalopods are also present at this level.

In the critique by Meledina et al. (2009), much attention is paid to belemnites. I.S. Barskov described and illustrated (in Mitta et al., 2004) the species *Nannobelus bellus* Barskov, *N. parabellus* Barskov (the generic placement of these two species was only conditional), *Paramegateuthis* cf. *pressa* Nalnjaeva, *P.* cf. *manifesta* Nalnjaeva, and *Pachyteuthis subrediviva* (Lemoine). All the rostra illustrated in the above-mentioned work originate from the *Ishmae* Zone (beds 4 and 5); in the opinion of Meledina et al. (2009), their identifications are doubtful.

Meledina et al. (2009) also do not agree that the new species belong to the genus *Nannobelus*, considering them to be more closely related to *Brachybelus* or *Mesoteuthis*. Moreover, they note that *Brachybelus* forms are characteristic of the interval from the Toarcian to the Lower Aalenian in Siberia and of the Bajocian–Bathonian in Europe. Such different non-overlapping intervals suggest that the initial data might be faulty. It is conceivable that two new species attributed (conditionally and during the first description) to the genus *Nannobelus* might belong to the other genus. They are most similar to the species *Mesoteuthis pyramidalis* (Zieten), which is reported from the uppermost Pliensbachian–basal Bajocian. At the same time, attribution of Saratov forms to the genus *Mesoteuthis* seems groundless at least for two reasons: (1) most species of the genus, except for the above-mentioned one, are characterized by long subcylindrical rostra (Saks and Nal'nyaeva, 1975, p. 42); (2) the known stratigraphic range of the genus *Mesoteuthis* corresponds to the Pliensbachian–Aalenian in Europe and Pliensbachian–Bajocian in Siberia. The attribution of Saratov species to this genus would make its stratigraphic range unreasonably wide and the age of the host sediments, which is established as being undoubtedly Bathonian based on ammonites, older. In any case, new species are of little use for biostratigraphic correlation until they have been found in other areas. The same is also true of the placement of Saratov forms in the genus *Brachybelus*. It seems that it is in fact more correct to treat these species as *Nannobelus (?) bellus* and *N. (?) parabellus* until their internal structure can be studied.

Our opponents (Meledina et al., 2009) consider identifications of *Paramegateuthis* forms to be correct. The occurrence of *Paramegateuthis* species correlates host layers with the base of the middle Bathonian, which is consistent with our data.

In their opinion, rostra of Saratov *Pachyteuthis subrediviva* belong to *P. optima* Sachs et Nalnjaeva and *?Cylindroteuthis* sp. It should be noted that species diagnostics of the group of species *Pachyteuthis optima, P. subrediviva*, and *P. tschernyschevi* are difficult and extremely subjective (see discussion in Saks and Nal'nyaeva, 1966, pp. 21, 27); most of their quantitative parameters are overlapping. Specimens illustrated in Mitta et al. (2004) are attributed to *P. subrediviva* based on the more central position of the alveola and the rounded cross-section of the rostrum in contrast to the rounded–trapezoid section characteristic of *P. optima*. Additional material from this section (beds 1–5, mostly without more exact stratigraphic position) donated by M.A. Grigor'ev includes rostra, which may be attributed also to *P. optima* (Pate I, fig. 4). In addition, this collection also contains *Cylindroteuthis spathi* Sachs et Nalnjaeva (Plate I, figs. 1–3).

According to our opponents, the co-occurrence of *Paramegateuthis* cf. *manifesta* Naln., *P.* cf. *pressa* Naln., *Pachyteuthis optima* Sachs et Naln., and *?Cylindroteuthis* species in Siberian sections is "characteristic of the *Cylindroteuthis spathi* belemnite zone that comprises the interval from the *Cranocephalites gracilis* to *Arctocephalites* aff. *greenlandicus* zones (Meledina et al., 2009, p. 65). If this belemnite zone (*Spathi*) corresponds to three ammonite zones of the Boreal scale (from the middle of the Bajocian to the middle part of the Lower Bathonian), why can it not also include the next ammonite zone (*Ishmae*), particularly taking into consideration that the *Greenlandicus* Zone is defined with the moderator "aff," i.e., with

Plate II

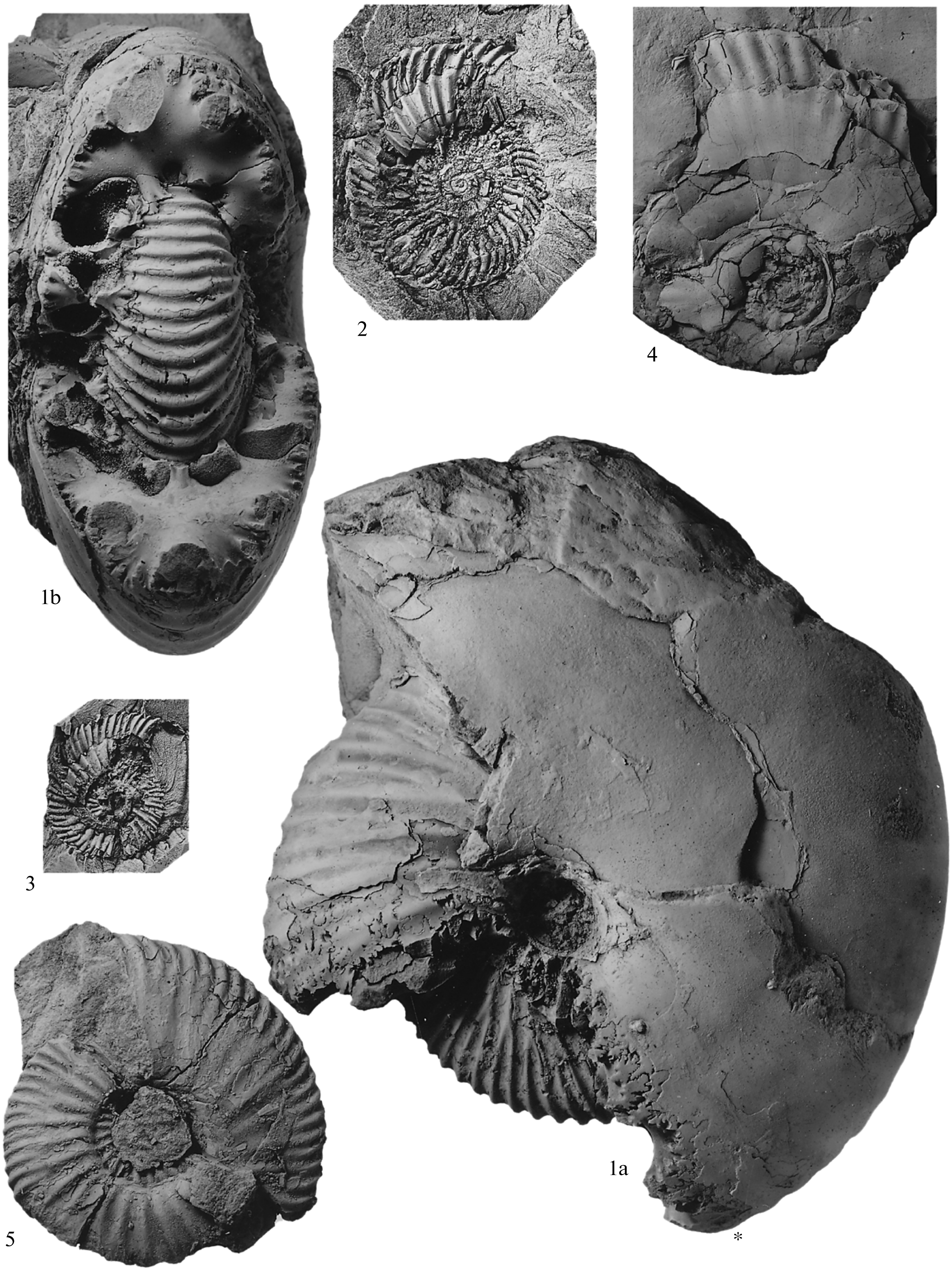

Plate II. Ammonites from the Upper Bajocian and Lower Bathonian Sokur section, Saratov.

All the images are given 0.75 of natural size; asterisk designates the beginning of the living chamber.

(1) (*Arcticoceras ishmae* (v. Keyserling) morpha *alpha*, Specimen PIN, no. 5029/089, phragmocone with the half-whorl of the living chamber, Bed 4, "belemnite level" (*Arcticoceras ishmae* Zone, *ishmae* α)faunal horizon), collection by A.V. Ivanov; (2) *Parkinsonia* sp., Specimen PIN, no. 5029/092, deformed shell, Bed 3 1.5 m above the base (Lower Bathonian, *Oraniceras besnosovi* Zone, *besnosovi* faunal horizon); (3) *Parkinsonia* sp., Specimen PIN, no. 5029/093, deformed shell, top of Bed 1 (Upper Bajocian, *Pseudocosmoceras michalskii* Zone); (4) *Parkinsonia* sp., Specimen PIN, no. 5029/090, deformed shell, Borehole Sokurskaya, depth of 4.7 m (Upper Bajocian, *Pseudocosmoceras michalskii* Zone, *masarowici* faunal horizon); (5) *Oraniceras* sp. juv., Specimen PIN, no. 5029/091, base of Bed 3 (*Oraniceras besnosovi* Zone, *besnosovi* faunal horizon).

some conditionality? In addition, the holotype of a single species, which is identified by our opponents from this assemblage in the binominal nomenclature (*Pachyteuthis optima*), originates from the "Bathonian–Callovian" interval (Saks and Nal'nyaeva, 1964, p. 209) of the Izhma River section, most likely from sandstones of the *Ishmae* Zone. Other rostra re-identified by V.I. Nal'nyaeva in open nomenclature can hardly be considered suitable for the dating of the host sediments.

In fact, the comments of our opponents and their re-identifications of belemnites, even if they are more correct, by no means disprove the age of sediments proposed in our stratigraphic model, despite discrepancies in species and generic identifications. Small discrepancies in age estimates are most likely explainable by insufficient information on the vertical distribution of belemnite taxa.

Of bivalves, our opponents commented on the genus *Retroceramus* described from the Lower Bathonian interval: *R. retrorsus* (v. Keyserling), *R.* ex gr. *retrorsus* (v. Keyserling), *R.* aff. *polaris* Koschelkina. These identifications were not contested. At the same time, they note that "the Siberian *R. retrorsus* and overlying *R. polaris* zones comprise the interval from the appearance of the ammonite genus *Cranocephalites* to the *Arctocephalites arcticus* Zone" (Meledina et al., 2009, p. 66), i.e. interval below beds with *Arcticoceras*. Unfortunately, our opponents provide no references to corresponding publications. According to the monograph dedicated to retrocerams (Koschelkina, 1963, p. 145), *Retroceramus retrorsus* (Keyserling) in the Lena River basin is found in siltstones with *Cranocephalites* and sandstones with *Arcticoceras*; information on co-occurrence of *Arcticoceras ishmae* and *Retroceramus retrorsus* is also available from other publications from the second half of the 20th century.

It should be emphasized that species of *Retroceramus* occur both at the "belemnite level" and are scattered through the entire *Ishmae* Zone. The young specimen of *R.* ex gr. *retrorsus* illustrated in (Mitta et al., 2004, Plate 8, fig. 2) originates from the interval located 1.0–1.5 m above the base of Bed 3 (*Besnosovi* Zone). Sediments occurring 0.5–1.0 m above this base yielded *Retroceramus* sp. juv. (Mitta et al., 2004, p. 5). M.A. Grigor'ev donated to us an additional *R. retrorsus* specimen from the *Besnosovi* Zone without indication of its exact stratigraphic position. Thus, the invasion of the Arctic fauna to the Saratov latitude took place as early as the Early Bathonian *Besnosovi* phase, and our assumptions on the distribution of *Arctocephalites* representatives in this zone are quite appropriate taking into consideration the confinement of this genus mostly to older layers as compared with *Arcticoceras* forms.

Taking into consideration the potential asynchrony of corresponding ammonite and belemnite assemblages in Bathonian sections of the Saratov Volga region and northern East Siberia, it follows from the comments of our opponents that it is of interest to compare the taxonomic composition of bivalve assemblages from the *Ishmae* Zone in the Saratov outskirts

Table 1. The comparative analysis of the taxonomic composition of bivalve assemblages from the Lower Bathonian *Arcticoceras ishmae* Zone of the Timan–Pechora and East European paleobiogeographic provinces

Saratov Volga region	Izhma River basin
Liostrea (*Deltostrea*) *eduliformis* (Schlotheim)	*Mclearnia broenlundi* (Ravn)
Liostrea (*Liostrea*) *multiformis* (Koch)	*Liostrea* (*Liostrea*) *multiformis* (Koch)
Modiolus (*Modiolus*) aff. *bipartitus* (J. Sowerby)	*Modiolus* (*Striatomodiolus*) sp. nov.
Quenstedtia sp.	? *Isocyprina* sp.
Protocardia sp.	*Mactromya* aff. *laevigata* (Lahusen)
Goniomya cf. *v-scripta* (J. Sowerby)	*Pachymya* (*Arcomya*) aff. *sinuata* (Agassiz)
Pleuromya? sp.	*Gresslya lunulata* Agassiz
	Pleuromya subpolaris Koschelkina

and Izhma River basin (northern Pechora region). Bivalves in the Izhma River basin (Dreshchanka Creek) were sampled by V.V. Mitta (description of sections in Mitta, 2006, 2009; identifications by V.A. Zakharov) (Table 1).

The comparative analysis of bivalve molluscan assemblages from the Timan–Pechora and Central Russia early Bathonian seas of the *Ishmae* phase reveals substantial differences. Despite the fact that both coeval (based on ammonites) assemblages are similar in their generic diversity (seven genera in the Saratov Volga region vs. eight genera in the Pechora River basin), they have only two genera and one species in common: *Liostrea* (*Liostrea*) *multiformis* (Koch). It should, however, be noted that the entire Lower Bathonian bivalve molluscan assemblage from the Saratov Volga region includes 26 species belonging to 23 genera (Mitta et al., 2004). Nevertheless, no genera and species occurring in the Saratov Volga region are found in the Pechora River basin or vice versa. The following biogeographic situation seems to exist: the assemblage from the Timan–Pechora province includes both Arctic (*Mclearnia broenlundi* (Ravn), *Modiolus (Striatomodiolus)* sp. nov., *Pleuromya subpolaris* Koschelkina, *Boreiothyris* Dagys[2] and low-Boreal taxa (*Liostrea* (*Liostrea*) *multiformis* (Koch), *Pachymya (Acromyia)* aff. *sinuata* (Agassiz), *Gresslya lunulata* Agassiz), while the assemblage from the East European province is dominated only by typical low-boreal taxa: *Liostrea* (*Deltostrea*) *eduliformis* (Schlotheim), *Liostrea* (*Liostrea*) *multiformis* (Koch), *Modiolus (Modiolus)* aff. *bipartitus* (J. Sowerby), *Goniomya* cf. *v-scripta* (J. Sowerby). Such a situation may most plausibly be explained by limited exchange between benthic molluscan communities. Differences in the biogeographic structure of mollusks are also known from the Berriasian–Ryazanian Stage of the East European Platform, where the *Riasanites rjasanensis* Zone contains, along with local Craspeditidae, diverse ammonites from the families Neocomitidae and Himalayitidae (immigrants from the Tethyan Ocean), while most bivalve molluscan taxa are represented by aboriginal forms (Zakharov and Mitta, 2010).

The critique by our Siberian colleagues (Meledina et al., 2009), who emphasize that they are the authors of parallel Middle Jurassic zonal scales based on various molluscan groups, poses numerous natural questions, for which their article provides no answers.

For example, if the *Harlandi/Ishmae* interval corresponds to the *Cylindroteuthis confessa* and *Pachyteuthis tschernyschevi* belemnite zones, their index species (belemnites) should also occur in the Saratov outskirts together with *Arcticoceras*. Nevertheless, no such species are present either in our or in Nal'nyaeva's faunal lists; the last researcher had additional materials from the Sokur quarry at her disposal. This supports heterochronous invasions of different molluscan groups to the Central Russian basin.

In the correlation model of Bajocian–Bathonian boundary units of Siberia (Meledina et al., 2009, fig. 2), the "belemnite level" of the Saratov outskirts is correlated with the *Manifesta* belemnite subzone, the base of which corresponds to the base of the *Arcticus* ammonite zone and lower boundary of the Bathonian Stage. At the same time, the authors note that "the *Medvediceras michalskii* and *Oraniceras besnosovi* zones attributed to the Upper Bajocian and lower half of the Lower Bathonian, respectively, seem to be well-grounded" (Meledina et al., 2009, p. 67). At the same time, if we admit the correctness of the correlation model proposed by our opponents, there is no place for the *Besnosovi* Zone (with typical early Bathonian *Oraniceras*) within the Bathonian Stage.

We would like to receive answers for the following questions: What are the grounds for the Bajoacian/Bathonian boundary in the Siberian scale? What are the arguments in favor of the boundary between the *Cranocephalites carlsbergensis* and *Arctocephalites arcticus* in order to consider it to correspond to the boundary between the *Parkinsonia parkinsoni* and *Zigzagiceras zigzag* zones or the Bajocian–Bathonian boundary in the West European scale? We were unable to find any answers to these questions in the publications of our opponents.

CONCLUSIONS

The sequence of Middle Jurassic clays with sideritic carbonate concretions in the upper part is studied in the Saratov outskirts. The largest lower part of this sequence corresponds to the *Pseudocosmoceras michalskii* Zone (an equivalent of *Parkinsonia parkinsoni* Zone, a terminal Bajocian unit of the standard scale) characterized exclusively by Peri-Tethyan mollusks. It is overlain by the *Oraniceras besnosovi* Zone corresponding (by the *Oraniceras* range) to the West European *Gonolkites convergens* and *Gonolkites macrescens* subzones of the *Zigzagiceras zigzag* Zone. Its sediments also contain Arctic taxa (retrocerams and, presumably, the earliest *Arctocephalites*), in addition to the Tethyan fauna. The *Oraniceras besnosovi* Zone is, in turn, overlain by the *Arcticoceras ishmae* Zone with the mixed Boreal–Arctic bivalve assemblage and exclusively Arctic cephalopods. The occurrence of intercalations with sideritic concretions and lenses with the rounded faunal remains indicate the stratigraphically condensed section and local erosion, respectively, although no distinct marks of large sedimentary hiatuses are found in the section. In our opinion, all three above-mentioned zones form a natural succession without any lacunae. Similar to the *Oxycer-*

[2] *Boreiothyris* Dagys, 1968 is a brachiopod genus (family Boreithyridae Dagys, 1968) endemic for the Arctic paleobiogeographic region; it is reported from the stratigraphic range spanning from the Callovian to Kimmeridgian stages in Arctic Siberia (Dagys, 1968); according to our interpretation, its appearance should be dated back to the Bathonian Age.

ites yeovilensis and *Arisphinctes tenuiplicatus* subzones of the *Zigzag* Zone in the West European zonal standard, parkinsoniids are completely absent from the *Ishmae* Zone. Taking into consideration the sedimentary succession (the *Besnosovi* and *Ishmae* zones constitute an element of a single sedimentation cycle), we believe that the *Ishmae* Zone may be correlated with the upper part of the Lower Bathonian in the standard scale (see correlation model in Mitta, 2009).

The critique by S.V. Meledina, T.I. Nal'nyaeva, and B.N. Shurygin is largely based on revised identifications of belemnites and the uncertain position of most *Arctocephalites* representatives found in the Sokur quarry. Reidentification of some belemnites by no means contradicts inferences in Mitta et al. (2004): despite discrepancies in species and generic identifications, the early Bathonian age of the host sediments is confirmed. *Arctocephalites* forms may originate from both the lower part of the *Ishmae* Zone and from the *Besnosovi* Zone. The last assumption is confirmed by the distribution of Arctic *Retroceramus* bivalves in this zone and finds of *Arcticoceras harlandi* in the upper part of Bed 3. Finds of *Arctocephalites freboldi* indicates the presence of the terminal faunal horizon of the *Greenlandicus* Zone in the section. No guide species of other faunal horizons of this or the underlying *Arctocephalites arcticus* Zone have been found in the outskirts of Saratov; consequently, the *Arcticus* and *Greenlandicus* ammonite zones are so far unknown in the Volga region.

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