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Correlation of Upper Bajocian–Bathonian Zones in Siberia with the Stage Standard

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Abstract—The suggestions to transfer the *Arcticoceras ishmae* Zone from the middle to the lower Bathonian and the *Arctocephalites arcticus* Zone from the lower Bathonian to the upper Bajocian put forward by some researchers, are critically considered. These suggestions are based on paleontological records from the Sokur quarry near Saratov. Based on paleontological data from Siberia represented in a number of regional ammonite, belemnite, and retroceram zonations, we infer that the proposed zonal subdivision of the Jurassic in the Sokur quarry to be untrue and believe the revision of the correlation of the above-mentioned zones with the stage and zonal standard to be premature because of insufficient argumentation.

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Key words: Bajocian, Bathonian, stratigraphy, correlation, ammonites, belemnites, Inoceramidae.

INTRODUCTION

The Bathonian stage in the modern central Siberian zonal scale includes the following zones: *Arctocephalites arcticus* and *A.* aff. *greenlandicus* (lower substage), *Arcticoceras harlandi* and *A. ishmae* (middle substage), and *A.(?) cranocephaloide* and *Cadoceras (Catacadoceras) barnstoni* (upper substage), and the upper substage of the Bajocian involves the *Boreiocephalites borealis* and *Cranocephalites gracilis* zones (Meledina, 1994; Zakharov et al., 1997; Shurygin et al., 2000).

The Siberian zonation is based on the evolutionary succession of genera and species of the ammonite family Cardioceratidae recorded in numerous Jurassic outcrops in central Siberia and East Greenland. Cardioceratidae is the only ammonoid family that dominated in the high-latitude Arctic seas in the second half of the Middle Jurassic. Among the genera listed above only *Cadoceras* and *Arcticoceras* were known in European Russia until recently (the latter from the Pechora River basin).

The past decade was marked by intense studies of the Middle and Upper Jurassic sections in the Russian Platform. The finds of *Arcticoceras* and *Arctocephalites* in the Volga River basin, the Saratov region (Mitta and Sel'tser, 2002), and that of *Arctocephalites* in the Pechora River basin (Mitta, 2006) became a real sensation. The ammonites indicate an earlier and deeper than previously considered penetration of Arctic waters to European Russia, i.e., already during the time span of *Arctocephalites*.

The discovery of belemnite and Inoceramidae forms common to the central Siberian taxa is no less significant. These two groups are widespread in the Middle Jurassic of Siberia and are well studied. Only in Siberia the numerous belemnite and inoceramid genera and species are reliably correlated with the ammonite-bearing sections. They are used in parallel zonal scales concurrent with those by ammonites (Zakharov et al., 1997; Shurygin et al., 2000, and other). The occurrence of these Arctic groups of mollusks in Middle Jurassic sediments of the Russian Platform induced us to use, along with the ammonite zonation, the Siberian belemnite and inoceramid scales for the correlation of the European Russia and Siberian Middle Jurassic.

In the Middle Jurassic the areas discussed referred to different paleobiogeographic regions, Siberia to the Arctic and European Russia to the Boreal Atlantic region. Marine fauna of the latter included both North Atlantic and Arctic elements. Belonging to distinct biogeographic regions resulted in a significant difference in the taxonomic composition of Middle Jurassic mollusks in these areas. Owing to the almost complete lack of common genera and species among Bajocian and Bathonian ammonites in Siberia and Western Europe the straightforward correlation of regional zonal units with those adopted in the international standard can be conducted only approximately. Because of this, both the definition of the range of the Bajocian and Bathonian stages and the substages in the Boreal Jurassic and the correlation of certain regional zones with the standard units are somewhat conditional.

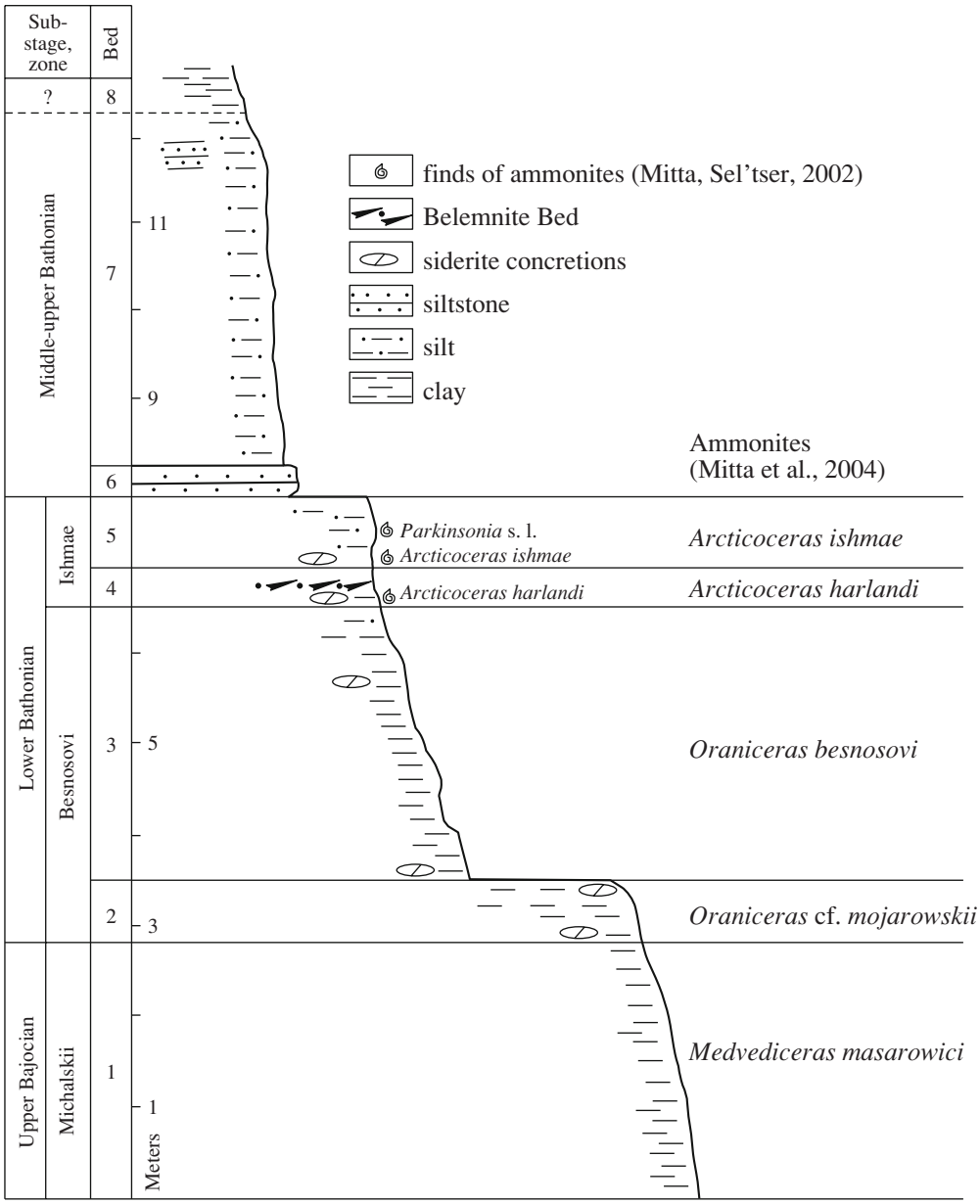

Fig. 1. Section of the Bajocian and Bathonian in the Sokurskii quarry (after Mitta et al., 2004; Mitta and Sel'tser, 2002).

The Middle Jurassic in European Russia is better correlated with the international standard owing to the presence of common with Western Europe ammonite genera and species at some stratigraphic storeys.

Below we discuss new paleontological records from the Russian Platform that some researchers use as arguments for the revision of the stratigraphic position of certain zones in the Boreal Middle Jurassic.

DISCUSSION

On the Izhma River in the Pechora River basin, *Arctocephalites arcticus* (Newt.) was encountered for the first time (Mitta, 2006). It is the index species of the Siberian (Meledina, 1994; Zakharov et al., 1997; and others) and East Greenland (Callomon, 1993; and others) zones. The *Ä. arcticus* Zone in the Siberian stratigraphic scales was placed in the lower Bathonian. Mitta (2007) suggested the late Bajocian age of the zone and correlated it with the *Parkinsonia parkinsoni* Zone. The finds of *Arctocephalites* sp., *A.* ex gr. *freboldi* (Spath), *Arcticoceras harlandi* Raws., and *A. ishmae* (Keys.) in the Sokur quarry, Saratov Volga region (Fig. 1) support this inference (Mitta and Sel'tser, 2002; Mitta et al., 2004).

In the stratigraphic scheme above the *A. arcticus* Zone Mitta (2007) shows the *Arctocephalites freboldi* (Spath) Beds as the upper part of the *Arctocephalites*

greenlandicus Zone in accordance with the position of the *A. freboldi* Subzone in East Greenland (Callomon, 1993).

The recognition of the latter biostratigraphic unit in the Russian Platform is based on finds of *A.* ex gr. *freboldi* (Spath) in the Sokur quarry near Saratov and that of *A. freboldi* (Spath) in the Pechora River basin.

In the bed-by-bed faunal characteristics of the Sokur quarry section (Mitta et al., 2004) *Arctocephalites* was not mentioned since the ammonites were found not in situ but in the quarry spoil. Thus the designation of the ammonite point in the section actually represents only an assumption of the authors. For instance, *A.* ex gr. *freboldi* (Spath) is said to originate probably from the *Oraniceras besnosovi* Zone (Mitta and Sel'tser, 2002, p. 20) and that "the specimen was encountered in the quarry spoil; it was presumably derived from siderite concretions of the *besnosovi* Zone" (the same paper, p. 24).

The authors attribute the finds of *Arctocephalites* and *Arcticoceras* to a relatively thin bed saturated with belemnite rostrums and called the Belemnite Bed. The latter was recorded in the quarry wall within Bed 2, in the upper part of the second highwall. "Somewhat below the extended Belemnite Bed a siderite concretion containing *Arcticoceras harlandi* Raws. was found (Plate 1, Fig. 1). From the same level, according to Bratashova, *Arctocephalites* sp. was derived (Mitta and Sel'tser, 2002, p. 20). It is the authors' opinion that *Arcticoceras harlandi* Raws. is associated with this interval (Mitta and Sel'tser, 2002, Table 6, Fig. 1). A mold of ammonite identified as *Parkinsonia* s.l. from a characteristic furcate rib branching that occurred in the upper part of the middle (second) highwall, above the Belemnite Bed. *Arcticoceras ishmae* (Keys.) obtained by the authors from Grigor'ev, is associated with the same level (Mitta and Sel'tser, 2002, Table 3, Fig. 1). As is evident, the reliability of the attribution of most of the ammonites is in doubt.

The belemnites derived from a distinct interval in the Sokur quarry section are of special interest as regards the stratigraphic position of the Jurassic *Arctocephalites* zones. Among them are the *Nannobelus, PachytÂuthis,* and *Paramegateuthis* species (Mitta et al., 2004). However, the new *Nannobelus* species described (Table 3, Figs. 5–8) can hardly be referred to this genus (the authors themselves noted a somewhat conditional generic identification, see p. 7). They lack the major diagnostic characteristics of *Nannobelus,* namely, a reduced postalveolar length, compressed flanks, and correspondingly a mostly oval cross-section at the alveole top.

The top sharpened and displaced toward the dorsum and the presence of radial top-located wrinkles marked for rostrums of the specimens described are not unique for this genus. They were also recorded in members of *Brachybelus* and *Mesoteuthis* (Saks and Nal'nyaeva, 1970, 1975). The genera *Brachybelus* and *Mesoteuthis* occurred in Siberia, from the Toarcian to the lower Aalenian and from the uppermost Pliensbachian to the Bajocian (*Arkelloceras* and *Chondroceras* Beds), respectively. *Brachybelus,* which members have like rostrums, is common in the Bajocian–Bathonian of Poland, England, and France. However, precise generic attribution requires data on ontogeny that can be revealed from longitudinal rostrum thin sections and from transverse thin sections made at the alveole top. Without these characteristics a precise generic definition is impossible.

The *Pachyteuthis subrediviva* (Lem.) (Mitta et al., 2004) identified from rostrums were reidentified by Nal'nyaeva as *Pachyteuthis optima* Sachs et Naln. (Mitta et al., 2004, Table 4, Figs. 1 and 2) and *?Cylindroteuthis* sp. (the same paper, Table 4, Fig. 3). *Paramegateuthis* cf. *manifesta* Naln. and *P.* cf. *pressa* Naln. are reported to be numerous.

In Siberian sections the concurrent occurrence of belemnites *Paramegateuthis* cf. *manifesta* Naln., *P.* cf. *pressa* Naln., *Pachyteuthis optima* Sachs et Naln., and *?Cylindroteuthis* is characteristic of the belemnite *Cylindroteuthis spathi* Zone that spans the interval from the regional ammonite *Cranocephalites gracilis* unit to the *Arctocephalites* aff. *greenlandicus* Zone. In this zone the mass occurrence of *Paramegateuthis* including *P. manifesta* Naln., marks the beds of the same name that correspond to the Siberian *Oxycerites jugatus* Subzone of the *Arctocephalites arcticus* Zone (Nal'nyaeva, 1986; Meledina et al., 1987; Zakharov et al., 1997).

Thus the Belemnite Bed in the Saratov Volga region, which represents the stratum bearing redeposited fauna, rounded rostrums, wood fragments, etc., most likely should be correlated with the Siberian *P. manifesta* Beds of the belemnite *Cylindroteuthis spathi* Zone. In any case it cannot be placed above the upper boundary of this zone and, according to belemnite generic and species composition, falls inside the scope of *Arctocephalites*-bearing sediments (Fig. 2).

Consequently, the attribution of *Arctocephalites* ex gr. *freboldi* (Spath) and even more so of *Arcticoceras harlandi* Raws. to the stratum below the Belemnite Bed in the Saratov section is questionable since in Siberia the *Arcticoceras* species are concurrent with the other *Cylindroteuthis* and *Pachyteuthis* forms, namely, the *A. harlandi* and *A. ishmae* zones corresponding to the belemnite *Cylindroteuthis confessa* and *Pachyteuthis tschernyschewi* zones, respectively.

The identified retroceramids encountered in the Sokur quarry spoils and hence not ascribed to the beds of the section (Mitta and Sel'tser, 2002, Fig. 2), are also represented by the index species of Siberian zones. Among them *Retroceramus retrorsus* (Keys.), *R.* ex gr. *retrorsus* (Keys.), and *R.* aff. *polaris* Kosch. are described. The Siberian *R. retrorsus* and the succeeding *R. polaris* zones correspond to the interval from the first occurrence of the ammonite genus *Cranocephalites* to

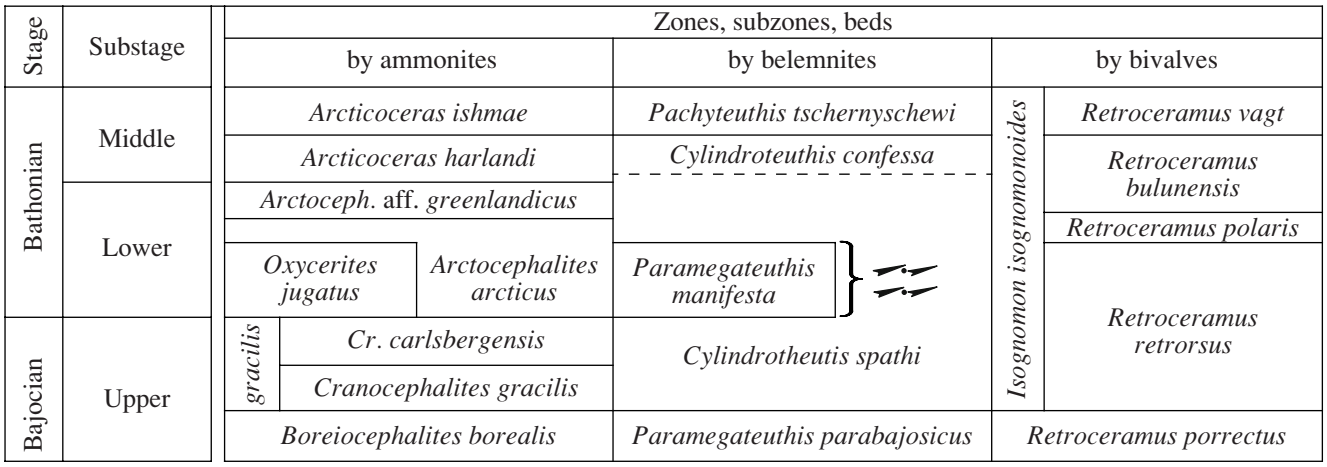

Fig. 2. Upper Bajocian and Bathonian zonal scales of Siberia and stratigraphic position of the Belemnite Bed described in the Sokurskii quarry in relation to them. Symbols as in Fig. 1.

the *Arctocephalites arcticus* Zone inclusive. This is the same interval indicated by belemnites, i.e., preceding the appearance of the *Arcticoceras*. Members of the latter are accompanied in Siberia by retroceramids of different morphology (*Retroceramus bulunensis* Kosch., *R. vagt* Kosch.) that are not found in the Sokur quarry.

Consequently, judging from the Arctocephalitinae succession in the Siberian and East Greenland sections and from concurrent belemnites and retroceramids that are well studied in Siberia, the stratigraphic level of *Arcticoceras harlandi* Raws. and *Arctocephalites* ex gr. *freboldi* (Spath) from the Sokur quarry was defined inexactly. The recorded position of *Arctocephalites* ex gr. *freboldi* in the mid-second highwall of the quarry, i.e., within the *Oraniceras besnosovi* Zone (Mitta and Sel'tser, 2002, Mitta et al., 2004), seems to be rather questionable. More likely these ammonites were derived from a layer above the Belemnite Bed or immediately from it, because the Arctic species could hardly appear in the center of the East European sea earlier than in the Arctic itself.

Among the major arguments in favor of the greater age of the *Arcticoceras harlandi* and *A. ishmae* zones in Siberia (or of the *A. ishmae* Zone with the *A. harlandi* Subzone in the Volga region) is the position of the ammonite *Parkinsonia* s.l. that has been shown to be above that of *A. ishmae* (Keys.), in the uppermost part of the second highwall (Mitta and Sel'tser, 2002, Fig. 2).

The ammonite identification as *Parkinsonia* s.l. made from a mold cannot be accepted implicitly since the ammonite has overly narrow umbilicus for *Parkinsonia,* lacks nodes in the point of rib branching and, essentially, the morphology of its ribs is not seen on the ventral side. The furcate ribs on the flank marked by the authors as its major diagnostic characteristic, are also characteristic of Arctocephalitinae taxa of similar size that can occur above the Belemnite Bed.

Thus the arguments in favor of the lower stratigraphic position of the Siberian *Arctocephalites* and *Arcticoceras* zones in relation to that of the stage and zonal standard do not seem well-documented and exhaustive for such an important decision.

The *Medvediceras michalskii* and *Oraniceras besnosovi* zones referring to the late Bajocian and lower half of the lower Bathonian, respectively, are well justified.

The upper part of the lower Bathonian *besnosovi* Zone is denoted as a provisory *Arctocephalites freboldi* faunal bed (Mitta, 2007, p. 162). As indicated earlier, according to the known faunal succession in Siberia, the *A. freboldi* (Spath) bed is bound to occur above rather than below the Belemnite Bed or coincide with it when it is considered a condensed succession of the *A. arcticus, A. greenlandicus*, and likely *A. harlandi* zones.

If we believe that the Belemnite Bed falls inside the scope of the Siberian *A. arcticus* Zone, then the overlying sediments at the top of the second highwall correspond to the Siberian *Arctocephalites* aff. *greenlandicus, Arcticoceras harlandi*, and *A. ishmae* zones.

The underlying Siberian *Cranocephalites gracilis* and *Boreiocephalites borealis* zones can be correlated with the East European *besnosovi–michalskii* units on condition of the absence of a hiatus between the Parkinsoniidae- and Arctocephalitinae-bearing sediments, which is not proved. In other words, the Siberian *ë. gracilis* and *B. borealis* zones likely correspond to the lowermost Bathonian–uppermost Bajocian interval of the East European stratigraphic scale.

In modern Siberian zonations (Fig. 2) both zones are placed in the upper Bajocian and the *Arctocephalites*-bearing sediments in the lower Bathonian. We emphasize that this inference is rather conditional as exact paleontological evidence is missing.

The find of *Arctocephalites* and *Arcticoceras* in the Saratov Volga region is remarkable and significantly corrects the notion on Middle Jurassic paleogeography. However, the problem on age refinement of the Arctocephalitinae-bearing sediments of the Russian Platform and Siberia in relation to the stage and zonal standard units has not been solved owing to the lack of reliable bed-by-bed ascription of Arctic ammonites in the Volga section, which prevents the elucidation of their true relationship with the southern Parkinsoniidae taxa, and because of the probable hiatuses in the section.

Mitta (2007) drew special attention to the magnetostratigraphic records that confirm in his opinion the paleontologists' inference on the lower Bathonian age of the *Oraniceras besnosovi* and *Arcticoceras ishmae* zones. Three normal polarity intervals recorded in the Sokur quarry section were correlated by Pimenov et al. (2006) with the three lower Bathonian magnetozones in the integrated magnetostratigraphic scale by Gradstein et al. (1995).

However, whereas the correlation of the lower N-interval confirms the correspondence of the *Oraniceras besnosovi* faunal bed to the lower Bathonian *macrescens* Subzone of the standard, the two overlying N-microzones unfortunately are not correlated in Gradstein's magnetostratigraphic scale with the boundary between the standard *zigzag* and *tenuicostatum* zones (Pimenov et al., 2006, p. 52). Thus we can believe that one N-microzone corresponds to the top of the *zigzag* Zone (*yeovilensis* Subzone) and the other to the *tenuiplicatus* Zone. Then the *ishmae* Zone should correspond to the *yeovilensis* Subzone and the overlying *tenuiplicatus* Zone of the lower Bathonian of the standard or only to its uppermost zone.

Samples for paleomagnetic research (Samples 3–5, Pimenov et al., 2006) were actually taken from the *O. besnosovi* Zone that was in our opinion partly mistakenly assigned to the *Arctocephalites freboldi* faunal bed, according to the arbitrary attribution of *A.* ex gr. *freboldi* (Spath) to the *O. besnosovi*-bearing sediments. Thus the conclusion of magnetostratigraphers was almost predetermined since neither paleontological characteristics nor the age of the lower Bathonian *O. besnosovi* Zone is in doubt.

It should be also emphasized that in studies of paleomagnetic properties of the Sokur section Pimenov et al. (2006) particularly noted the preliminary character of the correlation. Intervals of normal polarity in the Sokur quarry section were distingushed based on samples derived from one or two levels, whereas the validity of a magnetozone requires at least three levels to be investigated.

Molostovskii (2005, p. 162) noted that the middle Bathonian age of the *A. ishmae* Zone is as a whole confirmed by paleomagnetic records: "In the magnetostratigraphic scheme of the central Volga region *A. ishmae* is associated with a normal polarity zone; the middle Bathonian substage in the Mediterranean section is normally magnetized as well". Further, the author marked that Mitta's evidence of the concurrent occurrence of this boreal species with the lower Bathonian *Parkinsonia* s.l. "indicates a wider range of *A. ishmae* (Keys.)" than was considered and its probable correspondence not only to the middle Bathonian but to a part of the lower Bathonian as well. The extending of one ammonite zone to two substages shows once again the fallacy of the zonal unit based on the concurrent occurrence of the *Arcticoceras* and *Parkinsonia* species.

We believe that paleomagnetic studies are appropriate when the section includes a complete succession of zones represented in a relatively full range. In the Sokur quarry section only traces of two *Arctocephalites* and two *Arcticoceras* zones were recognized according to the ammonites, whereas the complete succession of these zones is known solely in Arctic regions.

It seems likely that in the Sokur quarry the Arctocephalitinae zones correspond to Beds 2 and 3 (Mitta and Sel'tser, 2002) that are lithologically different from the underlying Bed 1. The penetration in the East European basin of cold water mass with Arctic mollusks including ammonites, belemnites, and inoceramids, would likely have been pronounced lithologically, in the accumulation of sediments distinct from those formed during the southern transgression when Parkinsoniidae appeared.

Transgression in the East European sea during the range of *Arctocephalites* and *Arcticoceras* was most likely undulated and bottom deposits could be occasionally partly or completely washed out. Subsequently, by the time of accumulation of Bed 5 (Mitta and Sel'tser, 2002) it is likely that marine mollusks disappeared because of shallowing. This is indicated by hiatuses (Belemnite Bed and others bearing rounded belemnite rostrums) and fragmentary Arctocephalitinae zones.

CONCLUSIONS

The late Bajocian *Medvediceras michalskii* and early Bathonian *Oraniceras besnosovi* zones were recognized in the sediments of the Sokur quarry, Saratov region (Mitta and Sel'tser, 2002; Mitta et al., 2004). The latter was subdivided by Mitta (2007) into three faunal beds, the two lower beds defined by the Parkinsoniidae occurrence and the upper *Arctocephalites freboldi* unit. The overlying lower Bathonian sediments are distinguished as the *Arcticoceras ishmae* Zone that includes the lower *Arcticoceras harlandi* and upper *A. ishmae* faunal beds. They are separated by a stratum bearing numerous belemnite remains, the Belemnite Bed.

Most of Arctocephalitinae finds and all retroceramids were collected in the quarry spoil, therefore their exact position in the section was not determined. The

reported location of certain Arctocephalitinae taxa in the section is questionable.

We developed parallel Middle Jurassic zonations for central Siberia based on different mollusk groups; in so doing we relied upon the regularities of the distribution of their genera and species in the Middle Jurassic of the region and inferred that Arctocephalitinae, belemnite, and retroceramid taxa first occurred during the range of *Arctocephalites arcticus,* most likely at the beginning of this interval, namely, in Siberia these are the *Oxycerites jugatus* Subzone, *Paramegateuthis manifesta* Beds, and *Retroceramus retrorsus* Zone (Zakharov et al., 1997). This is also confirmed by a find of *Arctocephalites arcticus* (Newt.) on the Izhma River, Pechora River basin (Mitta, 2006).

As for ammonites, the presence of *A. arcticus* Zone in the Volga region can be indicated by *Arctocephalites* sp. encountered in the spoil. The find of *Arctocephalites* ex gr. *freboldi* (Spath) (Mitta and Sel'tser, 2002) which was renamed *A. freboldi* (Spath) (Mitta, 2007), indicates a younger zone. According to East Greenland records (Callomon, 1993), *A. freboldi* originated in the upper part of the *Arctocephalites greenlandicus* Zone that overlies the *A. arcticus* Zone.

The occurrence of *Arcticoceras harlandi* Raws. in the ammonite collection from the Sokur quarry suggests the presence of corresponding unit called the zone by Meledina (1994), subzone by Callomon (1993), and faunal bed by Mitta (2007).

The *Arcticoceras ishmae* Zone is recorded in the upper part of the second highwall in the Sokur quarry, above the Belemnite Bed. This is indicated by the index species found in situ. However, the illustrated ammonite mold referred to *Parkinsonia* s.l. (Mitta and Sel'tser, 2002) and shown at the same level casts doubts upon its identification. According to Meledina, this mold can represent *Arcticoceras* or other Arctocephalitinae.

Accordingly we infer the fallacy of the suggested paleontological interpretation of the Sokur quarry section. The *Arctocephalites* and *Arcticoceras* zones most likely make up the upper part of the second highwall and occur at one level with the bed bearing numerous belemnite remains or close to it. This bed resulted from the reworking of the older sediments of the *Arctocephalites arcticus* and *A. greenlandicus* zones, which is indicated by ammonites as well as by belemnites and retroceramids.

It is not clear whether the *Arctocephalites* zones directly overlie the lower Bathonian *Oraniceras besnosovi* Zone or they are separated by hiatus. However, we consider untrue that *Arctocephalites freboldi* (Spath) is shown in the upper part of the *Oraniceras besnosovi* Zone and *Arcticoceras harlandi* Raws. below the Belemnite Bed.

From the above discussion it follows that the revision of the age of regional Bajocian and Bathonian units presently recognized in Siberia is premature. What can be now stated is the correlation between the *Arctocephalites freboldi*-bearing sediments in the Volga region and the *Arctocephalites* aff. *greenlandicus* Zone in Siberia; the Belemnite Bed and Siberian *A. arcticus* Zone (likely its lower part); and between the *A. ishmae* Zone including *A. harlandi* Subzone and the two corresponding Siberian zones.

The problem whether these zones should be considered Bajocian as suggested by Mitta and his coauthors or Bathonian as was accepted (*Decisions…,* 2004), has not been solved with any certainty. We believe that there is no point in replacing one conditionality by another, no better proved.

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