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DISCUSSIONS

Geological Features of the Bajocian–Bathonian in the Reference Section of the Izhma River Basin (European North of Russia) and the Succession of Ammonites of the Subfamily Arctocephalitinae Meledina

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Abstract—The article discusses the main disagreements between two published models (the authors' model and the previously published model by V.V. Mitta et al.) of the structure and stratigraphic subdivision of the Bajocian–Bathonian reference section in the north of European Russia (near the Dreshchanka River mouth, Izhma River basin). Calculation of dip and strike makes it possible to verify mutually exclusive correlation schemes for key outcrops exposed near the Dreshchanka River mouth. It is shown that the correlation model for outcrops proposed by V.V. Mitta is inconsistent. According to this model, the actual thickness of the Bajocian part of the succession is understated. Some disagreements in ammonite stratigraphy are also discussed. Ammonites occurring in the lower Bathonian Ishmae Zone of the Timan–Pechora region belong to a single species, *Arcticoceras ishmae*, characterized by a wide range of intraspecific variability. The available data for the studied region does not allow any further division of the Ishmae Zone into either subzones or biohorizons. The classical succession, including four consecutive biohorizons in East Greenland, is based on the change of chronosubspecies/chronovariations of the species *A. ishmae*, which differ in the ratio of intraspecific morphs of the proposed variability. Currently, it is impossible to define these horizons in the Timan–Pechora region sections because representative sets of well-referenced samples are absent.

Keywords: upper Bajocian, lower Bathonian, stratigraphy, structural geology, ammonites, Timan–Pechora region

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INTRODUCTION

In 2021, the article by V.V. Mitta, "On the Stratigraphy of the Bajocian–Bathonian Boundary Beds (Middle Jurassic) of the Izhma River Basin, Northern European Russia," was published in *Stratigraphy and Geological Correlation* (vol. 29. no. 5, pp. 598–605). Despite the neutral heading of the article, its significant part is reduced to a critical discussion of the results obtained and published in some recent works with our participation (Ippolitov et al., 2019; Kiselev, 2020a, 2020b; Kiselev and Ippolitov, 2020; Zakharov et al., 2020) devoted to the study of the reference sections of the Bajocian–Bathonian deposits of the Timan–Pechora region, located in the area of the Dreshchanka River mouth, Izhma River basin.

V.V. Mitta has repeatedly visited this area and is the leading author of many articles concerning its geology and biostratigraphy (Mitta, 2006, 2009; Mitta et al., 2013, 2014, 2015). Therefore, his comments on our works require careful attention and comprehensive analysis. The fundamental differences with our results are as follows:

(1) other ideas of the correlation of a series of outcrops in the lower reaches of the Dreshchanka River;

(2) different view of the classification of ammonites of the genus *Arcticoceras* and their biostratigraphic interpretation;

(3) other ideas of the relationship of Boreal ammonite zones with the scale of Jurassic stages. On the basis of this, V.V. Mitta disagrees that it is possible to date the most ancient interval of the studied sequence to the early Bajocian (Zakharov et al., 2020).

The present paper aims to verify the validity of conflicting geological interpretations proposed by the authors and V.V. Mitta (chapter I, written by A.P. Ippolitov) and to provide the necessary explanations for the classification of ammonites of the early Bathonian genus *Arcticoceras* (chapter II, written by D.N. Kiselev). We do not discuss controversial issues concerning the correlation of the Arcticus Zone and the age of the ~3 m underlying interval, which was characterized by the finds of the *Retroceramus* species (Zakharov et al., 2020). This is because all known attempts of correlating the Arcticus zone with the greater part of the lower Bathonian (Callomon, 1993; Westermann, 1992), the lower part of the lower Bathonian (Callomon et al., 2015), the terminal upper Bathonian (Mitta et al., 2004; Mitta, 2007, 2009), or the upper Bajocian in full volume (Meledina, 2013, 2014) have no rigorous substantiation supported by reliable paleontological data. Therefore, until new evidence is obtained in favor of a particular point of view, the discussion on this issue does not seem constructive.

I. CORRELATION OF SECTIONS IN THE LOWER REACHES OF THE DRESHCHANKA RIVER AND VERIFICATION OF RELIABILITY OF EXISTING CORRELATION MODELS

The correlation schemes of outcrops in the Dreshchanka River lower reaches presented in publications with our participation (Kiselev and Ippolitov, 2020; Zakharov et al., 2020) and Mitta's works (Mitta et al., 2015; Mitta, 2021) contradict each other. Our colleague considers those sections that we interpret as parts of the generalized sequence that are superimposed on each other to be parallel. This leads to a completely different interpretation of the structure of the generalized section of the Bajocian–Bathonian.

Research Methods

Standing up for his views on the structure of the sequence and the correlation scheme of outcrops, Mitta (2021) supports them by discussing the pattern of bedding of the Bajocian–Bathonian, in particular, the approximate dip direction, the difference in elevation of the Dreshchanka River channel and their potential impact on the correlation of outcrops, and the absence of faults. Indeed, it is possible to verify the reliability of existing models objectively and independently, namely, using structural and geological patterns. We use this approach in the present paper.

The main volume of the actual data that served as the basis of our research was collected in August 2018, during the summer–autumn low-water season. The additional field works were conducted in August 2019 at an abnormally high (flood) amount of surface water.

The topographic maps the data from which are used in this work are taken from https://satmaps.info/. All distances were measured using the CorelDRAW 2020 drawing software using the Google Maps satellite images. The equation of the interpolation curve of the downstream tract of the Dreshchanka River channel was chosen using the Statistica 10 software program.

The location diagram of the outcrops mentioned in this work is shown in Fig. 1. The numbers of the outcrops in the text and figures correspond to those in (Kiselev and Ippolitov, 2020; Zakharov et al., 2020). The numbers of the same outcrops given in square brackets are from Mitta's recent works (Mitta, 2021; Mitta et al., 2015).

Profile of the Dreshchanka River Channel

To begin with, let us calculate the parameters of the profile of the Dreshchanka River channel, which is necessary for further structural constructions. Mitta (2021, p. 116) states that "the difference of altitudes from the outcrop D-5 [the most distant from the mouth for the site under consideration (author's note)] along the Dreshchanka River channel to its mouth is insignificant, within 1 m." But is this really the case?

On the 1 : 100000 topographic map (sheet P-39-11,12; 1999)[1], two marks of low-water level can be found along the Dreshchanka River channel and the intersection of the river channel with the 80th topographic contour line in the middle reaches (Fig. 1). In addition, at ~230 m below the mouth of the Dreshchanka River, the Izhma River intersects with the 60th topographic contour line. Considering that the slope of the Izhma River channel is insignificant (the mark of 61 m is located 5 km upstream, approximately opposite the mouth of the Obyhodny Yol' Stream, according to the data from the 1 : 200000 topographic map; Fig. 1), one can neglect the displacement of a reference point relative to the Dreshchanka River mouth and assume that the water level altitude is 60.0 m here. Thus, we have four reference points in total for modelling the profile of the Dreshchanka River channel. As seen from the arrangement of reference points following their distance from the Dreshchanka River mouth (Fig. 2), the channel's inclination is uneven. It is steep in the estuary part, becoming relatively flat slightly upstream. More upstream, the inclination is again noticeable. Using these four reference points, the following equation of the interpolation curve of the riverbed profile can be selected:

$$H = 0.001555L^3 - 0.072795L^2 + 1.81925L + 60,$$

where L is the distance from the mouth along the channel (m) and H is the water level in the low-water season (m).

Using the equation of this curve, it is easy to calculate the water level in the low-water season at any arbitrary point, knowing its distance from the mouth. The results of calculations of water level marks at observation points that are important for further constructions are presented in Table 1.

[1] Hypsometric data on the Dreshchanka River represented on this map are slightly different from the data on the less detailed 1 : 200 000 map (sheet P-39-V, VI, 1969). Therefore, to avoid the conflict of data, we did not use the latter.

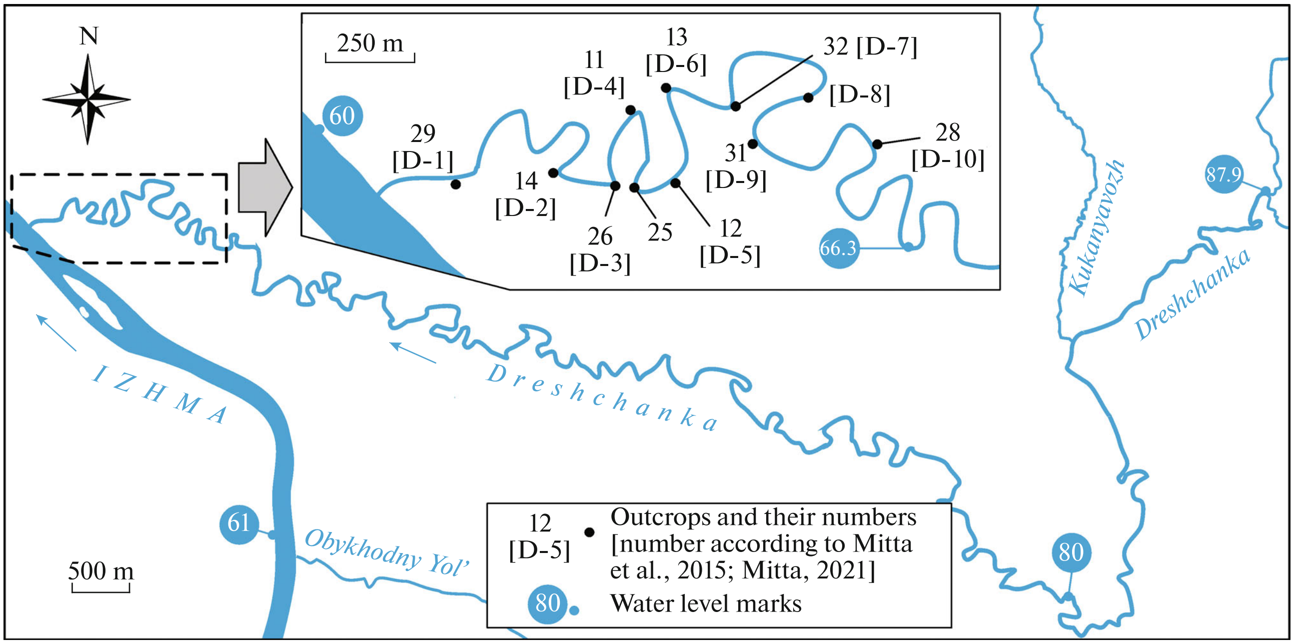


Fig. 1. The location diagram of outcrops mentioned in the text and known hypsometric marks of the riverbed of the Dreshchanka River.

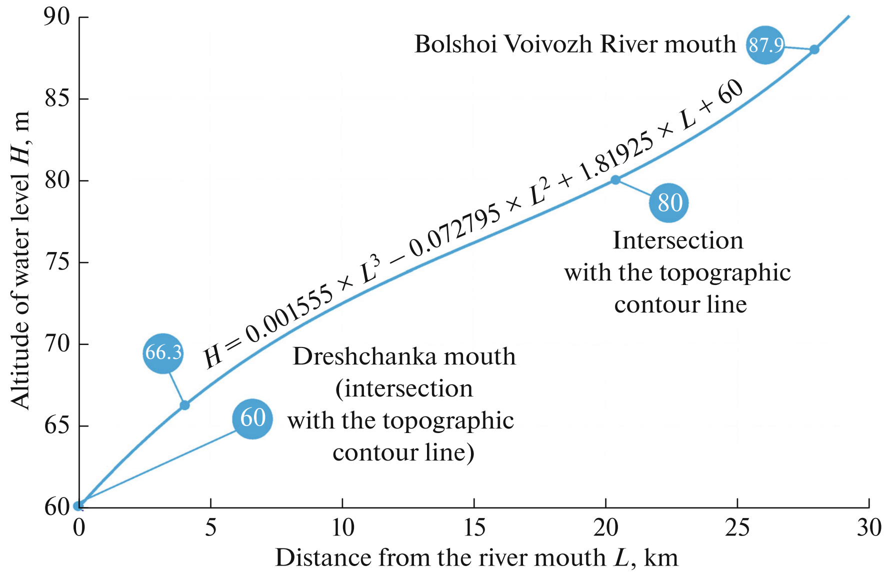


Fig. 2. The model of the riverbed depth profile of the downstream tract of the Dreshchanka River compiled using the known altitude marks of the water level.

Dip and Strike of the Jurassic Strata

We will need to measure the dip and strike of deposits in the Bajocian–Bathonian strata for further constructions. The direct measurement in sections is impossible. The massive varieties of rocks are lumpy (sandstones) or lenticular (lithified clay layers enriched in iron oxide), and their surfaces do not reflect the apparent orientation of the stratification planes. However, the dip and strike can be calculated geometrically on the basis of the reference points, where a sole well-recognized marker horizon is recognized in the sections. "*Arcticoceras* sandstone" ("horizon C" after (Zakharov et al., 2020) = "unit III" after (Mitta et al., 2015; Mitta, 2021)) is considered such a horizon.

A fundamentally crucial methodological aspect is the need to use only those sections the structure of which we and V.V. Mitta interpret in the same way. Otherwise, the very idea of verifying correlation models using the calculated dip and strike becomes a priori meaningless because of discrepancies in the interpretation of the primary data underlying the structural calculations.

In the works by V.V. Mitta (Mitta, 2021; Mitta et al., 2015), there are indications of the presence of *Arcticoceras* sandstone in eight sections along the Dreshchanka River: 29 [D-1], 26 [D-3], 11 [D-4], 12 [D-5], 13 [D-11], 31 [D-7], [D-8], and 32 [D-9]. Not all of these points are suitable for calculating the dip and strike. In our opinion (Ippolitov et al., 2019; Ippolitov in Zakharov et al., 2020; Kiselev and Ippolitov, 2020), Mitta mistakenly identified the lower sandstone horizon ("bed B" after (Zakharov et al., 2020)) as *Arcticoceras* sandstone at points 29 [D-1] and 26 [D-3].

Arcticoceras sandstone is present at point 11 [D-4] as loose blocks in the right bank of the Dreshchanka River and as the talus at the water level. However, we cannot determine the exact position of its bottom and top in the exposure. Judging by the fact that we have found fragments of this sandstone on the slope 2.5 m above the riverbed, the bedrock exposure, contrary to the reference by Mitta (2021), is located not at the water level, but higher, inside the grass-covered slope. At point 32 [D-9], a small outcrop of *Arcticoceras* sandstone is observed at the water's edge. Still, its top is unconformably overlain by Quaternary alluvium, and the bottom of the bed is located below the water level. Because of this, we were not able to reliably establish its upper and lower boundaries. At the point [D-8] mentioned by Mitta (2021), we found no bedrock outcrops.

Thus, there are only three suitable reference points in the Dreshchanka River basin, exactly as many as are necessary for calculating the dip and strike. Regarding the interpretation of these points, we have no disagreements; i.e., together with V.V. Mitta, we admit the presence of a marker horizon and its bedrock exposure. These are points 12 [D-5], 13 [D-6], and 32 [D-9].

Note that only the bottom of *Arcticoceras* sandstone can be observed at point 12 (the top is overlain unconformably by the Quaternary alluvium). At points 13 and 32, on the contrary, only the position of the top is established (Fig. 3a) by pyrite nodules scattered on the surface and silty-clay mudslides immediately above the obvious bend in the profile of the bank corresponding to the top of the sandstone bed. Since the bed has a significant thickness, it is necessary to use its top or bottom as a reference level. First of all, it is required to evaluate the entire thickness. This can be done at point 13, where there is a deep niche under the sandstone bed lying below the water level. By analogy with the section profile at point 12, we assume that the transition to this niche corresponds to the base of the dense part of the sandstone bed. It turns out that the total thickness of *Arcticoceras* sandstone, taking into account the looser lower part in outcrop 12 (Fig. 3a), is 1.5 m. This value does not contradict the actual data published by our colleague in recent years (see Mitta et al., 2015, text-fig. 2), although a larger thickness of up to 2.5 m for the same horizon is noted in earlier works (Kravets et al., 1976; Meledina, 1987; etc.), which is not confirmed by our studies.

Table 1. Calculated hypsometric water levels at key observation points

Observation point	Distance from the mouth along the riverbed (m)*	Calculated altitude of water level (m)**
29	239	60.4
14	986	61.7
26	1117	61.9
25	1614	62.8
12	1739	63.0
13	2014	63.4
31	2987	64.7

* Rounded to a whole number.
** Rounded to 0.1 m.

Knowing the hypsometric position of the water level at the reference points (Table 1) and calculating the position of the *Arcticoceras* sandstone top relative to it (Fig. 3a), using the structural triangle of points 12, 13, and 32 (Fig. 3b), it is easy to calculate the dip and strike of the Bajocian–Bathonian. They are as follows: dip direction 30.9° NE, dip 1.07°. The dip direction is in good agreement with the geological map of the studied area, showing the Mesozoic strata to dip slightly to the northeast (Fig. 3b). Note that the obtained dip angle value of ~1° does not refute our previous statement about "the NE dipping of layers at an angle of ~0.5" (Ippolitov in Zakharov et al., 2020, p. 74) since the calculated value refers to a small site of the studied area considered in this paper. In contrast, in general, the Jurassic sediments have smaller dip angles (Ippolitov, unpublished data).

Correlation of Outcrops in the Lower Reaches of the Dreshchanka River: Verification of Existing Models Using Structural and Geological Data

Using the entire set of the obtained data, we will proceed directly to verify conflicting correlation schemes. One of the significant and, at first glance, convincing arguments against our variant of correlation in a critical article by Mitta (2021) is the correlation scheme of sections by marker sandstone beds at points 12 [D-5], 25, 26 [D-3], 14 [D-2], and 29 [D-1] (Mitta, 2021, text-fig. 3). It follows from this scheme

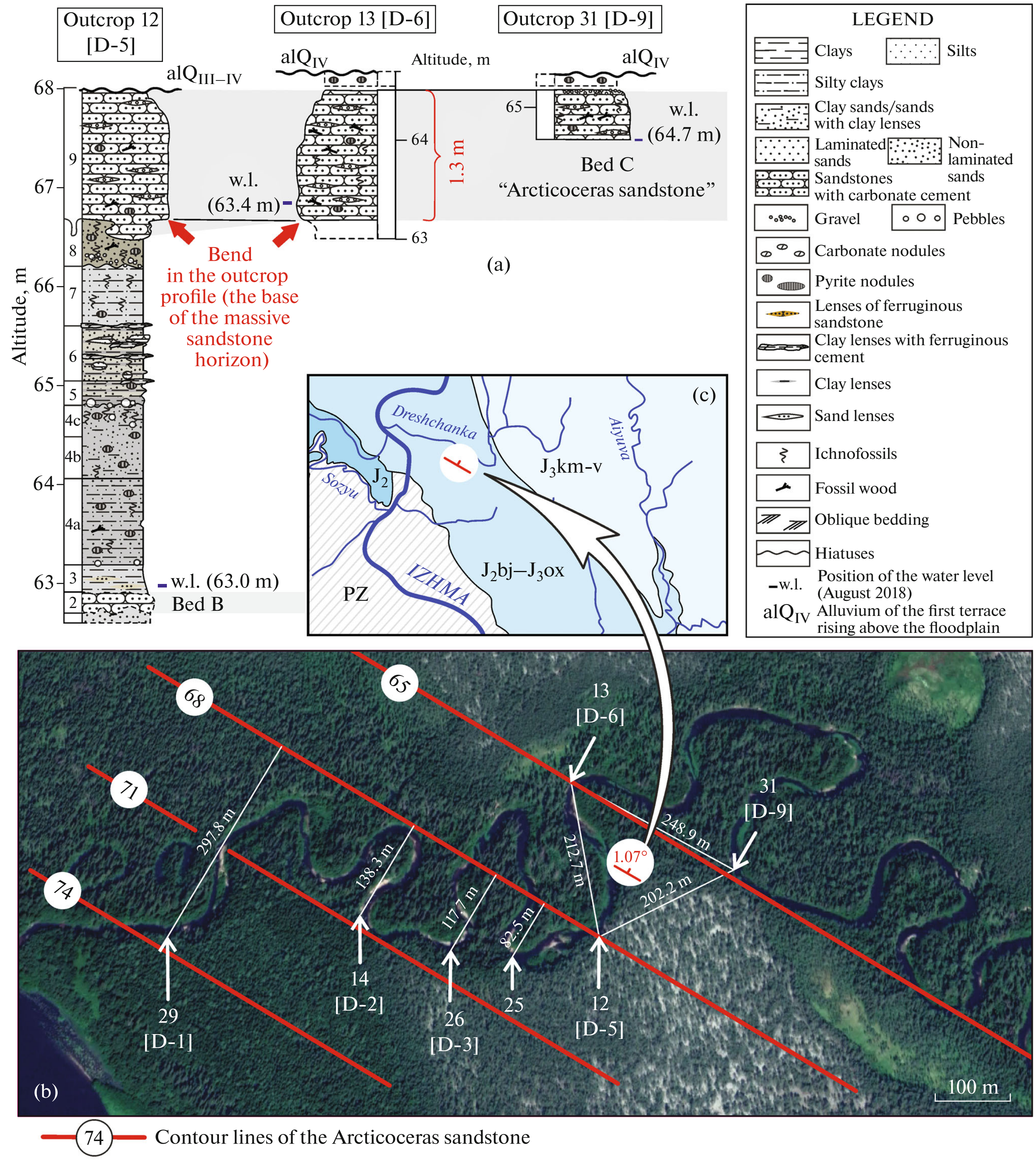


Fig. 3. Calculated dip and strike of the Bajocian–Bathonian stratum in the Dreshchanka River basin based on a marker horizon (*Arcticoceras* sandstone). (a) Schematic sections at three reference points and their correlation; (b) structural diagram (a Google Earth satellite image was used as a backing sheet) compiled for the top of the *Arcticoceras* sandstone; (c) a fragment of the geological map of the studied area and the relationship between calculated dip and strike with a general structural plan.

that the levels that we consider to be isochronous (Kiselev and Ippolitov, 2020; Zakharov et al., 2020) allegedly “dive” into the bottom of the succession in an illogical way eastwards, from the mouth of the Dreshchanka River. A corrected version of the same scheme in which both variants of correlation are compared with the forecast model calculated on the basis of the dip and strike of the strata is given below.

Table 2. Calculated altitudes of marker levels (Bed B and *Arcticoceras* sandstone) at reference points

Point no.	Calculated altitude of the water level (m)	Thickness of the section above the water level (m)	Altitude of the top of the section (m)	Bed C ("*Arcticoceras* sandstone")		Bed B	
				bottom	top	bottom	top
31 [D-9]	64.7			63.7	**65.2**	60.0	60.1
13 [D-6]	63.4			63.0	**64.5**	59.3	59.4
12 [D-5]	63.0	5.0	68	**66.5**	68.0	**62.8**	**62.9**
25	62.8	3.4	66.2	68.0	69.5	64.3	64.4
26 [D-3]	61.9	3.4 *	65.3	68.7	70.2	65.0	65.1
14 [D-2]	61.7	5.5 **	67.2	69.1	70.6	65.4	65.5
29 [D-1]	60.4	4.8	65.2	71.1	73.6	68.4	68.5

* Thickness is given after (Mitta, 2009), because we studied this section in 2019 when an abnormally high water level of the river was observed, and the lower part of the outcrop was unavailable for study. ** The upper part of the outcrop at the point shown in Fig. 3b was eroded in the Quaternary; its thickness is 4.5 m. The thickness of 5.5 m is indicated, taking into account the offlap of the section in the northeastern part of the extended outcrop. The levels directly observed at the points of the reference triangle are shown in bold.

Compared to the original drawing from Mitta's article, the following changes were made to the scheme:

(1) The scheme was compiled taking into account the altitude scale.

(2) The position of all marker sandstone beds in the sections was revised, and "extra" beds were removed. The statement by Mitta (2021, p. 113) that "the data [A.P. Ippolitov et al.] on the structure of the sections ... do not contradict my previously published data in general" is fundamentally incorrect. The reference sections 26, 14, and 29 in our version have entirely different internal content. In particular, they do not include the sandstone interbeds in the middle part, mapped by Mitta (2021, text-fig. 3). The reasons for these discrepancies are discussed in the next section.

(3) The horizontal scale is not considered in the scheme since this no longer makes much sense if there are geometrically calculated forecast values of the position of the beds. Only the correspondence/discordance of the observed actual position of the marker beds to the calculated one is important.

As a reference outcrop for further constructions, we took the section at point 12 [D-5], regarding the structure of which we have no fundamental disagreements with our colleague. In this outcrop, two sandstone interbeds can be directly observed. The lower bed, lying at the water level, is called "Bed B" in our works and corresponds to the "unit 0" in Mitta's scheme, and the upper one is "Bed C," or "*Arcticoceras* sandstone," corresponding to the "unit III" according to Mitta (Fig. 3a). Knowing the hypsometric position of these beds at point 12 [D-5] and using the dip and strike of the strata calculated in the previous section (see also Fig. 3b), we can calculate the altitudes of the same beds in outcrops 25, 26, 14, and 29 (Table 2).

The final correlation for columns is shown in Fig. 4. According to the calculated model, it is easy to see that both the *Arcticoceras* sandstone bed and Bed B rise toward the mouth of the Dreshchanka River by almost 6 m. This corresponds to our ideas about the correlation of outcrops and, on the contrary, contradicts Mitta's correlation scheme. That is especially noticeable in the interval of section 12 [D-5]–section 26 [D-3].

Of course, we cannot expect an ideal coincidence of the observed positions of sandstone beds with the predicted values. When calculating, we cannot take into account, for example, small deviations of the downstream tract of the Dreshchanka River channel from the equation of the interpolation curve and changes in the dip and strike over the area. In addition, the calculated dip and strike initially contain an error, which can lead to maximum deviations from the model in the sections most remote from the reference outcrop 12, that is, in sections 14 [D-2] and 29 [D-1]. Although the predicted position of both sandstone horizons in the most remote section 29 [D-1] does not coincide with any of the models, it is still much closer to our interpretation, according to which the crowning sandstone bed in section 29 corresponds to Bed B of the reference outcrop 12.

The Reasons for the Erroneous Correlation in the Works by V.V. Mitta

As follows from the previous section, it is our correlation scheme of outcrops in the lower reaches of the Dreshchanka River that is confirmed by structural and geological constructions, and reference sections 12 [D-5] and 26 [D-3] build on each other and are not parallel, as our colleague suggests. However, if we look at the geological data (Mitta, 2021, text-fig. 2; Mitta et al., 2015, text-fig. 2), it turns out

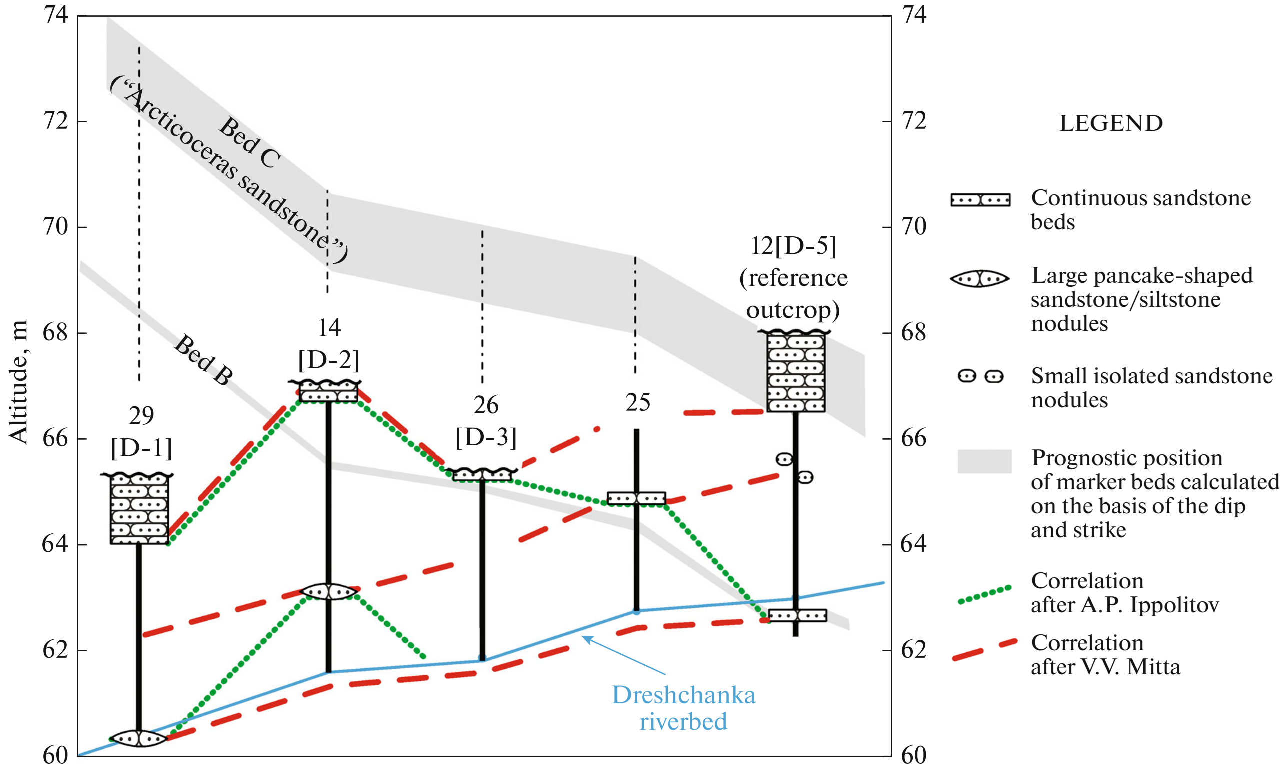


Fig. 4. Correlation diagram of outcrops in the lower reaches of the Dreshchanka River: correlation of models by V.V. Mitta and A.P. Ippolitov with a proposed model compiled on the basis of the dip and strike of the studied stratum.

that the columns of sections 12 [D-5], 26 [D-3], and 29 [D-1] have an absolutely identical structure (drawing) and they can be correlated layer-to-layer. What is the reason for this contradiction, and why do we insist on an erroneous correlation of sections in the work of our colleague?

During the field works in the Izhma River basin in 2018, our team was not planning to change the numbering of outcrops published in the literature and redescribe the published columns layer-by-layer. However, this turned out to be necessary for two reasons.

Firstly, in the articles of our predecessors published by that time, there were no coordinates of the outcrops, and the tracing of the Dreshchanka River channel on maps indicating the positions of the sections was extremely schematic (Mitta, 2009, text-fig. 1a; Mitta et al., 2015, text-fig. 2), and some of the outcrops mentioned in the text were absent on these maps (for example, D-8 and D-9). This made it challenging to identify the localities of previously known sections in field. Therefore, all the outcrops in the Dreshchanka River basin were numbered anew to understand their relationship with the points previously described in the literature in laboratory conditions.

Secondly, the use of layer-by-layer subdivision given in the summarizing work of our predecessors (Mitta et al., 2015, text-fig. 2) turned out to be impossible. We did not recognize the beds defined on the columns in the cited work in sections 14 [D-2[2]], 26 [D-3], and 29 [D-1]. For this reason, it also became impossible to use some lithostratigraphic units recognized by our predecessors ("unit I" and "unit II").

Figure 5 represents a very illustrative comparison of images of actual geological sections with columns published in our works and Mitta's works.

Figure 5a shows the reference outcrop 12 [D-5]. As seen in the natural erosion profile, the central part of the section, about 0.6 m below the *Arcticoceras* sandstone bottom, encloses a unit of contrasting interlayers of clays and medium- to coarse-grained sands with a pebble horizon at the base. The sand beds in the upper half of the unit enclose massive sandstone nodules, often of a regular spherical shape. This unit is recognizable both on Mitta's column (Fig. 5a, on the right) and our column (Fig. 5a, on the left). Let us also pay attention to the talus of *Arcticoceras* sandstone, clearly visible in the image, represented by characteristic medium- and large-plated crushed stone of a reddish color. This is an actual example of how does the *Arcticoceras* sandstone talus looks like in all outcrops in the

[2] Section 14 in (Zakharov et al., 2020) was erroneously correlated with section D-3 sensu Mitta et al., 2015 due to inaccurate original indication of location of this section (see discussion in Zakharov et al., 2020, p. 75).

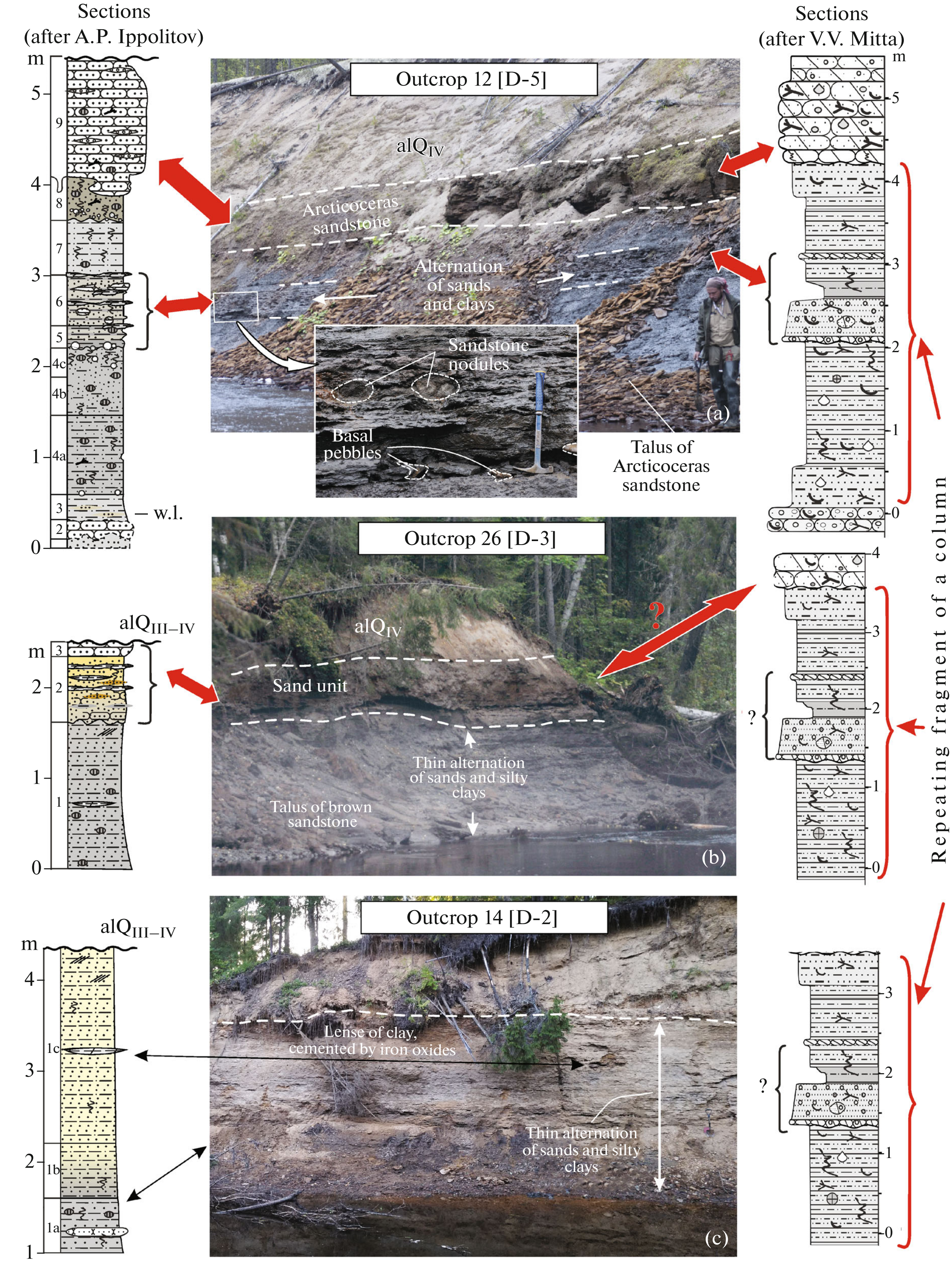


Fig. 5. Comparison of columns from the authors of this paper (Kiselev and Ippolitov, 2020; Zakharov et al., 2020) and V.V. Mitta et al. (Mitta, 2021; Mitta et al., 2015) with real geological sections. (a) Outcrop 12 [D-5], image by D.N. Kiselev, 2019; (b) outcrop 26 [D-3], image by D.N. Kiselev, 2019; (c) outcrop 14 [D-2], image by D.N. Kiselev, 2018. The column of outcrop 14 differs from the previously published one (Zakharov et al., 2020), being somewhat cropped at the top and bottom. It demonstrates only a fragment of the laterally extended outcrop, corresponding with the actual photo. See legend in Fig. 3.

Dreshchanka River basin, where this horizon is reliably recognized.

If we turn to Fig. 5b (outcrop 26 [D-3]), then according to Mitta's column (Mitta et al., 2015, text-fig. 2; Mitta, 2021, text-fig. 2), the section of this outcrop has a layer-by-layer structure similar to that in section 12 [D-5]. However, we do not observe in the image either the characteristic talus of *Arcticoceras* sandstone or the unit of alternating sands and clays visible in the profile. Accordingly, neither the pebble horizon at the base of this unit nor the sand nodules characteristic of its upper part have been established in this section. Below the sandy brown horizon crowning the section, the entire succession is represented by regular thin alternation of silty clays and fine-grained sands.

Like in the section 26 [D-3], the sequence available for study in section 14 [D-2] (Fig. 5b) is represented by the regular thin alternation of silty clays and sand, which again contradicts our colleague's data on the structure of the section.[3] There is also no alternation unit with a pebble horizon at the base and sandstone nodules.

Finally, marker horizons in section 29 [D-1], which are also layer-by-layer identical to section 12 [D-5] (Mitta, 2021, text-fig. 2; Mitta et al., 2015, text-fig. 2), established in the latter, are also absent. Unfortunately, it is impossible to demonstrate an image where the stratification pattern in this section is evident, as this outcrop is overlain by thick debris and was opened by a narrow, constantly collapsing trench.

It follows from all the above that the columns presented in the works of V. V. Mitta et al. show nonexistent layers in some sections. This means that these publications contain fictitious data. Sections D-1 and D-3 presented in these works could not be described in the field. We can only assume that their columns were compiled speculatively at the stage of preparing the summarizing article (Mitta et al., 2015). The firm confidence of our colleague that all these sections are parallel to the sequence interval available for study in section 12 [D-5] could be the basis for such an extrapolation. This point of view is reflected in his earlier article (Mitta, 2009, text-fig. 2), which means that the similarity of the layer-by-layer structure of all these outcrops was assumed a priori.

From all the above, it follows that the correlation scheme of outcrops in the lower reaches of the Dreshchanka River made by our colleague (Mitta et al., 2015, text-fig. 2; Mitta, 2021) is untenable. Accordingly, arguments about the facies variability of *Arcticoceras* sandstone based on the erroneous identification of this horizon in sections 26 [D-3] and 29 [D-1] (Mitta et al., 2015, p. 313), as well as paleogeographic conclusions obtained from the analysis of this "facies variability" (Mitta et al., 2015, p. 326; Mitta, 2021, p. 116), lose their meaning. We consider the proofs of our point of view given in this article to be exhaustive.

[3] V.V. Mitta did not provide an independent column for this section in his recent works. However, taking into account the general correlation scheme (Mitta, 2009, Fig. 2; 2021, Fig. 3) and the position of this section between the sections 26 [D-3] and 29 [D-1] that are closely located and at the same time absolutely identical in the distinguished beds, it is obvious that column D-2 should repeat the column of section D-3, from which it differs (Mitta, 2009, Fig. 2) only in the absence of the crowning sandstone horizon.

II. ON THE SEQUENCE OF ARCTOCEPHALITINAE IN THE LOWER BATHONIAN

There is no single idea about the taxonomic subdivision of the genus *Arcticoceras* Spath—one of the most stratigraphically important genera of Arctocephalitinae. This largely prevents the detailing of the zonal scale of the Boreal lower Bathonian. According to one point of view, this genus includes several chorospecies, chronospecies, and chronosubpecies, some of which form the sequence in the lower Bathonian Ishmae Zone consisting of three–four links: *A. harlandi* Rawson, *A. ishmae* α, *A. ishmae* β, and *A. crassiplicatum* Callomon [MS]. This sequence is best represented in the lower Bathonian of East Greenland (Callomon, 1993; Callomon et al., 2015). Besides, in general terms, it is believed that it can be recognized in sections of European Russia (Mitta, 2009; Mitta and Seltser, 2002; Mitta et al., 2015).

According to another point of view (Kiselev, 2020a, 2020b; Kiselev and Ippolitov, 2020), the most available species of *Arcticoceras* are synonyms of the species *A. ishmae*, and there is no sequence of *Arcticoceras* in the Ishmae Zone of the Volga region and the Pechora River basin. Being a supporter of the first point of view, Mitta (2021) has critically evaluated the results of a recent revision of the genus *Arcticoceras* (Kiselev, 2020a), on the basis of which most of the available lower Bathonian species were combined to the synonymy of the species *A. ishmae* (Keys.). In particular, he summarized that the data given in the article by D.N. Kiselev are not sufficiently convincing to consider the most available species of *Arcticoceras* as isochronous morphs of one species. As an argument, Mitta, in particular, cites a link to Plate I in (Kiselev, 2020a), demonstrating a series of the variability of *Arcticoceras* from two areas of the Pechora North (Izhma and Ad'zva rivers). He notes that the specimens in this plate come mainly from museum collections and do not have a reliable reference to a bed that allows assuming their different ages.

This remark requires a detailed discussion. Let us consider the data that allow us to clarify the features of the stratigraphic distribution of *Arcticoceras* species in the Ishmae Zone of the Greenland paleobiogeographic realm: in the Pechora River basin and East Greenland.

Arcticoceras from the Pechora River Basin

There are no documented observations of the change of taxa of the species group of the genus *Arcticoceras* in the lower Bathonian sections (in the Pechora river basin). The only exception is the data of V.V. Mitta on the sequence of species and chronosubspecies of *Arcticoceras*, shown in the generalized section in the Dreshchanka River basin (Mitta et al., 2015, text-fig. 3). However, these observations are not supported by images of ammonites, so there is no strong reason to state that there is a change of *Arcticoceras* species in the lower Bathonian of the Timan–Pechora region. Consequently, the idea of wide intraspecific variability of arctocephalitins and a single ammonite biohorizon of the Ishmae Zone in the Pechora North (Kiselev, 2020a, 2020b), as a minimum, does not contradict the previously published factual data. We did not reveal any sequence of *Arcticoceras* species/subspecies in the known sections of the Dreshchanka and Adzva rivers during our field works. Moreover, very wide variability in *A. ishmae* was detected within the presumably isochronous assemblage in these sections. It was demonstrated for the section of the Nikiforova Shcheliya (Adzva River) by images of specimens collected from a single bed (Kiselev, 2020a; Plate I, figs. 1, 2, 4; Plate II, figs. 1, 3, 4). These species form series of morphs from the laterally compressed *A. ishmae* (Keys.) morpha ishmae (Keys.) to the cadicone *A. ishmae* (Keys.) morpha pseudishmae (Spath). A wide variability of ornamentation of *A. ishmae* from the same section is shown in another article (Kiselev, 2020b; Plate 3, figs. 1–5; Plate 4, figs. 1, 4). Note that most of the depicted specimens (except fig. 1 from Plate 3) were collected personally by D.N. Kiselev from the same bed.

Also, we reveal no change in the species of arctocephalitins in the *Arcticoceras* sandstone bed of the Ishmae Zone in the most important outcrop 12 [D-5] on the Dreshchanka river. All ammonites were collected in the interval of 0–0.5 m above the base of the *Arcticoceras* sandstone bed and are represented by various morphs of the single species *A. ishmae*, from the norm of the species (Kiselev, 2020b; Plate 4, fig. 3; Plate 4, figs. 1, 4) and densely ribbed morph *A. ishmae* morpha tenuicostatum Repin (Plate I, fig. 2) up to bradymorphic specimens with a more sporadic and coarser sculpture, which are most often defined by Russian researchers as *A. harlandi* Rawson (this work, Plate I, fig. 1; Kiselev, 2020b; Plate 3, fig. 6).

The high diversity of *Arcticoceras* species in this interval can be explained by the condensation of different-age beds, as Meledina (1994) suggested. As mentioned earlier (Kiselev, 2020a, p. 78), however, the absence of any lithological or taphonomic features within *Arcticoceras* sandstone horizon, indicating the possibility of erosion or redeposition of the beds forming it, does not give any grounds to consider them condensed.

The absence of the succession of *Arcticoceras* species in the two main sections of the Ishmae Zone in the Pechora River basin does not allow us to assume that we encounter a different situation in other sections of the same region. That is why the specimens from the historical section "Razlivnoi Porog" (Izhma River basin) collected by A.N. Zamyatin and stored at the TsNIGR Museum (St. Petersburg) are considered by us to be of the same age. Their morphological differences are considered to be a manifestation of intraspecific variability but not species-specific characters. This collection demonstrates the variability in characters of *A. ishmae* (Kiselev, 2020a; Plate I, figs. 5–8), similar to that from the Nikiforova Shcheliya section.

The results of the study of the Middle Jurassic sections in the Tsilma River basin (Kiselev and Ippolitov, 2020) also show no directional changes in the taxonomic composition of arctocephalitins within the Ishmae Zone. Ammonite assemblages were collected in four consecutive beds in the most fully studied section. Each of these beds is dominated by *A. ishmae* morpha ishmae. The distribution of arctocephalitins in the Ishmae Zone has been traced in the Tsilma sections with the most remarkable detail, compared with other sections of the Pechora North. Still, even here, it is currently impossible to establish more than one ammonite biohorizon.

Arcticoceras from East Greenland

The problem of recognizing the chronovariations or species of *Arcticoceras* is also complicated by the fact that the change of arctocephalitins in the reference sections of East Greenland, where the first and most detailed infrazonal division of the Ishmae Zone was performed (Callomon, 1993; Callomon et al., 2015), has not yet been adequately described. The absence of monographic descriptions and images of the index species *A. harlandi* Rawson and *A. crassiplicatum* Callomon [MS] from East Greenland does not allow us to make an adequate comparison of arctocephalitins of this region with those from the Timan–Pechora region, which belonged to the Greenland Province in the Middle Jurassic (before the Callovian). The chronovariations[4] *A. ishmae* α and *A. ishmae* β also require a special description since the originals from Spath's work, which are referred to by Callomon (1993; Table 1), do not provide sufficient information for their recognition.

Thanks to the kind assistance of P. Alsen (GEUS, Copenhagen), we have been able to get acquainted with the samples of *Arcticoceras* from the collection of J. Callomon (Geological Museum of the University of Copenhagen). This possibility allowed us to reveal the general features of index species of biohorizons of the lower and middle Bathonian of East Greenland. In the present paper, we will note only some of the results

[4] All the intraspecific varieties of different age, species, designated by non-Linnean symbols, are called "chronovariations" in this article. Until the correct diagnosis is provided, according to the rules of the International Code of Zoological Nomenclature, such species should not be considered in the status of "chronosubspecies," since such a decision will inevitably lead to nomenclature confusion.

of observations. A detailed description will be given in a separate article.

First, the samples of *Arcticoceras* species from four East Greenland biohorizons of the Ishmae Zone (harlandi, ishmae α, ishmae β, crassiplicatum) is very representative and significantly (by several times) exceeds in the number of specimens the material from the Timan–Pechora region, stored in various collections and serving as the basis for the revision of *A. ishmae* in the recent works by Kiselev (2020a, 2020b). This makes it possible to make a comprehensive analysis of the distribution of characters and to establish the ratio of morphs in various biohorizons.

The sample set of *Arcticoceras* species of each biohorizons of the Ishmae Zone includes all morphs of *A. ishmae* previously recognized by the author (Kiselev, 2020a): *A. ishmae* (Keys.) morpha ishmae (Keys.), *A. ishmae* (Keys.) morpha stepankovi Tuchkov (=*A. harlandi* Rawson, *A. excentricum* Voronetz), *A. ishmae* (Keys.) morpha pseudishmae (Spath). This means that individual specimens do not characterize the chronovariations or species of *Arcticoceras* of the Ishmae Zone. This conclusion is quite important because it is not uncommon, when recognizing the infrazonal subdivisions of the Ishmae Zone in the Russian (Saratov) and Timan–Pechora (Izhma) plates, to establish biohorizons by single or a few specimens.

Secondly, the *Arcticoceras* assemblages from various biohorizons of the Ishmae Zone of East Greenland differ only in the ratio of the above morphs. In this case, the same morphs from different biohorizons do not have any qualitative differences. Thus, the proportion of the stepankovi morph in the biohorizons “harlandi,” “ishmae α,” and “ishmae β” is 54, 25, and 7%, respectively; i.e., it is constantly decreasing. Similarly, the proportion of the morph pseudishmae decreases—10.5, 9.1, and 1.4%. On the contrary, the proportion of the morph ishmae in the same biohorizons increases—35.5, 66, and 90.4%, respectively. Thus, the differences between index species of the biohorizons of the Ishmae Zone of the Greenland scale are in the different ratio of morphs. At the same time, at least within the Greenland Province, they can be recognized only by sample sets but not by single specimens. Unfortunately, sufficient material has not yet been collected in the sections of the Timan–Pechora region for this kind of diagnosis. Therefore, it is at least problematic or even impossible to establish biohorizons of the Greenland scale in the studied region. In the future, the separation of various intervals of the Ishmae Zone in the Pechora River basin is quite possible using subdivisions of the infrazonal scale of East Greenland, but only after the collection of representative sample sets of well-referenced arctocephalitins.

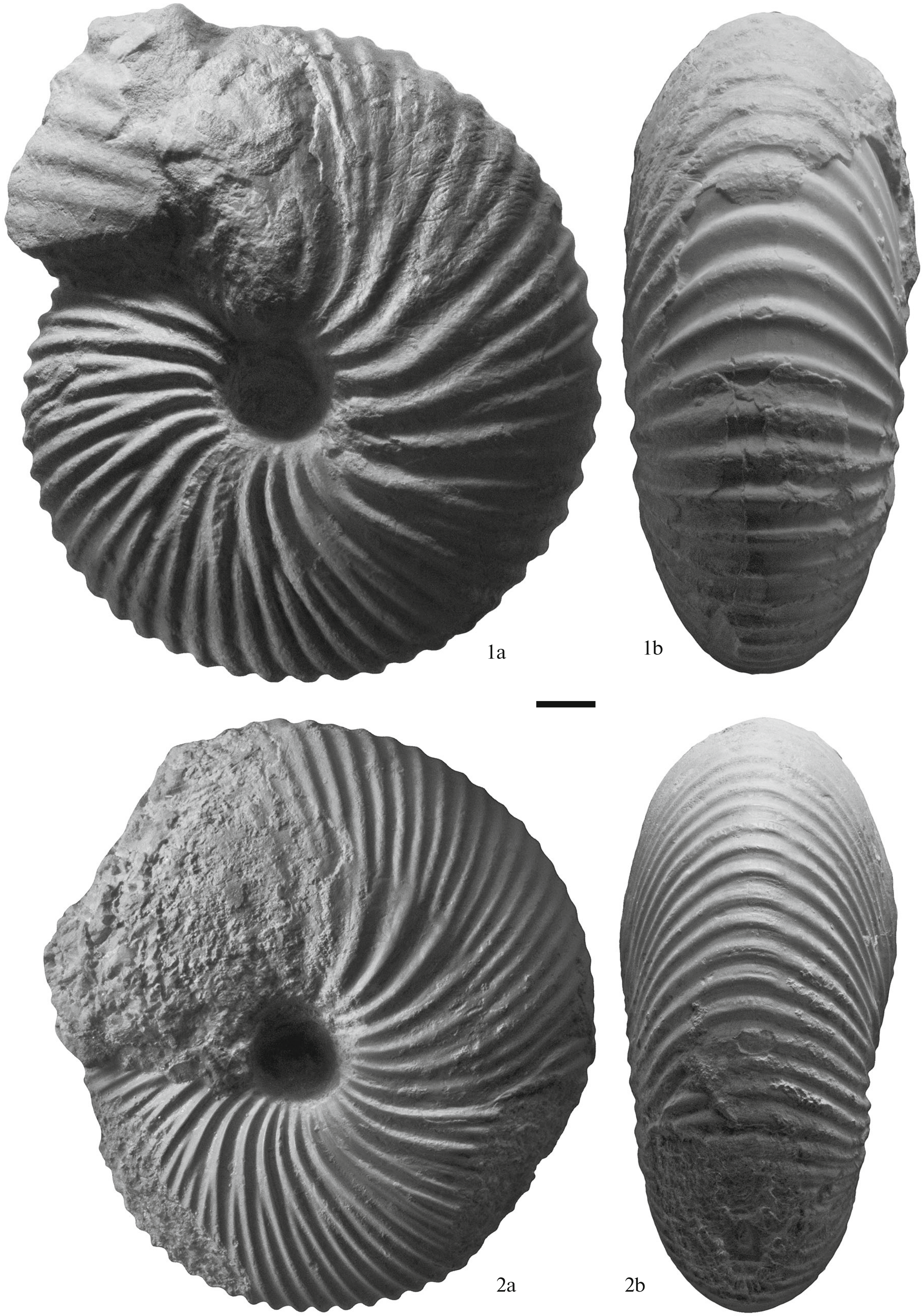
On the Status of the Genus Greencephalites Repin

The study of the Greenland collection also allows us to solve the problem of understanding the essence of the genus *Greencephalites* Repin, which initially included arctocephalitins from the Greenlandicus Zone, such as *G. freboldi* (Spath) and *G. belli* (Poulton) (Mitta and Alsen, 2013; Mitta et al., 2015; Repin et al., 2007). Previous works (Kiselev, 2020a, 2020b) proposed considering these species as the members of the genus *Arctocephalites*. Mitta (2021) has stated in his critical article that the independence of the genus *Greencephalites* is confirmed by the absence of transitional forms between the above species and *A. ishmae*. Meanwhile, the study of the Greenland collection showed that specimens with the cadiconic “*Greencephalite*” morphotype, which belongs here to the morph pseudishmae, are present in all the lower Bathonian biohorizons. Only their proportion in different biohorizons changes. The continuous variability of shell shape in all chronospecies and chronosubpecies of the lower Bathonian arctocephalitins incontrovertibly proves that specimens with the cadiconic morphotype represent one of the morphs of the assumed intraspecific variability but not an independent taxon. J. Callomon also noted this in the characterization of the species *Arctocephalites greenlandicus* (Callomon, 1993, pp. 99–100): “new collections from both localities are sufficiently numerous to leave little doubt that the two “species” [[*Arctocephalites greenlandicus* and *Arctocephalites crassum* (author’s note)] came from the same horizon; and intermediates show that they are merely the extreme variants of a single biospecies”.

The “*Greencephalites*” morph is also present in other arctocephalitins, which corresponds to Callomon’s concept of the biospecies (Callomon, 1985), which was developed mainly in the study of boreal ammonites. This morph occurs in all *Arctocephalites* species from the Greenlandicus Zone and is present in the *Arcticoceras* sets from the Ishmae Zone (including biohorizon crassiplicatum) and *Cranocephaloide* sample sets, which reflects a uniform structure of variability of these taxa. The uniformity of this structure in different chronospecies serves as evidence that typical *A. ishmae* and early Bathonian ammonites, defined as *Greencephalites*, represent the range of variability of a single species. Following this approach, the specimen of “*Greencephalites* sp. nov.” (Mitta and Alsen, 2013, Plate I, fig. 2) should be considered as *A. ishmae* (Keys.) morpha pseudishmae (Spath), and the remaining species

Plate I. Figures 1a, 1b. *Arcticoceras ishmae* (Keys.) morpha “harlandi”, spec. YarGPU no. Dr/1-25. Figs. 2a, 2b. *Arcticoceras ishmae* (Keys.) morpha tenuicostatum, spec. YarGPU no. Dr/1-26. All specimens are from the Republic of Komi, Dreshchanka River, outcrop 12 (D-5), bed 9, lower part; lower Bathonian, Ishmae Zone, biohorizon ishmae ishmae. Specimens are shown in full size; scale bar is 10 mm.

Plate I



of "greencephalites" indicated by Mitta (2021, p. 118) should be attributed to the genus *Arctocephalites*.

CONCLUSIONS

The above can be summarized as follows.

(1) The structural and geological features of the Bajocian–Bathonian in the lower reaches of the Dreshchanka River (Izhma River basin, Bajocian–Bathonian reference section of the Timan–Pechora region), first presented in the present paper, show the inconsistency of the scheme of outcrop correlation, provided in Mitta's recent works (Mitta, 2009; 2021; Mitta et al., 2015). On the contrary, the data obtained confirm the correlation scheme published in our works (Ippolitov et al., 2019; Kiselev and Ippolitov, 2020; Zakharov et al., 2020).

(2) The identical layer-by-layer structure of the reference outcrops 29 [D-1], 26 [D-3], and 12 [D-5] in the lower course of the Dreshchanka River depicted by V.V. Mitta on the lithological columns (Mitta et al., 2015, text-fig. 2; Mitta, 2021, text-fig. 2) and providing, at first glance, their confident correlation is fictitious. The selected beds can be recognized only in the outcrop 12 [D-5], whereas in sections 26 [D-3] and 29 [D-1], they do not exist in reality.

(3) Thus, the model of the parallel correlation of the outcrops listed above, which our colleague defends in his critical article (Mitta, 2021), is untenable, and the generalized section (Mitta et al., 2015; text-figs. 3, 4) has understated thickness. In addition, in light of the above evidence, paleogeographic reconstructions based on erroneous ideas about the facies variability of beds that have an actually different position in the section lose their relevance.

(4) At present, there is no convincing evidence of stratigraphic change of species or chronovariations of the genus *Arcticoceras* in the lower Bathonian Ishmae Zone of the Pechora River basin. Macroconch arctocephalitins of the Ishmae Zone are represented, apparently, by a sole species *Arcticoceras ishmae* (Keys.), which is characterized by high variability. Owing to this, the population sample set of this species includes all the diversity of intraspecific morphs (harlandi, ishmae, pseudishmae). The same morphs make up the intraspecific variability of *Arcticoceras* in the Ishmae Zone of East Greenland. Their ratio in different intervals of the zone allows us to distinguish biohorizons on a statistical basis. By the proportion of morphs, biohorizons of the East Greenland scale for the lower Bathonian are recognized.

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