ISSN 0869-5938, Stratigraphy and Geological Correlation, 2023, Vol. 31, No. 4, pp. 275–298. © Pleiades Publishing, Ltd., 2023.
Russian Text © The Author(s), 2023, published in Stratigrafiya, Geologicheskaya Korrelyatsiya, 2023, Vol. 31, No. 4, pp. 61–86.

The Ammonite *Catacadoceras barnstoni* Beds and the Problem of the Separation of the Middle and Upper Substages of the Bathonian Stage in Northern Siberia

E. S. Shamonin[a, b, *], V. G. Knyazev[c], and O. S. Dzyuba[a, b]

[a] *Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch, Russian Academy of Sciences, Novosibirsk, 630090 Russia*

[b] *Novosibirsk State University, Novosibirsk, 630090 Russia*

[c] *Diamond and Precious Metal Geology Institute, Siberian Branch, Russian Academy of Sciences, Yakutsk, 677000 Russia*

**e-mail: shamonines@ipgg.sbras.ru*

Received July 17, 2022; revised October 18, 2022; accepted November 18, 2022

Abstract—The taxonomic composition of the ammonite family Cardioceratidae is studied in the Bathonian of northern Siberia in the range of distribution of the last representatives of the genus *Arcticoceras* and the first representatives of the genus *Catacadoceras,* aiming to solve the problem of the Middle-Upper Bathonian boundary. It is shown that all previous identifications of northern Siberian material as the Middle Bathonian species *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985, were incorrect. The misidentified specimens were mainly the Late Bathonian ammonite species *Catacadoceras barnstoni* (Meek, 1859) or the form with a narrow umbilicus referred to herein as *Cat*. aff. *barnstoni*. An updated ammonite zonal scale of the Middle–Upper Bathonian of Siberia is proposed, which is recommended for use both in the regional stratigraphic schemes of the Jurassic deposits of Eastern (Middle) Siberia and in the Boreal (Siberian) zonal standard of the Bathonian Stage. The extreme importance of preserving an auxiliary biostratigraphic subdivision in this scale, the *Cat. barnstoni* Beds, is emphasized, because of the wide distribution and abundance of the index species in Siberian sections, as well as its significance for the correlation of the lower part of the Upper Bathonian of northern Canada, northern Siberia, Franz Josef Land, and East Greenland. In addition, two intervals, i.e., the interval with *Cat*. aff. *barnstoni* and interval with *Cat. perrarum*, are fixed as marker levels, which are useful for rapid age determination and correlation of the Upper Bathonian deposits in Arctic sections within the upper part of the *Cat. barnstoni* Beds.

Keywords: ammonites, Cardioceratidae, biostratigraphy, interregional correlations, Middle Jurassic, Arctic

DOI: 10.1134/S0869593823040032

INTRODUCTION

The Bathonian reference sections in Siberia are located on the coast of the Laptev Sea and adjacent territory. Traditionally, rocks exposed locally are mainly dated using ammonites. Despite the long history of the study of Siberian sections and increased attention to fossil ammonites, ammonite zonal scales need at times to be revised and updated. Currently, as discussed in recent publications, such revision is needed for the Bathonian, where there are conflicting ammonite identifications in some sections, some index taxa and biostratigraphic units require revision, and data on ammonites need to be linked with the results of recent stratigraphic studies on other fossil groups of the Bathonian of Siberia, as well as with new biostratigraphic data from other Boreal areas (Mitta and Alsen, 2013; Meledina, 2014; Mitta et al., 2014, 2015; Gulyaev, 2015; de Lagausie and Dzyuba, 2017; Dzyuba et al., 2019; Alsen et al., 2020; Shamonin and Knyazev, 2020, 2021; Shamonin et al., 2020; Kiselev, 2022; Urman et al., 2022; etc.).

The zonal ammonite scale of the Bathonian Stage of Siberia uses representatives of the family Cardioceratidae. Each of the substages has various unresolved problems concerning these mollusks. However, perhaps the most pressing issues currently concern the Middle and Upper Bathonian. Examples of the level of existing problems include the issue of recognizing "beds without ammonites" in Siberia in the range of the entire Middle Bathonian (Meledina, 2014) and the problem of the age relationships and identification on the Siberian material of the species *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 and *Catacadoceras barnstoni* (Meek, 1859), used as indices of

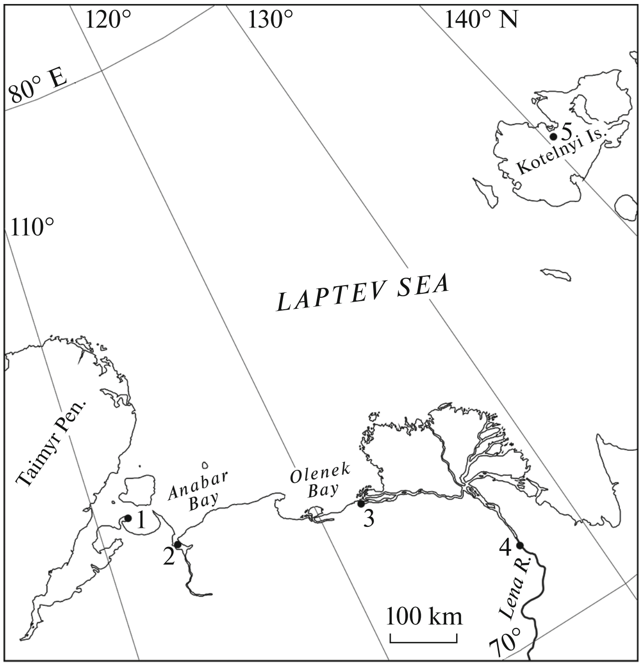


Fig. 1. Main localities of the Middle-Upper Bathonian ammonites in the north of Eastern Siberia. (1) Yuryung-Tumus Peninsula; (2) coast of Anabar Bay; (3) the coast of Olenek Bay near the village of Ystannah-Khocho; (4) lower reaches of the Lena River in the area of the village of Chekurovka; (5) Kotelnyi Island.

boreal ammonite zones (Shamonin and Knyazev, 2021). Therefore, the study of cardioceratids in the distribution range of the last representatives of the genus *Arcticoceras* and the first representatives of the genus *Catacadoceras* is especially important.

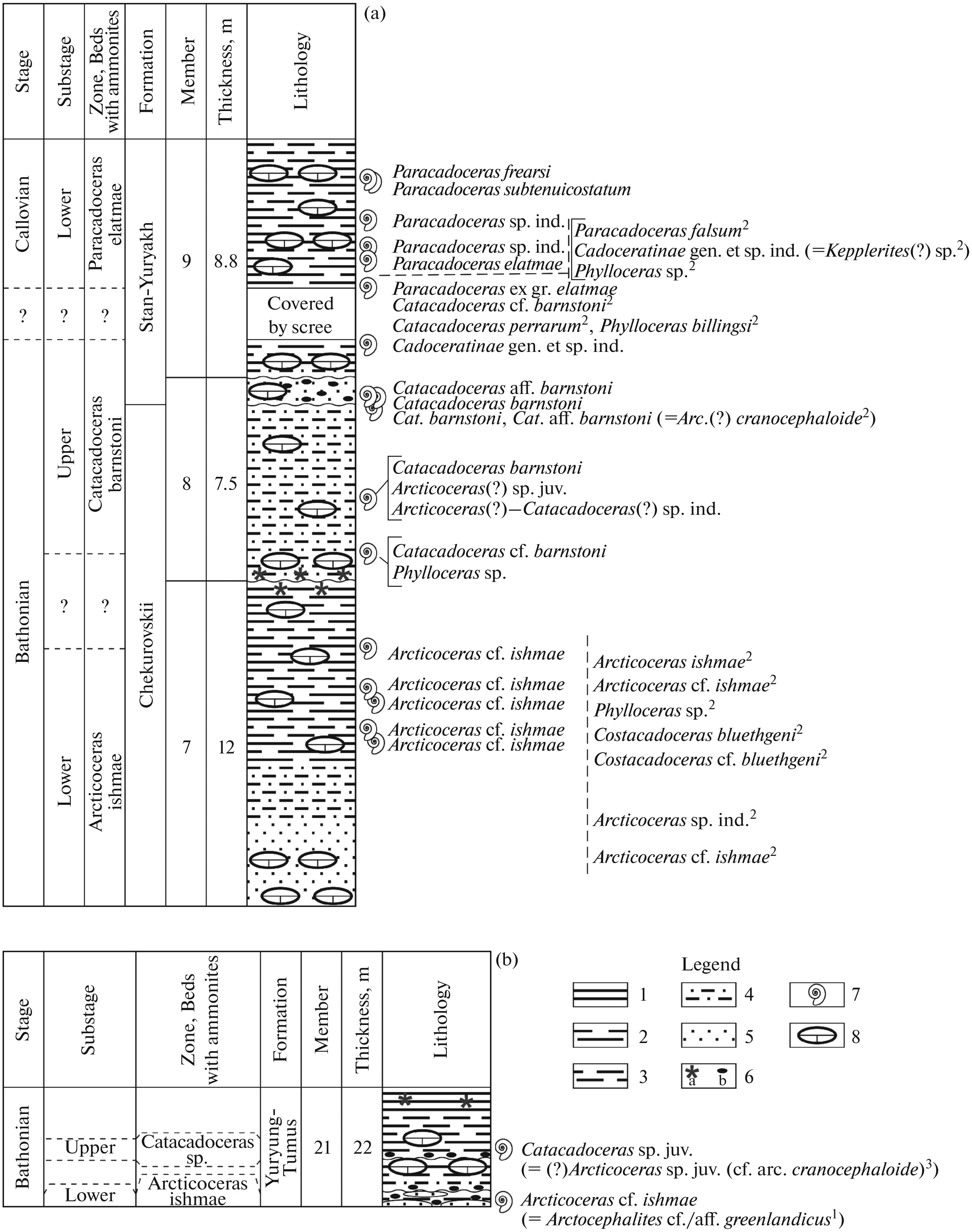
In this work we discuss the accuracy of identification of *Arcticoceras cranocephaloide* in the Bathonian of northern Siberia and, accordingly, the problem of the Middle-Upper Bathonian boundary in this region on the basis of new ammonite collections and the revision of previously known records. Accordingly, we propose updates for the regional ammonite scale. The species *Catacadoceras barnstoni* is described taking into account new findings and a revision of its composition, as well as a presumed new species of *Catacadoceras*, similar morphologically and geochronologically to *C. barnstoni*, but so far only known from a few specimens only.

MATERIAL, METHODS AND TERMINOLOGY

This research was mostly focused on ammonite shells collected in 2019 during the expeditionary work of the field team of the IPGG SB RAS–NSU in the lower reaches of the Lena River from the Middle Jurassic beds, exposed on the left bank of the river north of the village of Chekurovka (Fig. 1). The studied section is located on the northern wing of the Chekurovskaya Anticline and is known as the "northern section" or Outcrop 2 (Meledina et al., 1991). In this work, we consider the results of a study of material originating from members 7–9 of the Bathonian part of this section, which is represented by silty-sandy rocks of the upper Chekurovskii Formation and predominantly clayey-silty rocks of the lower part of the Stan-Yuryakh Formation with a total thickness of 28.3 m (Galabala, 1991; Shamonin and et al., 2020) (Fig. 2a). This material includes 49 ammonite specimens, all belonging to the family Cardioceratidae except for a single representative of Phylloceratidae. One ammonite specimen was found during sampling of talus at Cape Chucha below Outcrop 3 (see Meledina et al., 1991), on the southern flank of the Chekurovskaya Anticline (collected by I.N. Kosenko, 2018). In addition, the material (26 examples) collected by V.G. Knyazev in the Bathonian on the coast of Olenek Bay near the village of Ystannakh-Khocho (Fig. 1), kept in the Laboratory of Paleontology and Stratigraphy of the Mesozoic and Cenozoic at the Institute of Geology and Geology, Siberian Branch of the Russian Academy of Sciences, was studied. The specimens used for this paper were transferred to the monographic collection department of the Central Collective Use "GEOCHRON Collection" at the IPGG SB RAS (formerly a department within the Central Siberian Geological Museum, Novosibirsk), collection no. 2112. We also used published collections of ammonites housed in the same collection department as above and photographs of the East Greenland collection of ammonites made by J. Callomon and T. Birkelund (Geological Museum of Copenhagen University) provided by V.V. Mitta. The previous identifications of the Bathonian ammonites from Member 21 of Outcrop 19 D on the Yuryung-Tumus Peninsula were completely revised (Fig. 2b).

The ammonites were studied systematically and morphologically using the classical comparative morphological method, ontogenetic studies with separa-

Fig. 2. Ammonites and biostratigraphic subdivision of the upper part of the Middle Jurassic section, in the lower reaches of the Lena River north of the village of Chekurovka, Outcrop 2 (a) and on the eastern coast of the Yuryung-Tumus Peninsula, Outcrop 19 "G" (b). Lithological columns are shown in a generalized form; (a): the outcrop number and member numbering are given according to Meledina et al. (1991), the name of the formations is given taking into account the work of Galabala (1991), the thickness of the members and the position of the top of the Chekurovskii Formation are given according to Shamonin et al. (2020); (b): outcrop number, unit number and thickness, formations are given according to Meledina et al. (1987). ([1,2,3]) Ammonite occurrences (Meledina et al., 1987[1], 1991[2]; de Lagausie and Dzyuba, 2017[3]); for the Chekurovka section, they are shown approximately, taking into account the recalculation of member thicknesses. Legend: (1) argillite; (2) clayey siltstone; (3) siltstone; (4) sandy siltstone; (5) sandstone; (6) glendonites (a) and pebbles (b); (7) ammonite occurrences; (8) calcareous nodules.


(a)
Stage
Substage
Zone, Beds with ammonites
Formation
Member
Thickness, m
Lithology
Callovian
Lower
Paracadoceras elatmae
Stan-Yuryakh
9
8.8
?
?
?
Covered by scree
Bathonian
Upper
Catacadoceras barnstoni
Chekurovskii
8
7.5
?
?
Lower
Arcticoceras ishmae
7
12
Paracadoceras frearsi
Paracadoceras subtenuicostatum
Paracadoceras sp. ind.
Paracadoceras sp. ind.
Paracadoceras elatmae
Paracadoceras falsum2
Cadoceratinae gen. et sp. ind. (=Kepplerites(?) sp.2)
Phylloceras sp.2
Paracadoceras ex gr. elatmae
Catacadoceras cf. barnstoni2
Catacadoceras perrarum2, Phylloceras billingsi2
Cadoceratinae gen. et sp. ind.
Catacadoceras aff. barnstoni
Catacadoceras barnstoni
Cat. barnstoni, Cat. aff. barnstoni (=Arc.(?) cranocephaloide2)
Catacadoceras barnstoni
Arcticoceras(?) sp. juv.
Arcticoceras(?)–Catacadoceras(?) sp. ind.
Catacadoceras cf. barnstoni
Phylloceras sp.
Arcticoceras cf. ishmae
Arcticoceras cf. ishmae
Arcticoceras cf. ishmae
Arcticoceras cf. ishmae
Arcticoceras cf. ishmae
Arcticoceras ishmae2
Arcticoceras cf. ishmae2
Phylloceras sp.2
Costacadoceras bluethgeni2
Costacadoceras cf. bluethgeni2
Arcticoceras sp. ind.2
Arcticoceras cf. ishmae2
(b)
Stage
Substage
Zone, Beds with ammonites
Formation
Member
Thickness, m
Lithology
Bathonian
Upper
Lower
Catacadoceras sp.
Arcticoceras ishmae
Yuryung-Tumus
21
22
Catacadoceras sp. juv.
(= (?)Arcticoceras sp. juv. (cf. arc. cranocephaloide)3)
Arcticoceras cf. ishmae
(= Arctocephalites cf./aff. greenlandicus1)
Legend
1
2
3
4
5
6
a
b
7
8

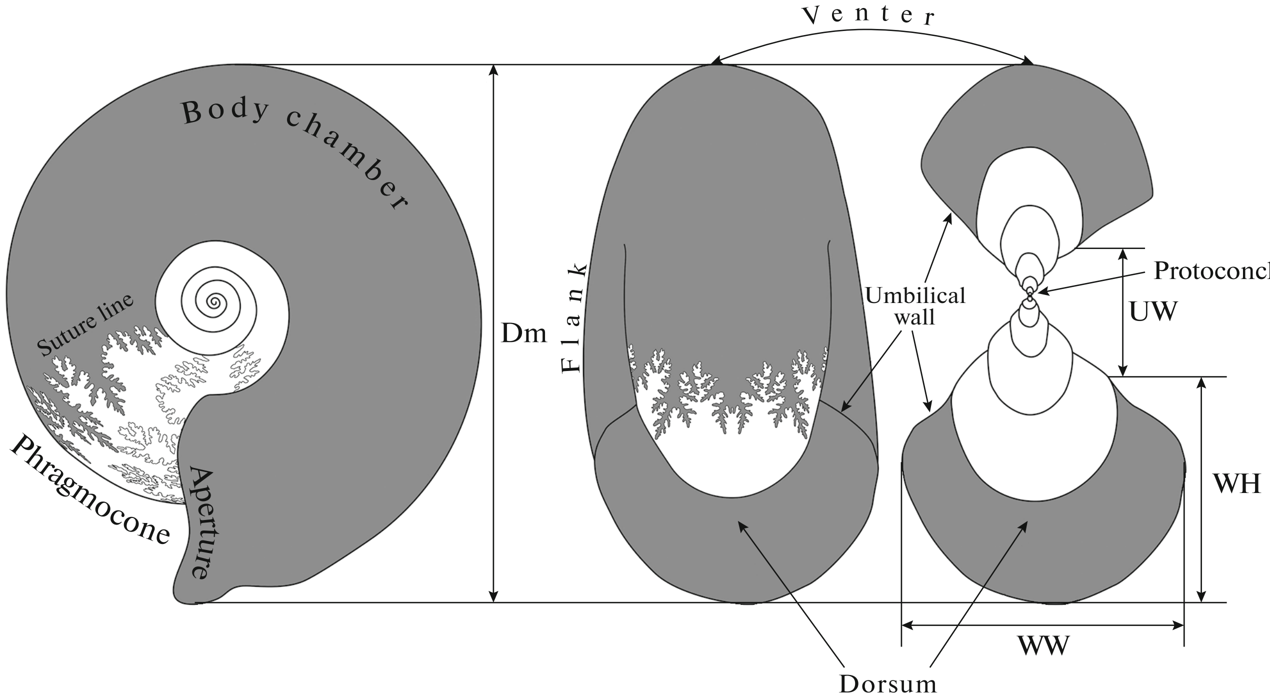


Fig. 3. Basic elements of ammonite shell morphology. From left to right: lateral view, apertural view and cross section. The area of the body chamber is shaded in gray. Dm, diameter; WH, whorl height; WW, whorl width; UW, umbilical width.

tion ("uncoiling") of whorls, and morphometric analysis. The terminology used in the paper for the elements of the morphology of ammonite shells followed Ruzhencev (1962) and Meledina (1973). The shell shape and ornamentation, as well as the measured parameters and their ratios play an important role in the taxonomy of ammonites. In this work, we measured the shell diameter (Dm), whorl height (WH), whorl width (WW), umbilicus width (UW) (Fig. 3), and calculated the ratios of whorl height to shell diameter (WH/Dm), whorl width to shell diameter (WW/Dm), umbilicus width to shell diameter (UW/Dm), whorl width to whorl height (WW/WH), and the branching coefficient (K) was calculated as the ratio of the number of secondary (Sr) and primary (Pr) ribs.

Ammonite shells vary in diameter: less than 50 mm—small; 50–120 mm—medium; 120–200 mm—large. The WW/Dm parameter characterizes the relative width of the shell: less than 20% is discoid; 20–30%—flattened; 30–40%—medium width; 40–50%—inflated; 50–70%—strongly inflated. The UW/Dm parameter characterizes the relative width of the umbilicus: less than 17%—narrow; 17–25%—moderately narrow; 25–33%—moderately wide; more than 33%—wide.

SYSTEMATIC PALEONTOLOGY

Following Meledina (1977) and Alifirov et al. (2018), *Catacadoceras* Bodylevsky, 1960 is considered as a separate genus.

FAMILY CARDIOCERATIDAE SIEMIRADZKI, 1891

SUBFAMILY CADOCERATINAE HYATT, 1900

Genus *Catacadoceras* Bodylevsky, 1960

Catacadoceras barnstoni (Meek, 1859)

Plate I, figs. 1–4; Plate II, fig. 1; Fig. 4

Ammonites barnstoni: Meek, 1859, p. 184, pl. 2, figs. 1–3.
Cadoceras elatmae: Ognev, 1933, partim, pl. 4, figs. 3, 4.
Cadoceras (Catacadoceras) laptievi: Bodylevsky, 1960, p. 64, pl. I, fig. 1; pl. II, fig. 1.
Cadoceras (Catacadoceras) ognevi: Bodylevsky, 1960, p. 65.
Cadoceras crassum: Frebold, 1961, pl. 14, fig. 2.
Cadoceras ognevi: Voronets, 1962, p. 47, pl. 23, figs. 2.
Cadoceras subcalyx: Voronets, 1962, p. 51, pl. 20, figs. 1, 2, 4.
Cadoceras subcatostoma: Voronets, 1962, p. 54, pl. 24, fig. 1; pl. 25, fig. 1.

Plate I. *Catacadoceras barnstoni* (Meek, 1859) from the Upper Bathonian of northern Eastern Siberia; (1, 2) from the lower reaches of the Lena River, northern section near the village of Chekurovka, Outcrop 2, Member 8; (3, 4) from the coast of Olenek Bay near the village of Ystannah-Khocho, Outcrop 23, Bed 28, 7–8 m above the base; (1) specimen GEOCHRON, no. 2112/1, 1 m above the base of Member 8, lateral view; (2) specimen GEOCHRON, no. 2112/2, 4.5 m below the top of Member 8: (a) lateral view, (b) ventral view; (3) specimen GEOCHRON, no. 2112/5: (a) lateral view, (b) ventral view, (c) apertural view; (4) specimen GEOCHRON, no. 2112/6: (a) lateral view, (b) apertural view.

Plate I

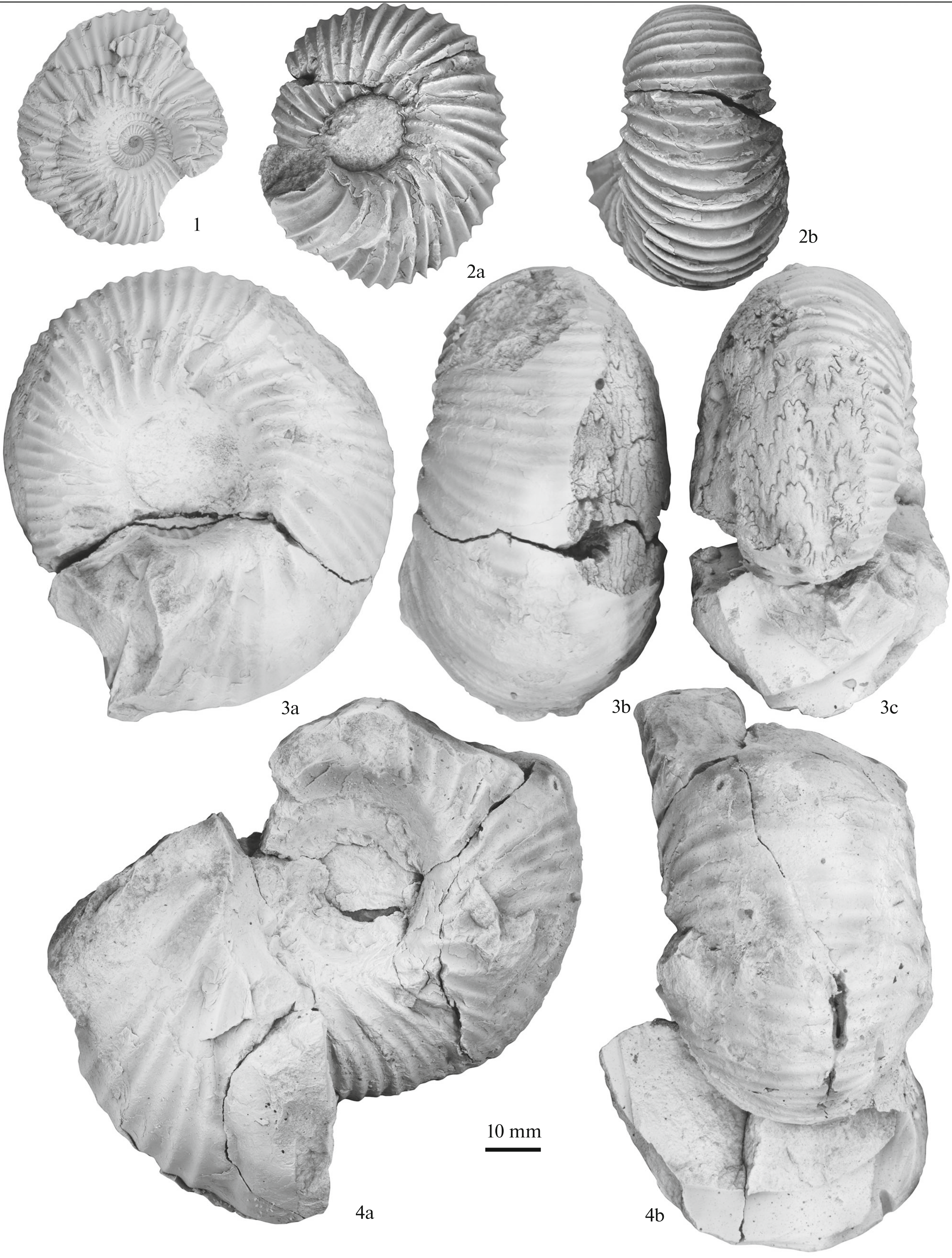


Plate II

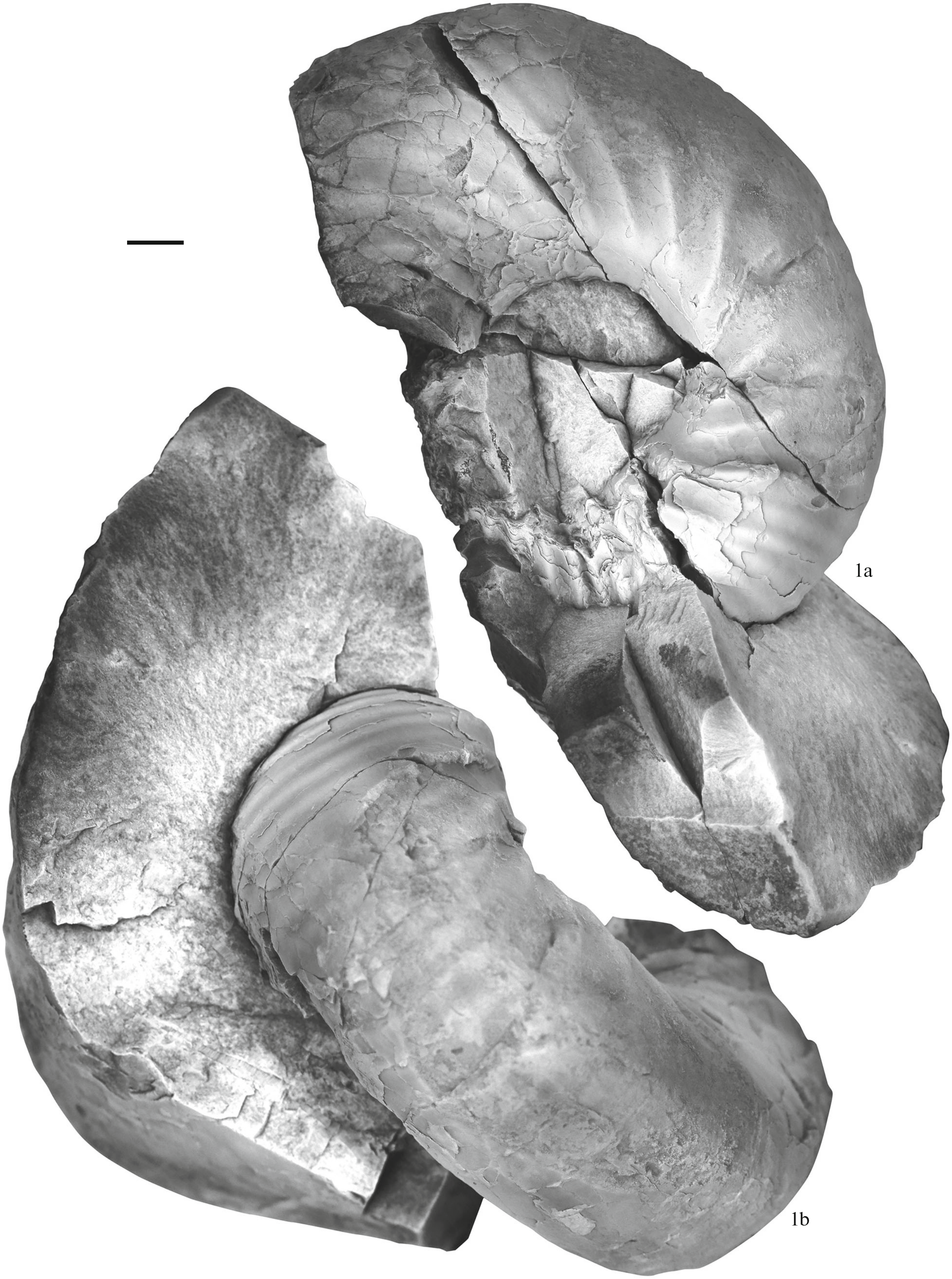


Plate II. *Catacadoceras barnstoni* (Meek, 1859) from the Upper Bathonian of northern Eastern Siberia; (1) specimen GEOCHRON, no. 2112/4, lower reaches of the Lena River, Cape Chucha, Outcrop 3, talus: (a) lateral view, (b) ventral view. Here and in Pl. III, asterisk (*) shows the last observed suture.

Cadoceras variabilis: Voronets, 1962, pl. 20, fig. 3.
Cadoceras barnstoni: Frebold, 1964a, pl. 39, fig. 3; Frebold, 1964b, p. 14, pl. 8, fig. 3; pl. 12, fig. 2; Poulton, 1987, p. 54, pl. 24, figs. 1–18, pl. 25, figs. 1–8, pl. 26, figs. 1–18; Knyazev et al., 2009, p. 93, pl. 2, figs. 1–3.
Cadoceras (Streptocadoceras) aff. *kialagvikense*: Meledina, 1977, p. 86, pl. 24, fig. 2; pl. 25, fig. 1.
Catacadoceras laptievi: Meledina, 1977, p. 91, pl. 8, fig. 4; pl. 15, fig. 3; pl. 38, fig. 1; pl. 39, fig. 2.
Cadoceras (Catacadoceras) barnstoni: Meledina et al., 1991, pl. 8, figs. 3; Meledina, 1994, pl. 4, figs. 3, 4; pl. 5, figs. 4; Meledina, 1999, p. 139, pl. I, figs. 1–7, pl. 2, figs. 1–5; Kiselev, 2022, p. 177, partim, pl. 22, figs. 1, 2; pl. 23, fig. 1 (1a, 1b), figs. 2 (1c, 1d).
Arcticoceras(?) cranocephaloide: Meledina et al., 1991, pl. 6, fig. 1; pl. 8, fig. 2, non fig. 1; Meledina, 1994, pl. 5, figs. 1–3; Knyazev et al., 2009, p. 90, pl. 1, fig. 2.
Catacadoceras ognevi: Repin, 1999, pl. 3, figs. 2; pl. 4, figs. 3; Repin et al., 2007, pl. 6, figs. 6.
cf. C*adoceras (Catacadoceras)* cf. *barnstoni*: Meledina et al., 1991, pl. 6, figs. 2, 3.
cf. *Arcticoceras(?) cranocephaloide*: Meledina et al., 1991, pl. 9, fig. 3.
cf. *Cadoceras (Catacadoceras) barnstoni*: Kiselev, 2018, pl. 3, fig. 2; Kiselev, 2022, pl. 26, fig. 1.

H o l o t y p e (by monotypy). Specimen GSC 4811, Geological Survey of Canada, Ottawa; Mackenzie River valley, northern Canada; figured (Meek, 1859, pl. 2, figs. 1–3), refigured (Frebold, 1964a, p. 39, fig. 3; Frebold, 1964b, pl. 8, fig. 3).

D e s c r i p t i o n. The shell is inflated to strongly inflated (WW/Dm from 40 to 66%). The cross section up to the 4th whorl arcuately oval in shape, the ratio of whorl width to height is 1.2–1.5. From the 7th half-whorl to the 11th, the cross-section has an isometric-rounded or rounded-square appearance, the whorl width is slightly more or slightly less than its height. From the end of the 6th whorl to the end of the shell, the cross section has the shape of an arcuately bent strip, the width of the whorl exceeds its height (WW/WH up to 1.7) (Fig. 4).

Umbilicus moderately wide or moderately narrow, deep, cup-shaped. The umbilical wall is steep. The body chamber occupies more than half of the whorl. The aperture is overhanging, at the terminal stage bounded by a pre-apertural constriction The largest shell in the collection with a fragment of the body chamber is 173 mm in diameter.

The ornamentation appears on the 4th whorl. On the 5th whorl, the primaries are simple with intercalatories and bifid. They begin on the umbilical wall; the branching point is in mid-flank. Primaries and secondaries are arcuately bent forward; on the ventral side, the ribs are bent toward the aperture. On the 6th whorl, K = 2.1. By the end of the 6th whorl, the ventral projection disappears. On the 7th whorl, the primaries become more massive than the secondaries. The primaries begin at the umbilical shoulder, with umbilical bullae, and inclined at about 45° relative to the radius. The ribs bifurcate at mid-flank or slightly higher. Three or two thinner secondary ribs extend from the primary rib, and intercalaries are sometimes present. The ribbing coefficient can reach 3.1. On the 8th whorl (Dm = 120 mm), the secondaries disappear, and the primaries are somewhat smoothed out in the distal part. At Dm > 170 mm, judging by specimen no. 2112/4 (Pl. II, fig. 1), the ornamentation is completely missing.

D i m e n s i o n s i n m m a n d r a t i o s:

Specimen no.	Dm, mm	WH, mm	WW, mm	UW, mm	UW/Dm, %	WW/Dm, %	WH/Dm, %	WW/WH	Pr	Sr	K
2112/1	42.5	24.5	–	10.5	24.7	–	57.6	–	26	41	1.6
2112/2	51	22	29	12.6	24.7	56.9	43.1	1.3	16	34	2.1
2112/5	81	30.5	48	23	28.4	59.3	37.7	1.6	22	52	2.4
2112/6	98.5	44.5	50	32	32.5	50.8	45.2	1.1	11	30	2.7
2112/7	76	32.5	43	24	31.6	56.6	42.8	1.3	17	43	2.5
2112/8	–	31	40	20	–	–	–	1.3	9	22	2.4
2112/9	68	30	36	19.5	28.7	52.9	44.1	1.2	10	24	2.4
2112/10	–	24.5	38	–	–	–	–	1.6	7	17	2.4
2112/11	51	19	23	17.5	34.3	45.1	37.3	1.2	6	13	2.2
2112/12	–	31.5	45.5	24.5	–	–	–	1.4	–	–	–
2112/13	72	27	42	26	36.1	58.3	37.5	1.6	–	–	–
2112/14	–	31	41	–	–	–	–	1.3	5	12	2.4
2112/15	–	40	60	–	–	–	–	1.5	–	–	–
2112/16	55	24	28	21	38.2	50.9	43.6	1.2	8	20	2.5
2112/17	59	28	33.5	19	32.2	56.8	47.5	1.2	19	43	2.3
2112/18	102	40	63	29	28.4	61.8	39.2	1.6	–	–	–
2112/19	–	38.5	59	30.5	–	–	–	1.5	5	12	2.4

Specimen no. 2112/20 (Alifirov et al., 2018, text-fig. 2A)

No. half-whorl[1]	Dm, mm	WH, mm	WW, mm	UW, mm	UW/Dm, %	WW/Dm, %	WH/Dm, %	WW/WH
13 (15)	90	34.7	59.4	24.8	27.6	66.0	38.6	1.7
12 (14)	73.2	31.2	47	21.6	29.5	64.2	42.6	1.5
11 (13)	55.8	21.7	30.9	17.9	32.1	55.4	38.9	1.4
10 (12)	42.9	17.6	20.4	13.8	32.2	47.6	41.0	1.2
9 (11)	31.2	12	12.5	10	32.1	40.1	38.5	1.0
8 (10)	22.4	9.4	8.9	6.5	29.0	39.7	42.0	0.9
7 (9)	15.26	6.43	6.7	4.5	29.5	43.9	42.1	1.0
6 (8)	10.16	4.41	5.43	3.05	30.0	53.4	43.4	1.2
5 (7)	7.37	3.05	3.58	2.13	28.9	48.6	41.4	1.2
4 (6)	5.43	2.22	2.79	1.6	29.5	51.4	40.9	1.3
3 (5)	3.81	1.6	1.96	1.1	28.9	51.4	42.0	1.2
2 (4)	2.72	1.1	1.64	–	–	60.3	40.4	1.5
1 (3)	1.96	–	1.31	–	–	66.8	–	–

C o m p a r i s o n. From the morphologically similar species *Cat. perrarum* (Voronets, 1962), the described species differs mainly in ornamentation. Secondaries of *Cat. perrarum* are much wider and less frequent, and are similar to the primaries in width.

R e m a r k s. *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985, first established in East Greenland, has a certain similarity with the described species, which has been repeatedly revised (Poulton, 1987; Meledina, 1994; Knyazev et al., 2009; Kiselev, 2022; etc.). For over 30 years, this species was also cited from the Bathonian of the north of Eastern Siberia, where it was mainly assigned conditionally to the genus *Arcticoceras* (Meledina et al., 1991; Knyazev et al., 2009; etc.). As was recently indicated (Shamonin and Knyazev, 2021), the main problem of *Arc. cranocephaloide* was its insufficiently detailed original description (Callomon and Birkelund in Callomon, 1985) and the absence of images of adult macroconchs in either the apertural or ventral views. A more detailed discussion of the occurrences of this species in Arctic sections is given in a separate section of this work. It should be noted here that the Siberian specimens attributed to "*Arc.(?) cranocephaloide*" included in the synonymy list differ from true representatives of that species in more strongly inflated shells and the absence of noticeable bends of the ribs on the venter, which is the basis for their assignment to *Cat. barnstoni*.

A specimen attributed to *Cadoceras (Catacadoceras) barnstoni* (Kiselev, 2018, pl. 3, fig. 1; Kiselev, 2022, pl. 1, fig. 1) was recently identified from Franz Josef Land. That specimen shows characters similar to those of *Cat. perrarum* (Voronets, 1962), which Kiselev (2022) synonymized under *Cat. barnstoni*. However, in our opinion, the species *Cat. barnstoni* is present in Franz Josef Land. We consider it a senior synonym of *Cadoceras (Catacadoceras) ognevi* (Bodylevsky, 1960, p. 65), the holotype of which had been previously incorrectly identified as *Cadoceras elatmae* (Ognev, 1933, pl. 4, figs. 3, 4). Later finds of *Cat. barnstoni* in Franz Josef Land were identified as *Catacadoceras ognevi* (Repin, 1999; Repin et al., 2007).

[1] Here and further, the number (#) of a half-whorl means its ordinal number in ontogeny, starting from the protoconch or (if the protoconch has not been preserved for some reason) from the earliest preserved half-whorl. In the latter case, the presumed ordinal number of a half-whorl from the protoconch is indicated in parentheses.

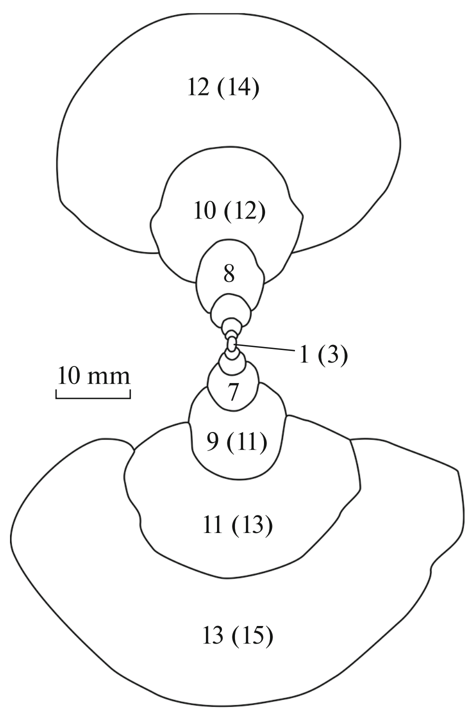


Fig. 4. Drawing of the cross-section of a shell of *Catacadoceras barnstoni* (Meek, 1859), specimen GEOCHRON, no. 2112/20 (Alifirov et al., 2018, Fig. 2A), emended. Here and in Fig. 5 numbers indicate serial numbers of half-whorls, starting from the earliest preserved whorl. In parentheses, the suggested serial number of half-whorl from the protoconch is given, no. 2112/20 (Alifirov et al., 2018, text-fig. 2A), emended.

Kiselev (2022) described five morphs of *Cat. barnstoni*, which differ in a specific set of characters depending on the relative umbilicus width, prominence and frequency of the ribs, the obliqueness and shape of the ribs in the late whorls of the phragmocone and the adult body chamber: morph *barnstoni*, morph *ognevi*, morph *perrarum*, morph *subcalyx*, and morph *subcatostoma*. The morph *perrarum* identified by Kiselev does not correspond to our interpretation of the species under discussion.

Occurrence. Bathonian, upper substage, Cat. barnstoni Zone of northern Canada and Franz Josef Land, upper part of the Paracadoceras variabile Zone of East Greenland, Beds with *Cat. barnstoni* in the north of Eastern Siberia.

Material. 31 specimens of good and satisfactory preservation: lower reaches of the Lena River, northern section near the village of Chekurovka (Outcrop 2, Member 8, interval 1–6.75 m above the base, 4 specimens), Cape Chucha (Outcrop 3, talus, 1 specimen); coast of Olenek Bay near the village of Ystannakh-Khocho (26 specimens).

***Catacadoceras* aff. *barnstoni* (Meek, 1859)**

Plate III, fig. 1; Fig. 5

Description. The shell diameter of specimen no. 2112/3 is 125 mm. After it was photographed, a cross section of the shell was made, which made it possible to draw its cross section (Fig. 5). The observed part of the shell ontogeny shows first the stage of a slight predominance of the whorl height over its width (half-whorl 2); the cross section has the form of a slightly elongated oval. As the shell grows, its width becomes greater than its height, and the cross section becomes first rounded, and then wide oval. At all observed stages of ontogeny, in terms of the relative width, the shell is characterized as inflated.

The umbilicus is moderately narrow to narrow, deep, cup-shaped, with a moderately steep umbilical wall. Throughout the ontogeny, the relative diameter of the umbilicus gradually decreases to 22.8%. The preserved fragment of the body chamber occupies more than half of a whorl; the aperture is missing.

In the visible part of the internal whorls, the ornamentation is represented by bifid, approximately equal in width and size, primary and secondary ribs directed towards the aperture, K = 2. At the beginning of the last whorl, the primaries are bullae-shaped and split mainly into two more gently sloping and thin secondaries; secondary intercalaries are also present, K = 2.3. On the body chamber, the ornamentation gradually weakens: at first, the secondary ribs disappear and only bullae remain at the umbilical shoulder; by the end of the preserved part of the body chamber, the shell becomes completely smooth.

Dimensions and ratios:

Half-whorl no.	Dm, mm	WH, mm	WW, mm	UW, mm	UW/Dm, %	WW/Dm, %	WH/Dm, %	WW/WH	Pr	Sr	K
Specimen no. 2112/3											
8 (16)	125	55.4	(51.5)	28.5	22.8	?	44.3	?	6	14	2.3
7 (15)	95.5	39	46.8	23.7	24.8	49.0	40.8	1.2	–	–	–
6 (14)	74.4	31	38.6	20.7	27.8	51.9	41.7	1.2	–	–	–
5 (13)	54.6	22.8	26.8	15.4	28.2	49.1	41.8	1.2	8	16	2
4 (12)	40.5	17.4	18.7	12.3	30.4	46.2	43.0	1.1	–	–	–
3 (11)	29.5	12	14.7	8.7	29.5	49.8	40.7	1.2	–	–	–
2 (10)	20.7	10.3	9.6	–	–	46.4	49.7	0.9	–	–	–
1 (9)	13.8	–	6.4	–	–	46.4	–	–	–	–	–
Specimen no. 856-21 (Knyazev et al., 2009, pl. 1, fig. 1)											
14	83.5	35.6	49.6	18.7	22.4	59.4	42.6	1.4	–	–	–
13	67	29	40.5	14.8	22.1	60.4	43.3	1.4	–	–	–
12	51	23	30.1	11	21.6	59	45.1	1.3	–	–	–
11	38.5	16.6	21.6	9.4	24.4	56.1	43.1	1.3	–	–	–
10	28.9	12.5	14.4	7.2	24.9	49.8	43.3	1.2	–	–	–
9	21.3	9.4	9.4	5	23.5	44.1	44.1	1.0	–	–	–
8	15.3	7.2	6.7	3	19.6	43.8	47.1	0.9	–	–	–
7	10.5	5.1	5.3	1.7	16.2	50.5	48.6	1.0	–	–	–
6	6.9	3.7	3.9	0.9	13	56.5	53.6	1.1	–	–	–
5	4.5	2.5	2.8	0.6	13.3	62.2	55.6	1.1	–	–	–
4	3	1.5	2.1	–	–	70	50	1.4	–	–	–
3	2	1	1.25	–	–	62.5	50	1.3	–	–	–
2	1.3	0.79	0.92	–	–	70.8	60.8	1.2	–	–	–
1	0.6	–	0.73	–	–	–	–	–	–	–	–

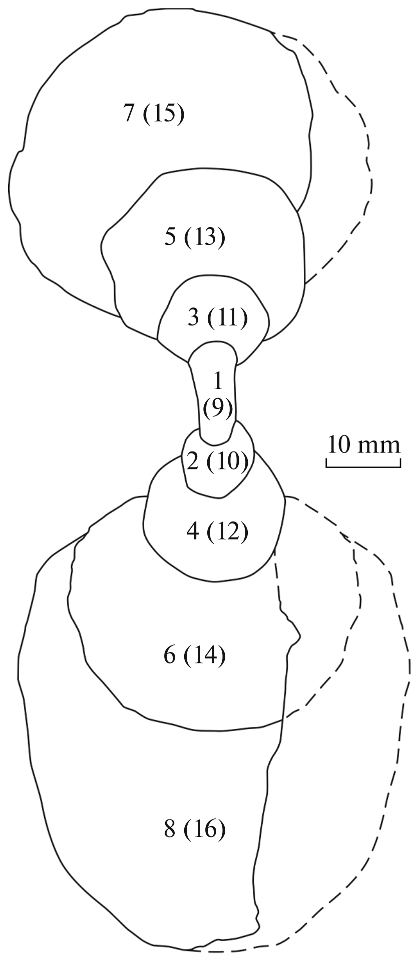


Fig. 5. Drawing of the cross-section of a shell of *Catacadoceras* aff. *barnstoni* (Meek, 1859), specimen GEOCHRON, no. 2112/3 (see Pl. III, fig. 1).

R e m a r k s. The specimen found in the northern section near the village of Chekurovka is very close to *Cat. barnstoni*, in the shell ontogeny, the shape of the shell cross-section and ornamentation. However, it is distinguished by a noticeably narrower umbilicus (*Cat. barnstoni* is characterized by an interval of variation in the relative diameter of the umbilicus, starting from 25–27%). Specimen no. 856-21, identified from a close level in the same section as *Arcticoceras(?) cranocephaloide* (Meledina et al., 1991, pl. 8, fig. 1) has a similar feature. Knyazev et al. (2009, pl. 1, fig. 1c) illustrated the cross-section of this ammonite, which makes it possible to study the ontogeny of its shell shape (see Dimensions and ratios). The explanation of the plate (Knyazev et al., 2009, p. 88) incorrectly indicates the provenance of the specimen as from Member 9, while the ammonite was found in Member 8 of Outcrop 2 "in a narrow interval, 20 cm under the Bed with pebbles" (Meledina et al., 1991, p. 16) and, as is clear from the explanation of the plate in the same work, in Bed 13 of Outcrop 2 (Meledina et al., 1991, p. 194), which also corresponds to Member 8, according to B.N. Shurygin field notes.

Another record of an ammonite close to the one described, illustrated as *Arc. cranocephaloide* (Kiselev, 2022, pl. 18, fig. 1), is represented by a relatively large and semi-crushed mold, with a narrow umbilicus, which makes it more similar to *Cat.* aff. *barnstoni* than to *Arc. cranocephaloide*. This specimen, the undeformed diameter of which was presumably 120–130 mm, is distinguished from *Cat.* aff. *barnstoni*, by well-pronounced ribbing up to the end of the body chamber. There is not sufficient material of *Cat.* aff. *barnstoni* to accurately estimate the limits of variability of this character. The discussed find of "*Arc. cranocephaloide*" comes from the southern section near the village of Chekurovka, from the top of Member 7, which corresponds to the top of Member 8 in Outcrop no. 2 in Meledina et al. (1991).

M a t e r i a l. 1 well-preserved specimen from the Beds with *Cat. barnstoni* in the lower reaches of the Lena River, northern section near the village of Chekurovka (Outcrop 2, Member 8, 0.7 m below the top).

ARCTICOCERAS CRANOCEPHALOIDE CALLOMON ET BIRKELUND, 1985 VS. *CATACADOCERAS BARNSTONI* (MEEK, 1859)

Both species named in the title are indices of the ammonite scales of the Bathonian stage of the Arctic regions (Callomon, 1985, 1993, 2003; Poulton, 1987; Meledina, 1991, 2014; Poulton et al., 1992; Shurygin et al., 2000, 2011; Knyazev et al., 2009; Nikitenko et al., 2013; Callomon et al., 2015; Kelly et al., 2015; etc.). However, the insufficiently informative original description of *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 (Callomon, 1985) and the significant similarity of the shell of this species with *Catacadoceras barnstoni* (Meek, 1859) in morphology of the flanks and in the ornamentation of the outer whorls often made it difficult to distinguish them in practice. The problem was exacerbated by the geographic isolation of the finds of most representatives of *Arc. cranocephaloide* and *Cat. barnstoni* illustrated in publications vs. close stratigraphic position of these species, and for a long time not fully clarified (documented) chronological relationships with each other and with a number of other cardioceratid species. All this led to different opinions on the biostratigraphy and Pan-Arctic correlation of the boundary Middle-Upper Bathonian interval using ammonites. Below we consider the results of a detailed analysis of the morphological features of *Arc. cranocephaloide* compared to *Cat. barnstoni*, made possible in many ways by photographs of the East Greenland *Arc. cranocephaloide* collection, kindly provided by V.V. Mitta (pl. IV).

Arc. cranocephaloide was originally described from the Jameson Land Peninsula in East Greenland (Callomon and Birkelund in Callomon, 1985). The description of this species says that the inner whorls have the appearance of early representatives of *Cadoceras*, i.e., relatively evolute (W/L about 30%) with a rounded cross section, while the outer whorls are more

Plate III

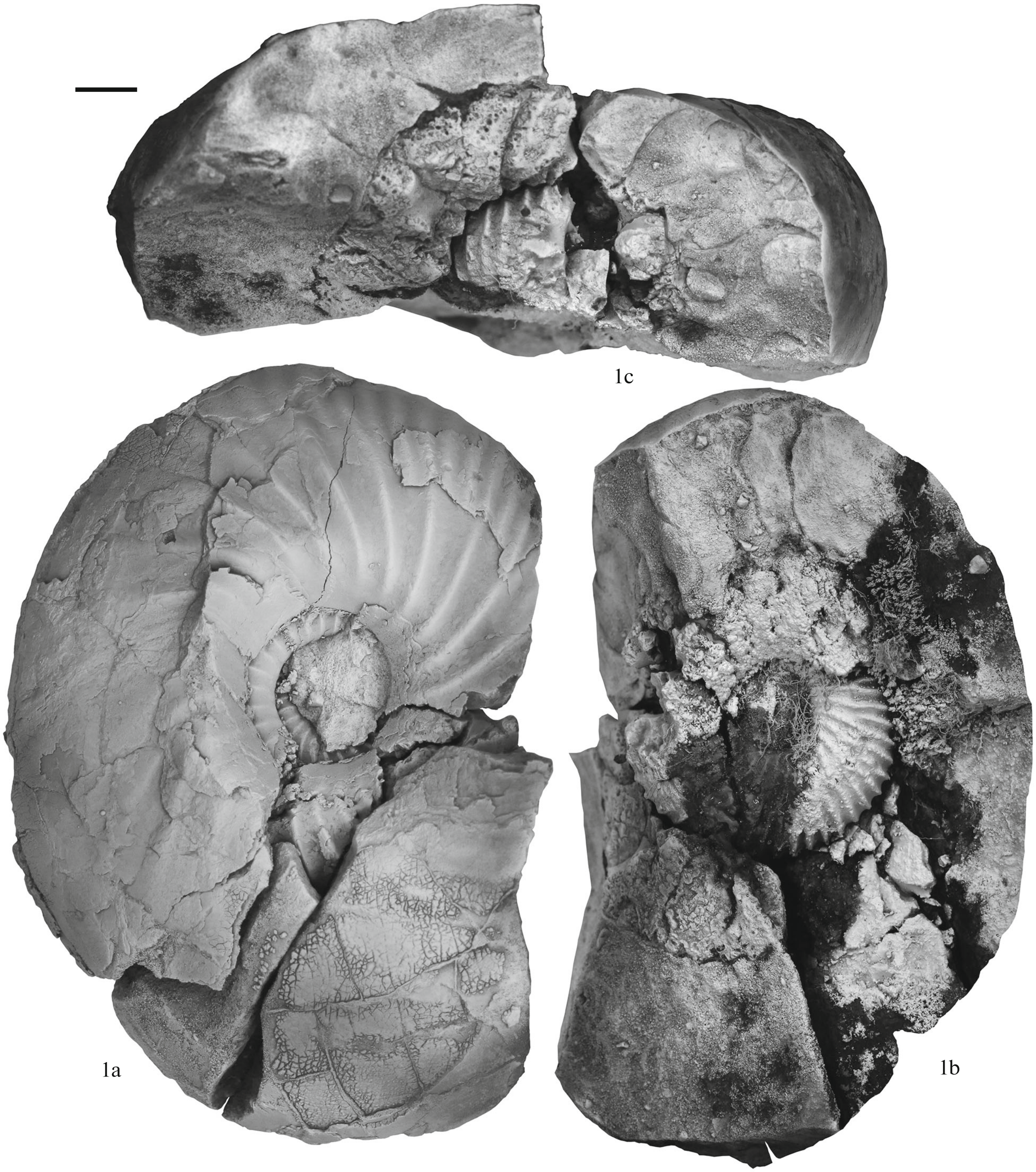


Plate III. *Catacadoceras* aff. *barnstoni* (Meek, 1859) from the Upper Bathonian of northern Eastern Siberia; (1) specimen GEOCHRON, no. 2112/3, lower reaches of the Lena River, northern section near the village of Chekurovka, Outcrop 2, Member 8, 0.7 m below the top: (a) lateral view of an outer whorl, (b) lateral view of an inner whorl, (c) apertural view.

involute and compressed at the adult body chamber; the relative width of the shell (WW/Dm) varies on average from 40 to 50%, but in one case it reaches 80%. According to the description and cited images (Callomon, 1985, pl. 1, figs. 1–3; text-figs. 8i, 9A, 9B), the ribbing on the inner whorls is prominent, regularly bifurcating, and slightly slanting forward. The ornamentation continues on the body chamber, the primary ribs become coarser than the secondaries, sometimes with intercalaries. However, the description of

Plate IV. *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 from the Middle Bathonian of East Greenland (photographs by V.V. Mitta in the Geological Museum of Copenhagen University); (1) specimen MGUH 16569, holotype, southwest of Fossilbjerg Mountain, Outcrop 42, Bed 2: (a) lateral view, (b) ventral view; (2) topotypes, not to scale, coll. by J. Callomon and T. Birkelund.

inner whorls of *Arc. cranocephaloide* is relatively brief with no indication of specific diameters. Specimens of the type series of *Arc. cranocephaloide*, except for the paratype MGUH 16573 (Callomon, 1985, pl. 1, fig. 3), separately illustrated topotypes (Callomon, 1993, fig. 3), including the photographs provided by V.V. Mitta (pl. IV), and also two specimens from Callomon's collection from Outcrop 43 (near the type locality—Outcrop 42) by Kiselev (2022, pl. 13, figs. 1, 2), represented by adult forms, most of which are deformed and/or do not have inner whorls. Thus, it can be assumed that the inner whorls could only be described from specimen MGUH 16573, later whorls of which are not known; the identification of this specimen as *Arc. cranocephaloide* was most likely made on the basis of its occurrence at the same stratigraphic level with adult specimens of this species. This specimen, along with the allotype MGUH 16570, was reported to have been discovered southwest of Mount Olympen, in Outcrop 70, while the holotype, the other two illustrated paratypes, and other topotypes come from sections near Mount Fossilbjerg (Callomon, 1985, 1993), which is 25–30 km southeast of Outcrop 70. Because typical adult forms of *Arc. cranocephaloide* are not listed in Outcrop 70 together with specimens MGUH 16573 and MGUH 16570, this does not allow us to confidently attribute the latter to this species. It is possible that the first illustrated adult forms, – "*Arc. cranocephaloide* sp. nov. MS" (Callomon, 1975, fig. 4D) and "*Arc.* cf. *cranocephaloide* sp. nov. MS" (Callomon, 1975, fig. 4E), come from a locality near Outcrop 70; of these occurrences it is only known that they come from a locality south of Mount Olympen, but these specimens are not mentioned in the formal first description of the species in question. If, however, we accept the point of view of J. Callomon and interpret the juvenile specimen as internal whorls of *Arc. cranocephaloide*, perhaps its generic name should be reconsidered according to the ontogenetic principle of taxonomy since the shape of the shell of MGUH 16573 has more in common with cadoceratins than with early *Arcticoceras*.

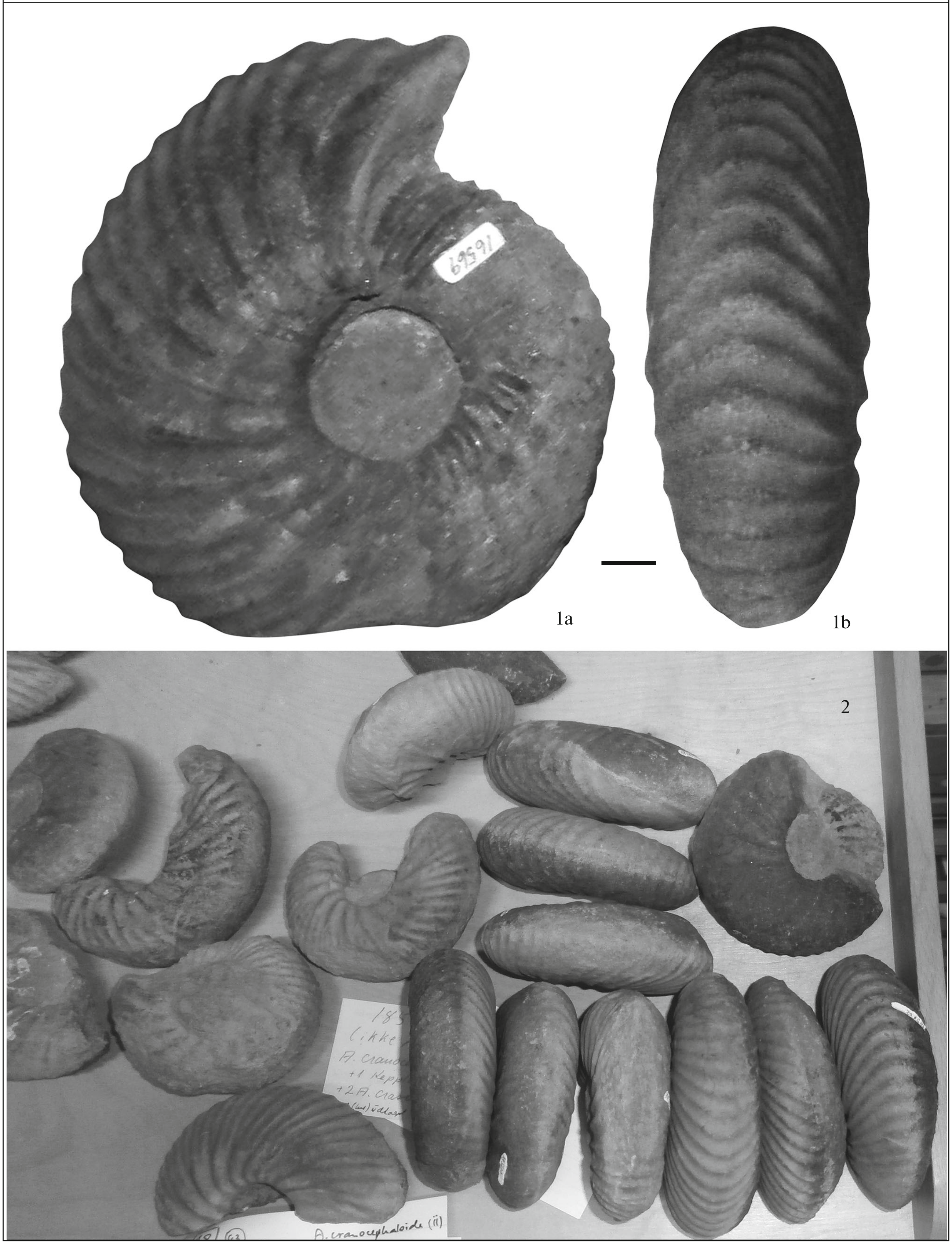
Also, the original description did not pay enough attention to the shape of the outer whorls of the *Arc. cranocephaloide* shell, while no images of the shell in the apertural or ventral view were provided. In addition to the characteristic of the relative width of the shell mentioned above, the description mentioned a flattened venter of the adult body chamber of this species. The umbilicus was described as open, shallow, with a rounded umbilical edge. The variability of the relative width of the umbilicus and the relative height of the adult shells of *Arc. cranocephaloide* can only be obtained from images, e.g., of holotype MGUH 16569 and paratypes MGUH 16571 and 16572. Thus, the UW/Dm ratio varies from 26 to 29%, while the WH/Dm of adult shells is 38 and 40% (paratypes) and 41% (holotype). Consequently, the WW/WH ratio varies approximately in the range from 1 to 1.25. Considering the indication of the presence of a specimen with a WW/Dm ratio of 80%, then the range of WW/WH ratio will expand to approximately 2; accordingly, the whorl height will be noticeably less than its width. Judging by the photographs of paratypes MGUH 16571 and 16572 at our disposal, the WW/WH of these specimens is 1.1 and 1; the whorl height is equal to or slightly less than the width, while in the holotype (Pl. IV, fig. 1) the height exceeds its width: WW/WH is 0.88. The general view of adult shells in the photographs gives the impression that the species under discussion is characterized by a flattened shell, while the cross-section of the outer whorls should be isometric-rounded or slightly extended in height. No shell image with a relative width of reliably 80% was found.

The description of the ornamentation of adult shells of *Arc. cranocephaloide* is not very detailed. It reflects only the information that is visible in the images presented in Callomon's (1985) paper. Almost nothing was known for a long time about the nature of the ribbing on the venter. In a photograph of a general view of a part of the collection (Birkelund and Perch-Nielsen, 1976, text-fig. 269), reflected in synonymy (Callomon and Birkelund in Callomon, 1985) and later re-illustrated (Callomon, 1993, text-fig. 3), in a small number of specimens it can be seen that the ribs on the venter have a well-defined bend directed towards the aperture. After examining all available photographs, including those chosen for illustration (pl. IV) and those given in (Kiselev, 2022, pl. 13, figs. 1, 2), it became clear that such a pattern of ribbing on the venter is typical of the species *Arc. cranocephaloide*.

In the north of Siberia, the species "*Arc.(?) cranocephaloide*" was first identified from finds in the lower reaches of the Lena River, in the sections of the northern and southern wings of the Chekurovskaya Anticline (Meledina et al., 1991), and then on the coast of Olenek Bay near the village of Ystannah-Khocho as a result of reidentifying a specimen from Outcrop 16, Bed 28, originally described by Meledina (1977) as *Cadoceras (Streptocadoceras)* aff. *kialagvikense* Imlay, 1953 (Meledina, 1994[2]). The first detailed description of the North Siberian "*Arc.(?) cranocephaloide*" was published by Knyazev et al. (2009). In it, shells of this

[2] In this work, in Fig. 17, it is erroneously indicated coming from Beds 26–27.

Plate IV



species are characterized as strongly inflated (WW/Dm about 60%) with a moderately narrow umbilicus (UW/Dm 20–25%), reaching more than 100 mm in diameter. In the available images, the ornamentation of the initial whorls of the shells is represented by relief bifurcating ribs with intercalaries, forming a bend towards the aperture on the venter. On the outer whorls, the primary and secondary ribs are differentiated: the primaries begin from the umbilical shoulder, acquire the appearance of a strongly elongated tubercle, and on the lateral side they bend noticeably forward; the secondary ribs, which are considerably less coarse than the primary ribs, cross the venter almost straight. For each primary rib, there are two or three secondary ones.

Thus, "*Arc.(?) cranocephaloide*" identified in the north of Eastern Siberia are similar to *Arc.(?) cranocephaloide* in morphological characters visible on the flanks of the East Greenland specimens since the UW / Dm ratio of the images cited in publications is 28–30% (the UW/Dm value of 20–25% indicated in the description of this species (Knyazev et al., 2009) is typical only of specimen no. 856-21, identified as *Catacadoceras* aff. *barnstoni* in the present paper; WH/Dm is 38–40%, the ornamentation consists of primary and secondary ribs, varying in width and prominence and slanting forward. There are two or three secondary ribs for one primary. However, in shell shape and ornamentation on the venter, they differ significantly from the East Greenland specimens of *Arc. cranocephaloide*: in the North Siberian specimens, the shell is more strongly inflated, and ribs on the venter do not bend towards the aperture, while in the East Greenland specimens, the WW/Dm ratio does not exceed 50% and ribs definitely bend on the venter.

The original description of *Arc. cranocephaloide* says (Callomon and Birkelund in Callomon, 1985, p. 78): "Nothing comparable appears yet to have been described from anywhere else". However, in the ornamentation on the flanks, ribbing retained in the later whorls, relative whorl height variability range and relative umbilicus diameter, i.e., in characters visible on the flanks, this species is quite similar to geochronologically younger cadoceratins, i.e., *Catacadoceras barnstoni*. These two species differ in the shell shape. In *Cat. barnstoni,* the shell is strongly inflated (WW/Dm 50–60%), whereas in *Arc. cranocephaloide* it is more flattened (WW/Dm 40–50%) and have a pronounced rib bending on the venter, which is not observed in *Cat. barnstoni*. Deformed and especially compressed shells, with characters similar to both of these species, cannot be attributed with complete certainty to either of them. Thus *Arc. cranocephaloide* differs from *Cat. barnstoni* mainly in the shell shape and ornamentation on the venter, which allow positive assignments of most Siberian ammonites previously identified as *Arc. cranocephaloide*, to *Cat. barnstoni*. The two specimens discussed in the "Remarks" section of the systematic description of *Cat*. aff. *barnstoni* are an exception.

A specimen of (?)*Arcticoceras* sp. juv. (cf. *Arc. cranocephaloide*), found on the Yuryung-Tumus Peninsula 10.5 m above the base of Member 21 (de Lagausie and Dzyuba, 2017, pl. 1, figs. 6–8), is represented by a fragment of an inner whorl, which has isometrically rounded cross-section with a wide venter (WW = 10 mm, WH = 10 mm), slight forward bending of the ribs on the venter. *Arc. ishmae* (Keyserling, 1846), the type species of the genus *Arcticoceras*, is characterized by an oval and sometimes subacute cross-section of the inner whorls. The isometric section is more characteristic of the genus *Arctocephalites*, however, ribs in the latter are not bent forward. Judging by ornamentation, the specimen under consideration may correspond to the genus *Catacadoceras*, in which, the cross section is isometric with similar height and width. Therefore, in this work, this specimen is identified as *Catacadoceras* sp. juv. (Fig. 2b). A species-level identification of this specimen is not possible due to its small size.

It is possible that a juvenile ammonite shell found approximately 2 m below the base of the Paracadoceras variabile Zone on the eastern coast of Anabar Bay and identified as *Arcticoceras* sp. (Knyazev et al., 2009, pl. 1, figs. 3) in fact belongs to *Arc. cranocephaloide*. This specimen differs from *Arc*. *ishmae* (Keyserling, 1846) and *Arc. crassiplicatum* Callomon, 1993 [MS] in Kiselev, 2022, in the isometrically rounded cross-section. However, as stated above, there are no reliable data on the internal whorls of *Arc. cranocephaloide* of East Greenland. *Arc*. aff. *cranocephaloide* sensu Callomon, 1993 (= *Arcticoceras/Cadoceras* sp. nov. ? aff. *variabile* Spath: Callomon and Birkelund, 1980, pl. 1, fig. 1 (macroconch), fig. 2 (microconch)) was published from the *Kepplerites tychonis* Biohorizon of East Greenland, i.e. from the topmost beds of the Arc. cranocephaloide Zone. The illustrated microconch is clearly deformed and in lateral view differs little from microconchs from adjacent levels. The macroconch *Arc*. aff. *cranocephaloide* is interesting as in contrast to *Arc. cranocephaloide,* it has only well-defined elongated umbilical nodes at a late growth stage, which makes quite similar to early members of the subfamily Cadoceratinae. The relative umbilicus width and external morphology of the flanks of this specimen are similar to those of *Cat*. aff. *barnstoni* (pl. III, fig. 1). However, in the relative shell width, it still more closely resembles *Arc. cranocephaloide*. Apparently, compared to *Arc. cranocephaloide*, *Arc*. aff. *cranocephaloide* shows even more morphological characters that are similar in the later *Arcticoceras* with the earliest members of Cadoceratinae. The latest *Arcticoceras* in East Greenland were reported from the P. variabile Zone (Callomon, 1993). We could not find their illustrated description. In Siberia, representatives of *Arcticoceras* were not found in co-occurrence with *P. variabile*.

Thus, no reliable finds of *Arc. cranocephaloide* are yet known from Siberian sections.

POSITION OF THE CATACADOCERAS BARNSTONI BIOSTRATON IN THE AMMONITE ZONAL SCALE OF THE BATHONIAN OF SIBERIA

The zonal ammonite scale of the Bathonian Stage in northern Siberia is based on the phylogenetic sequence of taxa of the family Cardioceratidae. The subfamily Arctocephalitinae, which appeared in the Bajocian, was relatively quickly replaced by genera and species of the subfamily Cadoceratinae in the second half of the Bathonian. Below we substantiate the need to revise the modern ammonite zonation for the upper part of the Bathonian of Siberia and discuss stratigraphic position of the Catacadoceras barnstoni biostraton in the Arctic sections, and in particular in the north of Siberia.

The state of knowledge of the problem

For the first time, a biostratigraphic unit with *Catacadoceras barnstoni*[3] as an index species was recognized in northern Canada, in the Northern Yukon, where the Cat. barnstoni Zone was established above the Arcticoceras ishmae Zone and below the Cadoceras bodylevskyi Zone (Poulton, 1987). At the same time, the intervals between all three zones are characterized as poorly exposed. In fact, the used criteria for separating this zone correspond to those for identifying beds with fauna, if the author had to follow the recommendations of the stratigraphic code adopted for the territory of Russia (*Stratigraficheskii...*, 1977, 2019). Apart from the index species, the zonal assemblage included *Phylloceras billingsi*, *Iniskinites* sp., *Kepplerites* sp. aff. *K. rosenkrantzi*, and *Kepplerites* sp. B.

In Siberia, the Cat. barnstoni Zone was first established by Meledina (1991) between the Arcticoceras cranocephaloide and Paracadoceras falsum zones, also recognized here for the first time. The upper part of the Cat. barnstoni Zone was distinguished as the Beds with *Paracadoceras variabile* (Fig. 6). The entire ammonite sequence recognized by Meledina was included in the first version of the boreal zonal standard (Zakharov et al., 1997). Later, the Cat. barnstoni Zone was recognized as Beds with fauna and was moved to the top of the Arc. cranocephaloide Zone, above which the P. variabile zone was indicated (Knyazev et al., 2009). Gulyaev (2011) considered the Siberian biostraton as the Cat. barnstoni ammonite level corresponding to the *Kepplerites rosenkrantzi* faunal horizon of the P. variabile Zone of East Greenland. The biostraton *Cat. barnstoni* is absent in the boreal zonal standard version, for which Siberia is proposed as the stratotype region (Shurygin et al., 2011; Nikitenko et al., 2013). Kiselev (2022) synonymized the Cat. barnstoni Zone under the P. variabile Zone as its stratigraphic equivalent.

It should be noted that the co-occurrence of *Catacadoceras barnstoni* and *"Arcticoceras(?) cranocephaloide"* was reported only in relation to the northern section near the village of Chekurovka in the lower reaches of the Lena River (Shamonin and Knyazev, 2020; Shamonin et al., 2020). The above results of a repeated study of ammonites from this section and analysis of materials from other localities in Siberia showed that: (1) specimens previously identified here as *Arc.(?) cranocephaloide* should be assigned to *Cat. barnstoni* or to the form described in this work as *Cat.* aff. *barnstoni*, (2) recent find of *Arc. cranocephaloide* (Kiselev, 2022, pl. 18, fig. 1) is also not evidence for the presence of this species in Siberian sections. Thus, the stratigraphic interval, which previously corresponded in the Siberian sections to the Arc. cranocephaloide Zone should be entirely assigned to the range of distribution of *Cat. barnstoni*. This raises the question of whether it would be appropriate to replace the name of the Arc. cranocephaloide Zone to Cat. barnstoni Zone in the zonal ammonite scale of the Bathonian of Siberia and, accordingly, in the Boreal (Siberian) zonal standard of this stage. To answer this question, it is necessary to consider the problem of the geochronological age of the species *Cat. barnstoni* and *Arc. cranocephaloide* and *Paracadoceras variabile*, which has been the subject of much discussion (Poulton, 1987; Meledina, 1991, 1994; Hillebrandt et al., 1992; Callomon, 1993; Repin, 1999, 2005; Knyazev et al., 2009; Gulyaev, 2011, 2012, 2015; Knyazev and Meledina, 2011; Kiselev, 2022; etc.), apparently, with a no-consensus result. It should be noted that in this work, *Arc. cranocephaloide* is considered to be Middle Bathonian in age (Callomon, 2003; Mitta et al., 2014; Callomon et al., 2015; Kelly et al., 2015; Dzyuba et al., 2019; Alsen et al., 2020; Shamonin and Knyazev, 2020; Kiselev, 2022; etc.). The main localities of *Cat. barnstoni* are considered below.

Northern Canada. The bulk of finds of *Cat. barnstoni* in Northern Canada comes from a rather condensed section, according to the description of T. Poulton, of the Salmon Cache Canyon on the Porcupine River of the northern Yukon and is confined here only to Bed 62, 30 cm thick, composed of large concretions (Poulton, 1987). It is assumed that the holotype of the species could have originated from the same bed, the geographic reference of which is limited to the valley of the Mackenzie River (Meek, 1859). The concretions contained relatively diverse macrofaunal remains including *Paracadoceras variabile*, *Kepplerites* sp. aff. *K. rosenkrantzi*, *Phylloceras billingsi*, and the bivalves *Retroceramus* sp., i.e., taxa known in Siberia. The condensed nature of the Salmon Cache Canyon section does not exclude the possibility that the cited assemblage of the Cat. barnstoni Zone recognized there could be mixed from faunas of different ages.

[3] Here and below, the generic affiliation of index species of biostratigraphic units is cited in accordance with the taxonomy accepted in this work.

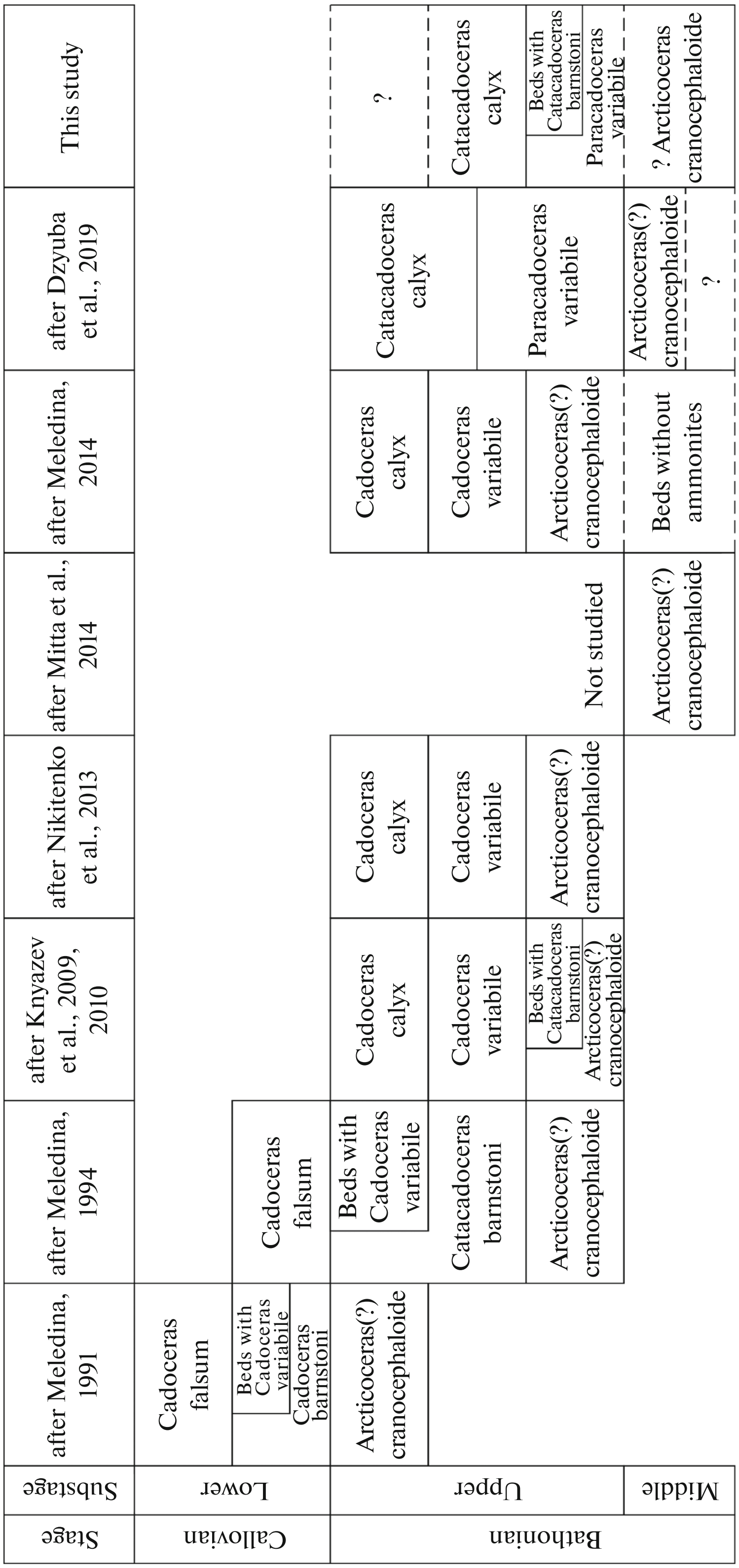


Fig. 6. Development of views on the ammonite stratigraphy of the Middle–Upper Bathonian of Siberia and the version of the subdivision of these deposits substantiated in this work.

East Greenland. The problem of this region for a long time was the lack of any images or descriptions of *Cat. barnstoni*. The only available evidence was the list of Latin names published by Callomon (1993), which accompanied the faunal horizons he identified in the Boreal (East Greenland) ammonite zonal scale, containing, among others, "*C.* cf. or aff. *barnstoni*" and its synonym "*C. subcatostoma*". According to this list, finds of *Cat. barnstoni* in East Greenland are confined to the *Kepplerites rosenkrantzi* faunal horizon, recognized in the upper half of the Paracadoceras variabile Zone, which overlies the Arcticoceras cranocephaloide Zone. The find of *Arcticoceras* sp. nov. 1, marking the upper limit of distribution of arctocephalitins in Greenland (this species has not been formally described) was also assigned to this horizon. The possibility of mixing in the *K. rosenkrantzi* horizon of two faunal assemblages of slightly different ages, not always recognizable in the field, was suggested (Callomon, 1993). Thus, documentary evidence of the distribution of the species *Cat. barnstoni* together with *K. rosenkrantzi* and later *P. variabile* was not provided. The problem was solved by the work of D.B. Gulyaev (2011, Fig. 2), which shows an image of two specimens of *Cat. barnstoni* from the collection of J. Callomon, which can be used to confirm the presence of this species in the *K. rosenkrantzi* faunal horizon of in East Greenland. Considering the presence of *Cat. barnstoni* in northern Yukon (Poulton, 1987; etc.) and *Kepplerites* aff. *rosenkrantzi* on the Kanin Peninsula in the European part of Russia (Meledina, 1987, pl. IV, fig. 1), Callomon (1993) suggested the presence of equivalents of the *K. rosenkrantzi* faunal horizon outside East Greenland.

Franz Joseph Land. All the illustrated finds, now attributed to *Cat. barnstoni* (see the "Remarks" section), come from Hooker Island and are confined to the Cat. barnstoni Zone (Repin, 1999; Repin et al., 2007), as in Northern Canada, established here in the absence of a continuous zonal sequence. Also, the Bathonian of Hooker Island contains *Cat. perrarum* (= *"Cadoceras (Catacadoceras) barnstoni"* (Kiselev, 2018, pl. 3, fig. 1; 2022, pl. 1, fig. 1)).

Northern Siberia. In northern Siberia, together with *Cat. barnstoni*, assemblages predominantly contain cardioceratids of the genus *Catacadoceras* – *Cat.* aff. *barnstoni* and *Cat. perrarum*. At the same time, occurrences of *Cat.* aff. *barnstoni* are confined to the upper part of the *Cat. barnstoni* range, while finds of *Cat. perrarum* come from the uppermost part of this range, thus marking different levels in the sections (Figs. 2a, 7). Beds with *Cat. barnstoni* are widely traced in northern Siberia. They are best represented in the lower reaches of the Lena River, where finds of this species (taking into account the revision reflected in the synonymy) are recorded in sections near the village of Chekurovka, on Cape Chucha and the Chubukulah River. As a result of the study, a relatively large vertical range of distribution of *Cat. barnstoni* was established in the northern section near the village of Chekurovka (Outcrop 2), almost throughout the entire Member 8 (Fig. 2a). Previously, its possible presence in this section was indicated only by a single find of *Cat.* cf. *barnstoni* in Member 9 (Meledina et al., 1991). It is noteworthy that in Member 9, we did not find *Cat. barnstoni*, which, however, could have resulted from about 1.7 m of the section of this member being completely covered by dense scree in 2019. Evidently, the "covered" interval is also associated with the erosion boundary observed in geochronologically similar portion of Outcrop 3 (Chucha) of the southern limb of the Chekurovskaya Anticline (Meledina et al., 1991). The lower part of the distribution interval of *Cat. barnstoni* contained *Phylloceras* sp. and *Arcticoceras*(?) sp. juv., and the upper part contained *Cat.* aff. *barnstoni* (Fig. 2a). Previously, *Cat. perrarum* (Meledina et al., 1991, pl. 9, fig. 1) and *Phylloceras billingsi* (Meledina et al., 1991, pl. 8, fig. 5) were found 3 m above the base of Member 9. Considering that, according to the occurrence of *Paracadoceras* ex gr. *elatmae* during fieldwork of 2019, the base of the Callovian in this section was established 3.3 m above the base of Member 9 (Shamonin and Knyazev, 2020), we analyzed the ammonite originally identified as *Cadoceras (Bryocadoceras) falsum* (Meledina, 1977, pl. 10, fig. 1; pl. 11, fig. 1; pl. 12, fig. 1; Meledina, 1994, pl. 4, fig. 1), later reidentified as *Catacadoceras calyx* (Knyazev et al., 2009). This ammonite was found 6 m above the base of Member 9 together with Cadoceratinae gen. et sp. ind. (= *Kepplerites*(?) sp. (Meledina et al., 1991, pl. 10, figs. 6–8)) and *Phylloceras* sp. In this paper, we accept the initial identification of this specimen by Meledina and other occurrences of *Paracadoceras falsum* in the Chekurovka sections. Outcrop 3 (Chucha) contained *Cat.* cf. *perrarum* (Meledina et al., 1991, pl. 9, fig. 2; pl. 10, fig. 4), established, according to Meledina et al. (1991, figs. 2, 4), above the distribution range of *Cat. barnstoni*. On Cape Chucha, *Paracadoceras variabile* (Kiselev, 2022, pl. 26, fig. 2), was discovered in the same locality with *Cat. barnstoni*, which is consistent with data from northern Canada and East Greenland.

On the eastern coast of the Yuryung-Tumus Peninsula, the interval under consideration probably corresponds to the middle part of Member 21, which contains an ammonite identified in this work as *Catacadoceras* sp. juv. (Fig. 2b). The level of the find is comparable to the lower part of the interval with *Cat. barnstoni* in the lower reaches of the Lena River, since bivalves of the genus *Retroceramus* (*R.* cf. *vagt*) are still found in the middle part of Member 21 on the Yuryung-Tumus Peninsula (Urman et al., 2022). Outside the Yuryung-Tumus Peninsula, the last representatives of *Retroceramus (R. vagt)* are associated with early *Cat. barnstoni*. This is best documented in the northern section near the village of Chekurovka, where the uppermost finds of this bivalve genus were found 1 m below the top of Member 8, near the

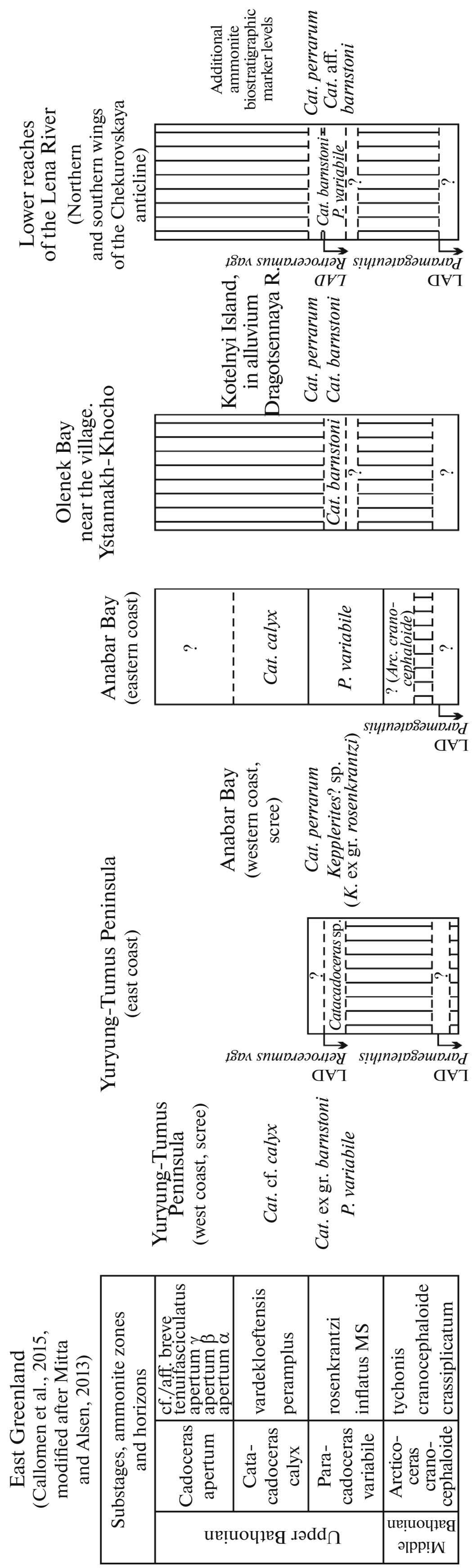


Fig. 7. Correlation of the main localities of the Middle-Upper Bathonian ammonites in the north of eastern Siberia with the East Greenland ammonite sequence. Compiled taking into account published data (Bodylevsky, 1960; *Stratigrafiya*, 1976; Meledina, 1977, 1994, 1999; Zakharov and Shurygin, 1978; Meledina et al., 1991, 2015; Knyazev et al., 2009; Knyazev and Meledina, 2011; Nekhaev et al., 2015; Dzyuba and de Lagausie, 2018; Shamonin et al., 2020; Kiselev, 2022; Urman et al., 2022). LAD (last-appearance datum)—stratigraphically latest finds of belemnites of the genus *Paramegateuthis* and bivalves *Retroceramus vagt*.

unconformity, above which, in contrast to *Cat. barnstoni*, they were not found (Shamonin et al., 2020). At Cape Chucha (Outcrop 3), according to Meledina et al. (1991) and taking into account the revision of the taxonomic composition of ammonites in this work, a similar pattern is observed. As noted above, in the Salmon Cache Canyon section of northern Canada, *Retroceramus* finds are known from the nodule bed, which also contains *Cat. barnstoni*, and above that level, no *Retroceramus* are found here (Poulton, 1987). In East Greenland, records of *Retroceramus* are rare and have not been mentioned above the Arcticoceras cranocephaloide Zone (Callomon and Birkelund, 1980; Kelly et al., 2015).

Higher horizons of the Bathonian of the Yuryung-Tumus section are exposed on the northwestern coast of the peninsula, from where, according to Bodylevsky (1960), *Cat.* cf. *calyx* has been recorded (Fig. 7). On approximately the same stretch of coast, *Cat.* ex gr. *barnstoni*, *Paracadoceras variabile* (Meledina et al., 2015, pl. 1, fig. 5), and Callovian taxa were found in talus, while Early Oxfordian ammonites were found in situ (Meledina et al., 2015; Nekhaev et al., 2015).

On the eastern coast of Anabar Bay, the upper part of Member 41 of Outcrop 109, that contained *Arcticoceras* sp. (Knyazev et al., 2009, pl. 1, fig. 3), also contained *Cat. barnstoni* (Meledina, 1994, 2014), but not confirmed, on the basis of a single find of loosely collected *“Cadoceras (Catacadoceras)* cf. *ognevi*” (= *Cat. barnstoni* sensu Meledina, 1991), previously mention without an illustration (Saks et al., 1963). It was originally suggested that *“C. (Cat.)* cf. *ognevi*” was found in Member 42 (*Stratigrafiya*..., 1976), currently assigned to the Paracadoceras variabile Zone (Knyazev et al., 2009). We consider any interpretation of this find to be too speculative. *Cat. perrarum* was recorded from the talus on the western coast of Anabar Bay (Knyazev and Meledina, 2011, p. 122, pl., fig. 1), and 2 km to the south, a poorly preserved shell identified as *Kepplerites* ex gr. *rosenkrantzi* (Knyazev and Meledina, 2011, p. 122, pl., fig. 2) was also found in the talus. Taking into account all the existing re-identification, *Cat. barnstoni* was found in Bed 28 of Outcrop 16 on the coast of Olenek Bay near the village of Ystannah-Khocho, according to Meledina (1977, 1994) and Knyazev et al. (2009). The new collections of Bathonian ammonites from this locality also contain specimens of *Cat. barnstoni* (pl. 1, figs. 3, 4). The presence of *Cat. barnstoni* and *Cat. perrarum* was also confirmed on Kotelnyi Island room to a large number of finds collected in alluvial deposits of the Dragotsennaya River (Meledina, 1999).

Thus, in northern Siberia, localities of *Cat. barnstoni* also contain *Cat.* aff. *barnstoni, Cat. perrarum*, and also single finds of *Paracadoceras variabile, Arcticoceras(?)* sp. juv., and *Phylloceras billingsi*. Presumably, this assemblage should also include "*Kepplerites* ex gr. *rosenkrantzi*". The available data, judging by the stratigraphic position of *Cat. barnstoni* in East Greenland, suggest that the range of distribution of *Cat. barnstoni* corresponds to the *K. rosenkrantzi* faunal horizon isolated in the upper part of the Upper Bathonian P. variabile Zone of East Greenland.

Biostratigraphic conclusions

It needs to be mentioned that compared to the Paracadoceras variabile Zone, a biostraton based on *Cat. barnstoni*, no matter what rank it is assigned, in practical terms will be more in demand in the Siberian sections due to the greater geographic distribution and abundance of the index species. However, given the confinement of the age range of *Cat. barnstoni* to the upper part of the P. variabile Zone, replacing the latter with the Cat. barnstoni Zone in the ammonite scale of the Upper Bathonian of Siberia is hardly justified. Also note that in none of the Siberian sections it is possible to establish biostratigraphic units adjacent to *Cat. barnstoni* distribution interval (Fig. 7). Therefore, in this case, the separation of the Beds with *Cat. barnstoni* in the upper part of the P. variabile Zone (Fig. 6) seems to be the best decision. Beds with *Cat. barnstoni* are recognized in Franz Josef Land and northern Canada, and their equivalents are present in the *Kepplerites rosenkrantzi* faunal horizon of East Greenland.

The relationship of the Beds with *Cat. barnstoni* with underlying deposits is well observed in the northern section near the village of Chekurovka in the lower reaches of the Lena River, where there is an interval, without ammonites and containing an unconformity, between the level of the first finds of *Cat. barnstoni* and the underlying Arcticoceras ishmae Zone (Fig. 2a). Summarizing the published data, we conclude that this is a typical situation for the northern Siberian sections (Fig. 7). In general, from bottom to top in these sections, the following sequence of event levels is observed: first the ammonite species *Arc. ishmae* disappears, slightly higher, one or two unconformities are observed near which the last appearance of belemnites of the family Megateuthididae (genus *Paramegateuthis*) is recorded, followed by the appearance of the earliest representatives of *Cat. barnstoni* up the section. The same pattern is typical of the Bathonian section on the eastern coast of Anabar Bay, with one exception: *Cat. barnstoni* is not found here, however, the first appearance of *Paracadoceras variabile* is recorded 25 m above the unconformity[4]. Obviously, stratigraphically, this is the most complete section in the region in the interval under consideration. In the same section, immediately below the occurrences of *P. variabile* finds, a small shell of *Arcticoceras* sp. was found, which could possibly be identified as *Arc. cranocephaloide*, as noted above. Therefore, it seems appropriate not to remove the Arc. cranocephaloide biostraton from the zonal ammonite scale of the Bathonian of Siberia, but to use it tentatively (Fig. 6), given the absence of reliable finds of the index species in Siberian sections. As possible options for designating this interval of the scale, the following units can be proposed: "? Arcticoceras cranocephaloide Zone" or "Beds with *Arcticoceras* ex gr. *cranocephaloide*".

We should also discuss the proposal of Meledina (2014) concerning the separation of "Beds without ammonites" between Arc. ishmae and Arc. cranocephaloide zones in the Siberian ammonite scale. Meledina proposed this informal subdivision for the entire middle Bathonian since the Arc. cranocephaloide Zone was dated Late Bathonian (Fig. 6). Nevertheless, even taking into account its Middle Bathonian age, the presence above the Arc. ishmae Zone of the interval with no ammonites, can be considered quite characteristic of boreal sections. For instance, in addition to Siberia, such an interval is also present in the basin of the Izhma River in the north of European Russia (Mitta et al., 2015). At the same time, it is evident (Fig. 7) that in Siberia, geochronological intervals without ammonites often correspond to unconformities, which may be associated with the loss of a significant part of the Middle Bathonian succession from the section. With increasing efforts in the search for ammonites in the preserved beds, the intervals not characterized by ammonites become not so large (Fig. 2). Accordingly, in our opinion, even though beds without ammonites should be recorded in specific sections, however, there is no need to distinguish such a special interval in the regional ammonite scale.

We also note in this context that we consider the proposals of Mitta and Alsen (2013) on updating the standard East Greenland ammonite scale of the Bathonian, especially the proposed transfer of the *Arc. crassiplicatum* faunal horizon from the upper part of the Arc. ishmae Zone to the lower part of the Arc cranocephaloide Zone. Despite the fact that this horizon was originally formally recognized as part of the Arc. ishmae Zone, in fact, throughout several decades, only the remaining part of this zone was recognized as the Arc. ishmae Zone. The reason for this was the lack of a formal description of its index species *Arc. crassiplicatum* until 2022 (Kiselev, 2022). Accord-

[4] A level with numerous rounded belemnite rostra and fragments of rostra in the middle part of Member 40 (the base of Member 23a in a different stratification system) was taken as the unconformity level (Zakharov and Shurygin, 1978).

ingly, it was not known what exactly should be recognized as the tops of the Arc. ishmae zone, which, unlike the Arc. cranocephaloide Zone is extremely widespread in Boreal regions. Unfortunately, one of the authors revised the previously put forward proposal (Alsen et al., 2020). However, in this work, following a number of authors (Kelly et al., 2015; Morton et al., 2020), we support Mitta and Alsen's (2013) proposal (Fig. 7).

The relationship of the Siberian Beds with *Catacadoceras barnstoni* with the overlying rock stratum is also most evident in the Chekurovka sections in the lower reaches of the Lena River (Fig. 2a), especially in the southern Chucha section—Outcrop 3 (Meledina et al., 1991, text-fig. 4). Apparently, Callovian deposits directly overlie these beds over an unconformity. The confinement of the occurrences of *Cat*. aff. *barnstoni* and *Cat. perrarum* to relatively narrow stratigraphic intervals within the upper part of the Beds with *Cat. barnstoni* (Figs. 2a, 7) makes it possible to recognize biostratigraphic marker levels, which can be used for dating and correlating of Upper Bathonian deposits. In essence, they correspond to the concept of biohorizons, however, due to the single occurrence of *Cat*. aff. *barnstoni* and *Cat. perrarum* in situ, a formal description of these biostratons appears to be premature. It is possible that it would be more correct to recognize the *Cadoceras lenaense* Biohorizon (Kiselev, 2022), previously placed in the upper part of the Paracadoceras variabile Zone, in the lower Callovian, rather than in the lower part of the Catacadoceras calyx Zone, as the author of the biostraton suggested. Expressing doubts about the dating of the biohorizon, Kiselev took into account that the holotype of the index species was found at the base of the "Cat. calyx" Zone on the southern flank of the Chekurovskaya Anticline (Meledina, 1977; Meledina et al., 1991), formerly known as the Paracadoceras falsum Zone (Meledina et al., 1991), but later renamed due to the reidentification of ammonites (Knyazev et al., 2009). However, as stated above, their original identification as *P. falsum* seems correct. Judging by the comments of D.N. Kiselev, given in the description of the *C. lenaense* Biohorizon, the decisive factor in determining its age was the co-occurrence of *C. lenaense* with *Paracadoceras variabile* in the Upper Bathonian on the eastern coast of Anabar Bay. Probably, the possible erroneous locality details of the Chekurovka specimens were implied. This is supported by the inclusion of information on ammonites obtained during the study of the southern section near the village of Chekurovka (Meledina, 1977), into the characterization of the upper 10 meters of Member 8 Outcrop 3 at Cape Chucha (Meledina et al., 1991, p. 21). Only from other parts of the latest work (Meledina et al., 1991, p. 23, fig. 2), where, when mentioning a number of finds, including *C. lenaense*, references are made to their images in the monograph by Meledina (1977), it becomes clear that they actually come from a different section. We did not find *C. lenaense* in the northern section near the village of Chekurovka, nor was it previously recorded from this section. Nevertheless, in our opinion, it is still premature to draw conclusions about the factual material from the typical locality for *C. lenaense*, the southern section near the village of Chekurovka (Outcrop 7, Bed 36, 4–5 m below the top, along with *P. falsum*; after Meledina, 1977). It is highly desirable to once again carefully study the Anabar material for its correspondence to the species *C. lenaense*.

The results of the research indicate a significant stratigraphic incompleteness of the Middle-Upper Bathonian deposits in the lower reaches of the Lena River, which is obviously a characteristic feature of most sections in northern Siberia (Fig. 7). A significant part of the middle and upper Bathonian has not been preserved here due to erosion. This problem is exacerbated by complete absence of a stratigraphic equivalent of the Cadoceras apertum ammonite zone of the East Greenlandic reference sequence, including in the most complete section of the Upper Bathonian on the eastern coast of Anabar Bay. Even though no traces of a surface of erosion at the Bathonian–Callovian boundary were mentioned here (Knyazev et al., 2009, 2010), the possibility of hidden unconformity should not be ruled out. According to the latest data, the C. apertum Zone overlying the Catacadoceras calyx Zone is compared with the international standard Discus chronozone (Mitta and Alsen, 2013; Callomon et al., 2015; Kelly et al., 2015; Mönnig and Dietl, 2017; Alsen et al., 2020; Morton et al., 2020; etc.). It seems necessary to reflect the described situation in the zonal ammonite scale of Siberia, at least by a question mark at this level (Fig. 6).

CONCLUSIONS

The main result of the study is the updated ammonite zonal scale of the Middle–Upper Bathonian Siberia, which is recommended for use both in the regional stratigraphic schemes of the Jurassic deposits of eastern (Middle) Siberia and in the Boreal (Siberian) zonal standard of the Bathonian Stage. The proposed version is in the best way adapted to the present knowledge of ammonite biostratigraphy in the region and takes into account the following results and conclusions.

(1) It has been established that all northern Siberian specimens previously assigned to *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 are misidentified and do not provide evidence of the presence of this species in Siberian sections. Most of these ammonites belong to *Catacadoceras barnstoni* (Meek, 1859) or the narrow umbilical taxon referred to in this paper as *Cat*. aff. *barnstoni*. Accordingly, the stratigraphic interval, which previously corresponded in the Siberian sections to the Arc. cranocephaloide Zone should be entirely assigned to Beds with *Cat. barnstoni*.

(2) *Arc. cranocephaloide* affinity is not excluded only for the juvenile ammonite *Arcticoceras* sp., the find of which is known 2 m below the base of the Paracadoceras variabile Zone on the eastern coast of Anabar Bay. Hence, as possible options for designating the interval located between the Arc. ishmae and P. variabile zones in the zonal ammonite scale of Siberia, the following options are proposed: "? Arcticoceras cranocephaloide Zone" or "Beds with *Arcticoceras* ex gr. *cranocephaloide*".

(3) At present it has been established that *Cat. barnstoni* co-occurs in northern Siberia with *Cat.* aff. *barnstoni, Cat. perrarum*, as well as with the ammonites *Paracadoceras variabile, Arcticoceras (?)* sp., *Phylloceras billingsi* and the last known members of the bivalve genus *Retroceramus*, similar to the fossil assemblages of northern North America. Judging from the macrofaunal composition and stratigraphic position of *Cat. barnstoni* in East Greenland, the Siberian Beds with *Cat. barnstoni* correspond to the *Kepplerites rosenkrantzi* faunal horizon marking the upper part of the P. variabile Zone in East Greenland. So far, only a single find of "*K.* ex gr. *rosenkrantzi*", represented by a strongly distorted loosely collected shell, is known in northern Siberia.

(4) It seems extremely important to preserve Beds with *Cat. barnstoni* in the Bathonian zonal ammonite scale of Siberia, since this biostraton is more in demand here compared to the Paracadoceras variabile Zone due to the greater areal distribution and abundance of the index species. Its auxiliary status results from the impossibility to establish biostratons adjacent to it in any of the known Siberian sections. The interregional correlation function of Beds with *Cat. barnstoni* is also of significant importance as it allows correlation of this interval in the Siberian sections with the eponymous biostratigraphic unit in northern Canada and Franz Josef Land, as well as with the *Kepplerites rosenkrantzi* faunal horizon of East Greenland.

(5) In view of the absence of any signs of a stratigraphic equivalent of the Cadoceras apertum ammonite Zone of the East Greenland reference scale in northern Siberia, an taking into account the presence of Bathonian-Callovian transitional beds in the Anabar region, it was concluded that it would be reasonable to designate with a question mark a gap in the zonal ammonite succession of Siberia. This gap is confined to the upper part of the Upper Bathonian of the regional scale.

In addition to the updating of the zonal ammonite scale of the Bathonian of Siberia, two reference intervals (with *Cat.* aff. *barnstoni* and *Cat. perrarum*) are recognized, successively located within the upper part of the Upper Bathonian Beds with *Cat. barnstoni* useful for intra-regional (and possibly, in the future, inter-regional) correlations.

ACKNOWLEDGMENTS

The authors are grateful to the reviewers D.B. Gulyaev (Commission for the Jurassic system of the Interdepartmental Stratigraphic Committee, Yaroslavl), D.N. Kiselev (K.D. Ushinsky Yaroslavl Pedagogical University, Yaroslavl) and M.A. Rogov (Geological Institute, Russian Academy of Sciences, Moscow) for critical analysis of the manuscript and suggestions for its improvement. We are grateful to V.V. Mitta (Paleontological Institute, Russian Academy of Sciences, Moscow) for providing photographs of the East Greenland ammonite collection (collected by J. Callomon and T. Birkelund), A.E. Igolnikov and A.G. Konstantinov (Trofimuk Institute of Petroleum Geology and Geophysics of the Siberian Branch of the Russian Academy of Sciences (IPGG SB RAS), Novosibirsk) for discussing a number of issues related to the morphogenesis of ammonites, B.N. Shurygin (IPGG SB RAS, Novosibirsk) for providing the 1987 field notes for Chekurovka sections and consultations on the location and geology of these sections, O.S. Urman (IPGG SB RAS, Novosibirsk) for the organization of field work on the northern Chekurovka section in 2019, in the study of which O.S. Dzyuba, E.K. Metelkin, E.S. Shamonin and P.A. Yan (IPGG SB RAS, Novosibirsk) also participated.

FUNDING

The study was supported by the Russian Science Foundation (grant no. 22-17-00228, https://rscf.ru/project/22-17-00228/, at Trofimuk Institute of Petroleum Geology and Geophysics of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk. The geological structure of the northern Chekurovka section was studied in the course of the fieldwork supported by the Russian Ministry of Education and Science (projects FUUM-2019-0004, FWZZ-2022-0004, IPGG SB RAS, Novosibirsk; budget project, Diamond and Precious Metal Geology Institute of the Siberian Branch of the Russian Academy of Sciences (DPMGI SB RAS), Yakutsk).

AUTHORS' CONTRIBUTIONS

Ammonite identifications and the section "*Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 vs. *Catacadoceras barnstoni* (Meek, 1859)" were prepared by E.S. Shamonin with consultations by V.G. Knyazev. The sections "Material, methods and terminology" and "Systematic paleontology" were written by E.S. Shamonin, who also prepared the ammonite specimens and prepared them for publication including photography. The sections "Introduction", "Position of the Catacadoceras barnstoni biostraton in the zonal ammonite scale of the Bathonian Stage of Siberia" and "Conclusions" were written by E.S. Shamonin together with O.S. Dzyuba (emphasis on comprehensive data analysis, taking into account information on associated groups of macrofauna).

The same authors, as part of the field team of the IPGG SB RAS–NSU, studied the northern section near the village of Chekurovka in the lower reaches of the Lena River, where new fossils were collected. Ammonites from the Bathonian of Olenek Bay coast were collected by V.G. Knyazev.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

Reviewers D.B. Gulyaev, D.N. Kiselev, and M.A. Rogov

REFERENCES

Alifirov, A.S., Knyazev, V.G., and Meledina, S.V., Ontogenesis of shell shape and sculpture of Late Bathonian and Callovian ammonites of the family Cardioceratidae from North Siberia, *Interekspo GEO-Sibir'*, 2018, vol. 2, pp. 128–135.

Alsen, P., Hovikoski, J., and Svennevig, K., Middle Jurassic sandstone deposition in the Wandel Sea Basin: Evidence from cardioceratid and kosmoceratid ammonites in the Mågensfjeld Formation in Kilen, North Greenland, *GEUS Bull.*, 2020, vol. 44, 5342.

Birkelund, T. and Perch-Nielsen, K., Late Palaeozoic–Mesozoic evolution of central East Greenland, in *Geology of Greenland*, Escher, A. and Watt, W.S., Eds., Copenhagen: Geol. Surv. Greenland, 1976, pp. 304–339.

Bodylevskii, V.I., Kelloveiskie ammonity Severnoi Sibiri, *Zap. Leningr. Gorn. Inst.*, 1960, vol. 37, pp. 49–82.

Callomon, J.H., Jurassic ammonites from the northern North Sea, *Norsk Geologisk Tidsskrift*, 1975, vol. 55, pp. 373–386.

Callomon, J.H., The evolution of the Jurassic ammonite family Cardioceratidae, in *Evolutionary Case Stories from the Fossil Record*, Cope, J.C.W. and Skelton P.W., Eds., *Spec. Pap. Palaeontol.*, 1985, vol. 33, pp. 49–90.

Callomon, J.H., The ammonite succession in the Middle Jurassic of East Greenland, *Bull. Geol. Soc. Denmark*, 1993, vol. 40, pp. 83–113.

Callomon, J.H., The Middle Jurassic of western and northern Europe: Its subdivisions, geochro-nology and correlations, *Geol. Surv. Den. Green. Bull.*, 2003, vol. 1, pp. 61–73.

Callomon, J.H. and Birkelund, T., The Jurassic transgression and the mid-late Jurassic succession in Milne Land, central East Greenland, *Geol. Mag.*, 1980, vol. 117, no. 3, pp. 211–310.

Callomon, J.H., Alsen, P., and Surlyk, F., The ammonites of the Middle Jurassic Cranocephalites beds of East Greenland, *Geol. Surv. Den. Green. Bull.*, 2015, vol. 34, pp. 1–145.

Dzyuba, O.S. and de Lagausie, B., New belemnites (Megateuthididae, Cylindroteuthididae) from the Bajocian and Bathonian of the Yuryung–Tumus Peninsula, northern Siberia, Russia and their palaeobiogeographic implications, *Paläont. Z.*, 2018, vol. 92, pp. 87–105.

Dzyuba, O.S., Shurygin, B.N., Mitta, V.V., Alifirov, A.S., Glinskikh, L.A., Goryacheva, A.A., Kosenko, I.N., Urman, O.S., and Metelkin, E.K., Problems and perspectives in Boreal–Tethyan correlation of the Middle Jurassic marine sediments of Siberia, "*Interekspo GEO-Sibir'*," 2019, vol. 2, no. 1, pp. 49–57.

Frebold, H., The Jurassic faunas of the Canadian Arctic: Middle and Upper Jurassic ammonites, *Geol. Surv. Canada Bull.*, 1961, vol. 74.

Frebold, H., Illustrations of Canadian Fossils. Jurassic of Western and Arctic Canada, *Geol. Surv. Canada*, 1964a, *Pap.* 63-4, pp. 1–107.

Frebold, H., The Jurassic faunas of the Canadian Arctic: Cadoceratinae, *Geol. Surv. Canada Bull.*, 1964b, vol. 119.

Galabala, R.O., The stratigraphy of Jurassic deposits in the Lena–Anabar trough, in *Regional'naya geologiya i poleznye iskopaemye Yakutii. Sb. nauchn. tr.* (Regional Geology and Mineral Resources of Yakutia. Coll. Sci. Works), Yakutsk: Yakutsk. Gos. Univ., 1991, pp. 155–158.

Gulyaev, D.B., Evolution of ammonites of the Paracadoceras genus and infrazonal correlation of the Bathonian–Callovian deposits of the Boreal regions, in *Paleontologiya, stratigrafiya i paleogeografiya mezozoya i kainozoya boreal'nykh raionov. Mater. Nauchn. Sess. (18–22 apr. 2011 g.). T. I. Mezozoi* (Proc. Sci. Sess. "Paleontology, Stratigraphy, and Paleogeography of the Mesozoic and Cenozoic of the Boreal Regions" (April 18–22, 2011). Vol. I: Mesozoic), Shurygin, B.N., Lebedev, N.K., and Goryachev, A.A., Eds., Novosibirsk: Inst. Neft. Geol. Geofiz. Sib. Otd. Ross. Akad. Nauk, 2011, pp. 74–78.

Gulyaev, D.B., On the revision of ammonites of the Genus Paracadoceras (Cardioceratidae) from the Upper Bathonian and Lower Callovian of East Greenland, in *Sovremennye problemy izucheniya golovonogikh mollyuskov. Morfologiya, sistematika, evolyutsiya, ekologiya i biostratigrafiya. Mater. Soveshch. (Moskva, 9–11 aprelya 2012 g.)* (Proc. Conf. "Contributions to Current Cephalopod Research: Morphology, Systematics, Evolution, Ecology, and Biostratigraphy" (Moscow, April 9–11, 2012)), Leonov, T.B., Barskov, I.S., and Mitta, V.V., Eds., Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2012, vol. 3, pp. 69–72.

Gulyaev, D.B., Stratigraphy of Bathonian–Callovian boundary deposits of European Russia, in *Nauchn. Mater. VI Vseross. soveshch. "Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii," 15–20 sentyabrya 2015 g., Makhachkala* (Proc. VI All-Russ. Conf. "Jurassic System of Russia: Problems of Stratigraphy and Paleogeography," September 15–20, 2015, Makhachkala), Makhachkala: ALEF, 2015, pp. 94–101.

Von Hillebrandt, A., Smith, P., Westermann, G.E.G., and Callomon, J.H., Ammonite zones of the circum-Pacific region, in *The Jurassic of the Circum-Pacific*, Westermann, G.E.G., Ed., Cambridge: Cambridge Univ. Press, 1992, pp. 247–272.

Hyatt, A., Cephalopoda, in *Text-book of Palaeontology*, Von Zittel, K.A., Ed., 1st ed., London: MacMillan & Co, 1900. pp. 502–604.

Kelly, S.R.A., Gregory, F.J., Braham, W., Strogen, D.P., and Whitham, A.G., Towards an integrated Jurassic biostratigraphy for eastern Greenland, *Volumina Jurassica*, 2015, vol. XIII, no. 1, pp. 43–64.

Von Keyserling, A., *Wissenschaftliche Beobachtungen auf einer Reise in das Petschora-Land im Jahre 1843*, St. Petersburg: Carl Kray, 1846.

Kiselev, D.N., Variability of relative body chamber length in Jurassic ammonites of the family Cardioceratidae Siemiradzki, 1891, and its taxonomic significance, *Paleontol. J.*, 2018, vol. 52, no. 13, pp. 517–1544.

Kiselev, D.N., Ammonites and infrazonal stratigraphy of the boreal and subboreal Bathonian and Callovian, in *Tr. Geol. Inst. Vyp. 628* (Trans. Geol. Inst. Vol. 628), Moscow: GEOS, 2022.

Kiselev, D.N. and Meledina, S.V., The upper Bathonian Ammonites first found in North Siberia, *Stratigr. Geol. Correl.*, 2011, vol. 19, no. 3, pp. 361–365.

Kiselev, D.N., Kutygin, R.V., and Meledina, S.V., The upper Bathonian ammonite zonation of East Siberia, *Stratigr. Geol. Correl.*, 2009, vol. 17, no. 2, pp. 192–203.

Kiselev, D.N., Kutygin, R.V., and Meledina, S.V., New ammonite zonation of the lower Callovian in North Siberia, *Stratigr. Geol. Correl.*, 2010, vol. 18, no. 4, pp. 392–410.

De Lagausie, B. and Dzyuba, O.S., Biostratigraphy of the Bajocian–Bathonian boundary interval in northern Siberia: new data on belemnites from the Yuryung-Tumus Peninsula, *Geol. Soc. Am. Bull.*, 2017, vol. 188, nos. 1–2, pp. 1–9.

Meek, F.B., Remarks on the Cretaceous fossils collected by Professor Henry Y. Hind, on the Assiniboine and Saskatchewan exploring expedition, with descriptions of some new species, in *North-West Territory: Reports of Progress, together with a Preliminary and General Report on the Assiniboine and Saskatchewan Exploring Expedition, Made under Instructions from the Provincial Secretary*, Canada. Hind H.Y. Toronto, 1859, pp. 182–185.

Meledina, S.V., Ammonites and Bajocian–Bathonian zonal stratigraphy of Siberia, in *Tr. IGiG SO AN SSSR. Vyp. 153* (Trans. Inst. Geol. Geophys. Sib. Branch USSR Acad. Sci., Vol. 153), Novosibirsk: Nauka, 1973.

Meledina, S.V., Ammonites and Callovian zonal stratigraphy of Siberia, in *Tr. IGiG SO AN SSSR. Vyp. 356* (Trans. Inst. Geol. Geophys. Sib. Branch USSR Acad. Sci., vol. 356), Moscow: Nauka, 1977.

Meledina, S.V., Ammonites and Callovian zonal stratigraphy of subboreal regions of the USSR, in *Tr. IGiG SO AN SSSR. Vyp. 691* (Trans. Inst. Geol. Geophys. Sib. Branch USSR Acad. Sci., Vol. 691), Moscow: Nauka, 1987.

Meledina, S.V., Zonal scale of the “Boreal Bathonian”–Lower Callovian in Siberia, in *Detal’naya stratigrafiya i paleontologiya yury i mela Sibiri. Tr. IGiG SO AN SSSR. Vyp. 769* (Detailed Stratigraphy and Paleontology of the Jurassic and Cretaceous in Siberia. Trans. Inst. Geol. Geophys. Sib. Br. USSR Acad. Sci., Vol. 769), Novosibirsk: Nauka, 1991, pp. 125–154.

Meledina, S.V., *Boreal’naya srednyaya yura Rossii (ammonity i zonal’naya stratigrafiya baiosa, bata i kelloveya)* (Boreal Middle Jurassic of Russia (Ammonites and Zonal Stratigraphy of the Bajocian, Bathonian, and Callovian)), Novosibirsk: Nauka, 1994 [in Russian].

Meledina, S.V., Ammonites from Boreal Upper Bathonian of Kotelnyi Island, *Geol. Geofiz.*, 1999, vol. 40, no.10, pp. 1397–1404.

Meledina, C.V., Correlation of the Bajocian and Bathonian zones in light of new paleontological data, *Stratigr. Geol. Correl.*, 2014, vol. 22, no. 6, pp. 594–605.

Meledina, S.V., Nalnyaeva, T.I., and Shurygin, B.N., *Yura Enisei-Khatangskogo progiba. Nordvikskaya zona, tipovoi razrez* (Jurassic of the Yenisey–Khatanga Depression: Nordvik Zone, Type Section), Novosibirsk: Inst. Geol. Geofiz. Sib. Otd. Akad. Nauk SSSR, 1987 [in Russian].

Meledina, S.V., Shurygin, B.N., Zlobina, O.N., Levchuk, M.A., Nal’nyaeva, T.I., and Nikitenko, B.L., The Chekurovka Formation (Bathonian–Callovian) in its stratotype section, in *Detal’naya stratigrafiya i paleontologiya yury i mela Sibiri. Tr. IGiG SO AN SSSR. Vyp. 769* (Detailed Stratigraphy and Paleontology of the Jurassic and Cretaceous in Siberia. Trans. Inst. Geol. Geophys. Sib. Br. USSR Acad. Sci., Vol. 769), Novosibirsk: Nauka, 1991, pp. 5–37.

Meledina, S.V., Knyazev, V.G., Marinov, V.A., Alifirov, A.S., and Igol’nikov, A.E., New data on the Jurassic ammonite stratigraphy of the Yuryung-Tumus Peninsula, in *Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii. Shestoe Vseross. Soveshch., 15–20 sentyabrya 2015 g. Tymen’. Nauchn. mater.* (Proc. VI All-Russ. Conf. “Jurassic System of Russia: Problems of Stratigraphy and Paleogeography”. September 15–20, 2015, Tyumen), Zakharov, V.A., Ed., Makhachkala: ALEF, 2015, pp. 199–202.

Mitta, V.V. and Al’sen, P., Ammonites and zonal stratigraphy of the Bathonian Stage in Greenland, in *Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii. Pyatoe Vseross. Soveshch., 23–27 sentyabrya 2013 g., Tyumen’. Nauchn. Mater.* (Proc. V All-Russ. Conf. “Jurassic System of Russia: Problems of Stratigraphy and Paleogeography”. September 23–27, 2013, Tyumen), Zakharov, V.A., Ed., Ekaterinburg: IzdatNaukaServis, 2013, pp. 149–151.

Mitta, V., Kostyleva, V., Dzyuba, O., Glinskikh, L., Shurygin, B., Seltzer, V., Ivanov, A., and Urman, O., Biostratigraphy and sedimentary settings of the Upper Bajocian–Lower Bathonian of the vicinity of Saratov (Central Russia), *N. Jb. Geol. Paläont. Abh.*, 2014, vol. 271, no. 1, pp. 95–121.

Mitta, V., Glinskikh, L., Kostyleva, V., Dzyuba, O., Shurygin, B., and Nikitenko, B., Biostratigraphy and sedimentary settings of the Bajocian–Bathonian beds of the Izhma River basin (European North of Russia), *N. Jb. Geol. Paläont. Abh.*, 2015, vol. 277, no. 3, pp. 307–335.

Mönnig, E. and Dietl, G., The systematics of the ammonite genus Kepplerites (upper Bathonian and basal Callovian, Middle Jurassic) and the proposed basal boundary stratotype (GSSP) of the Callovian Stage, *N. Jb. Geol. Paläont. Abh.*, 2017, vol. 286, pp. 235–287.

Morton, N., Mitta, V.V., and Underhill, J.R., Ammonite occurrences in North Sea cores: Implications for Jurassic Arctic–Mediterranean marine seaway connectivity, *Scottish J. Geol.*, 2020, vol. 56, pp. 175–195.

Nekhaev, A.Yu., Marinov, V.A., Alifirov, A.S., and Igol’nikov, A.E., A new section of the Middle and Upper Jurassic of the western coast of the Yuryung-Tumus Peninsula, in *Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii. Shestoe Vseross. Soveshch., 15–20 sentyabrya 2015 g., Tyumen’. Nauchn. mater.* (Proc. VI All-Russ. Conf. “Jurassic System of Russia: Problems of Stratigraphy and Paleogeography,” September 15–20, 2015, Tyumen), Zakharov, V.A., Ed., Makhachkala: ALEF, 2015, pp. 188–194.

Nikitenko, B.L., Shurygin, B.N., Knyazev, V.G., Meledina, S.V., Dzyuba, O.S., Lebedeva, N.K., Peshchevitskaya, E.B., Glinskikh, L.A., Goryacheva, A.A., and Khafaeva, S.N., Jurassic and Cretaceous stratigraphy of the Anabar area (Arctic Siberia, Laptev Sea coast) and the Boreal zonal standard, *Russ. Geol. Geophys.*, 2013, vol. 54, no. 8, pp. 808–837.

Ognev, V.N., The Upper Jurassic fossils from Hooker Island on Franz Josef Land, *Tr. Arktich. Inst.*, 1933, vol. XII, pp. 217–233.

Poulton, T.P., *Zonation and correlation of middle boreal Bathonian to lower Callovian (Jurassic) ammonites, Salmon Cache Canyon, Porcupine River, northern Yukon*, *Geol. Surv. Canada Bull.*, 1987, vol. 358.

Poulton, T.P., Detterman, R.L., Hall, R.L., Jones, D.L., Peterson, J.A., Smith, P., Taylor, D.G., Tipper, H.W., and

Westermann, G.E.G., Western Canada and United States, in *The Jurassic of the Circum-Pacific*, Westermann, G.E.G., Ed., Cambridge: Cambridge Univ. Press, 1992, pp. 29–92.

Repin, Yu.S., Jurassic ammonite zones on Hooker Island (Franz Josef Land Archipelago), *Dokl. Akad. Nauk*, 1999, vol. 367, no. 3, pp. 389–393.

Repin, Yu.S., Ammonite scales of the Circum-Arctic Middle Jurassic, in *Mater. Pervogo Vseross. Soveshch. "Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii"* (Proc. I All-Russ. Conf. "Jurassic System of Russia: Problems of Stratigraphy and Paleogeography"), Zakharov, V.A., Rogov, M.A., Dzyuba, O.S., Eds., Moscow: Geol. Inst. Ross. Akad. Nauk, 2005, pp. 203–205.

Repin, Yu.S., Fedorova, A.A., Bystrova, V.V., Kulikova, N.K., and Polubotko, I.V., Mesozoic of the Barentz sea sedimentological basin, in *Stratigrafiya i ee rol' neftegazovogo kompleksa Rossii* (Stratigraphy and its Role in Development of the Oil and Gas Complex of Russia), Kirichkov, A.I. and Dmitriev, T.V., Eds., St. Petersburg: Vseross. Neft. Nauchno-Issled. Geol. Inst., 2007, pp. 112–161.

Ruzhentsev, V.E., Superorder Ammonoidea. Ammonoidei. General section, in *Osnovy paleontologii. Mollyuski – golovonogie* (Foundations of Paleontology: Cephalopoda), Moscow: Izd. Akad. Nauk SSSR, 1962, pp. 243–333.

Saks, V.N., Ronkina, Z.Z., Shul'gina, N.I., Basov, V.A., and Bondarenko, N.M., *Stratigrafiya yurskoi i melovoi sistemy severa SSSR* (Stratigraphy of Jurassic and Cretaceous Systems in the North of the USSR), Moscow–Leningrad: Izd. Akad. Nauk SSSR, 1963.

Shamonin, E.S. and Knyazev, V.G., The succession of Upper Bajocian-lower Oxfordian ammonites in the Lena River lower reaches (Chekurovka section), in *Yurskaya sistema Rossii: problemy stratigrafii i paleogeografii. Mater. VIII Vseross. Soveshch. s mezhd. uchastiem. Onlain-konf., 7–10 sentyabrya 2020 g.* (Proc. VIII All-Russ. Conf. with Int. Participation "Jurassic System of Russia: Problems of Stratigraphy and Paleogeography". September 7–10, 2020), Zakharov, V.A., Ed., Syktyvkar: Inst. Geol. Komi Nauchn. Tsentr Ural. Otd. Ross. Akad. Nauk, 2020, pp. 239–242.

Shamonin, E.S. and Knyazev, V.G., The problem of recognizing the species *Arcticoceras cranocephaloide* Callomon et Birkelund, 1985 in Northern Siberia, in *Paleontologiya, stratigrafiya i paleogeografiya mezozoya i kainozoya boreal'nykh raionov. Mater. Nauchn. onlain-sessii, 19–22 aprelya 2021 g.* (Proc. Sci. Online-Conf. "Paleontology, Stratigraphy, and Paleogeography of the Mesozoic and Cenozoic of the Boreal Regions," (April 19–22, 2021)), Lebedev, N.K., Ed., Novosibirsk: Inst. Neft. Geol. Geofiz. Sib. Otd. Ross. Akad. Nauk, 2021, pp. 197–201.

Shamonin, E.S., Dzyuba, O.S., Knyazev, V.G., Urman, O.S., Shurygin, B.N., Metelkin, E.K., and Yan, P.A., The upper boundary of the Chekurovka Formaton in its stratotype section (the Lena River lower reaches): litho- and biostratigraphic criteria, in *Interekspo GEO-Sibir'–"Nedropol'zovanie. Gornoe delo. Napravleniya i tekhnologii poiska, razvedki i razrabotki mestorozhdenii poleznykh iskopaemykh. Ekonomika. Geoekologiya": Mater. XVI Mezhd. Nauchn. Konf., Novosibirsk, 20–24 aprelya 2020 g.* (Proc. Int. Sci. Conf. "Interexpo GEO-Siberia: Subsoil Use, Mining, Directions and Technologies of Prospecting, Exploration and Development of Mineral Deposits, Economy, Geoecology," Novosibirsk, April 20–24, 2020), Novosibirsk, 2020, pp. 269–279.

Shurygin, B.N., Nikitenko, B.L., Devyatov, V.P., Il'ina, V.I., Meledina, S.V., Gaideburova, E.A., Dzyuba, O.S., Kazakov, A.M., and Mogucheva, N.K., *Stratigrafiya neftegazonosnykh basseinov Sibiri. Yurskaya Sistema* (The Stratigraphy of Oil-and-Gas Basins of Siberia. Jurassic System), Novosibirsk: Izd. Sib. Otd. Ross. Akad. Nauk, fil. "Geo," 2000.

Shurygin, B.N., Nikitenko, B.L., Meledina, S.V., Dzyuba, O.S., and Knyazev, V.G., Comprehensive zonal subdivisions of Siberian Jurassic and their significance for Circum-Arctic correlations, *Russ. Geol. Geophys.*, 2011, vol. 52, no. 8, pp. 825–844.

Siemiradzki, J., *Fauna Kopalna Warstw Oxfordzkich i Kimerydzkich w Okręgu Krakowskim i Przyległych Częściach Królestwa Polskiego. Cz. 1. Głowonogi*, Kraków: Nakł. Akad. Umiejętności, 1891.

Stratigraficheskii kodeks SSSR (Stratigraphic Code of the USSR), Leningrad: Vseross. Nauchno-Issled. Geol. Inst., 1977 [in Russian].

Stratigraficheskii kodeks Rossii. 3-e izd., ispravl. dopoln. (Stratigraphic Code of Russia (3rd ed.), Revised and Updated), St. Petersburg: Vseross. Nauchno-Issled. Geol. Inst., 2019 [in Russian].

Stratigrafiya yurskoi sistemy severa SSSR (Stratigraphy of the Jurassic System of the North of the USSR), Saks, V.N., Ed., Moscow: Nauka, 1976 [in Russian].

Urman, O.S., Shurygin, B.N., and Dzyuba, O.S., Stratigraphic ranges of the Bajocian–Bathonian retroceramus zones on the Yuryung-Tumus Peninsula (North of Siberia), in *Geologiya i mineral'no-syr'evye resursy Sibiri* (Geology and Mineral Resources of Siberia), 2022, no. 11s, pp. 21–28.

Voronets, N.S., *Stratigrafiya i golovonogie mollyuski yurskikh i nizhnemelovykh otlozhenii Leno-Anabarskogo raiona* (Stratigraphy and Cephalopod Mollusks in the Jurassic and Lower Cretaceous Deposits of the Lena–Anabar Region), Leningrad: Gosgeoltekhizdat, 1962 [in Russian].

Zakharov, V.A. and Shurygin, B.N., *Biogeografiya, fatsii i stratigrafiya srednei yury Sovetskoi Arktiki* (Biogeography, Facies, and Stratigraphy of the Middle Jurassic in the Soviet Arctic), Novosibirsk: Nauka, 1978 [in Russian].

Zakharov, V.A., Bogomolov, Yu.I., Il'ina, V.I., Konstantinov, A.G., Kurushin, N.I., Lebedeva, N.K., Meledina, S.V., Nikitenko, B.L., Sobolev, E.S., and Shurygin, B.N., Boreal zonal standard and biostratigraphy of the Siberian Mesozoic, *Russ. Geol. Geophys.*, 1997, vol. 38, no. 5, pp. 965–993.

Translated by S. Nikolaeva