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The Upper Bathonian Ammonite Zonation of East Siberia

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Abstract—Modifications to the upper Bathonian zonal scale for northern East Siberia provided by the newly available paleontological record on Middle Jurassic reference sections in the Arctic regions of Yakutia and by the revised earlier collections, are justified. The oldest East Siberian members of *Cadoceras* are found to be characteristic not of the initial Callovian age as believed by Russian paleontologists, but of the terminal Bathonian age as was previously shown in the biostratigraphic scheme of East Greenland. The succession of zones and index species analogous to that of the latter is revealed in the studied region and the zonal boundaries in Siberia and East Greenland are inferred to be synchronous. Finds of *Cadoceras calyx* in the upper Bathonian scale permitted, for the first time, the recognition of a corresponding zone. The Bathonian-Callovian boundary is placed between the *calyx* and *anabarense* zones. The upper Bathonian zonal scale of northern East Siberia is now in total agreement with the East Greenland zonal scale.

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Key words: ammonites, *Cadoceras*, zonal scale, Bathonian, Callovian, East Siberia.

INTRODUCTION

The upper Bathonian zonation of the Boreal region was first developed for East Greenland (Spath, 1932; Callomon, 1959) and significantly later for the Canadian Arctic (Poulton, 1987). The East Greenland biostratigraphic succession was repeatedly refined (Callomon, 1984; 1985; 1993; 2003). The first detailed ammonite zonations for the discussed Jurassic interval of Siberia were developed by Meledina (Meledina, 1977; 1991; 1994; Meledina et al., 1991). During the past decade we obtained new data that significantly changed the notion of the Bathonian and Callovian zonal stratigraphy of central Siberia.

As is known, the Siberian upper Bathonian zonal scale is based on a succession of the Cadoceratinae genera and species. The lack of West European taxa prevents a direct correlation of the Siberian zonation with the West European standard. Correlation with standard zonal units is made by a comparison of successions of Cadoceratinae species with those from East Greenland and European Russia, where along with cadoceratins the Kosmoceratidae species also occur. The latter provide a correlation of these zonations with the standard one.

To date, it is obvious that the earlier Cadoceratinae members are characteristic not of the early Callovian age as previously believed by Russian researchers (Bodylevskii, 1960; Voronets, 1962; Saks et al., 1963, 1976; Meledina, 1977), but of the late Bathonian age as was originally shown in East Greenland's biostratigraphic schemes (Callomon, 1959; 1984; 1985). Sei and Kalacheva (1992) were the first in Russia to espouse Callomon's view. This resulted in a fundamental change of view on the correlation of certain regional zones with the standard ones.

The studies of the upper Middle Jurassic sections on the shores of the Anabarskii Bay were conducted during the past decade by Knyazev. He gathered a rich collection of Cadoceratinae and refined the stratigraphic range of certain taxa including zonal index species. The systematic study of the new ammonite collection conducted by the authors and the revision by Meledina of previous finds led the correction of the earlier species' identification, the widening of the taxonomic composition, and the application of changes to the regional zonal scale. The Siberian zonation was put into correspondence with the East Greenland zonal scale of the Bathonian and Callovian boundary sediments (Knyazev et al., 2006). This paper continues these investigations.

THE UPPER BATHONIAN ZONAL UNITS OF EAST SIBERIA

Outcrops in the Khatanga and Lena-Anabar depressions, namely, in scarps on the eastern and western shores of the Anabar Inlet, Olenek Bay, and the lower reaches of the Lena River (Fig. 1), are the reference sections for the Middle Jurassic zonation in northern East

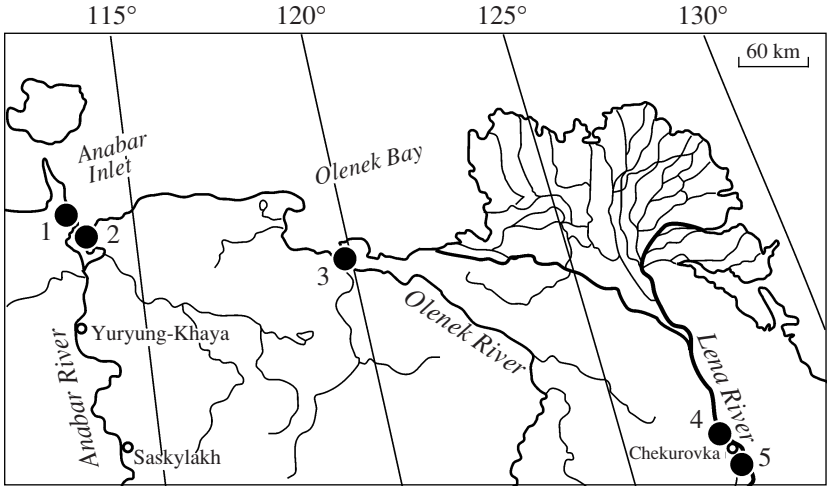


Fig. 1. Main upper Bathonian and lowermost Callovian sections in East Siberia: (1) western shore of the Anabar Inlet; (2) eastern shore of the Anabar Inlet; (3) Olenek Bay east of Stannakh-Khocho Village; (4) left bank of the Lena River, northern flank of the Chekurovka anticline; (5) left bank of the Lena River, southern flank of the Chekurovka anticline.

Siberia. A bed-by-bed description of the sections with the indicated points of ammonite finds was prepared previously (Meledina, 1994) and was refined for the eastern and western shores of the Anabar Inlet (Knyazev et al., 2006). The following zones were recognized in the upper Bathonian and early Callovian boundary sediments of East Siberia: *Arcticoceras (?) cranocephaloide, Cadoceras barnstoni* (including *C. variabile* Beds), *C. falsum, C. anabarense* (*C. elatmae* after Meledina (1977), and *C. emelianzevi* (Meledina, 1991, 1994; Zakharov et al., 1997; Shurygin et al., 2000).

The authors previously suggested to raise the *C. variabile* Beds to the rank of zones and to rename the overlying *C. falsum* Zone as *C. calyx,* which resulted from the ammonite reidentification and refinement of the stratigraphic position of the type *C. falsum* (Knyazev et al., 2006). Now, we discuss more thoroughly the justification of the zonal units recognized in the upper Bathonian scale and the lower Callovian of East Siberia.

The *Arcticoceras (?) cranocephaloide* Zone, first distinguished in East Greenland (Callomon, 1985), was recorded in the Jurassic sections on the left bank of the Lena River (Meledina et al., 1991). The zone yields ammonites transitional according to the shell morphology from *Arcticoceras* to *Cadoceras.* They have a deeper and wider umbilicus than the typical *Arcticoceras,* but a gently rounded shoulder of umbilical funnel, unlike the *Cadoceras* which succeeded them. The question mark following the generic name indicates the somewhat conditional attribution of the species to the genus.

The upper part of the *Arcticoceras (?) cranocephaloide* Zone includes the *Cadoceras barnstoni* Beds that are recorded in the Jurassic sections on the left bank of the Lena River and on the southern shore of the Olenek Bay near the Stannakh-Khocho Village. This zone was first recognized in northern Yukon, Canada (Poulton, 1987). It is characterized by the occurrence of *Cadoceras* with a cadiconic shell, narrow, deep, and funnel-shaped umbilicus, with a more or less coarsely ribbed phragmocone and more or less pronounced ribbing on the body chamber. Among numerous specific names available in the literature we use only *Cadoceras barnstoni* (Meek) and *C. perrarum* Vor. (Meledina, 1999). We emphasize that recognition of the *A. (?) cranocephaloide* Zone and *C. barnstoni* Beds in the upper Bathonian sections on the eastern and western shores of the Anabar Inlet (Figs. 2 and 3) is presently difficult owing to the lack of index species finds. An ammonite encountered here in the upper part of Member 41 (the numbering of the members from here on corresponds to that in Meledina (1994, p. 68, Fig. 17)) represents a modest-sized shell and according to external morphology can be identified only as *Arcticoceras* sp. (Plate I, fig. 3). The distinction of the *C. barnstoni* Zone on the eastern shore of the Anabar Inlet was previously justified by rare finds of *Catacadoceras,* unidentifiable below the genus level (Meledina, 1994). The probable occurrence of this zone in the Jurassic sections on the western shore of the Anabar Inlet can be witnessed by the report on the find of *Cadoceras subcalyx* Vor. (Voronets, 1962, Fig. 3), which we consider as a junior synonym of *C. barnstoni* (Meek). However, owing to the lack of illustration of the specimen we cannot be sure in the correctness of its specific identification.

The overlying sediments (Member 42) upward from the base contain *C. variabile,* the index species of the corresponding upper Bathonian zone. The *Cadoceras variabile* Beds recorded in the upper part of the zone, were originally distinguished on the eastern shore of the inlet based on a single find of the species. The new collection of Knyazev includes several specimens of

System	Series	Stage	Substage	Standard	East Greenland (Callomon, 1985, 1993)	East Siberia (author's variant)
Jurassic	Middle	Bathonian	Upper	*Clydoniceras discus*	*Cadoceras calyx*	*Cadoceras calyx*
				Oxycerites orbis	*Cadoceras variabile*	*Cadoceras variabile*
				Procerites hodsoni	*Arcticoceras* (?) *cranocephaloide*	*Cadoceras barnstoni* Beds *Arcticoceras (?) cranocephaloide*

Fig. 2. Upper Bathonian zonal scale of East Siberia.

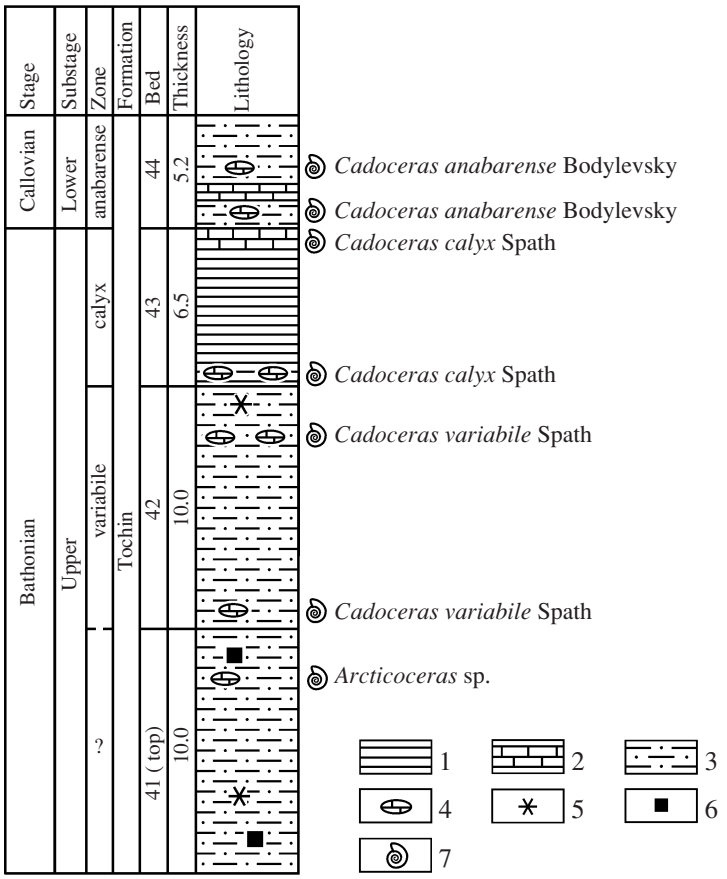
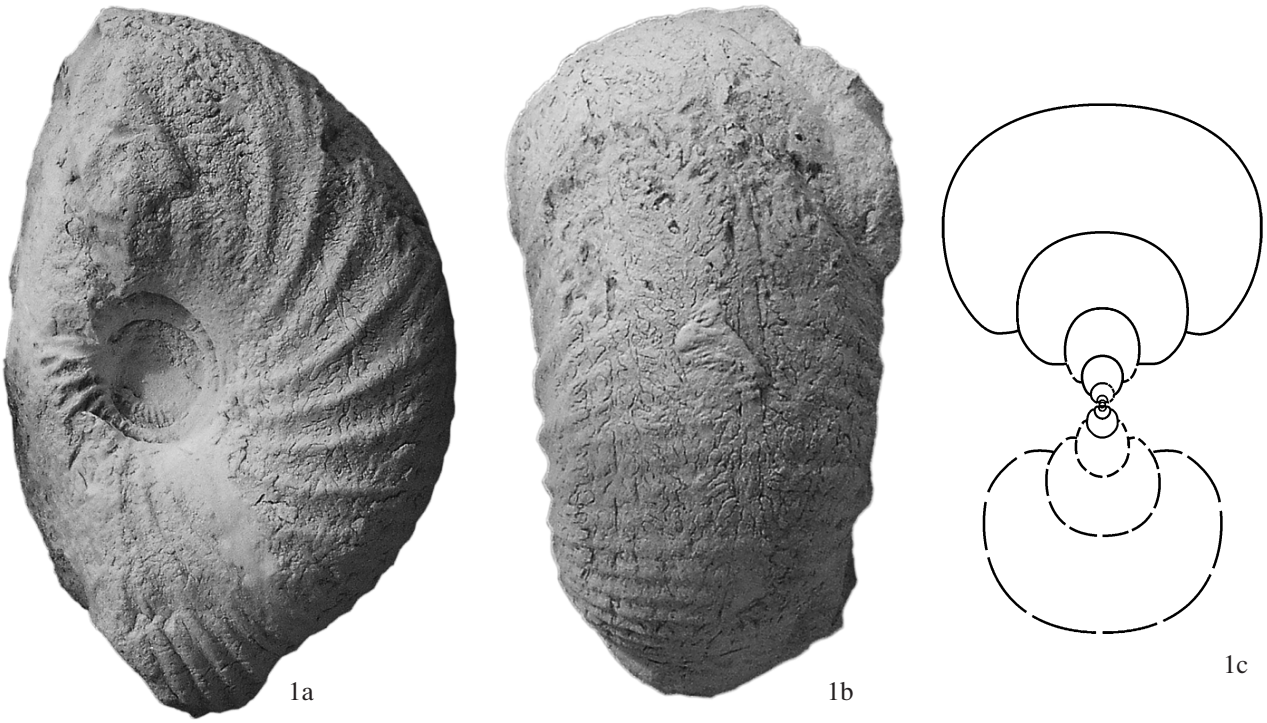
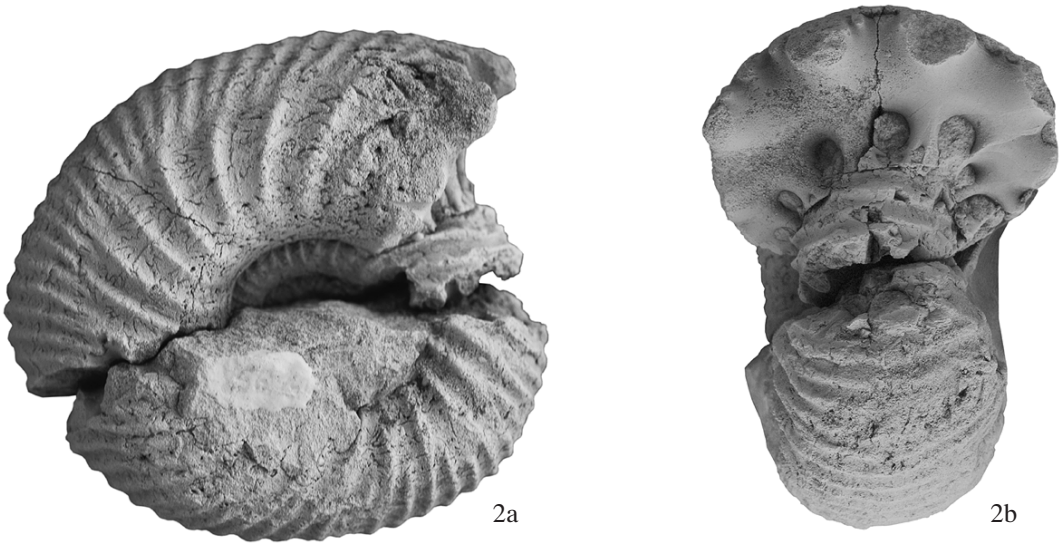


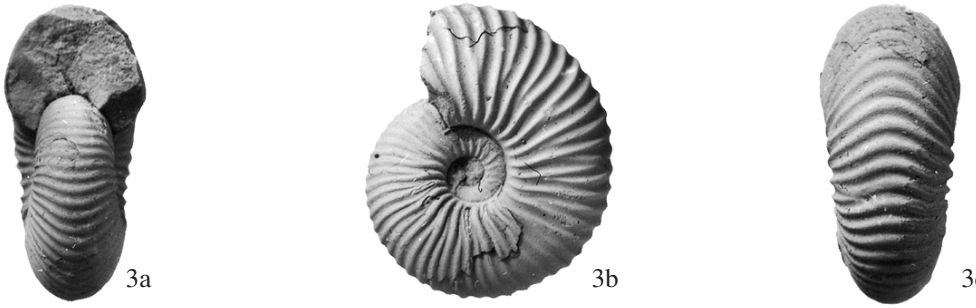
Fig. 3. Upper Bathonian and lowermost Callovian section on the eastern shore of the Anabar Inlet: (1) clay, silt; (2) limestone; (3) sandy silt; (4) carbonate concretions; (5) calcite inclusions; (6) coal; (7) ammonite beds.

Plate I. Ammonites of the *Arcticoceras (?) cranocephaloide* Zone. All specimens excluding the ones marked off are illustrated in natural size: (1, 2) *Arcticoceras (?) cranocephaloide* Callomon et Birkelund, 1985: (1) specimen No. 856-21, (a) lateral view, (b) ventral view, (c) cross-section; left bank of the Lena River, northern flank of the Chekurovka anticline, Outcrop 2, Member 9; (2) specimen No. 856-24, (a) lateral view, (b) apertural view; the same locality; (3) *Arcticoceras* sp., specimen No. 177/336, ×2, (a) apertural view, (b) lateral view, (c) ventral view; eastern shore of the Anabar Inlet, Outcrop 109, Member 41.

Plate I







C. variabile Spath from the same member; they were found both in its lowest and upper parts (the numbering of the members from here on corresponds to that in Meledina (1994, p. 68, Fig. 17). The authors recommended the recognition of a separate *C. variabile* Zone raising the rank of the species-bearing beds (Knyazev et al., 2006). Ammonites encountered in Member 43 and identified earlier as *Cadoceras falsum* Vor. (Meledina, 1977; 1991; 1994), are reidentified as *C. calyx* Spath. The upper Bathonian boundary in eastern Siberia is defined by the first occurrence of *Cadoceras anabarense* Bodyl. that was previously identified in Member 44 as *C. elatmae* (Nikitin) (Meledina, 1977).

Consequently, the upper Bathonian zonal succession in East Siberia includes the following biostratigraphic units: *Arcticoceras (?) cranocephaloide, Cadoceras barnstoni, C. variabile*, and *C. calyx.* In East Greenland the corresponding Middle Jurassic interval includes the *Arcticoceras (?) cranocephaloide, Cadoceras variabile,* and *C. calyx* zones. Contrary to the latter zonation, the Siberian zonal scale yields additionally the *Cadoceras barnstoni* Beds in the upper part of the *Arcticoceras (?) cranocephaloide* Zone. It should be also noted that the relationship of the *C. barnstoni* Beds with the overlying *C. variabile* Zone is still unclear; in the Lena sections where sediments have been recovered bearing *A. (?) cranocephaloide* and *C. barnstoni,* the *C. variabile* Zone is missing and the *C. barnstoni* Beds are overlain by the *C. calyx* zone. The succession of the *C. variabile* and overlying zones is recorded in the Anabar sections, however, the *A. (?) cranocephaloide* Zone and *C. barnstoni* Beds cannot be precisely defined there owing to the lack of index species. Above this level, the *C. variabile* and *C. calyx* zones common with those of East Greenland, are recognized in the sediments of East Siberia. The *C. calyx* Zone is overlain by the *C. apertum* in East Greenland and by the *C. anabarense* Zone in central Siberia (Meledina, 1994).

SYSTEMATIC DESCRIPTION OF AMMONITES

All described specimens are deposited in the Geological Museum, the Institute of Diamond and Precious Metal Geology, the Siberian Branch, the Russian Academy of Sciences, Yakutsk (No. 177) and in CSGM, Novosibirsk (Nos. 489 and 856). The stratigraphic and geographic reference points are in correspondence with the previously published description of the Bathonian and Callovian sections (Meledina, 1991, 1994; Shurygin et al., 2000).

Genus *Arcticoceras* Spath, 1932

Arcticoceras (?) cranocephaloide Callomon et Birkelund, 1985
Plate I, figs. 1 and 2

Arcticoceras cranocephaloide: Callomon, 1985, p. 79, Table 1, figs. 1–3, text–figs. 8I, 8i, 9A, 9B.

Arcticoceras (?) cranocephaloide: Meledina et al., 1991, pl. 8, figs. 1a, 1b, 2.

Arcticoceras (?) cranocephaloide: Meledina, 1994, pl. 5, figs. 1–3.

Cadoceras aff. *kialagvikense:* Meledina, 1977, p. 86, pl. 24, fig. 2; pl. 25, fig. 1.

Holotype. No. 16569. Geological Museum, Copenhagen University (MGUH). Illustrated by Callomon (1985, Table 1, figs. 1–3; text–figs. 8I, 8i, 9A, 9B). East Greenland, Jameson Land, upper Bathonian, *cranocephaloide* Zone.

Shell shape. Adult specimens moderately wide (W/D about 60%) with relatively narrow umbilicus (U/D 20–25%), reach 100-mm size and over. The body chamber makes up 60–70% of the whorl. Wide, slightly flattened ventral side grades into relatively narrow, convex flanks. The umbilicus is funnel-shaped, with sloping, slightly convex, rounded walls. At early stages (D up to 10 mm) shells are moderately wide (W/D over 50%) with narrow umbilicus (D/U below 20%). In middle stages (D 10–30 mm) umbilicus is wider (D/U 22–24%), whereas the shell becomes narrower (W/D 43–49%). At later stages umbilicus slightly decreases reaching 20–21% at D 50–70 mm, then expands to 23–24%. The shell becomes moderately wide (Plate I, fig. 1c).

Ornamentation. Ribs on inner whorls closely spaced, pronounced, regularly bifurcating at outer part of flanks. Intercalated ribs are common. Ribs on the ventral side form a low, wide, forward-directed curve. This ornamentation occurs up to the end of the body chamber. At the terminal growth stage the aperture is fringed with a foreapertural constriction.

Comparison. The species differs from other *Arcticoceras* members in the shape of the shell, namely, in wide, relatively flattened ventral and moderately narrow convex flanks. An important distinctive feature is the ribbing on the body chamber. These characteristics cast some doubt upon the attribution of the species to *Arcticoceras.* The specimen originally defined by Meledina as *Cadoceras* aff. *kialagvikense,* was subsequently reidentified as *A. (?) cranocephaloide* (Meledina, 1994). This specimen differs from other members of the species by its slightly more inflated

Plate II. Ammonites of the *Cadoceras barnstoni* Beds. All specimens illustrated in natural size: (1-3) *Cadoceras barnstoni* (Meek, 1859): (1) specimen No. 489-330, (a) lateral view, (b) ventral view; Olenek Bay, Stannakh-Khocho Village, Outcrop 16, Bed 28b; (2) specimen No. 856-27, (a, b) lateral view, (c) ventral view; left bank of the Lena River, southern flank of the Chekurovka anticline, Outcrop 3, talus of Beds 2 and 3; (3) specimen No. 489-332, (a) ventral view, (b) lateral view; Olenek Bay, Stannakh-Khocho Village, Outcrop 16, Bed 28b.

Plate II

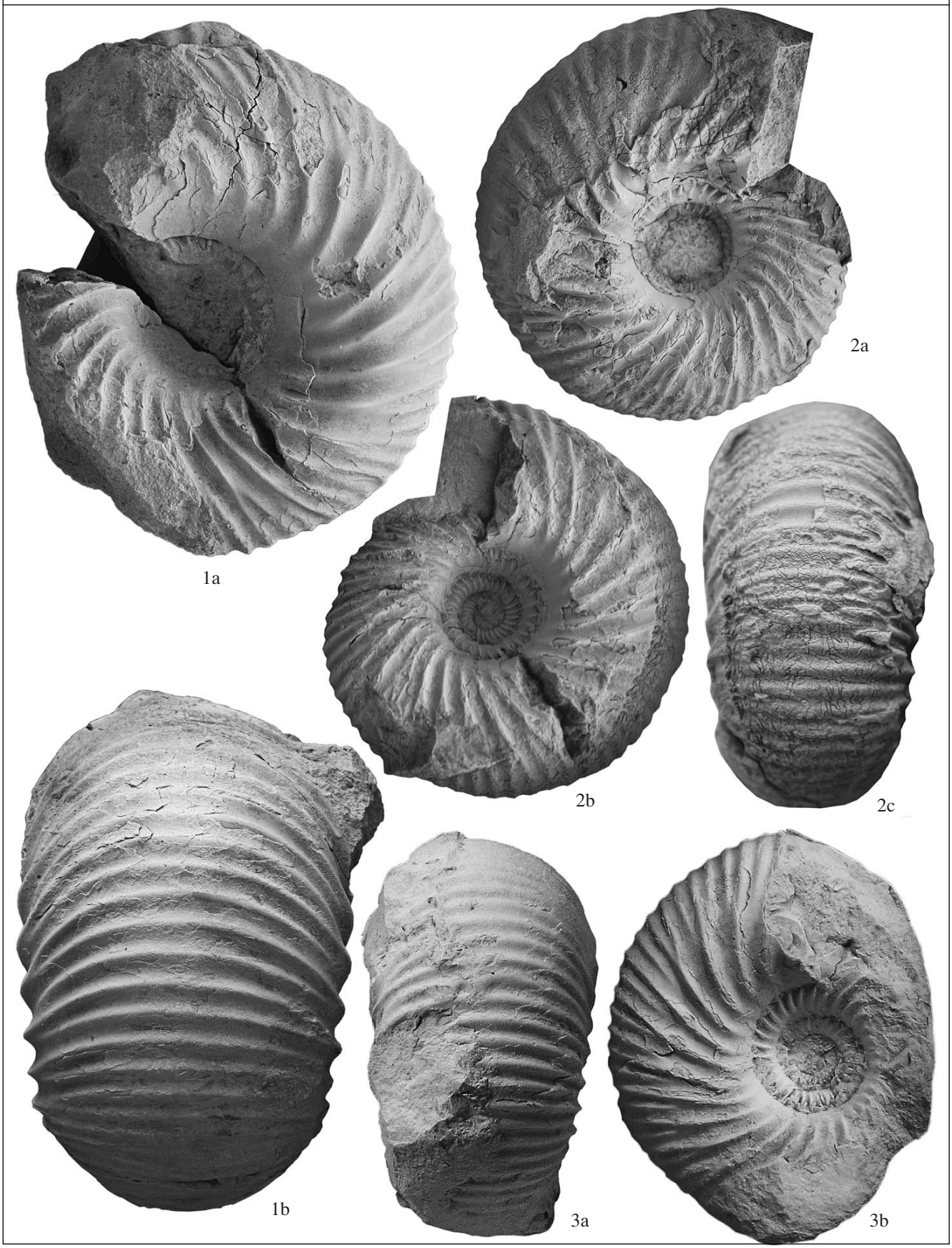
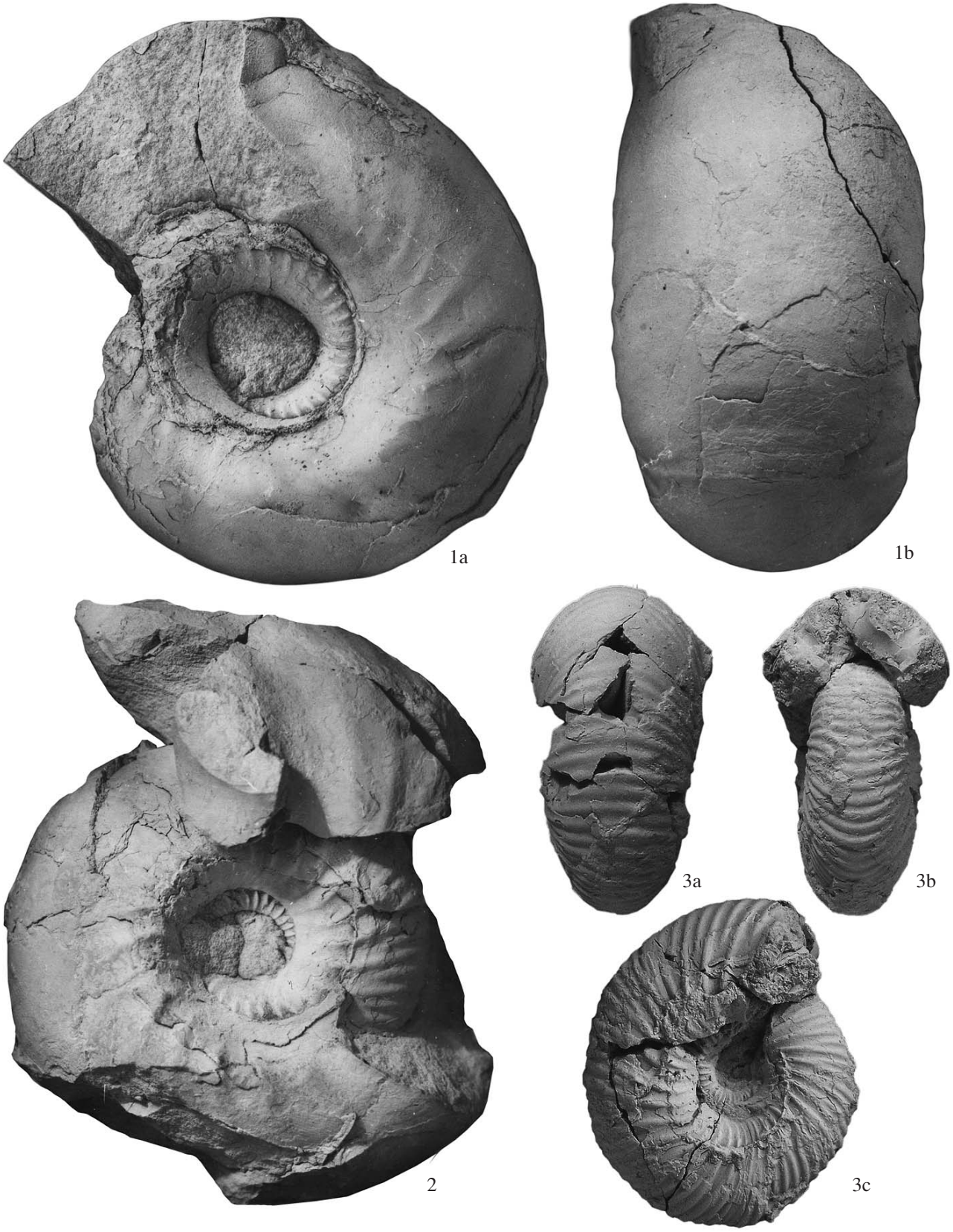


Plate III



shell (W/D = 62.6%), deeper umbilicus, steeper umbilical shoulder, and smoothed-out ribs on the venter in shells with D over 75 mm. We emphasize that the authors of the species also marked the presence of a strongly inflated variety with W/D up to 80% in the East Greenland association (Callomon, 1985, p. 79).

Occurrence. Upper Bathonian, *Arcticoceras (?) cranocephaloide* Zone. East Greenland, northern East Siberia (the lower reaches of the Lena River, Olenek Bay).

Material. Six specimens (nos. 856–21, 22, 23, 24, 25, 26) from the Lena River, Outcrop 2, Member 9 and Outcrop 3, Member 8 (Meledina et al., 1991, Fig. 2); and one specimen (nos. 489–336) from Olenek Bay, Stannakh-Khocho Village, Outcrop 16, Bed 28 (Meledina, 1977, 1994, Fig. 17).

Genus *Cadoceras* Fischer, 1882

Cadoceras barnstoni (Meek, 1859)

Plate II, figs. 1–3

Ammonites barnstoni: Meek, 1859, p. 184, pl. 2, figs. 1–3.

Cadoceras crassum: Frebold, 1961, p. 17, pl. XIV, fig. 2.

Cadoceras barnstoni: Frebold, 1964, p. 14–15, pl. VIII, fig. 3; pl. XII, fig. 2.

Cadoceras (Catacadoceras) laptievi: Bodylevskii, 1960, p. 64, pl. I, fig. 1; pl. II, fig. 1.

Cadoceras (Catacadoceras) ognevi: Bodylevskii, 1960, p. 65.

Cadoceras subcalyx: Voronets, 1962, p. 51, pl. XX, figs. 1, 2, and 4.

Cadoceras subcatostoma: Voronets, 1962, p. 51, pl. XXIV, fig. 1.

Cadoceras barnstoni: Poulton, 1987, p. 54–56, pl. 24, figs. 1–18; pl. 25, figs. 1–8; pl. 26, figs. 1–18.

Cadoceras (Catacadoceras) barnstoni: Meledina et al., 1991, p. 23, pl. 8, fig. 3; pl. 6, figs. 2 and 3.

Cadoceras (Catacadoceras) barnstoni: Meledina, 1994, pl. V, fig. 4.

Cadoceras (Catacadoceras) barnstoni: Meledina, 1999, p. 139, pl. I, figs. 1–7; pl. II, figs. 1–5.

Catacadoceras laptievi: Meledina, 1977, p. 91, pl. 8, fig. 4; pl. 15, fig. 3; pl. 39, fig. 2.

Holotype. No. 4811. Museum of Geological Survey of Canada, Ottawa. Illustrated by Poulton (1987, p. 12–15, pl. VIII, fig. 3; pl. XII, fig. 2). Northern Yukon, Mackenzie River, Upper Bathonian, *Cadoceras barnstoni* Zone.

Shell shape. Large (D up to 100 mm), moderately wide shells (W/D 52–66%) with a moderately narrow venter grading into wide, slightly flattened flanks. The latter grow apart near the umbilical shoulder where the whorls are widest. The umbilicus is relatively deep, cup-shaped, with wide, gentle, flattened walls. The body chamber reaches about 0.6 of the whorl.

Ornamentation. The ribs are bold, thick, and relatively widely spaced. On outer whorls, the ribs on the umbilical walls are thin and hardly visible. They become distinct on the outer edge of the umbilical walls. On the flanks, the ribs sharply deflect toward the aperture and near the ventrolateral shoulder bifurcate (the rib ratio is 2–2.2). Some ribs cross the venter without branching. Intercalated ribs occur. Ribs cross the ventral side with a very gentle forward-directed curve. On the intermediate whorls the ribs have an analogous shape though they are more closely spaced. Unlike outer whorls, at earlier ontogenetic stages, the ribs on the umbilical walls are distinct.

Comparison. An important character of the species is their sharp ribbing on the umbilical walls of the intermediate whorls and the presence of pronounced primary and secondary ribs on the body chamber of adult whorls.

The described species at adult stages differs from *C. infimum* Gulyaev et Kisselev (Gulyaev and Kiselev, 1999, p. 87) by its wider shell (W/D 52–66% versus 50% in *C. infimum*) and by its flattened ventral side. At early stages it differs by its sharp, widely spaced lateral ribs, straightened out secondary ribs and evolute shell with relatively low whorls. In the zonal scale suggested by Mitta (2005a, b) the *Paracadoceras keuppi* Zone is recognized in the Upper Bathonian of the Russian Plain. The species *P. keuppi* Mitta is considered as the junior synonym of *P. infimum* (Gulyaev et Kisselev) (Gulyaev, 2005, p. 64). We agree with this inference and believe it is correct to include in *P. infimum* two more species of the *P. keuppi* Zone, i.e., *P. nageli* Mitta and *P. efimovi* Mitta.

Occurrence. Upper Bathonian, *Cadoceras barnstoni* Zone, Western Canada, East Siberia (the lower reaches of the Lena River, Olenek Bay) and Northeast Russia (Kotel'nyi Island), *C. barnstoni* Beds.

Material. Three specimens (nos. 456-27, 28, and 34) from the Lena River, Outcrop 3, Bed 3; Outcrop 3, talus of Beds 2 and 3 (Meledina et al., 1991); one specimen (nos. 489-334) from the Olenek Bay, Stannakh-Khocho Village, Outcrop 16, Bed 28 (Meledina, 1977, 1994); and 17 specimens (no. 756) from the Kotel'nyi Island (Meledina, 1999).

Cadoceras variabile Spath, 1932

Plate III, figs. 1–3

Cadoceras variabile: Spath, 1932, p. 75, pl. XVIII, figs. 1a, 1b; pl. XIX, figs. 1a–c, 2a, b.

Cadoceras variabile: Sazonov, 1957, pl. I, fig. 4.

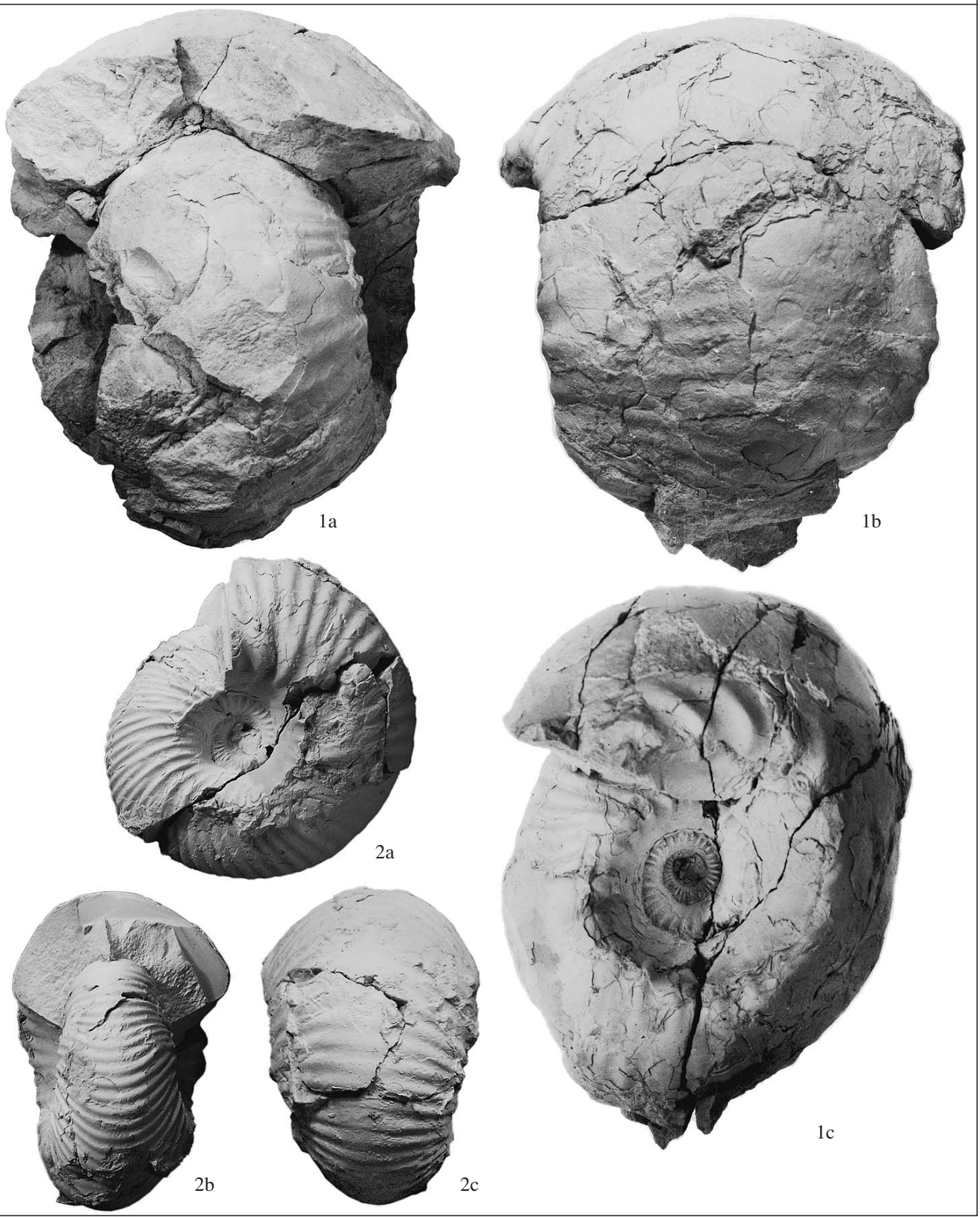
Cadoceras variabile: Callomon, 1985, text–figs. 8j, 8i.

Cadoceras variabile: Poulton, 1987, p. 56, pl. 27, fig. 1.

Cadoceras (Streptocadoceras) variabile: Meledina, 1994, pl. VI, fig. 2; pl. VIII, figs. 1 and 2; pl. XII, fig. 4.

Plate III. Ammonites of the *Cadoceras variabile* Zone. All specimens illustrated in natural size: (1–3) *Cadoceras variabile* Spath, 1932: (1) specimen no. 177/241, (a) lateral view, (b) ventral view; (2) specimen no. 177/248, lateral view; (3) the same specimen, (a) ventral view, (b) apertural view, (c) lateral view; eastern shore of the Anabar Inlet, Outcrop 109, Member 42, base.

Plate IV



Cadoceras variabile: Knyazev et al., 2006, p. 10, plate, figs. 3 and 4.

Cadoceras (Streptocadoceras) variabile: Repin et al., 2006, p. 97, pl. 16, fig. 2.

Holotype is illustrated by Spath (1932, p. 75, pl. XIX, figs. 1a–c). Upper Bathonian, *C. variabile* Zone, East Greenland.

Shell shape. Large shells (D up to 130 mm) with moderately wide whorls (W/D about 53%). Body chamber is 4/5 of the whorl. The flanks are slightly convex, subparallel, grading into rounded venter. The umbilicus is cup-shaped, moderately wide (U/D 32–33%), with a flattened inclined wall and rounded shoulder. The whorl cross-section is suboval; its width is 1.4–1.5 times greater than its height.

Ornamentation. Ribbing is most distinct on the inner and intermediate whorls. The primary ribs (21–24 on the whorl) originate on the umbilical wall, become slightly thicker on the shoulder, and further are sharply inclined towards the aperture. Most of them bifurcate at the mid-flanks. Intercalated ribs occur rarely. The secondary ribs cross the venter with a distinct forward-directed curve. On the outer whorl, the secondary ribs weaken and the primary ones are almost completely smoothed out with only 19–20 hardly noticeable umbilical nodes remaining. The aperture of the terminal whorl is fringed by a distinct wide constriction.

Comparison. The species at intermediate stages differs from other *Cadoceras* members by its moderately wide whorls, primary ribs that are sharply inclined forward, and its cup-shaped umbilicus.

Occurrence. Upper Bathonian, *C. variabile* Zone, East Greenland, and East Siberia.

Material. Four specimens from the Middle Jurassic section on the eastern shore of the Anabar Inlet (nos. 864-18, Outcrop 109, Bed 42, collected by Meledina; nos. 177/241, 177/248, Outcrop 109, base of Bed 42; No. 177/246, Outcrop 109, top of Bed 42).

Cadoceras calyx Spath, 1932

Plate IV, figs. 1 and 2

Cadoceras calyx: Spath, 1932, p. 69, pl. XX, figs. 1a, 1b.

Cadoceras victor: Spath, 1932, p. 67, pl. XVI, figs. 6a–c; pl. XXI, figs. 1a, 1b.

Cadoceras aff. *victor:* Spath, 1932, pl. XXI, figs. 1a, 1b.

? Cadoceras cf. *calyx:* Bodylevskii, 1960, p. 68, pl. VI, fig. 2.

Cadoceras (Bryocadoceras) falsum: Meledina, 1977, p. 62, pl. 10, fig. 1; 1994, pl. VI, fig. 1.

Cadoceras calyx: Callomon, 1985, text-fig. 8K–8k.

Cadoceras calyx: Knyazev et al., 2006, p. 106, plate, fig. 2.

Holotype No. 9263. Geological Museum, Copenhagen University (MGUH). Illustrated by Spath (1932, pl. XX, fig. 1). Upper Bathonian, *Cadoceras calyx* Zone, East Greenland, Jameson Land.

Shell shape. Large shells (D up to 115 mm). Body chamber is about 5/6 of the whorl. The inner whorls are semievolute and moderately wide; beginning with D = 60 mm they become inflated and strongly inflated (W/D = 70–80%). The umbilicus is moderately wide (U/D about 30–34%), funnel-shaped, deep, with a plumb wall and sharp shoulder. The whorl cross-section changes during the ontogenesis from oval, close to rounded (with D = 45 mm) to low subtrapezoidal, extended in width. The width is 2.5 to 3 times larger than the whorl height.

Ornamentation is represented by relatively closely spaced, bold primary and secondary ribs. The primary ribs originate at outer margin of the umbilical wall and thicken on the shoulder forming elongated nodes inclined forward. Near the mid-flanks, the ribs split into two or three secondary ribs. Intercalated ribs occur as well. The secondary ribs form a gentle, wide, forward-directed curve. In shells with D = 70 mm, 10 primary and 30 secondary ribs occur at the half-whorl. Ribbing gradually decreases with ontogeny.

Comparison. *C. calyx* mostly resembles *C. falsum* Voronetz, with which it was identified previously (Meledina, 1977, 1994). It differs by its wide outer whorls, less coarse and more closely spaced ribbing on the inner and intermediate whorls, and in the later (at D = 100 mm) smoothing out of its ribs.

Remarks. *C. calyx* is the oldest member of typical *Cadoceras,* the *C. sublaeve* group, characterized by a distinctly angular umbilical shoulder and deep, funnel-shaped umbilicus. Contrary to the younger members of the group, it has strongly evolute inner whorls and a very wide umbilicus.

The shells described by Mitta as *C.* aff. *calyx* (Mitta, 2004, pl. 1, figs. 2a, 2b) and *C. calyx* (Mitta, 2005, p. 641, pl. 8, fig. 1), differ in subparallel flanks, the whorl cross-section which is less extended in width, wider spaced ribs, which smooth out earlier. We believe that the attribution of these specimens to *C. calyx* is erroneous.

Occurrence. Upper Bathonian, *C. calyx* Zone, East Greenland and Central Siberia.

Material. Three specimens from the Middle Jurassic section on the eastern shore of the Anabar Inlet (nos. 177/243, 177/247, Outcrop 109, base of Bed 43; no. 177/244, Outcrop 109, top of Bed 43; collected by Knyazev).

Plate IV. Ammonites of the *Cadoceras calyx* Zone. All specimens illustrated in natural size: (1–2) *Cadoceras calyx* Spath, 1932: (1) specimen No. 177/243, (a) apertural view, (b) ventral view, (c) lateral view; (2) the same specimen, (a) lateral view, (b) apertural view, (c) ventral view; eastern shore of the Anabar Inlet, Outcrop 109, Member 43.

CONCLUSIONS

The proposed refinement of the current Upper Bathonian ammonite zonal scale of Siberia resulted from the reinvestigation of the Jurassic reference sections bearing ammonites in the Lena-Anabar region. The Upper Bathonian is represented by the *Arcticoceras (?) cranocephaloide* (including *Cadoceras barnstoni* Beds in the upper part), *Cadoceras variabile,* and *C. calyx* zones that correspond to the same units in East Greenland. The correlation of the Upper Bathonian zones with the West European standard is analogous to that for East Greenland after Callomon (2003).

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