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Boreal Upper Bathonian in the Volga River Middle Courses (Ammonites and Stratigraphy)

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Abstract—Deposits and boreal marine fossils of the Upper Bathonian are discovered in the Volga River middle courses, the central Russian plain. The deposits occur below the *elatmae* Zone considered as the East European equivalent of the standard *herveyi* Zone, the basal one in the West European Callovian. In generic and specific composition, the discovered ammonite assemblage is similar to those of the Upper Bathonian from eastern Greenland and Spitsbergen. Five ammonite species are described. One of them, *Cadoceras (Catacadoceras) infimum*, is new, whereas *Kepplerites (Kepplerites) svalbardensis* Sok. et Bodyl., *K. (K.)* cf. *rosenkrantzi* Spath, and *K. (Toricellites) pauper* Spath have been known before in the Arctic regions only. The local biostratigraphic *infimum* Zone, which immediately underlies the *elatmae* Zone, can be correlated with a basal part of the *calyx* Zone in eastern Greenland and with the upper part of the *barnstoni* Zone in northern Siberia. Its stratigraphic position in the West European standard is nor very clear and supposed to be in the interval spanning the upper part of the *orbis* Zone and the entire *discus* Zone. The data obtained suggest that the Boreal sea transgression advanced in the Russian platform to the Volga River middle courses at the end of the Bathonian.

Key words: *boreal Bathonian, ammonites, stratigraphy, correlation, Volga River middle courses.*

The problem that boreal marine facies of the Bathonian may occur in the central Russian plain has never been studied or even discussed. The general opinion was that it is unlikely for this area so perfectly studied from the standpoint of geology. Though the Middle Jurassic boreal transgression was accepted to commence in the Bathonian, the general opinion allowed the sea to cover the greater part of the Russian platform only in the early Callovian, at the time of the *elatmae* Zone. In the traditional reconstructions of the middle–late Bathonian paleogeography (Gerasimov *et al.*, 1962; Sazonov and Sazonova, 1967; *Paleogeografiya ...*, 1983), the entire territory of central Russia was considered as an area of continental sedimentation, which was bounded in the north and south by relatively small sea bays of the Boreal and Tethyan basins, respectively.

In the period of 1992–1996, we studied surroundings of the Prosek and Isady villages situated at the Volga River not far away from the Nizhnii Novgorod, where an aleurite–sand sequence underlies the *elatmae* Zone. The sequence yielded the diverse fossils of marine invertebrates, mostly of ammonites. According to all features, this fauna of the distinct boreal (Arctic) type must characterize the upper Bathonian deposits.

BATHONIAN DEPOSITS OF THE RUSSIAN PLAIN

Marine deposits of the Bathonian Stage in its current understanding were known in the north of the plain (Pechora depression) beginning from the middle of the last century (Keyserling, 1846). Not long ago, the majority of researchers considered them as early Callovian in age. This concerns the *Arcticoceras ishmae* (Keyserling) Beds corresponding to synonymous ammonite zone of the boreal middle Bathonian. Deposits of this age are studied best of all along the Izhma River (Bodylevsky, 1963; *Stratigrafiya ...*, 1976; Meledina, 1987). In her recent work, Meledina (1994) reported that deposits with the late Bathonian fossils (*Cadoceras variabile* Beds) are also exposed in the Pizhma River middle courses. However, ammonites pictured by Meledina and classed with *C. variabile* Spath (Plate 8, nos. 1, 2, and Plate 12, no. 2) differ from this species. They have a wider umbilicus, and their ornamentation is less coarse and quicker smoothing in ontogenesis. Both features are transitional between those of subgenera *C. (Catacadoceras)* predominantly occurring in the upper Bathonian sediments and *C. (Paracadoceas)* mostly typical of the lower Callovian. The form in question is best comparable with *C. bodylevskyi* Frebold widespread in the basal Callovian deposits of Canadian Arctic (Frebold, 1964) and northern Yukon (Poulton, 1987). Thus, the evidence in favor of marine upper Bathonian sediments presumably present in the Pechora depression is uncertain, although they should be expected there. In the same area of the Pizhma River, Meledina (1994) collected fragmented ammonite shells and classed these remains with *Oraniceras* cf. *gyrumbilicum* (Quenstedt) and *Gonolkites* ex

Fig. 1. Geographic position of the studied area (point of arrow).

gr. *convergens* Buckman, both characteristic of the lower Bathonian in western Europe. Her determinations are incompatible with the current understanding of the early Bathonian paleogeography of the Boreal belt and ammonite geochronology. As the remains are miserable, the conclusion has to be verified.

Marine Bathonian deposits are well known in the south of European Russia: in the Ul'yanovsk–Saratov segment near the Volga River and in the peri-Caspian lowland and neighboring areas. These deposits with remains of Tethyan and Mediterranean ammonites accumulated in the past sea basin, which originated in the late Bajocian time and considerably reduced in area by the end of the Bathonian (Sazonov, 1957; Gerasimov *et al.*, 1962; Sazonova and Sazonov, 1967; *Yurskaya sistema*, 1972).

Between the two above regions of unambiguous marine sedimentation of the Bathonian time, i.e., in a vast central area of the Russian plain, marine sediments of this age have never been detected. Sandy to clayey deposits, which are rather widespread here, are usually barren of fauna, rest on the eroded surface of Jurassic rocks, and underlie the Callovian beds (Gerasimov *et al.*, 1962; Sazonova and Sazonov, 1967; *Yurskaya sistema*, 1972; Olfer'ev, 1986). These deposits are interpreted to be of the continental and/or coastal-marine (brackish-water) types and attributed to the Bajocian–Bathonian, Bathonian, and Bathonian–Callovian intervals. Locally, they yield the impoverished foraminiferal fauna and occasional pelecypods pointing to the lagoonal environments of sedimentation. There is only a little information about Boreal ammonites from these beds. For instance, Sazonov (1957, 1965) reported on the occurrence of *Arcticoceras ishmae* below the *Cadoceras elatmae* (Nikitin) Beds in the Moksha Formation outcrops near the Elat'ma. This specimen has not been pictured, however, and lost somehow from the collection. According to the common opinion, the distribution area of *Arcticoceras* forms in European Russia is confined to the Pechora depression only, and, as Meledina (1987) remarked, their occurrence in the Oka River localities seems to be quite suspicious. One more, equally mistrustful and lost, specimen of *A. ishmae* was mentioned by Sazonov (1957) as detected in the Samarskaya Luka region near the village of Perevoloki in a bed overlying deposits with diverse foraminifers and underlying the occurrence level of *Cadoceras* cf. *elatmae*.

To the southeast of Nizhnii Novgorod and in Chuvashia close to our study area, there are outcrops of Bathonian and Bathonian–Callovian deposits scattered at random in the Sura, P'yana, Tsivilya, Khoma, and Volga river basins (Gerasimov and Kazakov, 1939). These deposits rest on the Tatarian Stage and are overlain by the lower Callovian beds bearing ammonites of the *elatmae* Zone. The deposits are represented by clay and sand, frequently by sand alone. They enclose plant remains and are up to 10–15 m thick. In the northern direction, sedimentary facies become glauconite-bearing and barren of plant remains.

DESCRIPTION OF THE STUDIED SECTION

Near the villages of Prosek and Isady, Jurassic deposits are constituents of an erosion remnant extending for a distance of about 6 km and resting on the rough surface of the Tatarian Stage of the Permian System. They are exposed in a quarry in the northwestern outer edge of the village of Prosek and in a series of exposures of the top slope of the Volga River valley within the Prosek–Isady segment. The Jurassic deposits range in age with some gaps from the Bathonian to Volgian Stage. Horizons of the upper Bathonian and basal Callovian are most persistent and thick among others. Beds above them are thinner, locally of a condensed type, and exposed sporadically.

A.R. Ferkhmin was first to report in 1886 on Jurassic bed exposures near the villages of Prosek and Isady.

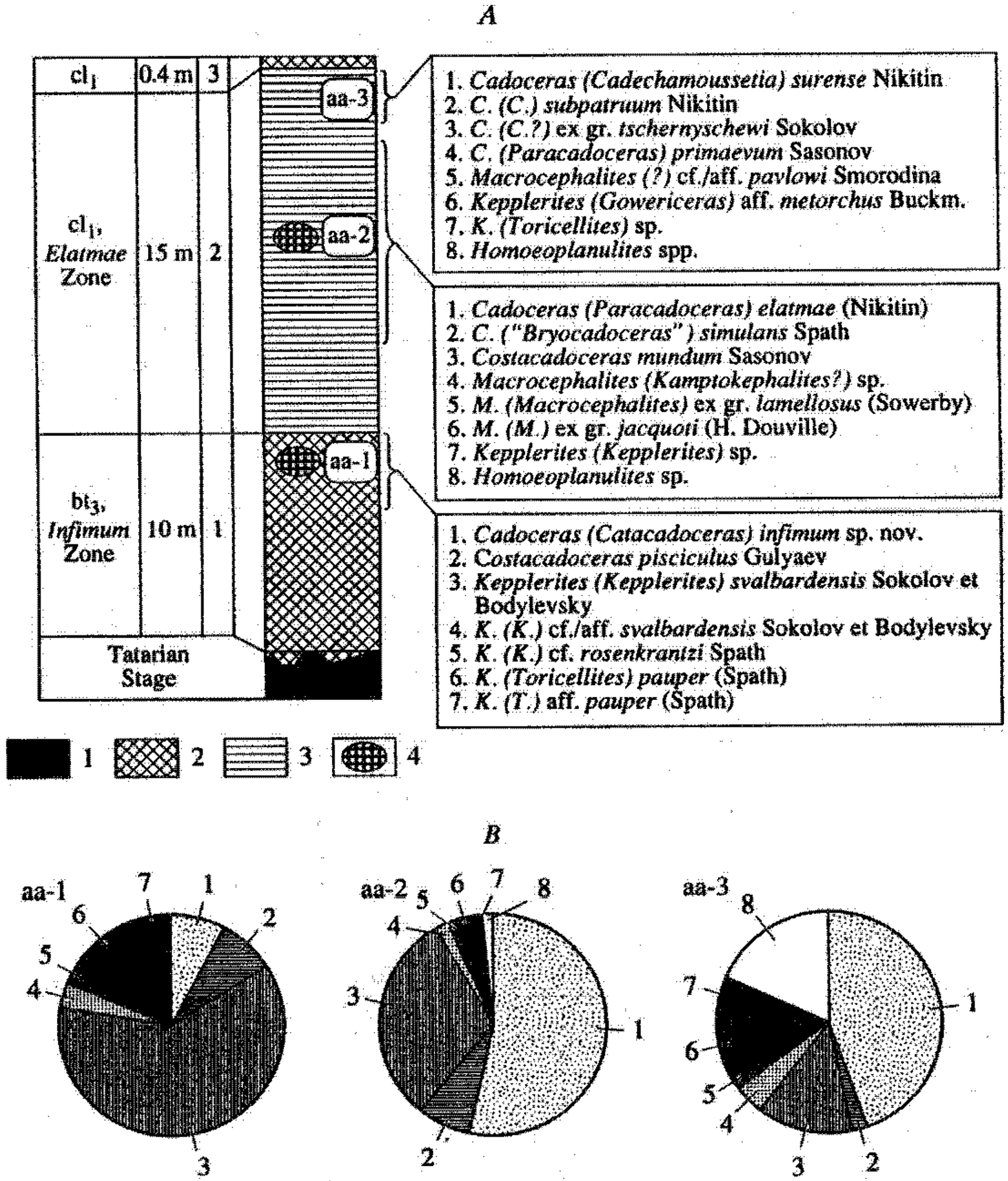


Fig. 2. Composite section (*A*) of Bathonian and lower Callovian deposits near the villages of Prosek and Isady with indicated levels of ammonite assemblages (aa-1, aa-2, and aa-3), and relative abundance (*B*) of species in the latter (species are numbered identically in A and B): (1) sandstone; (2) sand; (3) clay; (4) calcareous concretions.

Later, Sibirtsev (1886), Gerasimov and Kazakov (1939), Kulinich and Fridman (1990), and Gulyaev (1997) also studied these deposits. Silty sand beds of the Bathonian age, which are passed off in the first two works, are mentioned in later publications as presumably Bathonian deposits lacking faunal remains. However, we discovered the diverse assemblage of fossils at this level. The fossils allow us to identify the genesis of sediments, their relative age, and paleogeographic environments of the basin, where they accumulated.

The composite section of the studied Bathonian–lower Callovian deposits is described below (Fig. 2). Their best outcrops are located on the Volga River bank and 0.5 km away to the west from the village of Prosek.

The bed sequence overlying transgressively the rough surface of Tatarian sand and clay beds is as follows (from the base upward):

(1) Sand, grayish yellow, fine-grained, silty-micaceous, locally with vague lamination and glauconite; the bed locally encloses small clay pebbles, pyrite nodules, lentils of gray clayey sand, and small fragments of fossil wood. At the level of 0.5–2.5 m below the top, it shows spheroidal concretions of calcareous sand up to 0.7 m in diameter, which are filled with abundant ammonite shells.

In addition to these concretions, isolated shells and their small segregations occur in the upper interval of the bed (0–3 m below the top), where we identified ammonites *Cadoceras (Catacadoceras) infimum* sp. nov., *Costacadoceras pisciculus* Gulyaev, *Kepplerites (Kepplerites) svalbardensis* Sokolov et Bodylevsky; *K. (K.)* cf./aff. *svalbardensis* Sokolov et Bodylevsky; *K. (K.)* cf. *rosenkrantzi* Spath, *K. (Toricellites) pauper* (Spath), and *K. (T.)* aff. *pauper* (Spath) in association with undeterminable belemnite phragmocones, pelecypods (*Pinna* sp., *Pseudomytiloides* sp., *Oxytoma* sp., *Posidonia* sp., *Protocardia* sp., *Grammatodon* sp.), crustacean *Eryma* sp., and crinoid *Pentacrinus* sp. (thickness is 8–10 m).

(2) Clay, dark-gray, dense, micaceous, nonlaminated, carbonate-free; the bed has a sharp contact with the underlying sand, though there is no sign of erosion or sedimentation break, and the interval of about 5 cm in thickness consists here of intercalated sand and clay laminae. Lenticular interbeds of silt are present in the lower part of the bed. Other inclusions are represented by pyrite nodules, gypsum segregations, and occasional wood fragments. At the level of 5–8 m below the top, there are flattened concretions of massive gray marl up to 1 m in diameter.

Relatively rare fossils are dispersed in the upper two thirds of the bed, mainly in concretions and locally in the matrix. These are ammonites *Cadoceras (Paracadoceras) elatmae* (Nikitin), *C. ("Bryocadoceras") simulans* Spath, *Costacadoceras mundum* (Sasonov), *Macrocephalites (Kamptokephalites ?)* sp., *M. (Macrocephalites)* ex gr. *lamellosus* (Sowbery), *M. (M.)* ex gr. *jacquoti* (H. Douville), *Kepplerites (Kepplerites)* sp., and *Homoeoplanulites* sp; belemnites, predominantly small rostra and phragmocones; pelecypods *Retroceramus retrorsus* (Keyserling), *Grammatodon schourovskii* (Rouiller), *Entolium demissum* (Phillips), *Pleuromya uniformis* (Sowbery), *Meleagrinella* sp., *Tracia* sp., and *Astarte* sp.; and brachiopods *Aulacothyris* sp. Close to the top, we encountered ammonites *Cadoceras (Cadochamoussetia) surense* Nikitin, *C. (C.) subpatruum* Nikitin, *C. (C.)* ex gr. *tschernyschewi* Sokolov, *C. (Paracadoceras) primaevum* Sasonov, *Macrocephalites* (?) cf./aff. *pavlowi* Smorodina, *Kepplerites (Gowericeras)* aff. *metorchus* Buckman, *K. (Toricellites)* sp, *Homoeoplanulites* spp., and also small belemnite rostra (thickness is 12–15 m).

(3) Sand, greenish gray, medium-grained; the bed shows sporadic coaly plant remains and small ferruginous concretions. Gulyaev (1997) originally thought that *Costacadoceras pisciculus* Gulyaev and *Kepplerites* ex gr. *tychonis* Ravn, which have been collected from the talus apron, are derived from this level. At present, it is clear that both forms belong to Bed 1 (see above), where the form initially identified as *K.* ex gr. *tychonis* is now classed with *K. (K.) svalbardensis* (thickness is 0.4 m).

In some sections, these beds are overlain by a member of rusty-brown silt and siltstone, which is 0.6 m thick and bears the diverse fauna of the lower Callovian *koenigi* and *calloviense* zones. Above this member, there are calcareous clay beds of the Oxfordian (?)–Kimmeridgian up to 1–3 m thick. This unit yielded defective ammonite remains of Oppeliidae and Perisphinctidae s.l., among which we identified *Aulacostephanus undorae* (Pavlow) and *Subdichotomoceras* cf. *crassum* (Neaverson). Near the village of Isady, the section is crowned with a thin bed of greenish brown Volgian sandstone bearing *Buchia* sp.

DESCRIPTION OF AMMONITES

Species described below are encountered for the first time in the Russian plain and belong to the ammonite assemblage from Bed 1 (aa-1 in Fig. 2). The results of measurements are presented below in a form of tables, where we use the following letter symbols: (D) shell diameter; (W) shell width; (W/D) swelling index; (Ud) umbilical diameter; (Ud/D) relative width of umbilicus; (Pr) amount of primary ribs per a half of the whorl; (Sr) ditto for secondary ribs; (Rr) ribs ratio. The measurement results obtained close to the terminal aperture are marked with an asterisk. The described specimens are stored at the Department of Zoology, the Yaroslavl State University, and at the Department of Physical Geography, State Pedagogical University of Yaroslavl.

Family Kosmoceratidae Haug, 1887

Subfamily Gowericeratinae Buckman, 1926

Genus *Kepplerites* Neumayr, 1892

Subgenus *Kepplerites* Neumayr, 1892

Kepplerites (Kepplerites) svalbardensis Sokolov et Bodylevsky, 1931

Plate I, no. 4; Plate II, no. 7; Plate III, nos. 4, 5

Macrocephalites sp. cf. *evolutus*: Frebold, 1929, p. 10, nos. 1–3, non 4.

Kepplerites svalbardensis: Sokolov and Bodylevsky, 1931, p. 79, Plate 5, nos. 1, 2.

Kepplerites (Seymourites) svalbardensis: Ershova, 1983, Plate 2, nos. 1–4.

Kepplerites (Seymourites) svalbardensis: Kopik and Wierzbowski, 1988, p. 154, Plate 20, no. 2; Plate21, nos. 1, 2; Plate 22, nos. 8, 9.

Lectotype: Sokolov and Bodylevsky (1931, Plate 5, no.1); upper Bathonian of Spitsbergen (Delta Cape).

Material: more than 50 specimens of variable preservation degree.

Description. Shells are large (up to 140 mm), medium-thick, with moderately involute whorls having the upright low umbilical walls, convex lateral sides, and distinct ventral flattening, which is notable until the living chamber boundary. Whorls are trapezoidal in cross section, and their width is approximately equal or slightly greater than height of the living chamber. Ribs are usually quite prominent, thin, and frequent. Their ramification points are located at the level equal to 1/3–1/2 of the whorl height and marked sometimes by vague tubercles. The living chamber is as long as 2/3–3/4 of the terminal whorl.

Dimensions (mm) and ratios:

Specimen no.	D	W	W/D	Ud	Ud/D	Pr	Sr	Rr
A30	129*	46	0.36	46	0.36	27	88	3.3
	101	43	0.43	28	0.28	15	54	3.6
2/676	124*	50	0.40	44	0.35	22	74	3.4
	98	42	0.43	26	0.27	25	65	2.6
	76	36	0.47	17	0.22	20	54	2.7
2/639	61	30	0.49	14	0.23	14	41	2.9
2/648	44	19	0.43	10	0.23	13	39	3.0
2/668	25	11	0.44	7	0.28	14	35	2.5

Variability. Variable parameters of shells are the swelling index, umbilical diameter, frequency and relief of ribs. Sculptural characteristics are most variable. In this respect, the majority of shells are identical to pictured specimens of *K. (K.) svalbardensis* from the type area of Spitsbergen. However, some shells have less frequent ribs more embossed on the shell surface. There is no distinct boundary between two distinguished morphotypes, and, being coexistent, they are attributed to one species group. Shells with the most coarse ornamentation (Plate III, nos. 6, 7) are very close in morphology to *K. (K.) keppleri* (Oppel) and *K. (K.) cereale* (Buckman). Having scanty specimens of this type, we are not sure whether they represent an independent morphotype or an example of the extreme variability. Accordingly, these specimens with coarse ribs are classified as *K. (K.)* cf./aff. *svalbardensis.*

Comparison and remarks. In one of his recent works, Callomon (1993) nominated *K. tychonis* Ravn pictured by Spath (1932) as *K. (K.) vardekloeftensis.* This species coexist with *K. (K.) svalbardensis* in the *calyx* Zone of eastern Greenland and also occurs above this level. Outer whorls of both species are very similar in morphology. According to Callomon's description, the only difference between them is the almost round ventral side of inner whorls of *K. (K.) vardekloeftensis*, where signs of flattening are very insignificant.

In northern Alaska, Imlay (1953b, 1975) described the North American species *K. (K.) alticostatus* and *K. (K.) chisikensis*, both similar to *K. (K.) svalbardensis.* At present, they are attributed to the topmost Bathonian horizons (Callomon, 1993). *K. (K.) alticostatus* differs from the described species owing to shape of its primary ribs less curved and wider spaced in the terminal whorl; it also has the more prominent tubercles and wider ventral side. Distinctive features of *K. (K.) chisikensis* are the finer and denser ornamentation, narrower umbilicus, and higher whorls.

Distribution: upper Bathonian of Spitsbergen; upper Bathonian of eastern Greenland, *calyx* Zone, lower biohorizon (index species *K. peramplus* Spath); upper Bathonian of the Volga River middle courses, *infimum* Zone.

Kepplerites (Kepplerites) cf. *rosenkrantzi* Spath, 1932

Plate II, nos. 1 and 2

Material: three specimens of variable preservation degree.

Description. Shells are large, swelling in inner whorls. Their moderately involute whorls have the upright umbilical wall, convex lateral sides, and distinct ventral flattening. In the trapezoid cross section of whorls, the width is by one fourth greater than height, but this disproportion decreases, when shell grows. Ribs, which are coarse and wide-spaced in early whorls, become thinner and more frequently arranged in intermediate whorls. Their ramification takes origin at the level corresponding to 1/3–1/2 of the whorl height. This level is marked by tubercles spinulose at the beginning and less prominent in intermediate whorls. The living chamber is eliminated.

Dimensions (mm) and ratios:

Specimen no.	D	W	W/D	Ud	Ud/D	Pr	Sr	Rr
2/637	77	48	0.62	20	0.26	13	51	39
6/1	41	25	0.61	13	0.32	–	–	–
	28	18	0.64	9.5	0.34	9	–	–

Comparison and remarks. The form in question is almost identical to *K. (K.) rosenkrantzi* widespread in the upper biohorizon of the *variabile* Zone in eastern Greenland (Callomon, 1993). As shells corresponding to the mature stage of ontogenesis are missing from the studied collection, we can classify our specimens in the open nomenclature only.

From other *Kepplerites* species *s. str.*, they differ in ornamentation of early whorls covered with wide coarse ribs and spinulose tubercles. According to Spath (1932), these features are typical of the lower Callovian subgenus *Gowericeras* Buckman, and ammonites under consideration could be ancestors of the latter.

Distribution: upper Bathonian of eastern Greenland, *variabile* Zone, upper biohorizon (index species *K. rosenkrantzi*); upper Bathonian of the Volga River middle courses, *infimum* Zone.

Subgenus *Toricellites* Buckman, 1922

Kepplerites (Toricellites) pauper (Spath, 1932)

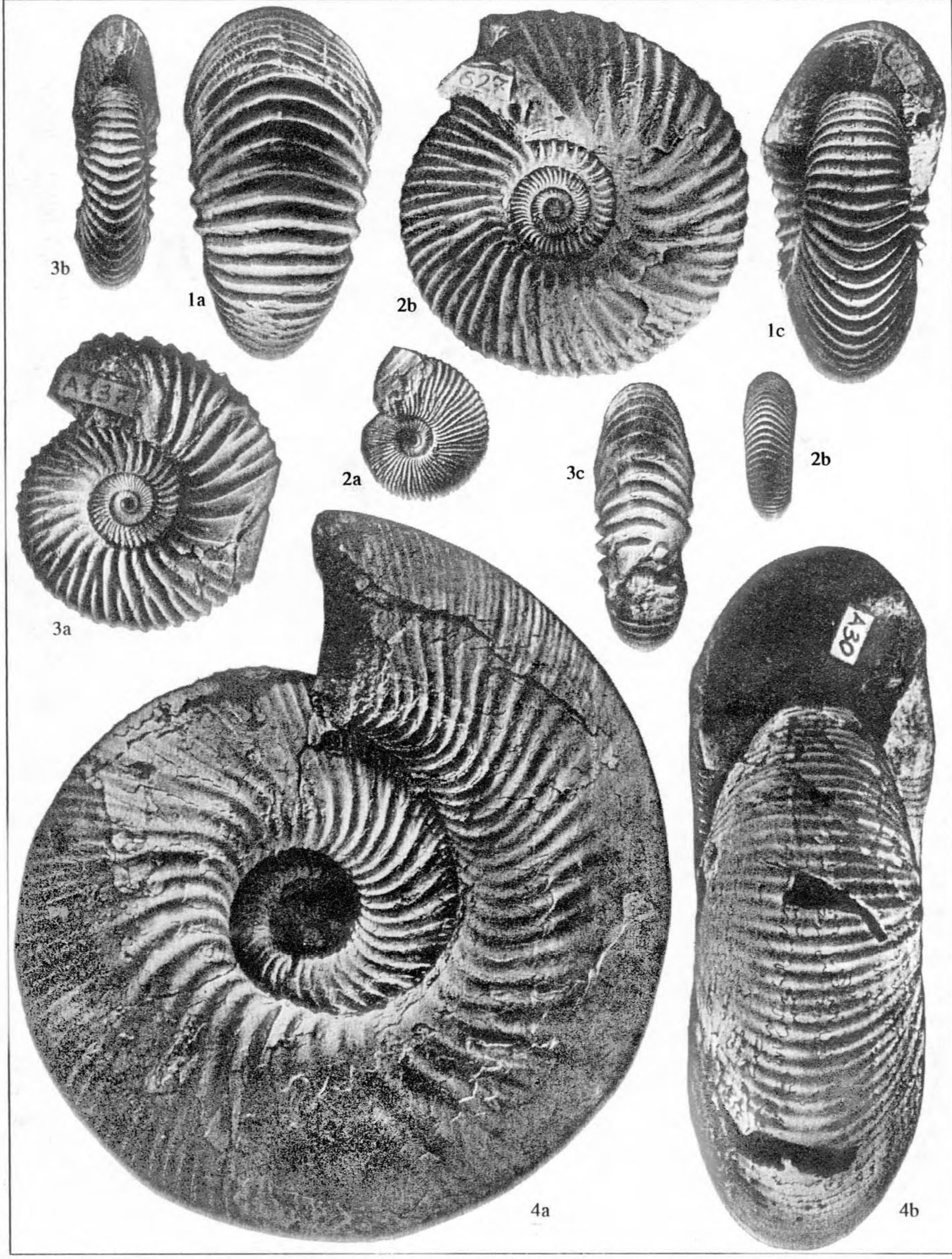
Plate II, no. 3

Kosmoceras (Gulielmiceras) pauper: Spath, 1932, p. 96, Plate 24, no. 3; Plate 26, no. 5.

Holotype: Spath, 1932, p. 96, Plate 24, no. 3; Plate 26, no.5; upper Bathonian of eastern Greenland, *calyx* Zone.

Material: eight specimens of variable preservation degree.

Plate I



Description. Shells are small (up to 40 mm) and flattened. Their semi-involute whorls have low umbilical walls, slightly convex to flat (in living chamber) lateral sides, and narrow ventral flattening. Trapezoid cross sections of whorls are extended along the height. Prominent ribs are thin and frequent, especially on the living chamber. Ramification points of ribs ornamented with blurred tubercles are at the level of one third of the whorl height. The living chamber is as long as two thirds of the whorl.

Dimensions (mm) and ratios:

Specimen no.	D	W	W/D	Ud	Ud/D	Pr	Sr	Rr
2/672	34*	10	0.29	11	0.32	26	60	2.3
2/671	28	9	0.32	10	0.36	–	–	–
2/655	22	8	0.36	7	0.32	22	42	1.9

Comparison and remarks. Late Bathonian *Kepplerites* microconchs are attributed now to subgenus *Toricellites*, where differences in morphology are very insignificant. At the same time, species of this group have flatter and thinner ribs than the early Callovian *Toricellites* forms. The form in question is classified as *K. (T.) pauper*, the species widespread in the upper Bathonian *calyx* Zone of eastern Greenland (Callomon, 1993). North American *K. (T.) knechteli, K. (T.) vigorosus, K. (T.) zortmanensis*, and *K. (T.) alascanus*, which were originally described by Imlay (1953a, 1953b) as species of the genus *Kosmoceras* Waagen, are also indistinguishable from *K. (T.) pauper.* Callomon (1984) considered them as forms characterizing the topmost Bathonian horizons and united the first three nominal species under the name *K. (T.) knechteli.* It is likely that *K. (T.) alascanus*, which is actually *nomen dubium* as one can judge from its holotype, also belongs to this group.

In addition to *K. (T.) pauper*, our collection includes microconchs, whose inner whorls are distinctly ornamented with coarse ribs and spinulose tubercles (Plate II, nos. 4, 5). We termed them as *K. (T.)* aff. *pauper*, and, if the popular hypothesis of sexual dimorphism is valid, they may be collated with *K. (T.)* cf. *rosenkrantzi* described above.

Distribution: upper Bathonian of eastern Greenland, *calyx* Zone; upper Bathonian of the Volga River middle courses, *infimum* Zone.

Family Cardioceratidae Siemiradzki, 1891

Subfamily Cardioceratidae Hyatt, 1900

Genus *Cadoceras* Fischer, 1882

Subgenus *Cadoceras* Bodylevsky, 1960

Cadoceras (Catacadoceras) infimum Gulyaev et Kiselev, sp. nov.

Plate I, nos. 1 and 2; Plate II, no. 6; Plate III, nos. 1 and 2

Species name: from Latin *infimus*, lowermost.

Holotype: specimen 2/267, Yaroslavl State University; the village of Prosek; upper Bathonian, *infimum* Zone.

Material: seven specimens of variable preservation degree.

Description. Shells are medium in size (up to 90 mm), changing in ontogenesis from flattened to swollen. Early semi-involute whorls have low and gentle umbilical slope, rounded umbilical shoulder, moderately convex lateral sides, and rounded but narrowed venter. When aging, whorls become more involute, and their umbilical slope turns out to be moderately high and steeper to form the umbilical shoulder. Lateral and ventral sides coalesce to form the gentle rounded ventral surface. Early whorls are oval in cross section, extended along the height. Ribs, thin and frequent on early whorls, gradually develop into coarse and wide during ontogenesis; the ornamentation extends up to the apertural margin. On the late whorls, primary ribs rise up as high apiculate ridges. Secondary ribs show distinct flexure on the ventral side of early and intermediate whorls; later, this element turns out to be more gentle. On the second half of living chamber, secondary ribs are not very prominent and become again distinct close to aperture. Ramification points of ribs are in the middle of the whorl height. Living chamber is as long as two thirds of the whorl.

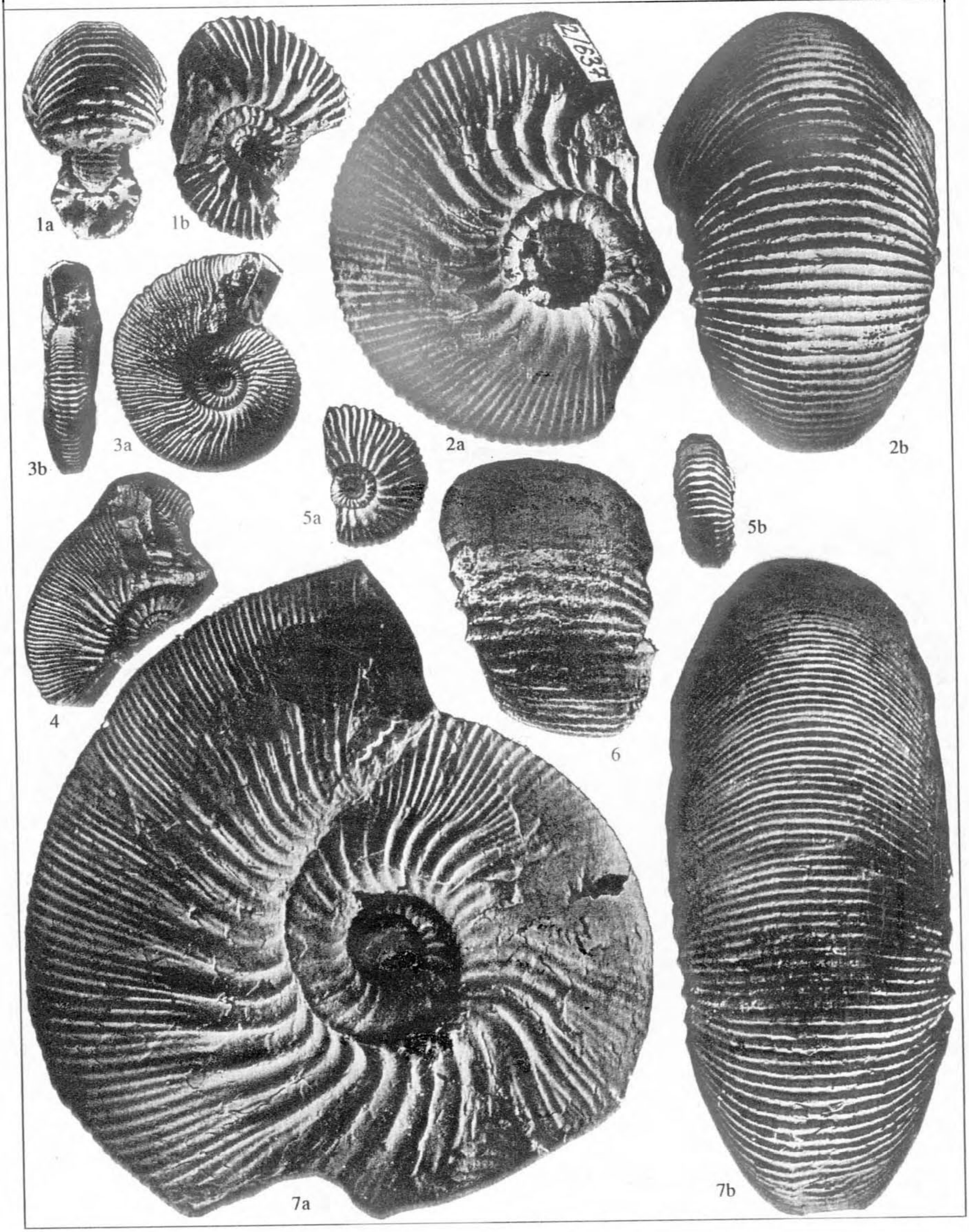
Dimensions (mm) and ratios:

Specimen no.	D	W	W/D	Ud	Ud/D	Pr	Sr	Rr
2/627	64	32	0.50	19	0.30	15	30	2
2/628	55	25	0.45	16	0.29	14	29	2.1
2/632	22	8	0.36	6	0.27	22	33	1.5

Comparison and remarks. The species in question is close in morphology to *C. (C.) barnstoni* (Meek) widespread in the upper Bathonian deposits almost everywhere in the following biohorizons of Arctic (circumpolar) regions: the *variabile* Zone of eastern Greenland (Callomon, 1993); the *barnstoni* Zone of northern

Plate I. Ammonites of the *infimum* Zone, the village of Prosek, the upper part of Bed 1 (without magnification except for no. 2)
(1, 2) *Cadoceras (Catacadoceras) infimum* sp. nov.: holotype, specimen 2/627 (1) and specimen 2/632, 1.3, Yaroslavl State University (YSU).
(3) *Costacadoceras pisciculus* Gulyaev, holotype, specimen A137, YSU.
(4) *Kepplerites (Kepplerites) svalbardensis* Sokolov et Bodylevsky, specimen A30, YSU.

Plate II



Siberia (Meledina, 1994), Canadian Arctic (Frebold, 1964), and northern Yukon (Poulton, 1987). Species *C. (C.) laptievi* Bodylevsky, *C. (C.) ognevi* Bodylevsky, *C. (C.) subcalyx* Voronetz, *C. (C.) subcatostoma* Voronetz, and *C. (C.) ventroplanum* Voronetz, which were originally described by Bodylevsky (1960) and Voronets (1962), are now accepted as synonyms of *C. (C.) barnstoni* (Poulton, 1987; Meledina, 1994). As compared to them, *C. (C.) infimum* sp. nov. has higher inner whorls and narrower ventral side ornamented with distinctly bending secondary ribs. It equally differs from *C. (C.) catostoma* Pompeckj sensu Imlay occurring in the basal lower Callovian beds of southern Alaska (Imlay, 1953b, 1975; Callomon, 1984). Callomon (1984) also reported on the late Bathonian *C. (C.) moffiti* Imlay from the same region, where it is a component of *Iniskinites intermedius* assemblage. It is difficult to compare new species with the last form, because the type material is inadequately representative. We should remark, however, that *C. (C.) infimum* sp. nov. has ribs thinner than those of *C. (C.) moffiti.*

Distribution: upper Bathonian of the Volga River middle courses, *infimum* Zone.

Genus *Costacadoceras* Rawson, 1982

Costacadoceras pisciculus Gulyaev, 1997

Plate I, no. 3

(?) *Pseudocadoceras* aff. *nanseni*: Efremova *et al.*, 1983, p. 130, Plate 10, no. 4.

Costacadoceras pisciculus: Gulyaev, 1997, p. 39, Plate 5, nos. 2 and 3.

Holotype: specimen A137, Yaroslavl State University; the village of Prosek; upper Bathonian, *infimum* Zone.

Material: seven specimens of variable preservation degree.

Description. Shells are small (up to 50 mm) and flattened. Their semi-involute whorls have low and gentle umbilical slopes, slightly to moderately convex lateral sides, and rounded narrow ventral sides. Oval cross sections of whorls are somewhat extended along the height. Embossed ribs are thin and frequent on early whorls; later, they coarsen and become spaced wider. On the living chamber, primary ribs emboss as apiculate ridges. Secondary ribs display distinct narrow flexures on the ventral side. Ramification points of ribs are located in the middle of the whorl height. Living chamber is as long as two thirds of the whorl.

Dimensions (mm) and ratios:

Specimen no.	D	W	W/D	Ud	Ud/D	Pr	Sr	Rr
A137	48*	16	0.33	17	0.35	13	26	2
A139	40	13	0.33	15	0.38	15	26	1.7
2/630	30	10	0.33	11	0.37	16	24	1.5

Comparison and remarks. As compared to *C. bluethgeni* Rawson, shells of the species under consideration are less involute and narrower in mature whorls; their ornamentation is coarser, and rib-ramification index is rather high. In comparison with microconchs designated as "allotypes" of *Cadoceras (Catacadoceras) cranocephaloide* (Callomon et Birkelund) and *C. (Paracadoceras) apertum* Callomon et Birkelund (Callomon, 1985, Plate 1, no.2; Plate 3, no. 1), *C. pisciculus* has the narrower ventral side displaying the greater curvature of ribs and the less dense ornamentation on mature whorls. This species is very similar in morphology to the shell fragment of *Costacadoceras bluethgeni* Rawson recovered presumably from the *ishmae* Zones of the Pechora River basin (Repin and Rashvan, 1996, Plate 30, no. 7).

Distribution: upper Bathonian of the Volga River middle courses, *infimum* Zone; (?) upper Bathonian of the Franz Josef Land.

AGE OF AMMONITES AND CORRELATION

Using new data on vertical distribution of fossils in the Jurassic section studied near the villages of Prosek and Isady, we distinguished three successive ammonite assemblages (aa-1, aa-2, and aa-3 in Fig. 2). The majority of species coexist within each of the assemblages. In the stratigraphic sense, ranges of the latter correspond to biohorizons termed after the most characteristic species of the genus *Cadoceras*: the lower *C. infimum* horizon spans approximately two thirds of Bed 1; the *C. elatmae* horizon is correlated with the middle and a part of the upper third of Bed 2; and the *C. surense* horizon characterizes the topmost part of Bed 2.

Both upper horizons (aa-2 and aa-3) include *C. (P.) elatmae* Nik., *C. ("B.") simulans* Spath, *C. (C.) surense* Nik., and some other species "classical" of the Russian plain and characterizing the lower Callovian *elatmae*

Plate II. Ammonites of the *infimum* Zone, the village of Prosek, the upper part of Bed 1 (without magnification)

(1, 2) *Kepplerites (Kepplerites)* cf. *rosenkrantzi*: specimen 6/1 (1), State Pedagogical University of Yaroslavl (SPUY), and specimen 2/637 (2), YSU.

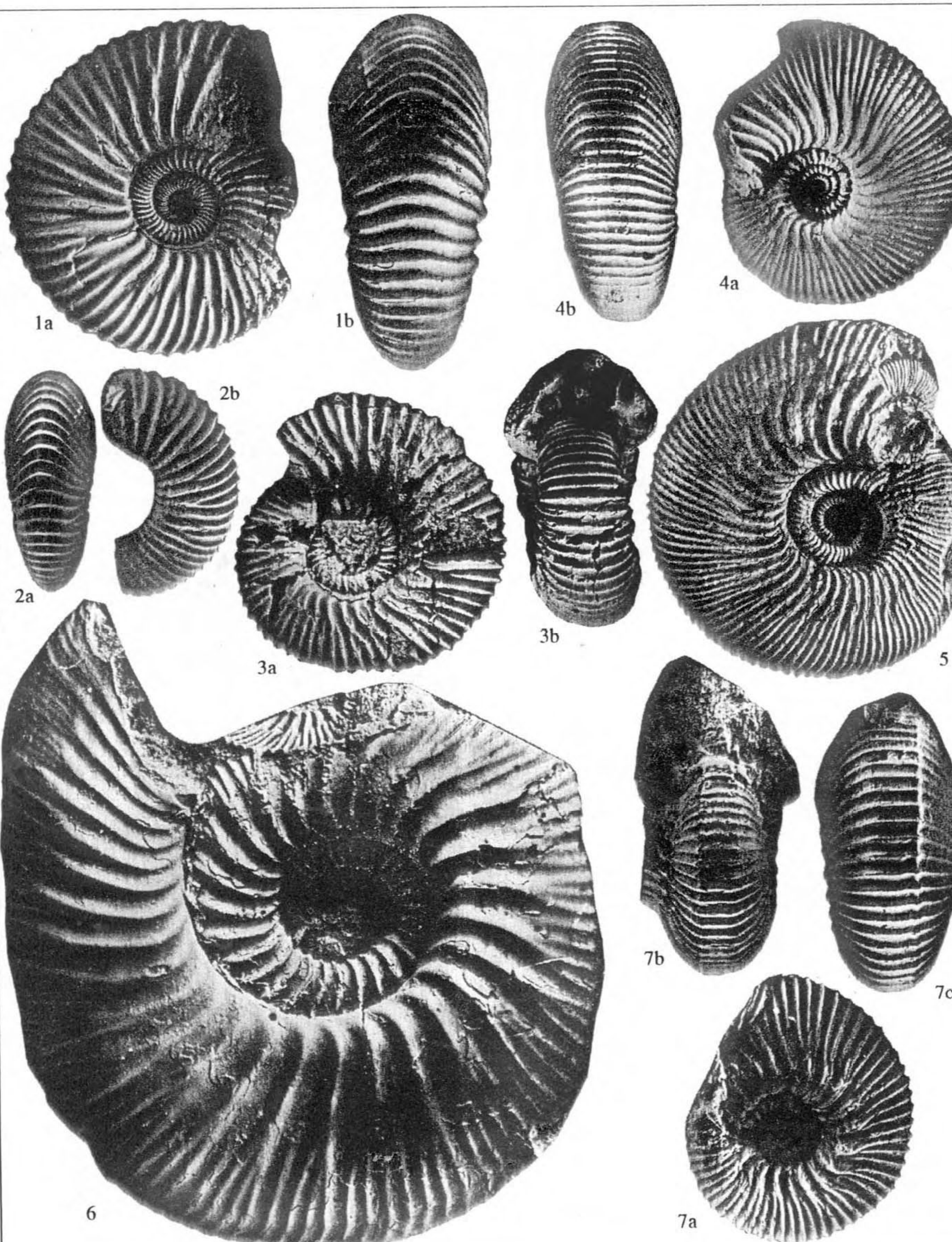
(3) *Kepplerites (Toricellites) pauper* (Spath), specimen 2/672, YSU.

(4, 5) *Kepplerites (Toricellites)* aff. *pauper* (Spath): specimen 2/640 (4), YSU, and specimen 2/663 (5), YSU.

(6) *Cadoceras (Catacadoceras) infimum* sp. nov.: specimen 6/3, SPUY.

(7) *Kepplerites (Kepplerites) svalbardensis* Sokolov et Bodylevsky, specimen 2/675, YSU.

Plate III



Zone. The lower assemblage (aa-1) of the *C. infimum* horizon is notably different from that of the *elatmae* Zone: its families are restricted in number (Kosmoceratidae and Cardioceratidae only); the dominant subgenus is *Kepplerites* s. str. [= *Seymourites* Kilian et Reboul]; and subgenus *Catacadoceras* is present at this level. Faunas similar in composition are known from the upper Bathonian beds of Arctic regions only: from eastern Greenland (Spath, 1932; Callomon, 1993) and Spitsbergen (Ershova, 1983; Kopik and Wierzbowski, 1988). However, it is impossible to correlate the *C. infimum* horizon with a particular subdivision of the Boreal ammonite zonation, because the standard index species are missing from the distinguished assemblage and the above regions are too far away. Accordingly, we consider the assemblage as characterizing the local *infimum* Zone, which corresponds to the assemblage range immediately below the *elatmae* Zone. Since the lower part of Bed 2 is barren of fossils, the boundary between *infimum* and *elatmae* zones is placed, though tentatively, at the level dividing beds 1 and 2. Lithological features suggest that there was no gap in sedimentation at this level, and consequently, there is no chronological hiatus between the *infimum* and *elatmae* zones.

Among two possibilities to establish age of the *infimum* Zone relative to the standard scale, one is to use its correlation with the Jurassic ammonite zonations in the Boreal (Arctic) regions, where they are well substantiated. The problem here is that these zonations are sometimes uncertainly correlated with the standard West European ammonite scale. Until the recent time, for instance, the level of Bathonian–Callovian boundary was interpreted in different ways (e.g., Meledina, 1986; Sei and Kalacheva, 1992), and there was discrepancy corresponding to the range of the substage. The problem becomes more intricate by positioning a single zone (Meledina, 1994).

The more fruitful opportunity is to use the available correlation schemes for the overlying *elatmae* Zone, whose position relative to the standard is better elucidated.

In the last decade, the Bathonian–Callovian stratigraphy has been revised several times in England and Germany (Callomon *et al.*, 1988, 1989, 1992; Dietl and Callomon, 1988; Page, 1989). As a result, stratigraphic ranges of ammonite species were refined, and the detailed infrazonation of the upper Bathonian and lower Callovian in northwestern Europe was elaborated. Critical for our case is the stratigraphic position of *Cadoceras* forms known from the Swabian Alb of Germany, (Quenstedt,1847, Plate 14, no. 6; Quenstedt, 1887, plate 79, nos. 1–7) and compared by Nikitin (1878) with *C. (P.) elatmae*. Later, Spath (1932) identified one of these forms (Quenstedt, 1847, Plate 14, no. 6; 1887, Plate 79, no.3) as new species *C. quenstedti*, and another one was termed *C. suevicum* (Callomon *et al.*, 1989). *C. quenstedti* and *C. suevicum* beds directly overlie the level of *K. keppleri*, which corresponds to the lower boundary of the *herveyi* Zone and Callovian Stage in subboreal regions of western Europe (Fig. 3). It is obvious that *C. quenstedti* is very close in morphology to *C. (P.) elatmae*, whereas *C. suevicum* is identical to the latter. Accordingly, we have grounds to correlate the lower boundary of the East European *elatmae* Zone with the base of the standard *herveyi* Zone (Sei and Kalacheva, 1992; Callomon, 1993), and even to lower it down a little, because there is a chance that boreal forms of the *C. (P.) elatmae* type appeared in the Russian platform earlier than in western Europe (Fig. 3). From this viewpoint, the *infimum* Zone underlying the *elatmae* range should be attributed to the Bathonian Stage and correlated with the *discus* but not higher zones of the standard scale.

As noted above, the boreal ammonite assemblage of the *infimum* Zone is similar to that of the upper Bathonian in eastern Greenland, where the same *Kepplerites* forms are identified (Callomon, 1993). Its species *Kepplerites (Toricellites) pauper* Spath and *K. (Kepplerites) svalbardensis* Sok. et Bodyl. are, respectively, characteristic of the upper *K. vardekloeftensis* and lower *K. peramplus* biohorizons of the *calyx* Zone in Greenland, whereas *K. (K.) rosenkrantzi* Spath (cf. *rosenkrantzi*) is known from the synonymous horizon of the lower *variabile* Zone (Fig. 3). Another typical taxon of the latter is subgenus *Cadoceras (Catacadoceras)*, although its representatives range up to the basal horizon of the *calyx* Zone. At the first glance, the *infimum* Zone seems to correspond to three ammonite horizons of eastern Greenland, where each of them has its own assemblage of species. However, this is a misleading impression. Ammonites of the *infimum* Zone represent an indivisible assemblage, and the zone should be correlated basically with the lower half of the *calyx* Zone (the level of *K. peramplus*), because *K. (K.) svalbardensis* occurring at this level in eastern Greenland is the dominant form of the studied assemblage. Species *K. (T.) pauper* have insignificant differences in morphology as compared to other late Bathonian microconchs of this genus (see description above), and they are unsuitable for the reliable correlation. *K. (K.)*

Plate III. Ammonites of the *infimum* Zone (excluding no. 3), the village of Prosek, the upper part of Bed 1 (without magnification)

(1, 2) *Cadoceras (Catacadoceras) infimum* sp. nov.: specimen 2/628 (1) and specimen 2/631 (2), YSU.

(3) *Cadoceras (Catacadoceras) barnstoni* (Meek): inner whorls of lectotype *Cadoceras subcalyx* Voronetz (Voronets, 1962, Plate 20, no. 1), museum of the Central Research Institute of Geological Prospecting, St. Petersburg, specimen 46/9209 (18b); upper Bathonian, *barnstoni* Zone; Chubukulakh River in the Lena River lower courses.

(4, 5) *Kepplerites (Kepplerites) svalbardensis* Sokolov et Bodylevsky, specimen 2/642, YSU, and specimen 6/2 (5), SPUY.

(6, 7) *Kepplerites (Kepplerites)* cf./aff. *svalbardensis* Sokolov et Bodylevsky, specimen 6/0 (6) and 6/4 (7), SPUY.

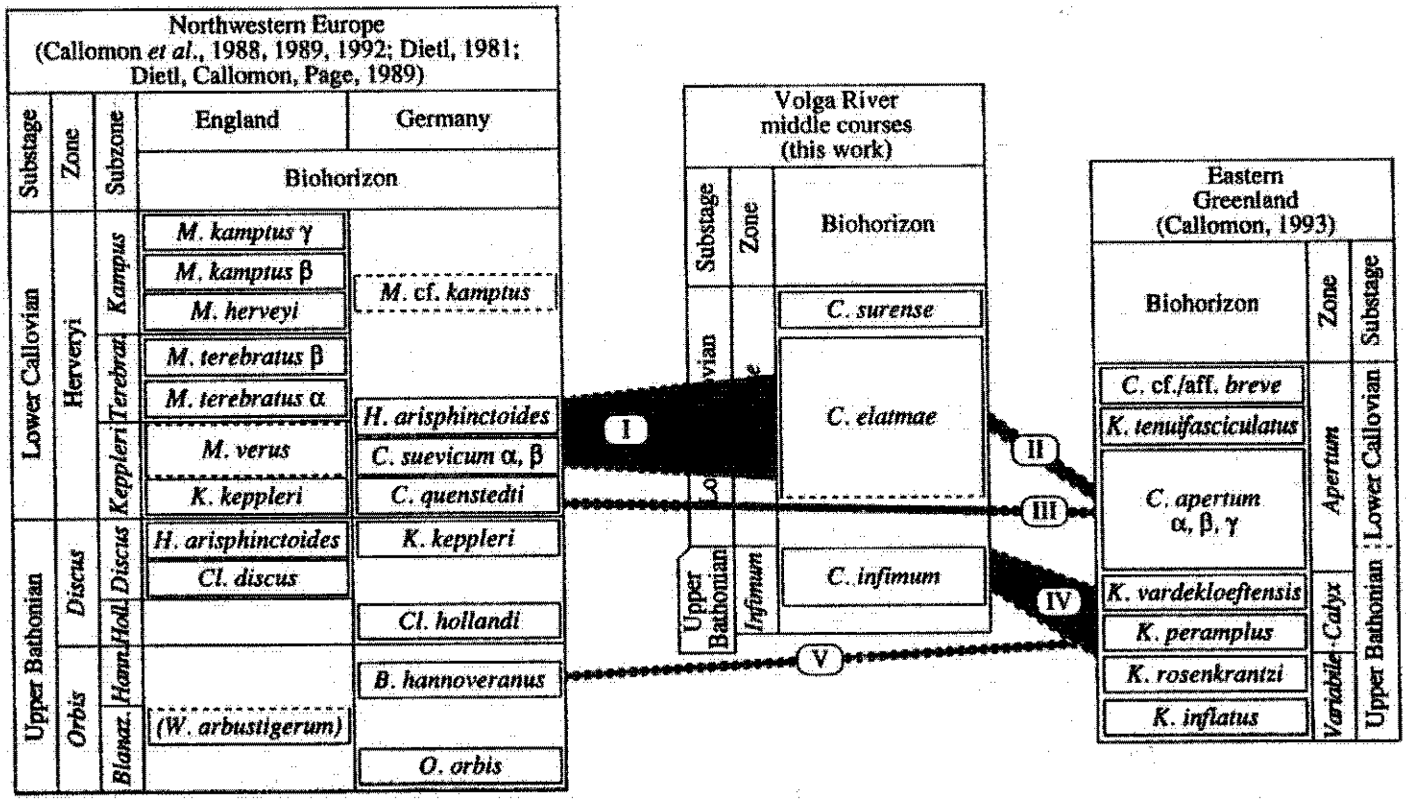


Fig. 3. Correlation of ammonite infrazonation in Bathonian–Callovian boundary deposits of the Volga River middle courses, northwestern Europe (England and Germany), and eastern Greenland:

(I) correlation on the basis of *C. elatmae* (Nik.) [synonymous biohorizon and zone of Russian plain], *C. quenstedti* Spath, and *C. suevicum* Call. et al. (= *C. elatmae*) [*keppleri* Subzone and basal level of *terebratus* Subzone, *herveyi* Zone of Germany];

(II) correlation on the basis of *C. frearsi* (d'Orb.) [*elatmae* Zone of Russian plain, Sazonov, 1957] and *C.* cf./aff. *frearsi* (d'Orb.) [*C. apertum* horizon, *apertum* Zone of eastern Greenland];

(III) correlation on the basis of *K. keppleri* (Opp.) [synonymous biohorizon and subzone, *herveyi* Zone of northwestern Europe] and *K.* cf./aff. *keppleri* (Opp.) [*C. apertum* horizon, *apertum* Zone of eastern Greenland];

(IV) correlation on the basis of *K. svalbardensis* Sok. et Bodyl., *K.* cf. *rosenkrantzi* Spath, *K. pauper* Spath, *C. infimum* sp. nov. [*infimum* Zone of the Volga River middle courses] and *K. svalbardensis* Sok. et Bodyl., *K.* cf. *rosenkrantzi* Spath, *K. pauper* Spath, *C. barnstoni* (Meek) [*calyx* Zone and the top of *variabile* Zone of eastern Greenland];

(V) correlation on the basis of *K. peramplus* Spath [synonymous biohorizon, *calyx* Zone of eastern Greenland] and *K.* cf./aff. *peramplus* Spath [*B. hannoveranus* horizon, *hannoveranus* Subzone, *orbis* Zone of Germany].

Abbreviated generic names: (*B.*) *Bullatimorphites*; (*C.*) *Cadoceras*; (*Cl.*) *Clidoniceras*; (*H.*) *Homoeoplanulites*; (*K.*) *Kepplerites*; (*M.*) *Macrocephalites*; (*O.*) *Oxycerites*; (*W.*) *Wagnericeras*.

cf. *rosenkrantzi* is represented by scanty specimens, and besides, it could exist longer at the periphery of the basin thus ranging up to higher biohorizons.

Callomon considers the *calyx* Zone as correlative to the standard *orbis* Zone of western Europe, because the *hannoveranus* forms from the upper subzone of the latter (Fig. 3) are comparable with *Kepplerites (Kepplerites)* cf./aff. *peramplus* Spath (Dietl and Callomon, 1988; Callomon, 1993). We do not know how reliable is this correlation scheme, but according to it, the *infimum* Zone must be at the level of the *orbis* Zone, and the lower part of the *elatmae* Zone must be lowered down to the standard *discus* Zone of the upper Bathonian. Other arguments in favor of this viewpoint are unknown. Instead of them, there are facts, according to which the lower boundary of the *elatmae* Zone either correlates with the base of the *herveyi* Zone, or runs, at least, somewhere lower, but not as far down as the whole zonal interval (see above). In view of these disagreements, the position of the *infimum* Zone relative to the standard upper Bathonian zonation remains uncertain and may vary within the interval spanning the upper part of the *orbis* Zone and the whole *discus* Zone (Fig. 4).

Cadoceras (Catacadoceras) infimum sp. nov., the index species of new zone, is close in morphology to *C. (C.) barnstoni* (Meek) from the synonymous upper Bathonian zone of northern Yukon, Canadian Arctic (Poulton, 1987), and of northern Siberia (Meledina, 1991, 1994). Poulton concluded that the *barnstoni* Zone spans the upper part of the *variabile* Zone together with the base of the *calyx* Zone, whereas Meledina (1994) considers it as identical to the former zone only. In eastern Greenland, ammonites resem-

Stage	Standard zones		Zones of Russian plain (this work)	Zones of eastern Greenland (Callomon, 1993)	Zones of northern Siberia (Meledina, 1994)
Callovian	*Herveryi*		*Elatmae*	*Nordenskjoeldi*	*Anabarense*
				Apertum	
					Falsum
Bathonian	*Discus*	Tentative correlation	*Infimum*	*Calyx*	*C. "variabile"* Beds
	Orbis			*Variabile*	*Barnstoni*
	Hodsoni			*Cranocephaloide*	*Cranocephaloide*

Fig. 4. Inferred stratigraphic position of the *infimum* Zone and correlated zonation of Bathonian–Callovian boundary deposits in northwestern Europe, Russian plain, eastern Greenland, and northern Siberia.

bling *C. (C.) barnstoni* are predominantly known from the upper part of the *variabile* Zone, although some representatives of this subgenus were also detected at the base of the *calyx* Zone (Callomon, 1993). As compared to typical *C. (C.) barnstoni* forms from Arctic regions, *C. (C.) infimum* seems to be more advanced in morphological evolution. Its narrower ventral side with distinctly convex ribs makes the young whorls of the species similar to inner whorls of some representatives of subgenus *C. (Paracadoceras)*, e.g., of *C. (P.) frearsi* (d'Orbigny). This may suggest that species from Russia are somewhat younger than *C. barnstoni*, and the *infimum* Zone, like that of the *calyx* forms, corresponds to the upper part of the *barnstoni* Zone in Siberia (Fig. 4). The *C. variabile* Beds of northern Siberia are at the same stratigraphic level. In contrast to ammonites from eastern Greenland, the species from the Anabar Bay, which was identified as *C. variabile* (Meledina, 1994, Plate 6, no. 2), shows the less coarse ornamentation quicker smoothing in ontogenesis and the more gentle umbilical slope of mature whorls. Apparently, this species should be attributed to subgenus *Cadoceras (Paracadoceras)*, whose early representatives, e.g., *C. (P.) ammon* Spath and *C. (P.) victor* Spath, show their first occurrence in the *calyx* Zone of eastern Greenland.

CONCLUSION

Deposits of the Volga River middle courses, which underlie the lower Callovian *elatmae* Zone, yielded the diverse fauna of marine invertebrates. The respective ammonite assemblage is of the Boreal type and has no analogue in the European Russia. This biostratigraphic range is distinguished as the local *infimum* Zone immediately underlying the *elatmae* Zone.

According to its relative position and composition of ammonite assemblage, the *infimum* Zone must be attributed to the upper Bathonian. It seems to be correlative with the lower part of the *calyx* Zone in eastern Greenland and with the upper part of the *barnstoni* Zone in northern Siberia. Relative to the West European standard scale for the upper Bathonian, its position is defined conventionally as ranging in the interval of the upper part of the *orbis* Zone and throughout the *discus* Zone.

The data obtained suggest that the Middle Jurassic boreal transgression advanced to the studied area already by the end of the Bathonian (the *infimum* phase). The hypothetical basin of that time represented the relatively narrow seaway extending from the Pechora depression to the latitude of the Volga River middle courses. Unfortunately, one studied area does not allow us to delineate boundaries of the postulated late Bathonian basin.

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