Infraunal Ammonite Scale for the Upper Bathonian-Lower Callovian of Central Russia

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Abstract—The regional infraunal scale for the upper Bathonian-lower Callovian is elaborated on the basis of successive ammonite assemblages in some Middle Jurassic sections of Central Russia. Four zones and 13 biohorizons, most of which are well correlated to the standard West European units, are distinguished in the studied stratigraphic interval. The Infimum Zone including the C. infimum and C. cf./aff. infimum biohorizons is the lowermost unit of the scale. According to its stratigraphic position below the Elatmae Zone, the above unit approximately corresponds to the Discus Zone and probably the upper part of the Orbis Zone of the standard upper Bathonian scale. The succeeding Elatmae Zone is subdivided into the M. jacquoti, C. elatmae, C. tschernyschevi, C. surensis, C. subpatruus, and Ch. saratovensis biohorizons. Due to some correlative stratigraphic levels, this zone is considered to be analogous to the basal Callovian Herveyi Zone of the standard scale. The Koeuigi Zone including the K. densicoostatus, K. curtilibus, and K. trichophorus biohorizons is an equivalent of the synonymous zone of the standard scale. The lower Callovian succession is completed by the Callovienne Zone comprising the S. callovienne and S. enodatum biohorizons. It is also analogous to the synonymous standard zone.

Key words: upper Bathonian, lower Callovian, ammonites, biohorizons, stratigraphy, Central Russia.

The terminal Bathonian-initial Callovian time of the Earth history is marked by an extensive sea transgression in the Northern hemisphere. As a result, the Russian platform turned into the East European sea basin, the central part of which could be termed the Central Russia sea. Being connected with the Arctic (boreal) and Tethyan (tropical) sea basins, the sea was favorable for migration of faunas of different biogeographic genesis. For this reason, sediments and fossils of the Central Russia sea are extremely important objects of stratigraphic and paleontological studies. On the one hand, they make it possible to correlate stratigraphic schemes for different regions. On the other hand, they represent perfect material to study evolution of biotas with heterogeneous components.

In spite of extensive list of publications on the Middle Jurassic of the Russian platform, which appeared since the last century, the investigation level of Bathonian–Callovian deposits in Central Russia is still lower than that in many other regions. Distribution and taxonomic composition of some stratigraphically important groups of ammonites remain here disputable or unclear. Until the recent time, the boreal Bathonian marine deposits have not been known to occur in this region and special investigations have not been carried out (Gulyaev and Kiselev, 1999; Gulyaev, 1999).

Accordingly, the main purpose of this work is to define vertical ranges and evolutionary links of the late Bathonian–early Callovian ammonites of Central Russia in order to elaborate a refined stratigraphic scale, which could be useful for thorough phylogenetic, paleoecological, and paleoecographic investigations.

The study material was obtained during the field works in 1991–1998. The collection of fossils is stored in the Chair of Paleontology of the Moscow State University.

DESCRIPTION OF SECTIONS

The upper Bathonian–lower Callovian stratigraphy and ammonites of Central Russia were studied in the following sites of the Nizhni Novgorod, Kostroma, Ryazan, Moscow, and Yaroslavl areas (Fig. 1): (1) the Prosek-Isady section (the Nizhni Novgorod area, a quarry in the northwestern outskirts of the Prosek Village and a series of outcrops at the right bank of Volga between the Prosek and Isady villages); (2) the Uzhovka section (the Nizhni Novgorod area, a quarry in the northwestern outskirts of the Uzhovka Settlement); (3) the Akatovo section (the Kostroma area, an outcrop at the right bank of the Unzha River, 1 km downstream from the Akatovo Village); (4) the Pezhenga section (the Kostroma area, an outcrop at the left bank of the Unzha River downstream from the Pezhenga River mouth); (5) the Manturovo–Znamenka section (the Kostroma area, the outcrops at the right bank of the Unzha River near the town of Manturovo and Znamenka Village); (6) the Ivkino section (the Kostroma area, an outcrop at the right bank of the
Unzha River between the Ivkino and Samylov villages; (7) the Cheremukha section (the Yaroslavl area, an outcrop at the right bank of the Cheremukha River near the Dmitrievka Village); (8) the Alpat'ev section (the Moscow area, a series of outcrops at the right bank of the Oka River near the Alpat'ev Settlement); and (9) the Nikitino section (the Ryazan area, an outcrop at the right bank of the Cheremukha River near the Dmitrievka Village).

The Prosek-Isady, Uzhovka, Pezhenga and Alpat'ev sections, which are most rich in fossils and best studied, are described below.

**The Prosek-Isady Section (Fig. 2)**

In the quarry located in northwestern outskirts of the Prosek Village (except for Bed 1) and in a series of outcrops at the right bank of the Volga River between the Prosek and Isady villages, the following beds rest on the uneven surface of sandstones and clays of the Tatarian Stage of the Permian System:

(1) Yellowish gray and gray fine-grained silty micaceous sandstones, which are highly clayey at the base; the sandstones are intercalated with discontinuous interbeds and lenticular bodies of gray clayey sand. Locally they include small clayey pebbles, rare pyrite concretions, and small wood fragments. Approximately 2.5–3.5 m below the bed top, there occur rare ball-like concretions of carbonate sandstone up to 0.7 m in diameter. The ammonite assemblage **a1** is discovered from the interval of 1.5–4.5 m below the top and from concretions, and the assemblage **a2** characterizes the interval of 0–1 m (Fig. 2). The bed thickness is 8–10 m.

(2) Dark gray micaceous massive clay; the lower sandy part of the bed includes lenticular basal interbeds of highly sandy clay, clayey sand, and silt up to 1 m thick. The bed is separated from the preceding one by finely alternating and plicated laminae of clay and sand about 5 cm thick. The bed contains scattered pyrite concretions, crystalline gypsum aggregates, and rare fragments of pyritized wood. Flattened septaria of compact gray marl up to 1 m in diameter occur approximately 5–8 m below the top, and rare small marl concretions are found also at the top of the bed. The ammonite assemblage **a3** is confined to the interval of 0–1.4 m above the base; the assemblage **a4** is predominantly concentrated in the middle and upper thirds of the bed, the enclosed concretions included; and assemblages **a5** and **a6** are characteristic of the uppermost part of the bed and of the enclosed concretions (Fig. 2). The bed thickness is 12–15 m.

(3) Greenish gray medium-grained sand locally with coalified plant remains; the bed has uneven contact with the preceding one. The bed thickness is 0.4 m.

(4) Yellow and yellowish brown clay silts and siltstones with interbeds and separate concretions of brownish gray oolitic marl; the ammonite assemblages **a7** and **a8** are confined to the lower half of the bed (Fig. 2). Above there are rare ammonites of the assemblage **a9** (Fig. 2). The assemblage **a10** is found near the bed top (Fig. 2). The bed thickness is 0.2–0.7 m.

These beds are overlain by gray carbonate clays of the Oxfordian(?)–Kimmeridgian age.

**The Uzhovka Section (Fig. 3)**

The quarry in northwestern outskirts of the Uzhovka Settlement exhibits the following beds:

(1) Light gray and white micaceous cross-bedded sand with thin (up to 1–4 cm) lenticular interbeds of gray sandy clay; apparent thickness of the bed is up to 3 m.

(2) Dark gray micaceous, massive clay slightly sandy in the basal and middle parts of the bed; pyrite concretions, fragments of pyritized wood, and rare concretions of gray marl are scattered in the bed that yielded successive ammonite assemblages **b1**, **b2**, **b3**, and **b4** (Fig. 3). The bed thickness is 8–10 m.

(3) Dark gray and brownish gray silt, which becomes sandy downward being locally oolitic; the bed has uneven contact with the previous one. The basal thin interbed of shell detritus contains the ammonite assemblage **b5a** (Fig. 2). In the top portion, concretions of gray oolitic marl bear the ammonite assemblage **b5b** (Fig. 3). The bed thickness is 0.2–0.4 m.

Above there are condensed silts and marls enclosing the diverse fossils the middle Callovian *Jason* and *Coronatum* zones.

**The Pezhenga Section (Fig. 4)**

The outcrop at the left bank of the Unzha River downstream from the Pezhenga River mouth exhibits the following bed sequence:

(1) Light gray and white, locally ferruginous and slightly micaceous loose sand that is intercalated with thin (up to 1 cm) lenticular clay interbeds; the bed contains rare fragments of coalified wood. Apparent thickness is 1.3 m.
Fig. 2. The composite Jurassic section at the Prosek-Isady site and levels of distinguished ammonite assemblages (biohorizons): (a1) C. infillum; (a2) C. cf. aff. infillum; (a3) M. jaqueti; (a4) C. elatmae; (a5) C. surensis; (a6) C. subpatrans; (a7) K. densicostatus; (a8) K. curtilobus; (a9) K. triennis; (a10) S. callovienne (index species of the biohorizons are indicated by asterisks).

Lithology:
1. Dark gray, locally almost black, slightly micaceous, compact and occasionally ferruginous sand with fragments of carbonaceous wood; the bed thickness is 0.3 m.
2. Light gray loose sand; the bed thickness is 0.15 m.
3. Dark gray micaceous and clayey condensed sand enclosing coalified wood and a horizon of flattened concretions of black phosphoritized sandstone; concretions bear rare ammonites representing the assemblage c1 (Fig. 4). The bed thickness is 0.12 m.
4. Light gray micaceous sand grading into light brown compact sandstone with coalified wood fragments; the bed thickness is 0.6 m.
5. Gray micaceous and clayey, locally ferruginous compact sand with clay interbeds; the bed thickness is 0.5 m.
Fig. 3. The composite Jurassic section at the Uzhovka site and distinguished ammonite assemblages (biohorizons): (b1) C. elatmae; (b2) C. surensis; (b3) C. subpatraus; (b4) Ch. saratovensis; (b5) K. densicostratus (other symbols as in Fig. 2).

(7) Light gray and loose micaceous, locally ferruginous sand; the bed thickness is 1.2 m.

(8) Sand analogous to that of Bed 6; the bed thickness is 0.7 m.

(9) Sand analogous to that of Bed 7; in the intervals of 10–20 cm above the bed base and 10–50 cm below the top, there are lenticular interbeds of gray sandy clay 0.5–10 cm thick. The interbeds contain flat septaria of black phosphoritized mudstone. The bed yielded the ammonite assemblage c3 (Fig. 4). The ammonite assemblage c2 may characterize the basal part of the bed (Fig. 4). However, it is difficult to define the precise location of the last assemblage that is recovered from a concretion found in the talus. The bed thickness is 1.6 m.

Above, there is bed of black micaceous clay varying in thickness. It contains crushed shells of Cardioceratidae supposed to be Oxfordian in age.

The Alpat'ev Stage (Fig. 5)

The series of outcrops at the right bank of the Oka River exhibits the following beds:
(1) Reddish micaceous, fine- to medium-grained sand; apparent thickness is up to 1 m.

(2) Dark gray fine- to medium-grained sand intercalated with light gray sand lenses in the upper part; the bed thickness is 2 m.

(3) Brownish gray cross-beded, medium- to coarse-grained sand with light gray clay interbeds; the bed thickness is 1.1 m.

(4) Greenish brown coarse-grained, loose sandstone locally grading into gravelstone; the sandstone includes basal thin interbeds of light clay. The bed thickness is 0.6 m.

(5) Sandstone intercalated with brown highly ferruginous mudstone; the ammonite assemblage d1 is confined predominantly to the upper part of the bed (Fig. 5). The bed thickness is 0.5 m.

(6) Brown ferruginous sandstone alternating with light reddish sand; the ammonite assemblage d2 is confined to the bed base, and the assemblage d3 is recovered from the upper part of the bed (Fig. 5). The bed thickness is 0.6 m.

(7) Light reddish loose sand; apparent thickness is up to 0.7 m.

The overlying sands and silts bear the middle–late Callovian fauna.

### PRINCIPLES OF INFRAZONAL SUBDIVISION

The Jurassic ammonite stratigraphy in Western Europe is predominantly elaborated at the precision level of subzones (Callomon, 1984, 1985, 1993; Callomon et al., 1988, 1989, 1992; Page, 1995; and many others). Regrettfully, this approach is of a limited acceptance in Russia. Subdivision up to subzones greatly increases resolution of local and regional scales, makes their correlation more precise, and reveals many local biotic and geological events, which cannot be distinguished when units of a higher rank are in use.

Two detailed biozonations are used in practice. French stratigraphers usually operate with units called "zonules", whereas English and German researchers use the term "biohorizon" that is more convenient in my opinion and closer related to biological events.

**Zonule** is the smallest chronostratigraphic unit defined, like units of higher ranks, by its lower boundary in the stratotype section. Page (1995) estimated that an average time range of zonule (biohorizon plus a potential hiatus) is about 200000 or, occasionally, only 80000 years.

**Biohorizon (or faunal horizon)** may correspond to a bed, or to a part of the bed and even to a bed sequence, when they yield a peculiar fossil assemblage (fauna or flora) that cannot be differentiated further in stratigraphy (Callomon, 1985). Therefore, both the lower and upper boundaries of biohorizon are detectable in a concrete section (Page, 1995). For the chronoequivalent of biohorizon, Callomon (1985) suggested the term "hemicrera" introduced by Buckman (1893, 1902).

Biohorizon is recognizable in a section, or in a series of sections of some region, if its index species (subspecies) is identified; taxonomic composition of associated fossils is of auxiliary importance only. It is expedient to use species (subspecies) of a single phyletic line as index taxa of successive biohorizons. As suggested by Callomon (1985), the possible highest resolution can be achieved by using transient species usually denoted by Greek letters. Successive biohorizons may have boundaries, which do not coincide. In correlation charts, potential hiatuses are indicated by intervals separating the neighboring units. Being established, the succession of biohorizons should be integrated with the existing zonal scale. At the present state of knowledge, boundaries and summary ranges of biohorizons may not coincide with those of higher rank units (Page, 1995), although such a coincidence should be aimed at.

As a rule, biohorizons are most convenient for correlation within biogeographic provinces, but some biohorizons or their successions can be stratigraphically significant for paleobiogeographic realms and even used as interregional markers.

The studied vertical successions and concurrent ranges of ammonite species enabled recognition of a
series of faunal assemblages stratigraphically outlining biohorizons of the upper Bathonian–lower Callovian sections (Figs. 2–5, Table 1). Their recognition and correlation were facilitated by the distinct species successions (phylectic lineages) established in subfamilies Cadoceratinae Hyatt, Gowericeratinae Buckman, and Macrocephalitinae Saffeld (Fig. 6). Every phylectic lineage shows persistent changes in species morphology (phylectic trend), which offer a basis to find the proper position of individual species in the general succession. However, the precise dating of faunal assemblages should be based on representative material elucidating variability of the constituent species, because the end members of isochronous (intraspecific) variation lines may have a set of either archaic or progressive features making them similar to ancestors or descendants, respectively, for which the given combination of distinctive features is a norm.

Examples can be found every time, when we have the representative collection of fossils. For instance, among abundant shells of Kepplerites (Kepplerites) svalbardensis Sok. et Bodyl. of the assemblage a1 from the Prosek-Isady section (Fig. 2), there are some specimens similar in their coarse ribbing to K. (K.) ex gr. keppleri (Opp.) of the assemblage a3. Another example is the subfamily Cadoceratinae. In the Uzhovka section (Fig. 3), the dominant representatives characterizing one of the successive species Cadachamousetia surensis (Nik.), C. subpatrurus (Nik.), and Chamousetia (?) saratovenensis Call. et Wright (assemblages b2, b3, and b4, respectively) associate at every particular level with the intermediate forms resembling in some characters the neighboring species of the given phylectic lineage. Assuming coexistence of these species, we come into collision with the principle of competitive exclusion of ecologically similar forms (the Gauze rule). In addition, it is evident that the coexistence of evolutionary allied species presupposes the preceding divergence and, at least, the initial isolation of species. Mechanism of such isolation is difficult to explain. Therefore, the model of phylectic (nondivergent) speciation seems to be more preferable.

The coexistence of archaic and progressive morphotypes of a single species can be explained in terms of the stabilizing selection theory (Shmal’gauzen, 1968; Shishkin, 1988; and others), according to which the speciation is related to the appearance of a new norm (a certain stable morphological-functional and genetic state). In population, where dominant representatives correspond to this norm, some forms may still have features corresponding in a certain sense to the previous norm, and, simultaneously, the combination of future standard features is under development.

The steady unidirectional evolution of individual phylectic lineages can be explained by limits of potential transformations controlled by the evolutionary ability of a given organization type; on the one hand, and by the environmental impact of abiotic and biotic factors on the evolving group of organisms, on the other hand. The integrated effect of all factors leads to the phylogenetic canalization, especially in the case of specialized groups having stable organization and low ecological valence.

Particular phylectic lineages may be of a great stratigraphic value for some section intervals. This depends on abundance (occurrence frequency) of representatives of the given group and on the clearness of evolutionary changes enabling discrimination of successive species. The comparative analysis of several phylectic lineages characterizing different taxa effectively controls the recognition and correlation of biohorizons.

Critical for recognition of infraonzonal subdivision in the Infimum Zone and in the lower part of the Elatmae Zone is the phylectic lineage of Cadoceratinae: Cadoceras (Catacadoceras) infimum Gul. et Kiss – C. (C.) cf.aff. infimum–C. (?Paracadoceras/Catacadoceras) aff. infimum (Fig. 6, nos.1–3). This phylectic lineage demonstrates the transition from representatives of the subgenus Catacadoceras Bodylevsky, which retain coarse ribbing on body chamber throughout the mature stage, to representatives of the subgenus Paracadoceras Crickmay, which have fine ribbing smoothening during the ontogenesis. The evolutionary transition from the fine-ribbed Kepplerites (Kepplerites) svalbardensis Sok. et Bodyl. to the relatively coarse-ribbed K.(K.) ex gr. keppleri (Opp.) (Fig. 6, nos. 21–22) is also of stratigraphic importance for the indicated interval.

Important for the lower and middle parts of the Elatmae Zone is also the phylectic lineage of scarce but characteristic species of Macrocephalitinae: Macrocephalites (Macrocephalites) jacquoti (Douv.)–M.(M.) prosekensis Gul.–M.(M.) pavlovii Smor. (Fig. 6, nos. 31–33). The succession shows the ventral side narrowing until its sharpening in the early whorls of M.(M.) pavlovii and reduction of sculpture on lateral sides.

By subdivision of the middle and upper parts of the Elatmae Zone and of the basal part of the Koenigi Zone, the key role belongs to the phylectic lineage of Cadoceratinae: Cadoceras (Bryocadoceras) tschernyschewi Sok.–Cadachamousetia surensis (Nik.)–C. subpatrurus (Nik.)–Chamousetia (?) saratovenensis Call. et Wright–Ch. chamoissetii (Orb.) (s.l.) (Fig. 6, 6–10). This phylectic lineage is characterized by the rapid transformation of shell morphology from cadicone (C. (B.) tschernyschewi) to oxycone (Chamousetia).

The phylectic lineage of Gowericeratinae takes origin in the Elatmae Zone and is characteristic of the Koenigi and Callovienne zones in subboreal regions of Europe and eastern Greenland. This lineage is as follows: group of Kepplerites (Gowericeras) unzhae Gul.–group of K.(G.) toricelli (Opp.)–species of the group of K.(G.) gowerianus (Sow.) and K.(G.) meteorus (Buckm.)–K.(G.) densicostatus Tint.–K.(G.) curtibus (Buckm.).–K.(G.) trichophorus (Buckm.) [?=K.(G.) galilaeii (Opp.) sensu Page, 1989]–species
### Infrazoan Ammonite Scale

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<th>Substage</th>
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### Stratigraphic Ranges of Genera and Subgenera of Ammonite Macroconchs and Main Phylogenetic Lineages of Cadoceratinae, Gowericeratinae and Macrocephalitinae

Cadoceratinae: (Cat.) Cadoceras (Catacadoceras); (Par.) C. (Paracadoceras); ["Bry."] C. (["Bryodoceras"] (group of C. simulans); (C-ch.) Cadocamussaetta; (Ch.) Chamousetia; (Cad.) C. (Cadoceras). Phylogenetic lineages 1–30: (1) Cadoceras (Catacadoceras) infimun --> (2) C. (C.) cf. aff. infimun --> (3) C. (Paracadoceras/Catacadoceras) aff. infimun 2 --> (4) C. (P.) elatmae 2 --> (5) C. (P.) cf. primaevum. Phylogenetic lineages 6–10: (6) C. (Bryocadoceras?) tschnyschevi --> (7) Cadocamussaetta surensis --> (8) C. subpatruus --> (9) Chamousetia (?) saratovensis --> (10) Ch. Chamousetia (s.l.) [?=Ch. philipsi, Ch. buckmani]. Phylogenetic lineages 11–17: (6) C. (Bryocadoceras?) tschnyschevi --> (11) C. (B?) ex gr. tschnyschevi --> (12–15) group of C. (Cadoceras) tolyte (and, probably, C. (C.??) confusum) --> (16) C. (C.) sublaeva --> (17) group of C. (C.?) tschnyschevi and C. (Rondiceras) C. tschnyschevi --> [C. (K.)] C. (Rondiceras) (el 1?). Phylogenetic lineages 18–20: (18) C. ("B?") simulans --> (19) group of C. ("B.") aff. simulans --> (20) group of C. ("B?") laetus [E.] Eichwaldiceras (el 2?)–3).

Gowericeratinae: (Kep.) Keppleriites (Keppleriites); (Gow.) K. (Gowericeras); (Sig.) Sigaloceras (Sigaloceras); (S.) S. (Catadigalogoceras). Phylogenetic lineages 21–22: (22) group of Keppleriites (Keppleriites) svalbardensis --> (22) group of K. (K.) keppleri. Phylogenetic lineages 23–30: (23) K. (K.) rosenkrantzii? --> (24) group of K. gowerianus --> (25) group of K. (K.) toricelli --> (26) group of K. (K.) gowerianus, K. (G.) metonchus and K. (G.) densicostatus species --> (27) K. (G.) curtihobus --> (28) K. (G.) trichophorus [?=K. (G.) gullheiti] --> (29) group of Sigaloceras (Sigaloceras) callovianus and S. (S.) nicas species --> (30) group of S. (Catadigalogoceras) enodatum --> [K. (G.)] Kosmoceras (Galilimites) (el 1?).

of the group of Sigaloceras (Sigaloceras) callovienne (Sow.) and S.(S.) micans Buckm.–group of S. (Catascigaloceras) enodatum (Nik.) (Fig. 6, nos. 24–30). In this case, we observe the gradual transition from forms, which have wide coarse-ribbed echinate whorls, the relatively high ribbing density on the terminal body chamber, and wide umbilicus (K.(G.) unzhae), to other forms having the high fine-ribbed whors, widely spaced broad or completely smoothen primary ribs on the terminal body chamber, and narrow umbilicus (Sigaloceras).

In addition to Gowericeratinae, Cadoceratinae and Perispincintidae are the main groups characterizing the Koenigi and Callovienne zones. However, phylogenetic links within these groups are insufficiently known (especially in the latter), and their significance for detailed stratigraphy is uncertain. For instance, the subfamily Cadoceratinae reveals transition from forms similar to Cadoceras (Cadoceras) tolype Buckm. to the forms similar to C.(C.) sublavee (Sow.) and C.(C.?)(tschekhini) (Orb.), and finally to the subgenus Roudiceras Troitskaya (Fig. 6, nos. 12–17). By this transition, ribbing becomes reduced and narrows umbilicus of the early whors grows wider afterward. However, in addition to this general trend, there could be some deviating or even parallel lines responsible for origin of C.(C.?)(confusum) (Gul.), C. (“Bryocadoceras”) proniense Sas., and some other species.

Species of the subfamily Cadoceratinae distinctly dominate components in most assemblages of the Infimum and Elatmae zones (Fig. 7). Accordingly, they can be used as index species of most biohorizons spanning this stratigraphic interval. Representatives of the subfamily Gowericeratinae serve as index species of biohorizons established in the Koenigi and Callovienne zones, where these forms are abundant.

THE UPPER BATHONIAN–LOWER CALLOVIAN INFRAZONAL SCALE

The upper Bathonian–lower Callovian zones and biohorizons of Central Russia are characterized below. Also presented in the article are infrazonal correlation schemes of the described sections (Table 1), the upper Bathonian–lower Callovian stratigraphic scales for Central Russia, Northwest Europe, eastern Greenland, and Northern Siberia (Table 2), as well as stratigraphic ranges of ammonite taxa (Fig. 6) and dynamics of relative abundance of ammonite subfamilies in the C. infimum–K. densicostatus biohorizons (Fig. 7).

Upper Bathonian

Infimum Zone

Index species: Cadoceras (Catascadoceras) infimum Gulyaev et Kiselev, 1999. The holotype no. 2/627 from the Prosek-Isady section, Nizhni Novgorod area, (Gulyaev and Kiselev, 1999, Plate I, fig. 1) is stored at the Chair of Zoology of the Yaroslavl State University.

Nomenclature. The local Infimum Zone is established on the basis of peculiar fauna discovered below the Elatmae Zone of the Middle Volga region (Gulyaev and Kiselev, 1999).

Paleontological characteristics. The Infimum Zone corresponds to the earliest formation stage of the East European sea basin prior to its connection with the Tethyan and West European seas. The ammonite fauna of exclusively boreal (arctic) origin includes archaic representatives of subfamilies Cadoceratinae Hyatt (Cadoceras (Catascadoceras) Bodlevsky [M] and Costacoceratinae Rawson [m]) and Gowericeratinae Buckman (Kepplerites (Kepplerites) Neumayr [M] and Toricellites Buckman [m]). Similar assemblages were previously known only from the upper Bathonian deposits of the Arctic regions, namely from eastern Greenland (Spath, 1932; Callomom, 1993; and others) and Spitsbergen (Ershov, 1983; Kopik and Wierzbowski, 1988; and others). The distinct predominance of Gowericeratinae in the lower part of the zone and of Cadoceratinae in the upper one serves as a basis for distinguishing the respective biohorizons. Changes in abundance are interrelated with morphological transformations. In the upper part of the zone, representatives of C. (Catascadoceras) group demonstrate less coarse ribbing and K. (Kepplerites) forms show wider spaced primary ribs on the mature body chamber.

Stratigraphic position. The Infimum Zone cannot be directly correlated with the standard West European
Table 1. Infrazonal correlation of the upper Bathonian–lower Callovian sections of Central Russia

<table>
<thead>
<tr>
<th>Substage Zone</th>
<th>Prosek-Isady</th>
<th>Uzhovka</th>
<th>Pezhenga</th>
<th>Alpat’ev</th>
<th>Biohorizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callovien</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>a10</td>
<td>S. calloviense</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>a9</td>
<td>K. trichophorus</td>
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<tr>
<td>a8</td>
<td>K. kurilobus</td>
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</tr>
<tr>
<td>a7</td>
<td>K. densicostatus</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Koenigi</td>
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</tr>
<tr>
<td>a6</td>
<td>C. subpatraus</td>
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</tr>
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<tr>
<td>a2</td>
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<td>S. calloviense</td>
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<td>a8</td>
<td>K. kurilobus</td>
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<td>a1</td>
<td>C. infimum</td>
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</table>

The boreal origin of ammonite faunas allows the *Infimum* Zone to be correlated with the Arctic zonal and infrazonal scales. As shown below, similarity and even identity of *Kepplerites* species validates correlation between biohorizons of the *Infimum* and *Calyx* zones of eastern Greenland.

The index species of the *Infimum* Zone is similar to *C. (C.) barnstoni* (Meek) representing the index species of the upper Bathonian zone that is recognized in the Northern Yukon region, Arctic Canada (Poulton, 1987), and Northern Siberia (Meledina, 1991, 1994). In eastern Greenland, forms similar to *C. (C.) barnstoni* are recorded predominantly in upper beds of the *Variabile* Zone, but some later representatives of *C. (Catacadasquerceras)* group were found at the base of the *Calyx* Zone (Callomon, 1993). Most likely, the *Infimum* Zone,
Table 2. Correlation of the upper Bathonian–lower Callovian zonal and infra-zonal scales for Central Russia, northwestern Europe, eastern Greenland, and northern Siberia (author’s interpretation)

<table>
<thead>
<tr>
<th>Substage</th>
<th>Zone</th>
<th>Biohorizon</th>
<th>Substage</th>
<th>Zone</th>
<th>Biohorizon</th>
<th>Substage</th>
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<th>Biohorizon</th>
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<td>*G.~callovio*</td>
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<td>*G.~callovio*</td>
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<td>M.~kampiusβ</td>
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<td>S.~enodatumβ</td>
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<td>S.~enodatumβ</td>
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<td>S.~mecans</td>
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<td>S.~mecans</td>
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<td>S.~enodatumα</td>
</tr>
</tbody>
</table>

Note. Abbreviations designate the following taxa: (B.) \*Bulatimorphites\*, (C.) \*Cedoceras\*, (Cal.) \*Callovio\*, (Ch.) \*Chamaansieta\*, (Cl.) \*Chidoniceras\*, (Gal.) \*Gali-\*laeitii, (H.) \*Homoeocephalites\*, (Hann.) \*Hannoverianus\*, (Holl.) \*Hollandii\*, K. \*Kepplerites\*, (M.) \*Macrocephalites\*, (Nordensk.) \*Nordenskjoldii\*, (O.) \*Oxycerites\*, (S.) \*Siga-\*lovecras, (Terebr.) \*Terebratula\* Var. \*Variabilis\*. 

as well as the Calyx Zone, should be correlated with the upper part of the Barnstoni Zone of Siberia.

**Distribution.** At present, the Infimum Zone is reliably established in the Prosek-Isady section only. However, it seems to be present not only in middle courses of the Volga River, but also in northern and eastern areas of European Russia (in accordance with the supposed configuration of the paleobasin).

C. *infimum* Biohorizon

Index species: *Cadoceras* (Cadacodoceras) *infimum* Gulyaev et Kissilev.

**Nomenclature.** The *C. infimum* Biohorizon is established in the upper part of sands underlying clays of the Elatmae Zone of the Prosek-Isady section (Gulyaev and Kissilev, 1999). My subsequent study in 1998 revealed two successive ammonite assemblages confined to this level. The lower assemblage (Fig. 2, a1) shows paleontological characteristics initially suggested for the *C. infimum* Biohorizon.

**Paleontological characteristics.** Representatives of subfamily Gowericeratinae, the dominant and highly variable Kepplerites (Kepplerites) svalbardensis Sok. et Bodily included, constitute approximately 80% of the ammonite assemblage (Plate I, Fig. 4). Few found specimens of *K. (K.)* cf. rosenkrantzi Spath have wide echinate early whorls decorated with coarse ribs. Microconchs of Toricellites pauper (Spalth) and *T. aff. pauper*, the latter with coarser ribs, represent up to 10–15% among all forms of Gowericeratinae. About 20% of ammonites belong to subfamily Cadoceratinae represented by species *C. (C.)* *infimum* Gul. et Kiss. (Plate I, fig. 5) and *Costacodoceras pisciculcns* Gul., which have coarse ribbing at the intermediate to late stages of growth and slightly involute whorls of shell up to 5 or 6 cm in diameter.

**Stratigraphic position.** The *C. infimum* Biohorizon corresponds to the lower part of the Infimum Zone. The ammonite assemblage of the biohorizon is similar to that of the upper Bathonian deposits in eastern Greenland, as they both include common Kepplerites forms (Callomon, 1993). *K. (K.)* svalbardensis of the *C. infimum* Biohorizon was reported from the lower *K. peramplus* Biohorizon of the Calyx Zone of eastern Greenland, and *K. (K.)* rosenkrantzi is characteristic of the synonymous upper biohorizon of the preceding Variabile Zone. Typical forms of the latter belong to the subgenus Cadoceras (Cadacodoceras), although younger representatives of this subgenus are also recorded at the base of the Calyx Zone. Thus, at the first sight, ammonite fauna of the *C. infimum* Biohorizon corresponds to that characterizing two biohorizons of eastern Greenland, where each bears its peculiar set of species. Such a conclusion is misleading, because all ammonites of the *C. infimum* Biohorizon were found associated in the same concretions. Most likely, the *C. infimum* Biohorizon should be correlated with the lower half of the *Calyx* Zone (the *K. peramplus* Biohorizon), where the assemblage is dominated by *K. (K.)* *svalbardensis*. Callomon (Dietl and Callomon, 1988; Callomon, 1993) correlates the *Calyx* Zone with the standard Orbis Zone of Western Europe, because its upper Hannoveranum Subzone in Bavaria contains Kepplerites (Kepplerites) cf./aff. *peramplus* Spath similar to that from eastern Greenland. It is difficult to evaluate how reliable is this version, but from the last standpoint, the *C. infimum* Biohorizon should also be correlated with the upper part of the Orbis Zone.

**Distribution:** the same as that of the zone as a whole.

C. *cf./aff. infimum* Biohorizon

Index species: the form tentatively identified as *Cadoceras* (Cadacodoceras?) *cf./aff. infimum* Gul. et Kiss. Because of the poor preservation state, it is still unclear whether this form represents an independent species or the transient *C. (C.)* *infimum* variety.

**Nomenclature.** The *C. cf./aff. infimum* Biohorizon is established in the uppermost sands underlying clays of the Elatmae Zone in the Prosek-Isady section (Fig. 2, assemblage a2). The unit is contiguous to the *C. infimum* Biohorizon.

**Paleontological characteristics.** Poorly preserved ammonites are identified in terms of open nomenclature. Species of subfamily Cadoceratinae represent more than 90% of the assemblage. *C. (C.)* *cf./aff. infimum* greatly resembles the index species of the preceding biohorizon, but it has less coarse ribbing. *Costacodoceras cf. pisciculcns* is almost indistinguishable from *Pisciculcns* typical of the underlying deposits. The subfamily Gowericeratinae is represented by rare specimens of Kepplerites (Kepplerites) sp. ind., which have ribbing slightly coarser than that of most specimens of *K. (K.)* *svalbardensis* from the preceding biohorizon.

**Stratigraphic position.** The *C. cf./aff. infimum* Biohorizon corresponds to the upper part of the Infimum Zone. According to its position relative to the previous biohorizon, the *C. cf./aff. infimum* Biohorizon should be correlated with the upper part of the *Calyx* Zone (the *K. vardekloefensis* Biohorizon) of eastern Greenland. Depending on dating of adjacent levels, the *C. cf./aff. infimum* Biohorizon can be correlated to either the upper or lower part of the standard Discus Zone.

**Distribution:** the same as that of the zone as a whole.

Lower Callovian

**Elatmae Zone**

Index species: *Cadoceras* (Paracodoceras) *elatmae* (Nikitin, 1878). The neotype no. 34/1344 from the Ryazan' area near the town of El'tma (Nikitin, 1881, Plate 11 (4), fig. 20) is stored at the Chernyshev Geological Museum of St. Petersburg.
Plate I. Characteristic late Bathonian–early Callovian ammonite species of central Russia (actual size)

(1) Macrocephalites (Macrocephalites) jacquit (H. Douville), no. 2/1277; (1a) left view, (1b) right view: the Prosek-Isady section. Elatmae Zone, the M. jacquit Biohorizon. (2) M. (M.) jacquit (H. Douville), no. 8/1355; (2a) side view, (2b) ventral view: the Churkina section (the Pizhma River area, Komi Republic). Elatmae Zone, M. jacquit Biohorizon. (3) Kepplerites (Govericeras) densicosstatus Tintant, no. 5/1175; (3a) side view, (3b) ventral view: the Uzhovka section. Koenigf Zone, K. densicosstatus Biohorizon. (4) K. (Kepplerites) svalbardensis Sokolov et Bodylevsky, no. 2/676: side view: the Prosek-Isady section. Infimum Zone. C. infimum Biohorizon. (5) Cadoceras (Catacadoceras) infimum Gulyaev et Kisselev, the holotype no. 2/627; (5a) side view, (5b) ventral view: the Prosek-Isady section. Infimum Zone. C. infimum Biohorizon.
Nomenclature. “Stage of Stephanoceras elatmae” was distinguished for the first time by Nikitin (1881) in the Callovian deposits of the Elat’ma area in the scope of the entire lower Callovian.

The Cadoceras elatmae Zone suggested by Sazonov (1953) was officially authorized for the Russian platform at the All-Union Conference on the Unified Mesozoic Stratigraphic Scheme (Resheniya..., 1955). The zone was positioned above the Arctioceras ishmae Zone and below the Kepplerites callovensis–K. gowerianus Zone. It is characterized by the following zonal assemblage: Macrocephalites macrocephalus (Schloth.) [until the recent time, this was the traditional name for most Macrocephalites forms with discoidal shells], Cadoceras elatmae (Nik.), C. modiolare (Luid.) [=C. simulans Spath], C. frearsi (Orb.), C. subpatatus Nik., Chamosnaita chamosseti (Orb.) [probably, Ch. (?) saratovensis Call. et Wright, or morphologically similar Macrocephalites pavlov Smor]. Kepplerites gowerianus (Sow.) [probably, K. unzhae Gul.], and others (Sazonov, 1953, 1957). Later (Resheniya..., 1962), the zone was named after two index species: Cadoceras elatmae and Macrocephalites macrocephalus.

When Meledina revealed that the Elatmae Zone yields only Cadoceratinae forms, the zone was denoted again after C. elatmae, and the underlying beds with M. macrocephalus were provisionally attributed to the lowermost Callovian (Zony..., 1982). Later Meledina (1986, 1987) concluded that there is no reliable evidence of Macrocephalites occurrence below the Cadoceras level in the Russian platform. Consequently, it is unnecessary to recognize the Macrocephalites level below the Elatmae Zone.

Analyzing vertical ranges of early Callovian ammonites in the Volga region near Saratov (the Malinovyi Ravine), Alekseev and Repin (1989), and afterward Repin and Rashvan (1996) suggested to change the nomenclature of the Elatmae Zone using the new index species Costacodoceras mundum (Sas.). They argued that C. (P) elatmae is confined to the upper part of the zone, whereas only single C. mundum and Macrocephalites (Macrocephalites) cf. triangularis Spath. were found below. Accordingly, the Mundum Zone was subdivided into the Macrocephalites ex gr. jacquoti and Cadoceras elatmae subzones. However, it is a norm, when the index species range corresponds only to a part of the corresponding stratigraphic unit, and this is not a reason to change the unit name.

In this article, the Elatmae Zone is considered in approximately the same scope as initially suggested by Sazonov. Previously Kiselev and myself (Gulyaev and Kiselev, 1999; Gulyaev, 1999) pointed to the provisional character of the lower boundary of the Elatmae Zone. After the additional study of the Prosek-Iscady section in 1998, this boundary was confidently establish at the first occurrence level of representatives of the genus Macrocephalites Zittel. This datum corresponds to the time, when the East European sea basin became connected with the Tethyan seas and entered the subbooreal stage of development.

Paleontological characteristics. In the ammonite assemblages of the zone, dominant boreal forms are associated with some Tethyan taxa. The faunas are highly endemic.

The boreal subfamily Cadoceratinae Hyatt is dominant (75–90%) throughout the zone (Fig. 7). In the lower and middle parts of the zone, the subfamily is represented by species of the subgenera Cadoceras (Paracerdos) Crickmay and, to a lesser extent, by those of C. (Bryocadoceras) Meledina. In the lower beds of the second half of the zone, the endemic genus Cadochamoussetia Mitaa separates from the latter subgenus to give rise the genus Chamoussetia Douville characteristic of the upper beds. Species of these taxa are much more abundant than macroconchs of Cadoceratinae. Species of the group of C. (“B.”) simulans Spath. occur sporadically but throughout the zone. Microconchs of the genus Costacodoceras Rawson also occur throughout the zone displaying the shell size diminishing, increasing ribbing density, and slightly growing involute of whorls.

Abundance of forms representing the low-boreal subfamily Gowericeratinae Buckman is not greater than 10–15% of the ammonite assemblages. At the base of the zone, the subfamily is represented by Kepplerites (Kepplerites) Neumayr and Toricellites Buckman, both retaining similarity with taxa of the previous Infinum Zone. Above (the C. elatmae Biohorizon), the Gowericeratinae forms disappear completely and occur again in the middle part of the zone, where the subfamily is represented by presumably endemic K. (Gowericeras) Buckman and Toricellites forms, which have wide echnate whorls in contrast to the earlier forms.

Scarce (not more than 10% of the assemblage) but characteristic species of the Tethyan subfamily Macrocephalitinae Salfeld were found in the lower and middle parts of the zone. Their occurrence suggests connections between the East European and Tethyan sea basins that was favorable for faunal exchange. Among the Macrocephalitinae forms, there are some peculiar and, most likely, endemic species.

Representatives of the Pan-Tethyan subfamily Pseudoperisphinctinae Shindewolf (the genus Homoeoplanulites Buckman) appear in the middle and upper parts of the zone representing up to 10% of the ammonite assemblages.

Stratigraphic position. In general, the Elatmae Zone is considered to be analogous to the basal Callovian Herveyi Zone of the standard scale. As shown below, some stratigraphic levels of both zones are correlative to each other owing to the occurrence of similar and identical representatives of genera Cadoceras, Kepplerites, and Macrocephalites. However, it is not improbable that the ambiguously dated lower boundary of the Elatmae Zone can be lowered down to the lower
part of the upper Bathonian Discus Zone of the standard scale (see below).

The occurrence of subgenera Cadoceras (Paracadoxoceras), C. (Bryocadoceras), and Kepplerites (Kepplerites) permits the Elatmae Zone to be correlated with the Apertum and Nordenskjoeldi zones of eastern Greenland (Callomon, 1993) and with the Falsum and Anaharense zones of northern Siberia (Medelina, 1994). The lower part of the Elatmae Zone may correspond to the Bodylevskyi Zone of the northern Yukon (Poulton, 1987).

**Distribution.** The Elatmae Zone can be recognized over the greater part of the European Russia.

**M. jacquoti Biohorizon**

Index species: Macrocephalites (Macrocephalites) jacquoti (H. Douville, 1878) [nom. nov. pro Amm. Macrocephalus compressus Quenstedt, 1849, p. 184, Plate 15, fig. 1].

**Nomenclature.** The M. jacquoti Biohorizon contiguous to the C. cf. aff. infimun Biohorizon is distinguished in basal clays of the Elatmae Zone of the Prosek-Isady section (Fig. 2, assemblage a3).

**Paleontological characteristics.** In general, the ammonite fauna inherits characteristics of the Infimum Zone assemblages. Up to 80%, it is constituted by representatives of the subfamily Cadoceratinae. The form identified as Cadoceras (?Paracadoxoceras/Catacadoxoceras) aff. infimun differs from C. (C.) infimun and C. (C.) cf. aff. infimun owing to more involute inner whorls and finer and denser ribbing. Ribbed shells of C. (?P.C.) aff. infimun are up to 60 mm in diameter. Their generic affiliation is uncertain, because the subsequent stages of growth are known. In contrast to C. piscicultris, microconchs of Costococercus sp. have smaller size and higher ribbing density. Representatives of the subfamily Gowerceratinae represent approximately 10% of the assemblage. Species Kepplerites (Kepplerites) ex gr. keppleri (Opp.) with coarser and wider spaced ribs are different from preceding forms of the genus. One microconch of Toricellites sp. that was found differs from older species T. pauper, since it has primary ribs wider spaced on the mature body chamber. The biohorizon in question marks the first occurrence level of representatives of the Tethyan subfamily Macrocephalitaenae (M. (M.) jacquoti (Plate I, figs. 1, 2), which have discoid-conical shell with high rounded-triangular whorls and fine sculpture rapidly smoothing on lateral sides. The Macrocephalitaenae forms represent about 10% of the ammonite assemblage.

**Stratigraphic position.** The M. jacquoti Biohorizon marks the lower boundary of the Elatmae Zone. The combination of M. (M.) jacquoti and K. (K.) keppleri characteristic of the basal K. keppleri Biohorizon of the North European Herveyi Zone (Callomon et al., 1988, 1989, 1992; Page, 1989) indicates that these biohorizons are correlative. In Germany (Schwabia) however, M. (M.) jacquoti appears for the first time in the lower part (the Hollandi Subzone or Cl. Hollandi Biohorizon) of the Discus Zone (Callomon et al., 1989). Forms similar to K. (K.) keppleri have a wide stratigraphic range (the C. apertum biohorizons) in eastern Greenland (Callomon, 1993). Owing to these facts, the M. jacquoti Biohorizon (and consequently, the base of the Elatmae Zone) can be placed at the level of the lower part of the Discus Zone. In this case, the preceding Infimum Zone corresponds to the interval of the Orbis Zone coupled with the lower part of the Discus Zone. Such a conclusion agrees with the scheme suggested by Callomon (Dietl and Callomon, 1988; Callomon, 1993), who correlated the Calyx Zone of eastern Greenland (correlative with the Infimum Zone) with the standard Orbis Zone.

**C. elatmae Biohorizon**

Index species: Cadoceras (Paracadoxoceras) elatmae (Nikitin).

**Nomenclature.** The C. elatmae Biohorizon was recognized in the sections of Prosek-Isady (Fig. 2, assemblage a4), Uzhovka (Fig. 3, assemblage b1), Pezhenga (Fig. 4, assemblage c1), Manturovo-Znamenka, and Ivkino localities (Gulyaev and Kiselev, 1999; Gulyaev, 1999). In the Prosek-Isady section, none of ammonites was found in the interval separating the first occurrence level of C. (P.) elatmae from the level of the M. jacquoti assemblage.

**Paleontological characteristics.** Ammonites of the subfamily Cadoceratinae, the dominated C. (P.) elatmae (Plate II, fig. 4) included, represent more than 90% of the assemblage. Single specimens of C. ("Bryocardoceras") simulans Spath have extremely inflated shells with radial ribs curved sometimes backward. Microconchs of Costacocercas mundum (Sas.) are smaller in size than the early forms of this genus. The biohorizon exhibits the maximal diversity of Macrocephalitaenae species, which represent, however, only about 10% of the assemblage. The most common species is Macrocephalites (Macrocephalites) volgae Gul. (Plate VI, Fig. 1) with widely spaced and broad primary ribs. M. (M.) proskeensis Gul. [nom. nov. pro M. (M.) ex gr. jacquoti (Douv.), holotype (Gulyaev, 1999, p. 73, Plate I, Fig. 1)] is also frequently occurring. This form
seems to be a descendant of *M. (M.) jacquoti*; its ventral side is narrower and lateral ribs become smoothed at an earlier stage of development. The Prosek-Isady section also yielded a single specimen of *M. (Kamptiokephalites?)* sp. juv.

**Stratigraphic position.** The *C. elatmae* Biohorizon approximately corresponds to the upper half of the lower third of the *Elatmae* Zone. In the scheme suggested, it overlies with a hiatus the *M. jacquoti* Biohorizon. The precise correlation of the *C. elatmae* Biohorizon to the standard scale is possible due to occurrence of some *Cadoceras* forms similar to *C. (P) elatmae* from the lower part of the *Herveyi* Zone of Germany (Schwab). These forms are *C. (P) quenstedti* Spath (nom. nov. pro *Amm. sublaevis* Quenstedt, 1887, Plate 79, fig. 7) from the synonymous biohorizon in the middle part of the *Kepperi Subzone* and *C. (P) suevicum* Call. et al. (nom. nov. pro *Amm. sublaevis macrolephali* Quenstedt, 1849, Plate 14, fig. 6; 1887, Plate 79, fig. 3), transient subspecies of which were found in the synonymous biohorizons situated in the upper part of the *Kepperi Subzone*, and also in the lower part of the *Terebratus Subzone* (Callomon et al., 1988, 1989, 1992). As is noted by many specialists (Callomon et al., 1988; Sei and Kalacheva, 1992, and others), *C. (P) quenstedti* is very similar to *C. (P) elatmae*, but *C. (P) suevicum* seems to be indistinguishable from the latter. Accordingly, the *C. elatmae* Biohorizon is correlative with the *C. suevicum* α, β biohorizons of Germany.

**Distribution:** probably the same as that of the entire zone.

### C. tschernyschewi Biohorizon

*Index species:* *Cadoceras* (Bryocadoceras) *tschernyschewi* Sokolov, 1912. The lectotype (Sokolov, 1912, Plate 1, fig. 2) is stored in the Chernyshev Geological Museum of St. Petersburg, no. 4/1370. The Tsil'ma River area.

**Nomenclature.** The *C. tschernyschewi* Biohorizon (Fig. 4, assemblage c3) is reliably established in the Pezhenga section only (Gulyaev, 1999).

**Paleontological characteristics.** Over 80% of the ammonite assemblage are represented by the subfamily Cadoceratinae. Shells of most common *C. (B.) tschernyschewi* (Plate III, fig. 1) are swollen to a various extent and show variably wide umbilici. Among these forms with relatively narrow umbilici, the extremely inflated variants resemble *Cadoceras* s.s., and the flattened ones are similar to *Cadomachampsia* shells. In addition, the coexisting single *C. ("B.") aff. simulans* Spath differ from *C. ("B.") simulans*, as they have slightly narrower umbilici and hardly noticeable ribbing bend in the middle of the ventral side of early whorls. Microconchs of Cadoceratinae are mainly represented by *Costacadoceras* sp nov. aff. *mendum* (Sas.), which have narrower ventral sides and more involute whorls than *C. mendum*. Representatives of the subfamily Gowericeratinae constitute approximately 10–15% of the assemblage. The biohorizon is proved to be marking the first occurrence of the subgenus *Kepperites* (*Gowericeras*) represented by the archaic species *K. (G.) unzei* Gul. (Plate VI, fig. 2), which retain dense ribbing on the mature body chamber (type feature of *Kepperites* s.s.) but already has relatively broad whors with well developed lateral spines (features of *Gowericeras* forms). Spines of this kind are also characteristic of microconchs *Toricellites pezhenae* (Gul.). The first occurrence of Pseudoperispinctiinae represented by sporadic *Homoeoplanulites* sp. ind. is also typical of the biohorizon.

**Stratigraphic position.** In the Pezhenga section, *C. (B.) tschernyschewi* was found above the level of *C. (P) elatmae*. According to its morphology, it is the ancestor of *Cadomachampsia tscherrii*. This enables positioning of the *C. tschernyschewi* Biohorizon between the *C. elatmae* and *C. surensis* biohorizons. The Prosek-Isady and Uzhovka sections of the Nizhnii Novgorod area yielded a similar form, which was identified as *C. (B.) ex gr. tschernyschewi* differing from the classic *C. (B.) tschernyschewi* in its narrower umbilicus. The form probably characterizes the *C. surensis* Biohorizon, however, its occurrence below the level of *C. surensis* is not improbable. The position of the *C. tschernyschewi* Biohorizon above the *C. elatmae* Biohorizon suggests its approximate correspondence to the middle part of the *Terebratus Subzone*.

**Distribution.** In Central Russia, the *C. tschernyschewi* Biohorizon is established in the northernmost Pezhenga section. Data on *C. (B.) tschernyschewi* finds in the lower Callovian beds near Saratov (Kamyshcheva-Elpat’evskaya et al., 1956, 1959) are doubtful and may characterize a swollen variety of *C. (P) elatmae*. The biohorizon may be distinguished in the Pechora River basin.

### C. surensis Biohorizon

*Index species:* *Cadomachampsia surensis* (Nikitin, 1985). The lectotype no. 36/1486, Sura River locality (Nikitin, 1985, Plate 10/12, no. 54) is stored at the Chernyshev Geological Museum (St. Petersburg).

**Nomenclature.** The *C. surensis* Biohorizon is distinct and well characterized by fauna in the Prosek-Isady (Fig. 2, assemblage a5) and Uzhovka (Fig. 3, assemblage b2) sections, where it overlies, after an insignificant interval, the *C. elatmae* Biohorizon (Gulyaev and Kiselev, 1999; Gulyaev, 1999).

**Paleontological characteristics.** Almost 80% of the ammonite assemblage are represented by the subfamily Cadoceratinae, where dominant species is *C. surensis* (Plate IV, fig. 2). Although its shells are variably swollen, this species is generally close to the classic narrow-shell type. Single specimens of *Cadoceras* (Bryocadoceras) ex gr. *tschernyschewi* Sok. are characterized by inflated shell and moderately narrow
C. (Paracococeras) cf. primaeveum Sas. with slightly involute inner whorls is supposed to be found at this level of the Prosek-Isady section. Microconchs of Cadoceratinae are represented by Costacococeras aff. mundum (Sas.), whose ventral side is narrower than that of C. mundum. The subfamily Gowericeratinae represented by forms similar to C. mundum. The subfamily Gowericeratinae representing up to 10% of the ammonite assemblage includes species Kepplerites (Gowericeras) unzhae Gul. and Toricellites pezhengaevi (Gul.). In addition, the Uzhovka section yielded single forms with closer spaced ribs, which are tentatively identified as K. (G.) aff. unzhae. The subfamily Macrocephalitinae constitutes only about 5% of the ammonite assemblage. It is represented by the peculiar species Macrocephalites (Macrocephalitinae) pavlovii Smor. (Plate 2, fig. 3; Plate III, fig. 2), whose narrow shells are sharpening toward the ventral side of early whorls and have lateral sculpture smoothening at the early growth stage. About 10% of the ammonite assemblage belong to the subfamily Pseudoperisphinctinae represented by several species of the genus Homoeoplanoitulites.

Stratigraphic position. In the Uzhovka and Prosek-Isady sections of the Nizhnii Novgorod area, the ammonite assemblage of C. surensis Biohorizon succeeds the C. elatmae assemblage after a minor interval. Probably, this interval includes ammonites similar to C. (B.) tschernyschewi. The stratigraphic position of the C. surensis Biohorizon suggests its position approximately corresponding to the Lower part of the Kamptus Subzone and, probably, to the uppermost interval of the Terebratula Subzone of the standard Herveyi Zone.

Distribution. The C. surensis Biohorizon is recognized in the Middle Volga region and adjacent areas.

C. subpatraus Biohorizon

Index species: Cadochamoussetia subpatraus (Nikitin, 1885). The holotype no. 38/1486 from the Sura River area (Nikitin, 1885, Plate 11) is stored at the Chernyshev Geological Museum of St. Petersburg.

Nomenclature. The C. subpatraus Biohorizon is best manifested in the Uzhovka section (Fig. 3, assemblage b3), where it immediately overlies the C. surensis Biohorizon. Single specimens of C. subpatraus (Fig. 2, assemblage a6) were also found in the Prosek-Isady section (Gulyaev, 1999).

Paleontological characteristics. Nearly 75–80% of the ammonite assemblage are represented in the studied collections by the only species C. subpatraus of the subfamily Cadoceratinae (Plate III, fig. 3). This species marks the stage that resulted in appearance of Chamoussetia forms among Cadoceratinae. Within its stratigraphic range, C. subpatraus demonstrates a complete spectrum of morphological changes from the forms similar to C. surensis (Nik.) to those virtually indistinguishable from C. (G.) saratovensis Call. et Wright. The subfamily Gowericeratinae represented by Kepplerites (Gowericeras) cf. unzhae Gul., whose relative abundance is approximately 10–15%. The subfamily Pseudoperisphinctinae (Homoeoplanoitulites sp. ind.) constitutes about 10% of the assemblage.

Stratigraphic position. The stratigraphic position of C. subpatraus Biohorizon suggests its approximate correlation with the middle part of the Kamptus Subzone of the standard Herveyi Zone.

Distribution. The C. subpatraus Biohorizon was reliably established only in middle courses of the Volga River.

Ch. saratovensis Biohorizon

Index species: Chamoussetia (?) saratovensis Callomon et Wright, 1989 (nom. nov. pro Ch. chamousseti (Sazonov, 1965, p. 38, Plate 9, Fig. 1). The holotype no. VI-146/28 from the Volga region near Saratov (Kamysheva-Elpat'evskaya et al., 1956, p. 47, Plate 19, Fig. 57; 1959, p. 148, Plate 11, Fig. 5) is stored at the Vernadsky Geological Museum.

Nomenclature. The Ch. saratovensis Biohorizon can be recognized only in the Uzhovka section (Fig. 3, assemblage b4) (Gulyaev, 1999) above the C. subpatraus Biohorizon.

Paleontological characteristics. The subfamily Cadoceratinae represents approximately 75–80% of the ammonite assemblage. According to morphological characters, one macroconch Ch. (?) saratovensis (Plate IV, fig. 3) that was found can be referred to the genus Chamoussetia Douville. However, some archaic characters, such as slightly sharpened ventral side, absence of opressed carina, and coarser sculpture persistent in ontogenesis, differ this species from representatives of the Ch. chamousseti (Orb.) group of the Koenigi Zone. At the same time, it is very similar to Cadochamoussetia forms. Microconchs of Cadoceratinae are represented by rare Costacococeras (?) sp. ind. About 10–15% of the ammonite fauna are represented by Kepplerites (Gowericeras) ex gr. toricelli (Opp.) from the subfamily Gowericeratinae, and about 10% by Homoeoplanoitulites (?) sp. ind. from the subfamily Pseudoperisphinctinae.

Stratigraphic position. In the scheme suggested here, the Ch. saratovensis Biohorizon is placed at the top of the Elatmae Zone. The assemblage including K. (G.) toricelli, Homoeoplanoitulites spp., and other ammonites characterizes the lowest K. toricelli Biohorizon of the lower Callovian Koenigi Zone in Germany (Schwabia) (Callomon et al., 1988, 1989). On this basis, the Ch. saratovensis Biohorizon can be correlated, at least partially, to the lower beds of the standard Koenigi Zone. However, the low preservation degree of ammonites representing genera Kepplerites and Homoeoplanoitulites is an obstacle for their comparison with counterpart from Western Europe, where they may be younger than in Central Russia. The precise correlation is also complicated by the ambiguous position of
the lower boundary of the Koenigi Zone (Callomon et al., 1988, 1989; Callomon, 1993). Until the moment when additional data will be available, the Ch. saratovensis Biohorizon should be included into the Elatmae Zone because of facies and paleontological affinity (Gulyaev, 1999).

**Distribution.** The Ch. saratovensis Biohorizon is established in the Middle Volga region. Finds of its index species suggest that this unit may extend into the Volga region near Saratov and adjacent areas.

**Koenigi Zone**

Index species: Proplanulites (Proplanulites) koerni (Sowerby, 1820). The lectotype was chosen by Buckman in England (1921, p. 36) and pictured by Arkell (1956, Plate 37, fig. 4).

**Nomenclature.** The Koenigi Zone was distinguished in the lower Callovian deposits of England by Buckman (1913). Callomon (1955, 1964) considered this stratigraphic unit as the lower subzone of the Callovienne Zone. At present the lower Callovian of the standard West European scale is again subdivided into the Herveyi, Koenigi, and Callovienne zones. The Koenigi Zone includes the Gowerianus, Curtilobus and Galilaei subzones (Callomon et al., 1988; Page, 1989).

The nomenclature of the uppermost Galilaei Subzone is doubtful. Oppel (1862) used name Amm. gali- laei for the form that was described by Orbigny (1847, Plate 162, figs. 10, 11) as Amm. calloviiensis Sow. Later, the original photograph by Orbigny was published by Tintant (1963, Plate 21, fig. 1) under name Sigaloceras callovienne. However, specimen pictured by Buckman (1922, Plate 290), but not that described by Orbigny, was chosen by Page (1989) and other West European authors (probably, following him) as the lectotype of K. (G.) gali laei (Opp.) under the name Galilaeiceras gali laei (Opp.). As is correctly noted by Meledina (1987), this ammonite is essentially different from the original of Orbigny. In my opinion, it should be classified as K. (G.) curtlobus (Buckm.). In Fig. 7 (2) reproduced by Page (1989), K. (G.) gali laei (Opp.) also differs from the "lectotype" of Buckman resembling instead K. (G.) trichophorus (Buckm.) intermediate in morphology between K. (Gowericeras) and Sigaloceras s.s.

In the Russian platform, the local Kepplerites callovianensis–K. gowerianus Zone was recognized long ago in the upper part of the lower Callovian deposits above the Elatmae Zone (Resheniya..., 1955, 1962; Postanovlenie..., 1978). Using the great similarity of ammonite faunas from Western Europe and Russian platform, Meledina (1986, 1987) proposed to apply the standard biozonation to the upper part of the lower Callovian in European Russia.

**Paleontological characteristics.** In contrast to the Elatmae Zone, the Koenigi Zone of Central Russia shows an increased percentage of forms of the subfamilily Gowericaterinae and a noticeable amount of representatives of the subboreal subfamily Proplanulitinae.

The subfamily Cadoceratinae represents in average 40–50% of the ammonite assemblage. The subfamily mostly consists of species of the subgenus Cadoceras s.s. The genus Chamoussetia Douville is also characteristic of the zone, especially of its lower part. These groups are associated with relatively rare forms similar to C. ("Bryococerds") laetum Gul. (descendants of the C. ("B") simulans group). Their last whorls resemble those of Cadoceras s.s., but the earlier growth stages are characterized by more inflated shell decorated with radial ribs slightly curved backward. Microconchs of Cadoceratinae are represented by subgenera Pseudococerds (Pseudococerds) Buckman and P. (Novococerds) Sasonov. Some evolute forms bear similarity to the genus Costacocerds Rawson.

The subfamily Gowericaterinae is also an important component of the ammonite assemblages (40–50 and occasionally up to 70%). Its representatives Keppler- ites (Gowericeras) Buckman [M] and Toricellites Buckman [m] gradually reshape into Sigaloceras (Sigaloceras) Hyatt [M] and Guliemina Buckman [m] respectively, which are characteristic of the following Callovienne Zone.

Forms of the subboreal subfamily Proplanulitinae s.s. (including one genus Propulanulites Teissysre) represent as much as 15–20% of the ammonite assemblage. The subfamily Pseudoperisphinctinae is represented in collections by single specimens of Homoeoplanulites.

In some publications (e.g., Lahnzen, 1883), there is doubtful statement that some forms of the subfamily Macrocephalitinae occur in the Koenigi Zone of Central Russia.

**Stratigraphic position.** The Koenigi Zone of Central Russia corresponds to the synonymous zone of the standard scale.

**Distribution.** The Koenigi Zone is recognized in the subboreal areas of Europe, eastern Greenland and Mangyshlak.

**K. densicostatus Biohorizon**

Index species: Kepplerites (Gowericeras) densicos tatus Tintant, 1963. The holotype from the Poix site of France is reproduced by Tintant (1963, p. 141, Plate 15, Fig. 1).

**Nomenclature.** The K. densicostatus Biohorizon is best manifested in the Uzhovka section (Fig. 3, assemblage b5). It is also present in the Prosek-Isady section (Fig. 2, assemblage a7), and probably in the lower Callovian section at the Cheremukha River. K. (G.) densicostatus was also found at the Unzha River locality.

**Paleontological characteristics.** Slightly more than 40% of the ammonite assemblage of the Uzhovka section are represented by the subfamily Cadoceratinae, where Chamoussetia chamousseti (Orb.) s.l.
Plate II. Characteristic early Callovian ammonite species of Central Russia (full size)

Plate III. Characteristic early Callovian ammonite species of Central Russia (full size)
(1) Cadoceras (Bryocadoceras) tchernyshevii Sokolov, no. 3/587: (1a) side view, (1b) apertural view: the Pezhenga section; Elatmae Zone, C. tchernyschevi Biohorizon. (2) Macrocephalites (Macrocephalites) pavlovii Smorodina, no. A155 (283/5), side view: the Prosek-Isady section, Elatmae Zone, C. surensis Biohorizon (see Plate II, no. 3). (3) Cadochamoussetta subpatruus (Nikitin), no. 5/1159: (3a) side view, (3b) view from the mouth: the Uzhovka section, Elatmae Zone, C. subpatruus Biohorizon.

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These species mark the next evolutionary stage of the ammonite assemblage are represented by the species K. diver and higher whorls, finer and closer spaced ribs on the mature body chamber. The subfamily Proplanulitinae represented by several species of the genus Proplanulites constitutes about 20% of the ammonite assemblage.

**Stratigraphic position.** In England, species K. (G.) curtilobus and C. (C.) tolype are confined to the synonymous biohorizons established in the lower and middle parts of the Curtilobus Subzone (Callomon et al., 1988; Page, 1989). Thus, the biohorizon under consideration can be correlated with this stratigraphic level of the standard scale.

**Distribution.** The K. curtilobus Biohorizon was distinguished in England and Central Russia. Found index species suggests its occurrence in the south of European Russian and in Mangyshlak.

**K. trichophorus Biohorizon**

Index species: Keppelerites (Gowericera) trichophorus (Buckman, 1922). The holotype from Yorkshire, England, is pictured by Buckman (1922, Plate 291).

**Nomenclature.** The K. trichophorus Biohorizon was established in the upper part of the Curtilobus Subzone of England (Callomon et al., 1988). In Central Russia, the synonymous biohorizon is recognized in the Prosek-Isady section (Fig. 2, assemblage a9) (Gulyaev, 1999). Specimens of K. (G.) trichophorus were also found at the Unzha River.

**Paleontological characteristics.** The biohorizon is reliably characterized only by the index species. (Plate IV, fig. 1).

**Stratigraphic position.** In England, K. (G.) trichophorus is mainly typical of the synonymous biohorizon in the upper part of the Curtilobus Subzone (Callomon et al., 1988, 1989). As stated above, this species seems to be indistinguishable from K. (G.) galilaei recovered from the synonymous subzone and biohorizon of Wiltshire and pictured by Page (1989, Fig. 7 (2)). Thus, the K. trichophorus Biohorizon can be correlated with the upper part of the Curtilobus Subzone and with the Galilaei Subzone of the standard scale.

**Distribution.** The K. trichophorus Biohorizon was recognized in England and Central Russia. It may also be present in Mangyshlak (Repin and Rashvan, 1996). K. (G.) trichophorus was reported as well from the Ch. philipsi Biohorizon of eastern Greenland (Callomon, 1993).

**Callovienne Zone**

Index species: Sigaliceratites (Sigaloceras) callovien-sis (Sowerby, 1815). The lectotype was chosen in England and described by Arkell (1933, Plate 36, fig. 5).

**Nomenclature.** The Callovienne Zone was initially distinguished by Oppel (1857) as a peculiar upper interval of the Amn. macrocephalus Beds of England (approximately the entire lower Callovian Substage).
Plate IV. Characteristic early Callovian ammonite species of Central Russia (full size)

The Callovienese Zone was subdivided by Callomon (1955) into three subunits: the lower subzone equivalent to the Koenigi Zone established by Buckman (1913), the middle nominal subzone, and the upper Planicercus Subzone. Later Callomon (1964) came to the conclusion that the forms described by Buckman (1923) as Sigaloceras (Catataigaloceras) planicercus, S. (C.) crispatum, and S. (C.) curvicerus from the Callovian deposits of England are synonyms of S. (C.) enodatum (Nikitin, 1881) from Central Russia. This allowed him to rename the Planicercus Zone into the Enodatum Zone. At present the Koenigi Zone is authorized as an independent unit, and the standard Callovienese Zone is subdivided into the Callovienese and Enodatum subzones (Callomon et al., 1988; Page, 1989).

By analogy with the standard zonation, Meledina (1986, 1987) suggested to distinguish the Callovienese Zone (Subzone) in the upper part of the lower Callovian of European Russia. However, she did not consider the Enodatum Subzone as the terminal subdivision of the lower Callovian. She included the species S. (C.) enodatum and similar forms described by Buckman into the genus Kosmoceras Waagen. In her opinion, these species are characteristic of the basal Jason Zone of the middle Callovian. This opinion is hardly acceptable because of the following reasons. (1) None of specialists doubts that the subgenus Sigaloceras (Catataigaloceras), including the species under discussion and its synonyms described by Buckman, is intermediate between Sigaloceras s.s. and Kosmoceras (Gulielmites). In practice, taxonomy of such intermediate groups is frequently defined by tradition (when other facts of the case are equal). (2) The phyletic succession Sigaloceras s.s.–S. (Catataigaloceras)–K. (Gulielmites) suggests that S. (C.) enodatum appeared earlier than its ancestors K. (G.) meadea (Call.) and K. (G.) jason (Rein.), which are subzonal index species in the Jason Zone (Callomon, 1955). (3) In the Alpa’ev and Nikitino sections, S. (C.) enodatum was actually found below the levels with the mentioned middle Callovian index species. Thus, it is obvious that the Enodatum and Jason zones should not be considered as stratigraphic units of the same level.

However, the problem of the lower–middle Callovian boundary is still unsolved. The Kepplerites enodatum Zone was originally distinguished by Sazonov (1953) in the basal middle Callovian of European Russia earlier than the synonymous subzone independently recognized by Callomon at the top of the lower Callovian in England. Sazonov placed the Kepplerites enodatum Zone above the Kepplerites callovienensis Zone and below the Kosmoceras jason Zone, i.e., at its present level in Western Europe. The substage boundaries in the current standard scale of the Callovian were established by Callomon (1955), who noted that (1) they mark significant faunal changes and (2) virtually coincide with the boundaries initially recognized by Oppel. In both scales, the suggested position of the lower–middle Callovian boundary is not indisputable. It is difficult to evaluate objectively the faunal changes at the upper and lower boundaries of the Enodatum Zone because the defined taxonomic affiliation of the index species is subjective. The boundary between the Amn. macrocephalus and Amn. anceps zones of Oppel (1857), which approximately correspond to the lower and middle Callovian, respectively, seems also uncertain from the standpoint of recent detailed subdivision.

Thus, if we consider “the triad of Arkell” (Arkell, 1946) as basic for positioning of the lower–middle Callovian boundary, the criteria of priority and suitability would be ambiguous, and we should be guided only by the last criterion of usage. Since the majority of researchers (Callomon et al., 1988, 1989; Page, 1989; Repin and Rashyan, 1996; Biostratigraphy..., 1997; and others) consider the Enodatum Subzone as a subdivision of the lower Callovian, I support their opinion to avoid contradictions.

Paleontological characteristics. In contrast to the previous zone, the Callovienese Zone of Central Russia is virtually lacking the subfamily Proplanulitinae, whereas the subfamily Pseudoperispinctinae turns out to be the dominant group in its ammonite assemblages beginning from the middle part of the zone.

Most significant in many ammonite assemblages is the subfamily Gowericeratinae represented by species of the genus Sigaloceras Hyatt, which have, in contrast to the ancestral Kepplerites (Gowericera) forms, the relatively high fine-ribbed whorls and narrow umbilicus. These species are lacking the developed lateral spines, and primary sculpturing of their mature body chamber is strongly reduced, sometimes completely (the secondary sculpture of younger forms is reduced as well). Macroconchs of Gowericeratinae are represented by the subgenus S. (Sigaloceras) in the lower part of the zone and by S. (Catataigaloceras) Buckman in the upper one. Shells of the latter are flattened and smaller, thus being similar to shells of the middle Callovian subgenus Kosmoceras (Gulielmites) Buckman.

The subfamily Cadoceratinae is widespread throughout the zone. Its macroconchs are represented by species of the subgenus Cadoceras (Cadoceras) Fisher, which demonstrate the gradual morphological transition to the subgenus C. (Rondicera) Troitskaya (reduction of sculpture, flattening of increasingly involute early whorls, and widening of umbilicus at the later growth stages). Less frequent forms are representatives of C. ("Brachycadoceras") (descendants of the group C. ("B.") laetus Gul.) having wide whorls with radial ribs. Among two microconch groups of Cadoceratinatae, the first one is represented by flattened involute and finely ribbed species of Pseudocaloceras (Pseudocaloceras) Buckman, and the second by moderately evo-

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1 The Enodatum Zone was first mentioned by Brinkmann (1929). However, Callomon (1964) stressed that Brinkmann applied terms "zone" and "subzone" to stratigraphic ranges of individual species distinguishing as many as five zones in some sequences.
Plate V. Characteristic early Callovian ammonite species of Central Russia (full size)

(1) Sigaloceras (Sigaloceras) calloviense (Sowerby), no. A60: (1a) side view, (1b) ventral view; the Prosek-Isady section, *Callovien* Zone, *S. calloviense* Biohorizon. (2) Kepplerites (Gowericeras) densicostatus Tintant, no. A35: (2a) side view, (2b) ventral side; the Prosek-Isady section, the *Koepeni* Zone, the *K. densicostatus* Biohorizon. (3) Sigaloceras (Cata sigaloceras) enodatum (Nikitin), no. 7/1250: (3a) side view, (3b) ventral side; the Nikitino section, *Callovien* Zone, *S. enodatum* Biohorizon. (4) *S. (Sigaloceras) calloviense* (Sowerby), no. A53: (4a) side view, (4b) ventral view; the Prosek-Isady section, *Callovien* Zone, *S. calloviense* Biohorizon.
Plate VI. Characteristic early Callovian ammonite species of Central Russia (actual size)

(1) *Macrocephalites (Macrocephalites) volgae* Gulyaev, holotype no. 2/1241 (283/3); (1a) side view, (1b) ventral view: the Prosek-Isady section. *Elatmae Zone. C. elatmae Biohorizon.* (2) *Kepplerites (Goverriceras) turchani* Gulyaev, holotype no. 3/1007 (283/7); (2a) side view, (2b) ventral side: the Pezhenga section. *Elatmae Zone. K. tschernyschewi Biohorizon.* (3) *Chamossetia chamoussetii* (Orbigny), no. A124; (3a) side view, (3b) ventral view: the Prosek-Isady section. *Koenigi Zone. K. densicostatus Biohorizon.*
lute and coarsely ribbed species of *P. (Novocadoceras) Sasonov.*

The lower part of the zone yields rare younger representatives of the subfamily Proplanulitinae (*Proplanulites (Crassiplanulites) Buckman*), while the upper one bears a noticeable amount of *Anoplanoctites* (Anoplanoctites) Buckman, *Indosphinctes* Spath, and *Choffatia* Siemiradzki forms representing the subfamily Pseudoperispinctinae.

**Stratigraphic position.** The Callovienste Zone of Central Russia corresponds to that of the standard scale.

**Distribution.** The Callovienste Zone is recognized in subboreal areas of Europe, eastern Greenland, and eastern Caspian Lowland.

*S. calloviense Biohorizon*

Index species: *Sigaloceras (Sigaloceras) calloviense* (Sowerby).

**Nomenclature.** The *S. calloviense* Biohorizon was distinguished at the base of the Callovienste Zone in England (Callomon *et al.* 1988). In Central Russia, it was established in the sections of Prosek-Iasady (Fig. 2, assemblage a10) (Gulyaev, 1999), Alpat’evo (Fig. 5, assemblage d2), Manturovo-Znamenka, Ivkino, and Nikitino localities.

**Paleontological characteristics.** Nearly 60–70% of the ammonite assemblage are represented by *S. (S.) calloviense* (Plate V, figs. 1, 4) and *Guelminia quintquepliicata* Buckm. species of the subfamily Gowericeratinae. The subfamily Cadoceratinae is frequently next in abundance. Macroconchs are dominated by forms similar to *Cadoceras (Cadoceras) sublaeae* (Sow.) and associated with rare shells of *C. ("Bryocadoceras") cf./aff. laetum* Gul. The Cadoceratinae microconchs are represented by several of *Pseudocadoceras s.s.* and *P. (Novocadoceras)* species, and also by ammonites similar in morphology to Costacodoceras forms. The subfamily Proplanulitinae including rare *Planoctites (Crassiplanulites)* sp. is a minor component of the ammonite assemblage.

**Stratigraphic position.** In England, species *S. (S.) calloviense* and *C. (C.) sublaeae* are confined to the *S. calloviense* Biohorizon of the lower part of the Callovienste Subzone (Callomon *et al.*, 1988; Page, 1989). This correlates the biohorizon under consideration with the respective stratigraphic level of the standard zonation.

**Distribution.** According to the index species finds, the distribution of the *S. calloviense* Biohorizon is as that of the entire zone.

*S. enodatum Biohorizon*

Index species: *Sigaloceras (Catarigaloceras) enodatum* (Nikitin, 1881) [= *C. crispatum* (Buckm.), *S. (C.) curvicerebus* (Buckm.), *S. (C.) planicerebus* (Buckm.)]. The lectotype no. 26/134/4 from the Elat’ma locality at the Oka River (Nikitin, 1881, Plate 10 (3), figs. 12, 13) is stored in the Chernyshev Geological Museum of St. Petersburg.

**Nomenclature.** The *S. enodatum* α, β, and γ biohorizons were established in the *Enodatum* Subzone of England (Callomon *et al.*, 1988; Page, 1989). In Central Russia, the *S. enodatum* Biohorizon was recognized in the Alpat’evo (Fig. 5, assemblage d3) and Nikitino sections.

**Paleontological characteristics.** The ammonite assemblages are usually dominated by extremely variable macroconchs *S. (C.) enodatum* (Plate V, fig. 3) and by microconchs *Guelminia (?) anterior* (Brinkm.) from the subfamily Gowericeratinae. The subfamily Pseudoperispinctinae is also abundant and frequently prevailing in the assemblages. Forms similar to *Homoeoplanoctites (Anoplanoctites) difficilis* (Buckm.) were found as well. In the Nikitino and Alpat’evo sections, this biohorizon also yielded *Indosphinctes (Indosphinctes)* spp. and *Choffatia* (Choffatia) spp. The subfamily Cadoceratinae is usually less abundant than other groups. In the Nikitino section, macroconchs of this family are mainly represented by forms similar to *Cadoceras (Cadoceras?) tschekifini* (Orb.) and to *C. (Rondiceras) miaschevici* (Nik.). The Cadoceratinae microconchs are classed with *Pseudocadoceras (Pseudocadoceras) homoeomorphum* Kiss. and *P. (Novocadoceras) cf. suraensis* (Sas.).

**Stratigraphic position.** According to succession of transient varieties of the index species, several biohorizons with *S. (C.) enodatum* were recognized in the *Enodatum* Subzone of England. In Central Russia, the undivided *S. enodatum* Biohorizon is considered as an analogue of the entire synonymous subzone of the standard zonation.

**Distribution.** Outside eastern Greenland, the *S. enodatum* Biohorizon (biohorizons) has almost the same distribution range as the synonymous zone.

**CONCLUSIONS**

Analysis of vertical ranges of ammonite taxa in some Middle Jurassic sections of the Nizhni Novgorod, Moscow, and Yaroslavl areas revealed the successive faunal (species) assemblages stratigraphically corresponding to biohorizons. This was used to work out the detailed infrazonal scale for the upper Bathonian–lower Callovian of Central Russia. The indicated stratigraphic interval comprises four zones and 13 biohorizons, most of which are well correlative with the standard units of Western Europe.

The lowermost *Infimum* Zone includes the *C. infimum* and *C. cf./aff. infumum* biohorizons. This zone marks an earliest formation stage of the East European sea that represented an Arctic bay at that time. Ammonite assemblages of the zone contain only boreal taxa (Cadoceratinae and Gowericeratinae). The sharp geo-
Nauch.-Issled. Alekseev, S.N. and
sion of the Lower Callovian in the Russian Platform.
for Basic Research, project no. 96-05-64934, and by
zonation includes the S.
West European basins. The low-boreal
became important components of the respective ammo-
nae) and Pan-Tethyan (Pseudoperisphinctinae) taxa
the time of widening connections between the East and
biohorizons. Like the preceding zone, it corresponds to
scale.
Central Russia corresponds to the same standard zone.
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The next Elatmae Zone includes M. jacquoti, C. elatmae, C. tschernyschewi, C. surensis, C. subpatrici,
and Ch. saratovensis biohorizons. The lower
boundary of the zone is dated by the time, when the East European basin became connected with the Tethyan seas and developed under subboreal conditions. Boreal elements (Cadoceratinae and Gowericeratinae) domi-
ant in the ammonite assemblages are combined with representatives of Tethyan taxa (Macroco-
cephalitinae and Pseudoperisphinctinae). Basing on
orrelation of some stratigraphic levels, the Elatmae
Zone as a whole is considered to be analogous to the
standard upper Bathonian zonation.

The Koenigi Zone includes K. densicostatus, K. cur-
ilobus, and K. trichophorus biohorizons. The zone
marks widening connections of the East European basin with the West European seas. The low-boreal
(Gowericeratinae) and subboreal (Proplanulitinae)
taxa, along with the high-boreal (Cadoceratinae)
groups, become significant components of the ammo-
nite assemblages of that time. The Koenigi Zone of Central Russia corresponds to the same standard zone.

The Callovienne Zone crowning the lower Callovian
zonation includes the S. callovienne and S. enodatum
biohorizons. Like the preceding zone, it corresponds to
the time of widening connections between the East and
West European basins. The low-boreal (Gowericeratinae) and Pan-Tethyan (Pseudoperisphinctinae) taxa
became important components of the respective ammo-
nite assemblages. The Callovienne Zone of Central Russia corresponds to the same zone of the standard scale.

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