

Infrazonal Ammonite Scale for the Upper Bathonian–Lower Callovian of Central Russia

D. B. Gulyaev

Moscow State University, Vorob'evy gory, Moscow, 119899 Russia

Received April 28, 1999

Abstract—The regional infrazonal 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 correlative 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. ischermyschewi*, *C. surensis*, *C. subpatruus*, and *Ch. saratoviensis* 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 *Koenigi* Zone including the *K. densicostatus*, *K. curtilobus*, and *K. trichophorus* biohorizons is an equivalent of the synonymous zone of the standard scale. The lower Callovian succession is completed by the *Calloviense* Zone comprising the *S. calloviense* and *S. enodatium* 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 Rus-

sia in order to elaborate a refined stratigraphic scale, which could be useful for thorough phylogenetic, paleoecological, and paleogeographic 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 Nizhnii 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



Fig. 1. Location of the studied upper Bathonian–lower Callovian sections in Central Russia: 1. Prosek-Isady; 2. Uzhovka; 3. Akatovo; 4. Pezhenga; 5. Manturovo-Znamenka; 6. Ivkino; 7. Cheremukha; 8. Alpat'evo; 9. Nikitino.

Unzha River between the Ivkino and Samylovo 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'evo section (the Moscow area, a series of outcrops at the right bank of the Oka River near the Alpat'evo Settlement); and (9) the Nikitino section (the Ryazan area, an outcrop at the right bank of the Oka River near the Nikitino Village).

The Prosek-Isady, Uzhovka, Pezhenga and Alpat'evo 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.

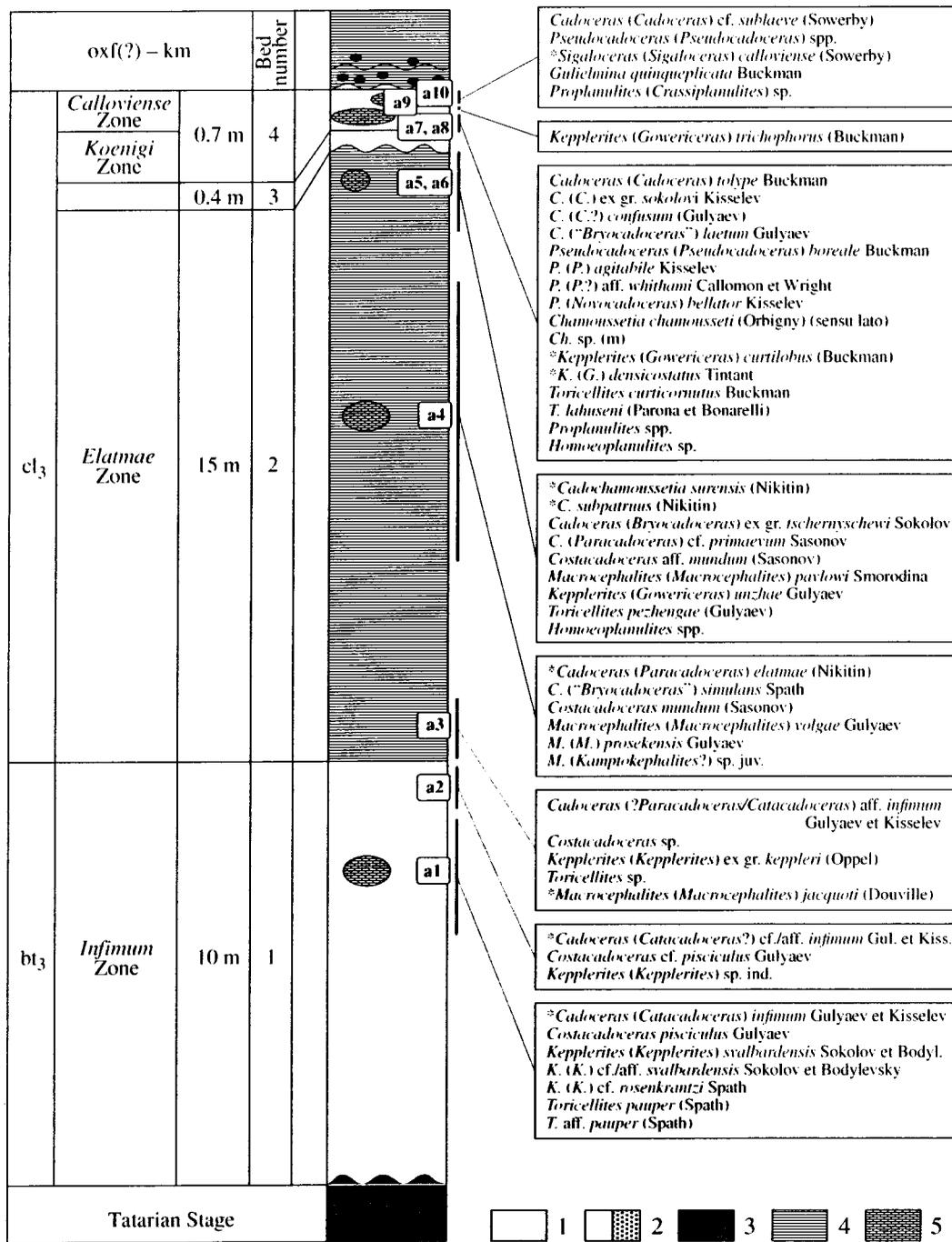


Fig. 2. The composite Jurassic section at the Prosek-Isady site and levels of distinguished ammonite assemblages (biohorizons): (a1) *C. infimum*; (a2) *C. cf. aff. infimum*; (a3) *M. jacquoti*; (a4) *C. elatmae*; (a5) *C. surensis*; (a6) *C. subpatruus*; (a7) *K. densicostatus*; (a8) *K. curtilobus*; (a9) *K. trichophorus*; (a10) *S. calloviense* (index species of the biohorizons are indicated by asterisks). Lithology: (1) silt and siltstone; (2) sand; (3) sandstone; (4) clay; (5) concretions; (6) stratigraphic hiatus.

(2) Dark gray, locally almost black, slightly micaceous, compact and occasionally ferruginous sand with fragments of carbonaceous wood; the bed thickness is 0.3 m.

(3) Light gray loose sand; the bed thickness is 0.15 m.

(4) Dark gray micaceous and clayey condensed sand enclosing coalified wood and a horizon of flattened concretions of black phosphoritized sandstone; concre-

tions bear rare ammonites representing the assemblage c1 (Fig. 4). The bed thickness is 0.12 m.

(5) Light gray micaceous sand grading into light brown compact sandstone with coalified wood fragments; the bed thickness is 0.6 m.

(6) Gray micaceous and clayey, locally ferruginous compact sand with clay interbeds; the bed thickness is 0.5 m.

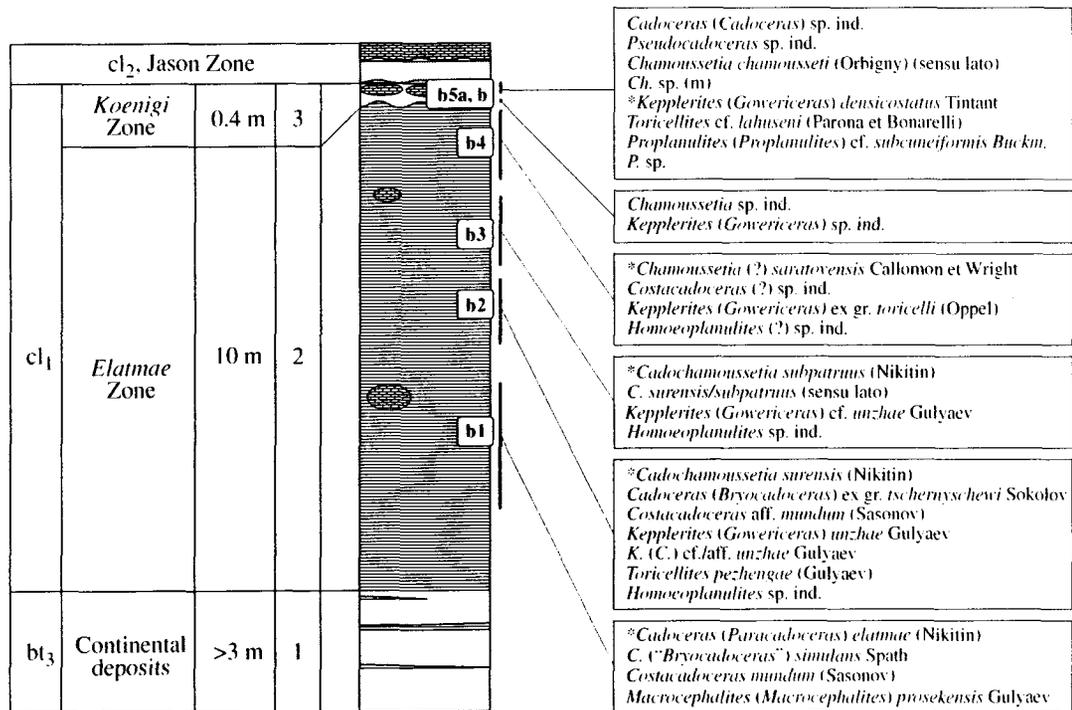


Fig. 3. The composite Jurassic section at the Uzhovka site and distinguished ammonite assemblages (biohorizons): (b1) *C. elatmae*; (b2) *C. surensis*; (b3) *C. subpatruis*; (b4) *Ch. saratovensis*; (b5) *K. densicostatus* (other symbols as in Fig. 2).

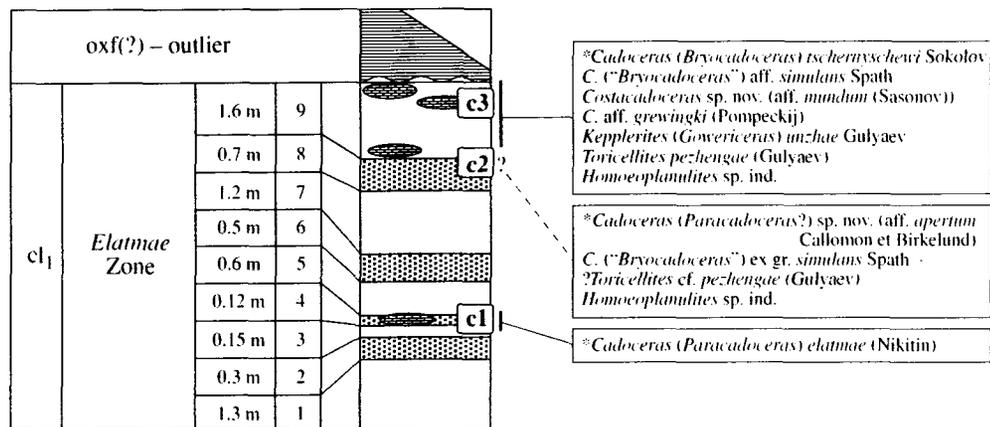


Fig. 4. The Jurassic section at the left bank of the Unzha River, downstream from the Pezhenga mouth, and distinguished ammonite assemblages (biohorizons): (c1) *C. elatmae*; (c2) *C. sp. nov.* (aff. *apertum*), hypothetical level; (c3) *C. tchernyschewi* (other symbols as in Fig. 2).

(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 *Cardiocerata* supposed to be Oxfordian in age.

The Alpat'ev Section (Fig. 5)

The series of outcrops at the right bank of the Oka River exhibits the following beds:

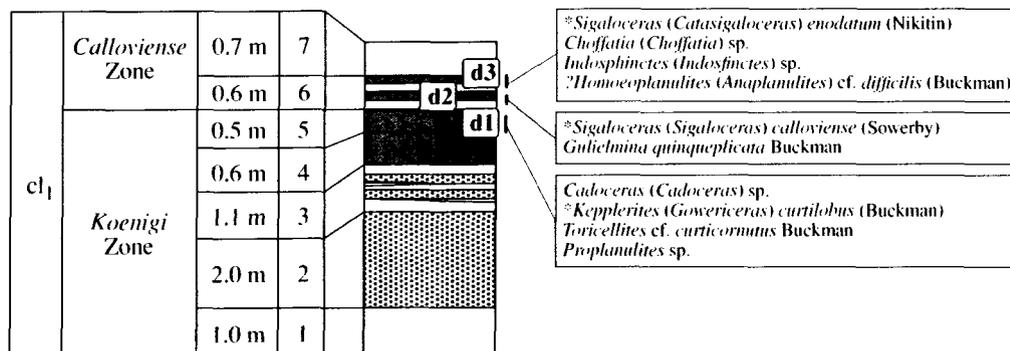


Fig. 5. The lower Callovian section at the right bank of the Oka River near the Alpat'evo Settlement and distinguished ammonite assemblages (biohorizons): (d1) *K. curtilobus*; (d2) *S. calloviense*; (d3) *S. enodatium* (other symbols as in Fig. 2).

(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-bedded, 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). Regrettably, 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 chrono-equivalent of biohorizon, Callomon (1985) suggested the term "hemera" 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 (phyletic lineages) established in subfamilies Cadoceratinae Hyatt, Gowericeratinae Buckman, and Macrocephalitinae Salfeld (Fig. 6). Every phyletic lineage shows persistent changes in species morphology (phyletic 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 *Keplerites* (*Keplerites*) *svabardensis* 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. *kepleri* (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 *Cadochamoussetia surensis* (Nik.), *C. subpatruus* (Nik.), and *Chamoussetia* (?) *saratovensis* 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 phyletic 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 phyletic (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 phyletic 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 phyletic 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 phyletic lineages characterizing different taxa effectively controls the recognition and correlation of biohorizons.

Critical for recognition of infrazonal subdivision in the *Infimum* Zone and in the lower part of the *Elatmae* Zone is the phyletic 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 phyletic 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 *Keplerites* (*Keplerites*) *svabardensis* Sok. et Bodyl. to the relatively coarse-ribbed *K. (K.)* ex gr. *kepleri* (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 phyletic lineage of scarce but characteristic species of Macrocephalitinae: *Macrocephalites* (*Macrocephalites*) *jacquoti* (Douv.)–*M. (M.)* *prosekensis* Gul.–*M. (M.)* *pavlovi* Smor. (Fig. 6, nos. 31–33). The succession shows the ventral side narrowing until its sharpening in the early whorls of *M. (M.)* *pavlovi* 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 phyletic lineage of Cadoceratinae: *Cadoceras* (*Bryocadoceras*) *tschernyschewi* Sok.–*Cadochamoussetia surensis* (Nik.)–*C. subpatruus* (Nik.)–*Chamoussetia* (?) *saratovensis* Call. et Wright–*Ch. chamousseti* (Orb.) (*s.l.*) (Fig. 6, 6–10). This phyletic lineage is characterized by the rapid transformation of shell morphology from cadicone (*C. (B.)* *tschernyschewi*) to oxycone (*Chamoussetia*).

The phyletic lineage of Gowericeratinae takes origin in the *Elatmae* Zone and is characteristic of the *Koenigi* and *Calloviense* zones in subboreal regions of Europe and eastern Greenland. This lineage is as follows: group of *Keplerites* (*Gowericerates*) *unzhae* Gul.–group of *K. (G.)* *toriceli* (Opp.)–species of the group of *K. (G.)* *gowerianus* (Sow.) and *K. (G.)* *metorchus* (Buckm.)–*K. (G.)* *densicostatus* Tint.–*K. (G.)* *curtilobus* (Buckm.)–*K. (G.)* *trichophorus* (Buckm.) [?=*K. (G.)* *galilaeii* (Opp.) *sensu* Page, 1989]–species

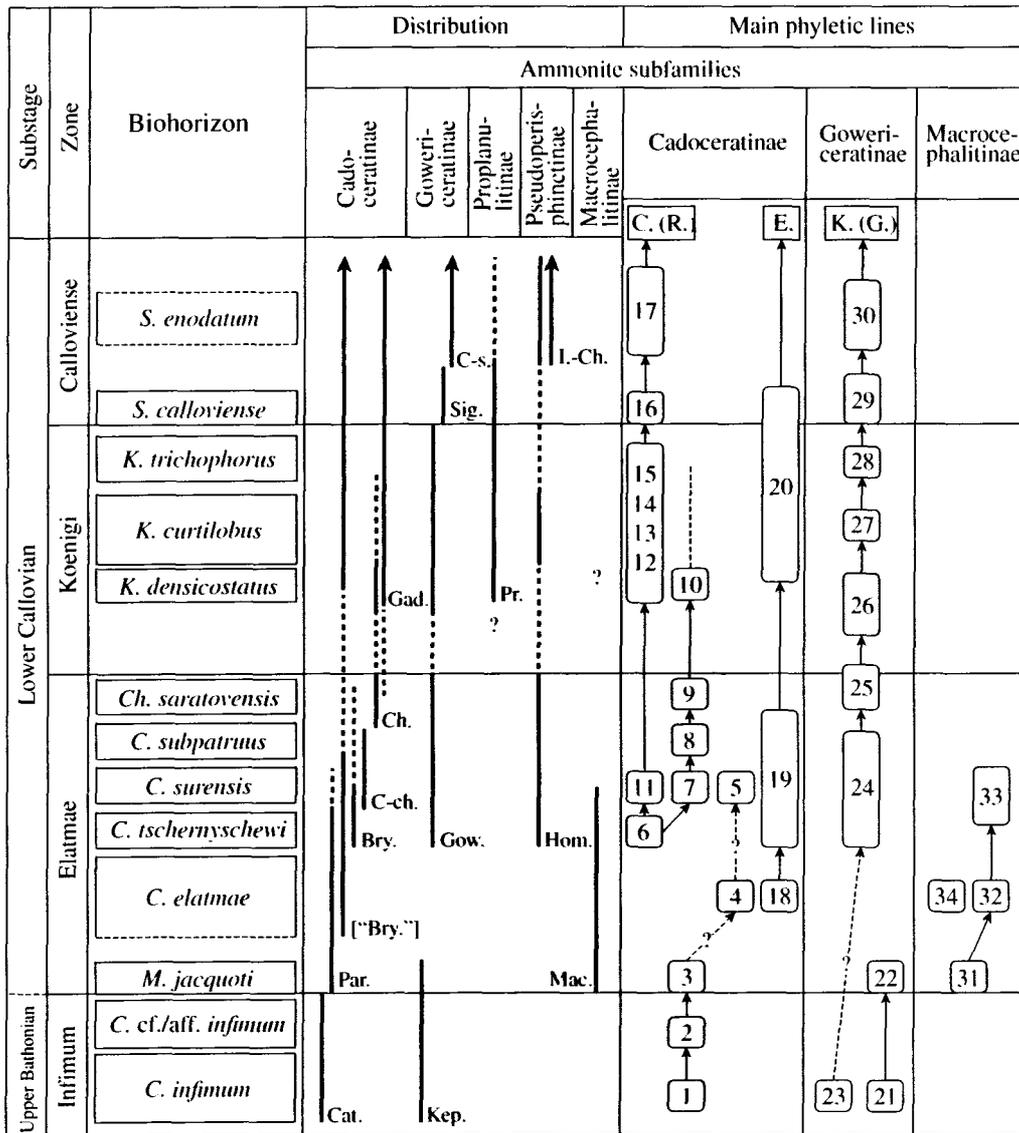


Fig. 6. Stratigraphic ranges of genera and subgenera of ammonite macroconchs and main phyletic lineages of Cadoceratinae, Gowericeratinae and Macrocephalitiniae, the upper Bathonian–lower Callovian of Central Russia (ranges of index species and biohorizons are shaded).

Cadoceratinae: (Cat.) *Cadoceras* (*Catacadoceras*); (Par.) (*C. (Paracadoceras)*; ["Bry."]) *C. ["Bryocadoceras"]* (group of *C. simulans*); (C-ch.) *Cadochamousetia*; (Ch.) *Chamousetia*; (Cad.) *C. (Cadoceras)*. Phyletic lineage 1–5: (1) *Cadoceras (Catacadoceras) infimum* → (2) *C. (C.?) cf. aff. infimum* → (3) *C. (?Paracadoceras/Catacadoceras) aff. infimum ?* → (4) *C. (P.) elatmae ?* → (5) *C. (P.) cf. primaevum*. Phyletic lineage 6–10: (6) *C. (Bryocadoceras?) tschernyschewi* → (7) *Cadochamousetia surensis* → (8) *C. subpatruus* → (9) *Chamousetia (?) saratovensis* → (10) *Ch. Chamouseti (s.l.)* [?= *Ch. phillipsi*, *Ch. buckmani*]. Phyletic lineage 6, 11–17: (6) *C. (Bryocadoceras?) tschernyschewi* → (11) *C. (B?) ex gr. tschernyschewi* → (12–15) group of *C. (Cadoceras) tolype* (and, probably, *C. (C.?) confusum*) → (16) *C. (C.) sublaeve* → (17) group of *C. (C.?) cf. tschekfinki* and *C. (Rondiceras) cf. milashevici* → [C. (R.)] *C. (Rondiceras) (c1)₂*. Phyletic lineage 18–20: (18) *C. ("B.") simulans* → (19) group of *C. ("B.") aff. simulans* → (20) group of *C. ("B.") laetum* [E.] *Eichwaldiceras (c1)₂(?)*-3).

Gowericeratinae: (Kep.) *Kepplerites (Kepplerites)*; (Gow.) *K. (Gowericeras)*; (Sig.) *Sigaloceras (Sigaloceras)*; (C-s.) *S. (Catasigaloceras)*. Phyletic lineage 21–22: (22) group of *Kepplerites (Kepplerites) svalbardensis* → (22) group of *K. (K.) keppleri*. Phyletic lineage 23–30: (23) *K. (K.) rosenkrantzi ?* → (24) group of *K. (Gowericeras) unzhae* → (25) group of *K. (G.) toricelli* → (26) group of *K. (G.) gowerianus*, *K. (G.) metorhus* and *K. (G.) densicostatus* species → (27) *K. (G.) curtilobus* → (28) *K. (G.) trichophorus* [?= *K. (G.) galilaei (Opp.) sensu Page, 1989*] → (29) group of *Sigaloceras (Sigaloceras) calloviense* and *S. (S.) micans* species → (30) group of *S. (Catasigaloceras) enodatum* → [K. (G.)] *Kosmoceras (Gulielmites) (c1)₂*.

Proplanulitinae: (Pr.) *Proplanulites* (several subgenera).

Pseudoperisphinctinae: (Hom.) *Homoeoplanulites* (several subgenera); (I-Ch.) *Indosphinctes* and *Choffatia* (several subgenera).

Macrocephalitiniae: (Mac.) *Macrocephalites (Macrocephalites)*. Phyletic line 31–33: (31) *Macrocephalites (Macrocephalites) jacquoti* → (32) *M. (M.) prosekensis* → (33) *M. (M.) pavlowi*; (34) *M. (M.) volgae*.

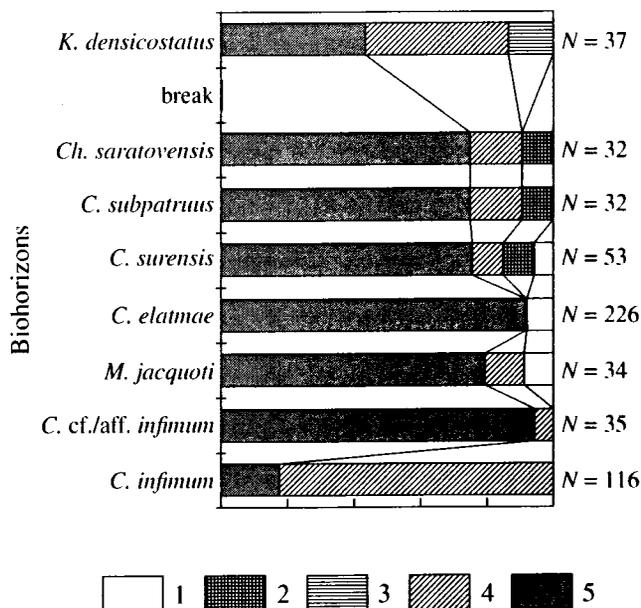


Fig. 7. Dynamics of relative abundance of ammonite subfamilies in the *Infimum* and *Elatmae* zones and at the base of the *Koenigi* Zone in the Nizhni Novgorod area (the Prosek-Isady and Uzhovka sections): (1) Macrocephalitinae; (2) Pseudoperisphinctinae; (3) Proplanulitinae; (4) Gowericeratinae; (5) Cadoceratinae.

of the group of *Sigaloceras* (*Sigaloceras*) *calloviense* (Sow.) and *S.(S.) micans* Buckm.—group of *S. (Catasigaloceras)* *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.) unzhiae*), to other forms having the high fine-ribbed whorls, widely spaced broad or completely smoothen primary ribs on the terminal body chamber, and narrow umbilicus (*Sigaloceras*).

In addition to Gowericeratinae, Cadoceratinae and Perisphinctidae are the main groups characterizing the *Koenigi* and *Calloviense* 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.) sublaeve* (Sow.) and *C.(C.?) tschekfinski* (Orb.), and finally to the subgenus *Rondiceras* Troitskaya (Fig. 6, nos. 12–17). By this transition, ribbing becomes reduced and narrows umbilicus of the early whorls 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 *Calloviense* 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* (*Catacadoceras*) *infimum* Gulyaev et Kisselev, 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* (*Catacadoceras*) Bodylevsky [M] and *Costacadoceras* 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; Callomon, 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. (Catacadoceras)* 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

Substage	Zone	Prosek-Isady	Uzhovka	Pezhenga	Alpat'evo
		Biohorizons			
Lower Callovian	Calloviense	a10			d3
					d2
		a9			
		a8			
		a7	b5		d1
	Elatmae			b4	
		a6		b3	
		a5		b2	
					c3
		a4	b1		c1
Upper Bathonian	Infimum	a3			
		a2			
		a1			

scale because of a high geographic differentiation of ammonite faunas. According to its position below the *Elatmae* Zone, the *Infimum* Zone most likely corresponds to the *Discus* Zone. Owing to ambiguous correlation of the lower boundary of the *Elatmae* Zone (see below), the *Infimum* Zone range may vary in scope within the interval of the *Discus* Zone coupled with the upper part of the *Orbis* Zone. The lower part of the *Infimum* Zone (*C. infimum* Biohorizon) can be indirectly correlated with the upper *Hannoveranus* Subzone of the *Orbis* Zone, as it follows from the *Keplerites* form found at this level in Bavaria. The form found is similar to the index species of the lower *K. peramplus* Biohorizon of the *Calyx* Zone of eastern Greenland (Dietl and Callomon, 1988). This biohorizon is directly correlative with the *C. infimum* Biohorizon on the basis of ammonites.

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 *Keplerites* 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. (Catacadoceras)* group were found at the base of the *Calyx* Zone (Callomon, 1993). Most likely, the *Infimum* Zone,

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* (*Catacadoceras*) *infimum* Gulyaev et Kisselev.

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 Kiselev, 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 *Keplerites* (*Keplerites*) *svabardensis* Sok. et Bodyl. 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* (Spath) 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 *Costacadoceras pisciculus* 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 *Keplerites* 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* (*Catacadoceras*), 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 *Hannoveranus* Subzone in Bavaria contains *Keplerites* (*Keplerites*) *cf. Jaff. 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. Jaff. infimum Biohorizon

Index species: the form tentatively identified as *Cadoceras* (*Catacadoceras*?) *cf. Jaff. 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. Jaff. 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. Jaff. infimum* greatly resembles the index species of the preceding biohorizon, but it has less coarse ribbing. *Costacadoceras cf. pisciculus* is almost indistinguishable from *C. pisciculus* typical of the underlying deposits. The subfamily Gowericeratinae is represented by rare specimens of *Keplerites* (*Keplerites*) 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. Jaff. infimum* Biohorizon corresponds to the upper part of the *Infimum* Zone. According to its position relative to the previous biohorizon, the *C. cf. Jaff. infimum* Biohorizon should be correlated with the upper part of the *Calyx* Zone (the *K. vardekloeftensis* Biohorizon) of eastern Greenland. Depending on dating of adjacent levels, the *C. cf. Jaff. 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* (*Paracadoceras*) *elatmae* (Nikitin, 1878). The neotype no. 34/1344 from the Ryzan' area near the town of Elat'ma (Nikitin, 1881, Plate 11 (4), fig. 20) is stored at the Chernyshev Geological Museum of St. Petersburg.

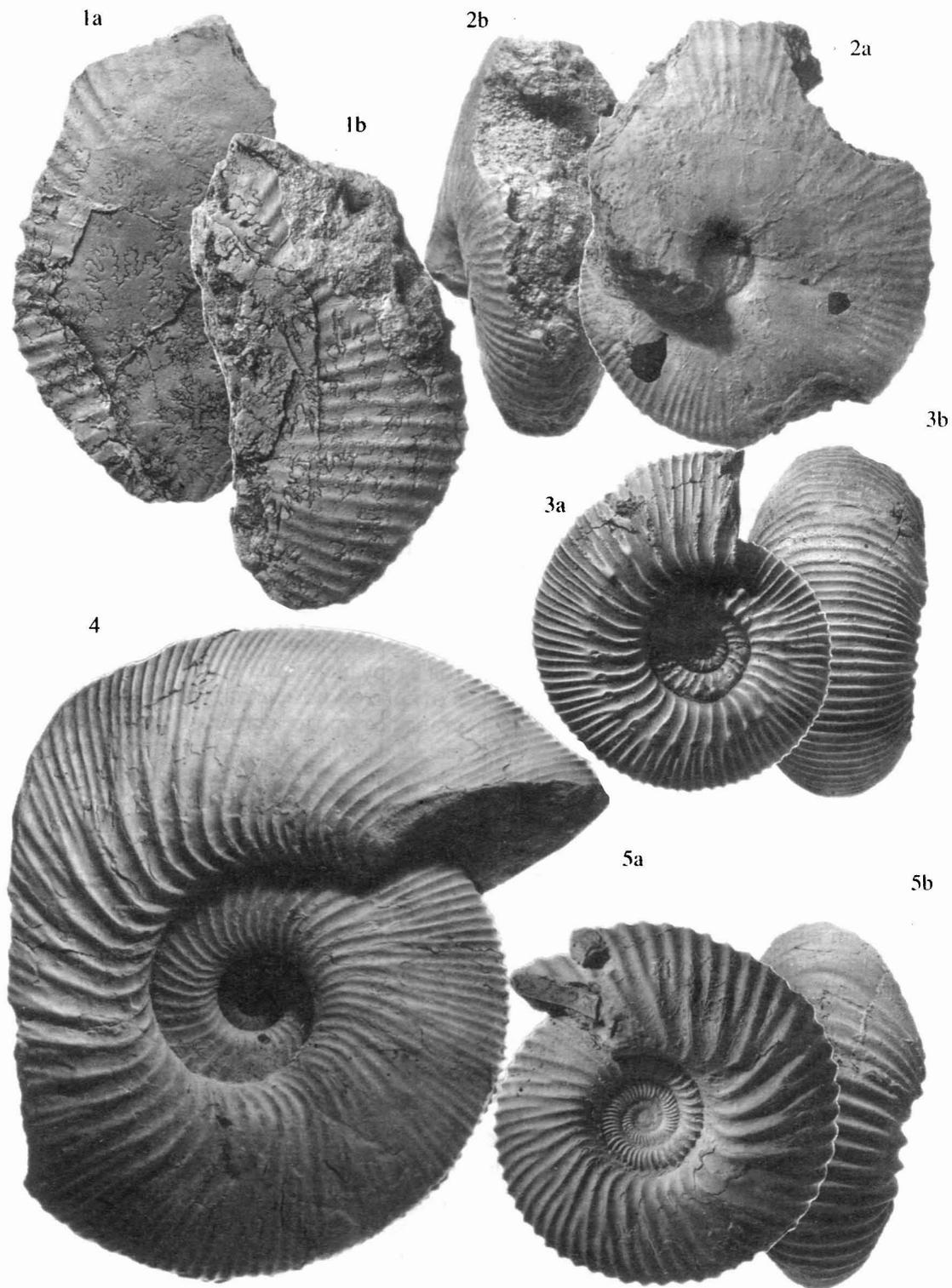


Plate I. Characteristic late Bathonian–early Callovian ammonite species of Central Russia (actual size)

(1) *Macrocephalites (Macrocephalites) jacquoti* (H. Douville), no. 2/1277: (1a) left view, (1b) right view; the Prosek-Isady section, *Elatmae* Zone, the *M. jacquoti* Biohorizon. (2) *M. (M.) jacquoti* (H. Douville), no. 8/1355: (2a) side view, (2b) ventral view; the Churkina section (the Pizhma River area, Komi Republic), *Elatmae* Zone, *M. jacquoti* Biohorizon. (3) *Keplerites (Gowerceras) densicostatus* Tintant, no. 5/1175: (3a) side view, (3b) ventral view; the Uzhovka section, *Koenigi* Zone, *K. densicostatus* Biohorizon. (4) *K. (Keplerites) 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 *Arcticoceras ishmae* Zone and below the *Keplerites calloviensis*-*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 discoid-conical shells], *Cadoceras elatmae* (Nik.), *C. modiolare* (Luid.) [= *C. simulans* Spath], *C. frearsi* (Orb.), *C. subpatruus* Nik., *Chamousetia chamouseti* (Orb.) [probably, *Ch. (?) saratovensis* Call. et Wright, or morphologically similar *Macrocephalites pavlovi* Smor.], *Keplerites gowerianus* (Sow.) [probably, *K. unzhai* 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 Malinovy 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 *Costacadoceras 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-Isady 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 subboreal 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 (Paracadoceras)* 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 *Cadochamousetia* Mitta separates from the latter subgenus to give rise the genus *Chamousetia* 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 *Costacadoceras* Rawson also occur throughout the zone displaying the shell size diminishing, increasing ribbing density, and slightly growing involution 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 *Keplerites (Keplerites)* Neumayr and *Toricellites* Buckman, both retaining similarity with taxa of the previous *Infimum* 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. (Gowericerates)* Buckman and *Toricellites* forms, which have wide echinate whorls in contrast to the earlier forms.

Scarce (not more than 10% of the assemblage) but characteristic species of the Tethyan subfamily Macrocephalitiniae 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 Macrocephalitiniae 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*, *Keplerites*, 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* (*Paracadoceras*), *C. (Bryocadoceras)*, and *Keplerites* (*Keplerites*) permits the *Elatmae* Zone to be correlated with the *Apertum* and *Nordenskjoeldi* zones of eastern Greenland (Callomon, 1993) and with the *Falsum* and *Anabarensis* zones of northern Siberia (Meledina, 1994). The lower part of the *Elatmae* Zone may correspond to the *Bodylevskiyi* 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. infimum* 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* (?*Paracadoceras/Catacadoceras*) aff. *infimum* differs from *C. (C.) infimum* and *C. (C.?) cf./aff. infimum* owing to more involute inner whorls and finer and denser ribbing. Ribbed shells of *C. (?P./C.) aff. infimum* are up to 60 mm in diameter. Their generic affiliation is uncertain, because the subsequent stages of growth are known. In contrast to *C. pisciculus*, microconchs of *Costacadoceras* sp. have smaller size and higher ribbing density. Representatives of the subfamily Gowericeratinae represent approximately 10% of the assemblage. Species *Keplerites (Keplerites) ex gr. kepleri* (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 Macrocephalitiniae (*M. (M.) jacquoti* (Plate I, figs. 1, 2), which have discoid-conical shell with high rounded-triangular whorls and fine sculpture rapidly smoothening on lateral sides. The Macrocephalitiniae 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.) kepleri* characteristic of the basal *K. kepleri* Biohorizon of the North European *Herveyi* Zone (Callomon *et al.*, 1988, 1989, 1992; Page, 1989) indicates that these biohorizons are correlative. In Germany (Schwabia) how-

ever, *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.) kepleri* 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 upper part 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.

Distribution. At present, the *M. jacquoti* Biohorizon is reliably recognized only in the Prosek-Isady section. However, it may be recognized in many other areas. For instance, this level probably corresponds to the lowermost part of the Callovian clays of the Volga region near Saratov (the Malinovyi Ravine), where *Macrocephalites (Macrocephalites) cf. triangularis* Spath (ex gr. *jacquoti*) was found (Repin and Rashvan, 1996). In 1998, I detected one specimen of *M. (M.) jacquoti* (Plate I, fig. 2) below the level of *Cadoceras (Paracadoceras) cf. elatmae* in the Pizhma River section of the Pechora River basin.

C. elatmae Biohorizon

Index species: *Cadoceras (Paracadoceras) 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. ("Bryocadoceras") simulans* Spath have extremely inflated shells with radial ribs curved sometimes backward. Microconchs of *Costacadoceras mundum* (Sas.) are smaller in size than the early forms of this genus. The biohorizon exhibits the maximal diversity of Macrocephalitiniae 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.) prosekensis* 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. (Kamptokephalites?)* 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 (Schwabia). 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 *Keppleri* Subzone and *C. (P.) suevicum* Call. et al. (nom. nov. pro *Amm. sublaevis macrocephali* 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 *Keppleri* 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 *Cadochamousetia* shells. In addition, the coexisting single *C. ("B.")* aff. *simulans* Spath differ from *C. ("B.") simulans*, as they have slightly narrower umbilicus 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. *mundum* (Sas.), which have narrower ventral sides and more involute whorls than *C. mundum*. Representatives of

the subfamily Gowericeratinae constitute approximately 10–15% of the assemblage. The biohorizon proved to be marking the first occurrence of the subgenus *Kepplerites (Gowericeras)* represented by the archaic species *K. (G.) unzhae* Gul. (Plate VI, fig. 2), which retain dense ribbing on the mature body chamber (type feature of *Kepplerites* s.s.) but already has relatively broad whorls with well developed lateral spines (features of *Gowericeras* forms). Spines of this kind are also characteristic of microconchs *Toricellites pezhengae* (Gul.). The first occurrence of Pseudoperisphinctinae 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 *Cadochamousetia surensis*. 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 (Kamysheva-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: *Cadochamousetia 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

umbilicus. *C. (Paracadoceras) cf. primaevum* 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 *Costacadoceras* aff. *mundum* (Sas.), whose ventral side is narrower than that of *C. mundum*. The subfamily Gowericeratinae representing up to 10% of the ammonite assemblage includes species *Keplerites (Gowericereras) unzhae* Gul. and *Toricellites pezhengae* (Gul.). In addition, the Uzhovka section yielded single forms with closer spaced ribs, which are tentatively identified as *K. (G.) cf. aff. unzhae*. The subfamily Macrocephalitiinae constitutes only about 5% of the ammonite assemblage. It is represented by the peculiar species *Macrocephalites (Macrocephalites) pavlowi* Smor. (Plate II, 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 *Homoeoplanulites*.

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.) tchernyschewi*. 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 *Terebratus* Subzone of the standard *Herveyi* Zone.

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

C. subpatruus Biohorizon

Index species: *Cadochamousetia subpatruus* (Nikitin, 1885). The holotype no. 38/1486 from the Sura River area (Nikitin, 1885, Plate (11) 13, fig. 58) is stored at the Chernyshev Geological Museum of St. Petersburg.

Nomenclature. The *C. subpatruus* Biohorizon is best manifested in the Uzhovka section (Fig. 3, assemblage **b3**), where it immediately overlies the *C. surensis* Biohorizon. Single specimens of *C. subpatruus* (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. subpatruus* of the subfamily Cadoceratinae (Plate III, fig. 3). This species marks the stage that resulted in appearance of *Chamousetia* forms among Cadoceratinae. Within its stratigraphic range, *C. subpatruus* demonstrates a complete spectrum of morphological changes from the forms similar to *C. surensis* (Nik.) to those virtually indistinguishable from *Ch. (?) saratovensis* Call. et Wright. The subfamily Gowericeratinae represented by

Keplerites (Gowericereras) cf. unzhae Gul., whose relative abundance is approximately 10–15%. The subfamily Pseudoperisphinctinae (*Homoeoplanulites* sp. ind.) constitutes about 10% of the assemblage.

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

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

Ch. saratovensis Biohorizon

Index species: *Chamousetia (?) saratovensis* Callomon et Wright, 1989 (nom. nov. pro *Ch. chamouseti* (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. subpatruus* 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 *Chamousetia* Douville. However, some archaic characters, such as slightly sharpened ventral side, absence of oppressed carina, and coarser sculpture persistent in ontogenesis, differ this species from representatives of the *Ch. chamouseti* (Orb.) group of the *Koenigi* Zone. At the same time, it is very similar to *Cadochamousetia* forms. Microconchs of Cadoceratinae are represented by rare *Costacadoceras (?)* sp. ind. About 10–15% of the ammonite fauna are represented by *Keplerites (Gowericereras) ex gr. toricelli* (Opp.) from the subfamily Gowericeratinae, and about 10% by *Homoeoplanulites (?)* 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*, *Homoeoplanulites* spp., and other ammonites characterizes the lowermost *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 *Keplerites* and *Homoeoplanulites* 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*) *koenigi* (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 *Calloviense* Zone. At present the lower Callovian of the standard West European scale is again subdivided into the *Herveyi*, *Koenigi*, and *Calloviense* zones. The *Koenigi* Zone includes the *Gowerianus*, *Curtilobus* and *Galilaeii* subzones (Callomon *et al.*, 1988; Page, 1989).

The nomenclature of the uppermost *Galilaeii* Subzone is doubtful. Oppel (1862) used name *Amm. galilaeii* for the form that was described by Orbigny (1847, Plate 162, figs. 10, 11) as *Amm. calloviensis* Sow. Later, the original photograph by Orbigny was published by Tintant (1963, Plate 21, fig. 1) under name *Sigaloceras calloviense*. 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.) galilaeii* (Opp.) under the name *Galilaeiceras galilaeii* (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.) galilaeii* (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 calloviensis*-*K. gowerianus* Zone was recognized long ago in the upper part of the lower Callovian deposits above the *Elatmae* Zone (*Resheniya...*, 1955, 1962; *Post-anovlenie...*, 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 subfam-

ily *Gowericeratinae* 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. ("Bryocadoceras") 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 *Pseudocadoceras* (*Pseudocadoceras*) Buckman and *P. (Novocadoceras)* Sasonov. Some evolute forms bear similarity to the genus *Costacadoceras* Rawson.

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

Forms of the subboreal subfamily *Proplanulitinae* s.s. (including one genus *Proplanulites* Teisseyre) 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., Lahuzen, 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*) *densicostatus* 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.

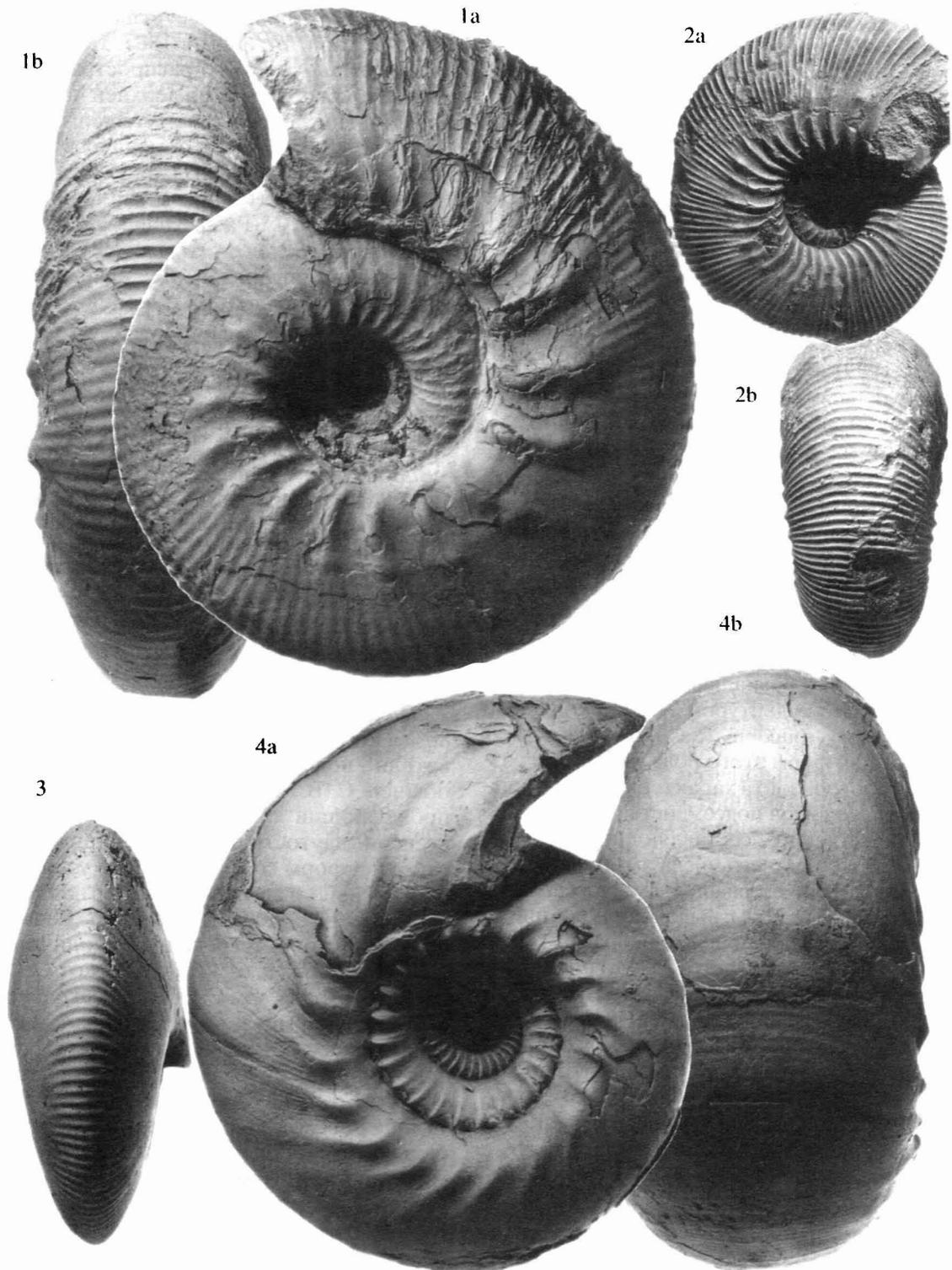


Plate II. Characteristic early Callovian ammonite species of Central Russia (full size)

(1) *Keplerites* (*Gowericeras*) *curtilobus* (Buckman), no. 2/865: (1a) side view, (1b) ventral view; the Prosek-Isady section, *Koenigi* Zone, *K. curtilobus* Biohorizon. (2) *K. (G.) curtilobus* (Buckman), no. 2/857: (2a) side view, (2b) ventral side; the Prosek-Isady section, *Koenigi* Zone, *K. curtilobus* Biohorizon. (3) *Macrocephalites* (*Macrocephalites*) *pavlovi* Smorodina, no. A155 (283/5), ventral side; the Prosek-Isady section, *Elatmae* Zone, *C. surensis* Biohorizon (see Plate III, no. 2). (4) *Cadoceras* (*Paracadoceras*) *elatmae* (Nikitin), no. A76: (4a) side view, (4b) ventral view; the Prosek-Isady section, *Elatmae* Zone, *C. elatmae* Biohorizon.

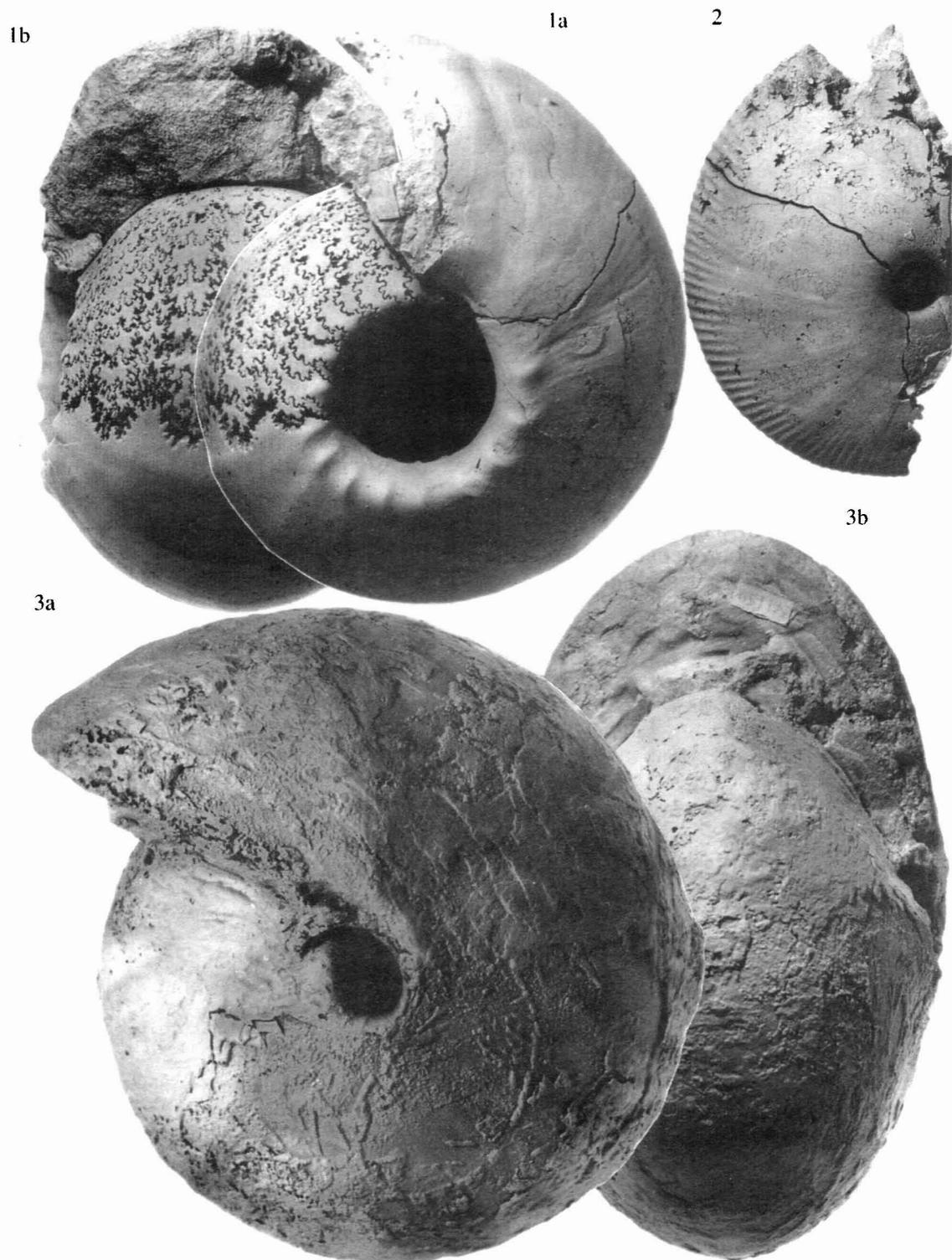


Plate III. Characteristic early Callovian ammonite species of Central Russia (full size)

(1) *Cadoceras* (*Bryocadoceras*) *tschernyschewi* Sokolov, no. 3/587: (1a) side view, (1b) apertural view; the Pezhenga section, *Elatmae* Zone, *C. tschernyschewi* Biohorizon. (2) *Macrocephalites* (*Macrocephalites*) *pavlowi* Smorodina, no. A155 (283/5), side view; the Prosek-Isady section, *Elatmae* Zone, *C. surensis* Biohorizon (see Plate II, no. 3). (3) *Cadochamousetia subpatrius* (Nikitin), no. 5/1159: (3a) side view, (3b) view from the mouth; the Uzhovka section, *Elatmae* Zone, *C. subpatrius* Biohorizon.

[?=*Ch. phillipsi* Call. et Wright, *Ch. buckmani* Call. et Wright] (Plate VI, fig. 3) is principal dominant species that demonstrates wide variations. *Chamoussetia* microconchs occur in abundance. In contrast, specimens of *Cadoceras* and *Pseudocadoceras* s.s. are rare. The subfamily Gowericeratinae also represents more than 40% of the ammonite assemblage. Its representatives *K. (G.) densicostatus* (Plate I, fig. 3; Plate V, fig. 2) are distinct from forms of the subgenus *K. (Gowericereras)* of the *Elatmae* Zone, as they have more involute whorls and wider spaced, coarser primary ribs on the mature body chamber. Microconchs of Gowericeratinae are represented by *Toricellites lahusei* (Par. et Bon.). Species *Proplanulites (Proplanulites)* cf. *subcuneiformis* Buckm. and others of the subfamily Proplanulitinae constitute approximately 15% of the ammonite assemblage.

Stratigraphic position. In Germany (Schwabia), species *K. (G.) densicostatus*, *Ch. cf. aff. phillipsi* and *P. (P.) cf. subcuneiformis* are reported from the *M. macrocephalus* Biohorizon of the upper part of the *Gowerianus* Zone (Callomon *et al.*, 1989, 1992). Accordingly, there is a reliable correlation between the *K. densicostatus* Biohorizon and this standard stratigraphic level.

Distribution. The *K. densicostatus* Biohorizon evidently occurs in many areas of Central Russia.

K. curtilobus Biohorizon

Index species: *Kepplerites (Gowericereras) curtilobus* (Buckman, 1922) [= *K. (G.) crucifer* (Buckm.), ? *K. (G.) galilaei* (Opp.) sensu Buckman, ? *K. (G.) indigestus* (Buckm.)]. Photograph of holotype from Yorkshire, England, was published by Buckman (1922, Plate 294).

Nomenclature. The *K. curtilobus* Biohorizon was first distinguished at the base of the *Curtilobus* Zone of England (Callomon *et al.*, 1988). In Central Russia, the synonymous biohorizon was recognized in the Prosek-Isady section (Fig. 2, assemblage a8) (Gulyaev, 1999) and in the sections of Alpat'evo (Fig. 5, assemblage d1), Akatovo, and Manturovo-Znamenka sites.

Paleontological characteristics. Approximately 40% of the ammonite fauna are constituted by the diverse *Cadoceras (Cadoceras)*, *C. ("Bryocadoceras")*, *Pseudocadoceras (Pseudocadoceras)*, and *P. (Novocadoceras)* species of the subfamily Cadoceratinae. Most common forms are *C. (C.) tolype* Buckm., *C. (C.) ex gr. sokolovi* Kiss, *P. (P.) boreale* Buckm., and *P. (P.?) aff. whithami* Call. et Wright. Single *Chamoussetia* specimens may also occur. About 40% of the ammonite assemblage are represented by the species *K. (G.) curtilobus* (Plate II, figs. 1, 2) and *Toricellites curticornutus* Buckm. of the subfamily Gowericeratinae. These species marks the next evolutionary stage of the genus *Kepplerites*. The former differs from the index species of the preceding biohorizon by its more involute and higher whorls, finer and closer spaced ribs at the early and intermediate growth stages, and by widely

spaced and thick primary 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, 1989; 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: *Kepplerites (Gowericereras) 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.) cf. trichophorus* was reported as well from the *Ch. phillipsi* Biohorizon of eastern Greenland (Callomon, 1993).

Calloviense Zone

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

Nomenclature. The *Calloviense* Zone was initially distinguished by Oppel (1857) as a peculiar upper interval of the *Amm. macrocephalus* Beds of England (approximately the entire lower Callovian Substage).

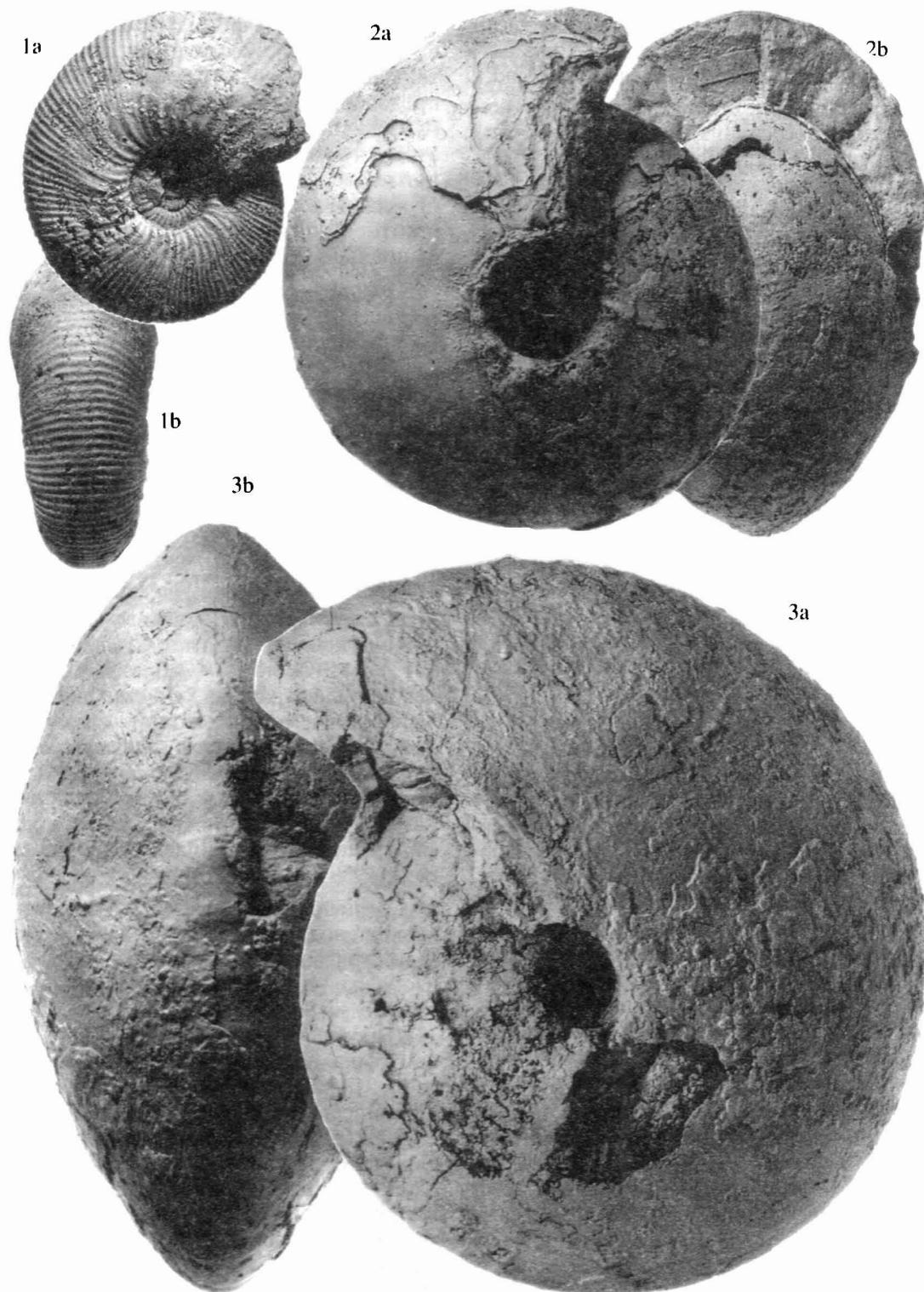


Plate IV. Characteristic early Callovian ammonite species of Central Russia (full size)

(1) *Kepplerites* (*Gowericeras*) *trichophorus* (Buckman), no. A10: (1a) side view, (1b) ventral side); the Prosek-Isady section, *Koenigi* Zone, *K. trichophorus* Biohorizon. (2) *Cadochamoussetia* *surensis* (Nikitin), no. A132: (2a) side view, (2b) apertural view; the Prosek-Isady section, *Elatmae* Zone, *C. surensis* Biohorizon. (3) *Chamoussetia* (?) *saratovensis* Callomon et Wright, no. 5/1142: (3a) side view, (3b) ventral view; the Uzhovka section, *Elatmae* Zone, *Ch. saratovensis* Biohorizon.

The *Calloviense* 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 *Planicerclus* Subzone. Later Callomon (1964) came to the conclusion that the forms described by Buckman (1923) as *Sigaloceras* (*Catasigaloceras*) *planicerclus*, *S. (C.) crispatum*, and *S. (C.) curvicerclus* from the Callovian deposits of England are synonyms of *S. (C.) enodatum* (Nikitin, 1881) from Central Russia. This allowed him to rename the *Planicerclus* Zone into the *Enodatum* Zone.¹ At present the *Koenigi* Zone is authorized as an independent unit, and the standard *Calloviense* Zone is subdivided into the *Calloviense* and *Enodatum* subzones (Callomon *et al.*, 1988; Page, 1989).

By analogy with the standard zonation, Meledina (1986, 1987) suggested to distinguish the *Calloviense* 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* (*Catasigaloceras*), 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. (Catasigaloceras)*—*K. (Gulielmites)* suggests that *S. (C.) enodatum* appeared earlier than its ancestors *K. (G.) medea* (Call.) and *K. (G.) jason* (Rein.), which are subzonal index species in the *Jason* Zone (Callomon, 1955). (3) In the Alpat'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 calloviensis* 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 estab-

lished 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 *Amm. macrocephalus* and *Amm. 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 Rashvan, 1996; *Biostratigraphie...*, 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 *Calloviense* Zone of Central Russia is virtually lacking the subfamily Proplanulitinae, whereas the subfamily Pseudoperisphinctinae 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* (*Gowericerates*) 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. (Catasigaloceras)* 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. (Rondiceras)* 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. (“Bryocadoceras”)* (descendants of the group of *C. (“B.”) laetum* Gul.) having wide whorls with radial ribs. Among two microconch groups of Cadoceratinae, the first one is represented by flattened involute and finely ribbed species of *Pseudocadoceras* (*Pseudocadoceras*) Buckman, and the second by moderately evo-

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.

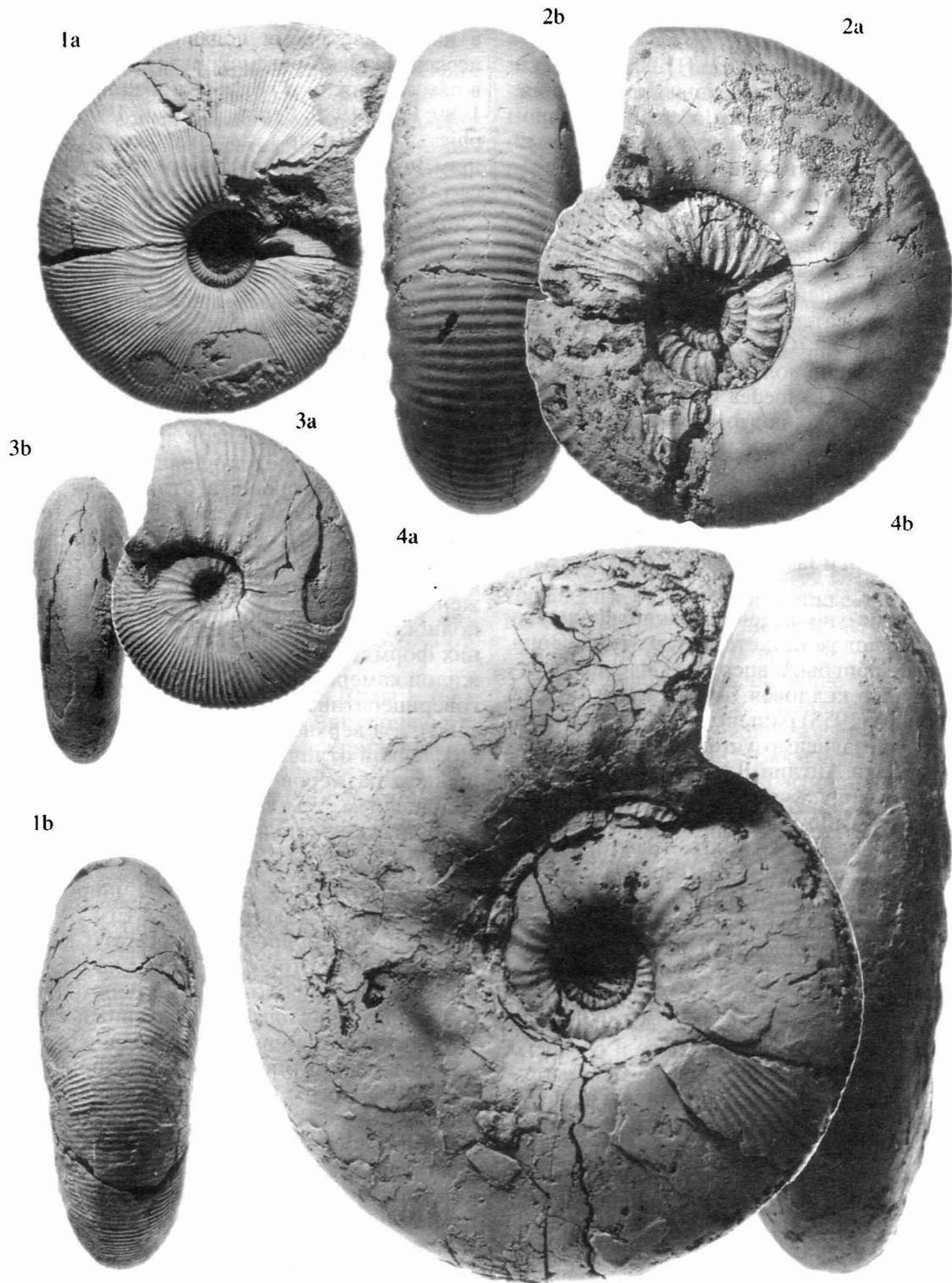


Plate V. Characteristic early Callovian ammonite species of Central Russia (full size)

(1) *Sigaloceras* (*Sigaloceras*) *calloviense* (Sowerby), no. A60: (1a) side view, (1b) ventral view; the Prosek-Isady section, *Calloviense* Zone, *S. calloviense* Biohorizon. (2) *Kepplerites* (*Gowericeras*) *densicostatus* Tintant, no. A35: (2a) side view, (2b) ventral side; the Prosek-Isady section, the *Koenigi* Zone, the *K. densicostatus* Biohorizon. (3) *Sigaloceras* (*Catasigaloceras*) *enodatium* (Nikitin), no. 7/1250: (3a) side view, (3b) ventral side; the Nikitino section, *Calloviense* Zone, *S. enodatium* Biohorizon. (4) *S.* (*Sigaloceras*) *calloviense* (Sowerby), no. A53: (4a) side view, (4b) ventral view; the Prosek-Isady section, *Calloviense* Zone, *S. calloviense* Biohorizon.

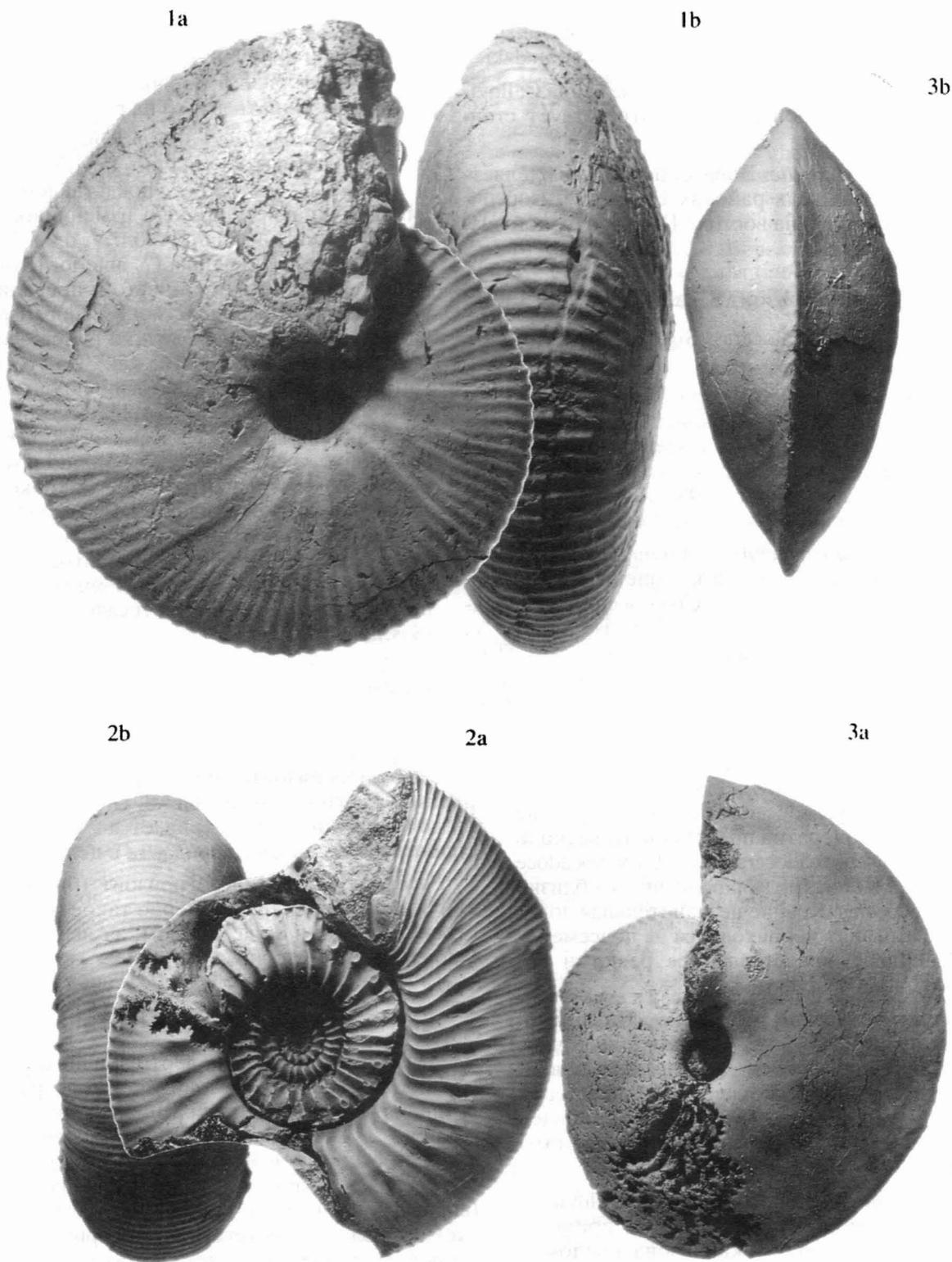


Plate VI. Characteristic early Callovian ammonite species of Central Russia (actual size)

(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) *Keplerites (Gowericeras) unzhae* Gulyaev, holotype no. 3/1007 (283/7): (2a) side view, (2b) ventral side: the Pezhenga section, the *Elatmae* Zone, the *C. ischernyschewi* Biohorizon. (3) *Chamoussetia chamousseti* (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 *Homoeoplanulites (Anaplanulites)* Buckman, *Indosphinctes* Spath, and *Choffatia* Siemiradzki forms representing the subfamily Pseudoperisphinctinae.

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

Distribution. The *Calloviense* 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 *Calloviense* Zone in England (Callomon *et al.*, 1988). In Central Russia, it was established in the sections of Prosek-Isady (Fig. 2, assemblage a10) (Gulyaev, 1999), Alpat'ev (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 *Gulielmina quinqueplicata* Buckm. species of the subfamily Gowericeratinae. The subfamily Cadoceratinae is frequently next in abundance. Macroconchs are dominated by forms similar to *Cadoceras (Cadoceras) sublaeve* (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 *Costacadoceras* forms. The subfamily Proplanulitinae including rare *Proplanulites (Crassiplanulites)* sp. is a minor component of the ammonite assemblage.

Stratigraphic position. In England, species *S. (S.) calloviense* and *C. (C.) sublaeve* are confined to the *S. calloviense* Biohorizon of the lower part of the *Calloviense* 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 (Catasigaloceras) enodatum* (Nikitin, 1881) [= *S. (C.) crispatum* (Buckm.), *S. (C.) curvicerelus* (Buckm.), ? *S. (C.) planicerelus*

(Buckm.)]. The lectotype no. 26/1344 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'ev (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 *Gulielmina (?) anterior* (Brinkm.) from the subfamily Gowericeratinae. The subfamily Pseudoperisphinctinae is also abundant and frequently prevailing in the assemblages. Forms similar to *Homoeoplanulites (Anaplanulites) difficilis* (Buckm.) were found as well. In the Nikitino and Alpat'ev 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?) tschefkini* (Orb.) and to *C. (Rondiceras) milashevici* (Nik.). The Cadoceratinae microconchs are classed with *Pseudocadoceras (Pseudocadoceras) homoeomorphum* Kiss. and *P. (Novocadoceras) cf. suraense* (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 Nizhnii 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 *Infirmum* Zone includes the *C. infimum* and *C. cf. aff. infimum* 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-

graphic differentiation of ammonite faunas is an obstacle for the direct correlation of the *Infinum* Zone with the standard scale. According to its stratigraphic position relative the *Elatmae* Zone, the zone in question must correspond approximately to the *Discus* Zone and, probably, to an upper part of the *Orbis* Zone of the standard upper Bathonian zonation.

The next *Elatmae* Zone includes *M. jacquoti*, *C. elatmae*, *C. tschernyschewi*, *C. surensis*, *C. subpatruus*, 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) dominant in the ammonite assemblages are combined with representatives of Tethyan taxa (Macrocephalitinae and Pseudoperisphinctinae). Basing on correlation of some stratigraphic levels, the *Elatmae* Zone as a whole is considered to be analogous to the lowermost *Herveyi* Zone of the standard Callovian scale.

The *Koenigi* Zone includes *K. densicostatus*, *K. curtilobus*, 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 ammonite assemblages of that time. The *Koenigi* Zone of Central Russia corresponds to the same standard zone.

The *Calloviense* Zone crowning the lower Callovian zonation includes the *S. calloviense* 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 ammonite assemblages. The *Calloviense* Zone of Central Russia corresponds to the same zone of the standard scale.

ACKNOWLEDGMENTS

The work was supported by the Russian Foundation for Basic Research, project no. 96-05-64934, and by the High School Scientific Program "Basic Research in Universities of Russia", project no. 5024.

Reviewers K.I. Kuznetsova and S.V. Meledina

REFERENCES

- Alekseev, S.N. and Repin, Yu.S., Problems of Zonal Subdivision of the Lower Callovian in the Russian Platform, *Metodicheskie aspekty stratigraficheskikh issledovaniy v neftegazonosnykh basseynakh* (Methodical Aspects of Stratigraphic Studies in Oil- and Gas-bearing Basins), Leningrad: Vses. Nauch.-Issled. Geol.-Razved. Inst., 1989, pp. 122–134.
- Arkell, W.J., *The Jurassic System in Great Britain*, Oxford: Clarendon Press, 1933.
- Arkell, W.J., Standard of the European Jurassic, *Bull. Geol. Soc. Am.*, 1946, vol. 57, no. 1, pp. 1–34.
- Arkell, W.J., *Jurassic Geology of the World*, London: Oliver Boyd, 1956.
- Biostratigraphie du Jurassique ouest-europeen et mediterraneen: zonations paralleles et distribution des invertebres et microfossiles, *Bull. Centre Rech. Elf Explor. Prod.*, 1997, Mem. 17.
- Brinkmann, R., *Monographie der Gattung Kosmoceras*, *Abhandl. Ges. Wiss. Gottingen, Math.-Phys. Kl., N.F.*, 1929, vol. 13, no. 4.
- Buckman, S.S., The Bajocian of the Sherborne District: Its Relation to Subjacent and Superjacent Strata, *Quart. J. Geol. Soc., London*, 1893, vol. 49, pp. 479–522.
- Buckman, S.S., The Term "Hemera", *Geol. Mag.*, 1902, no. 9, pp. 554–557.
- Buckman, S.S., *Yorkshire Type Ammonites*, London: Wesley and Son, 1909–1930, vols. 1–7.
- Buckman, S.S., The "Kelloways Rock" of Scarborough, *Quart. J. Geol. Soc., London*, 1913, vol. 69, pp. 152–168.
- Callomon, J.H., The Ammonites Succession in the Lower Oxford Clay and Kelloways Beds of Kidlington, Oxfordshire and the Zones of the Callovian Stage, *Phil. Trans. Royal Soc., Ser. Biol. Sci. London*, 1955, vol. 239, pp. 215–264.
- Callomon, J.H., Notes on the Callovian and Oxfordian Stages, *J. Colloq. du Jurassique, Luxemburg*, 1962, Paris, 1964, pp. 269–291.
- Callomon, J.H., A Review of the Biostratigraphy of the Post-Lower Bajocian, Jurassic Ammonites of Western and Northern North America, *Geol. Assoc. Canada Spec. Pap.*, 1984, no. 27, pp. 143–174.
- Callomon, J.H., The Evolution of the Jurassic Ammonite Family Cardioceratidae, *Spec. Pap. Paleont.*, 1985, no. 33, pp. 49–90.
- Callomon, J.H., The Ammonite Succession in the Middle Jurassic of East Greenland, *Bull. Geol. Soc. Denmark*, 1993, vol. 40, pp. 83–113.
- Callomon, J.H., Dietl, G., and Page, K.N., On the Ammonite Faunal Horizons and Standard Zonations of the Lower Callovian Stage in Europe, *2nd Int. Symp. on Jurassic Stratigraphy Lisboa*, 1988, pp. 359–376.
- Callomon, J.H., Dietl, G., and Niederhofer, H.-J., Die Ammonitenfaunen-Horizonte im Grenzbereich Bathonium/Callovium des Schwabischen Juras und deren Korrelation mit W-Frankreich und England, *Stuttgarter Beitr. Naturk. Ser. B*, 1989, no. 148, pp. 1–13.
- Callomon, J.H., Dietl, G., and Niederhofer, H.-J., On the True Stratigraphic Position of *Macrocephalites macrocephalus* (Schlotheim, 1813) and the Nomenclature of the Standard Middle Jurassic "Macrocephalus Zone", *Stuttgarter Beitr. Naturk. Ser. B*, 1992, no. 185, pp. 1–65.
- Callomon, J.H. and Wright, J.K., Cardioceratid and Kosmoceratid Ammonites from the Callovian of Yorkshire, *Palaeontology*, 1989, vol. 32, part. 4, pp. 799–836.
- Dietl, G., Über *Macrocephalites* (Ammonoidea) aus dem Aspidoidea-Oolith und die Bathonium/Callovium-Grenzsichten der Zollernalb (SW-Deutschland), *Stuttgarter Beitr. Naturk. Ser. B*, 1981, no. 68, pp. 1–15.

- Dietl, G. and Callomon, J.H., Der Orbis-Oolith (Ober-Bathonium, Mittl. Jura) von Sengenthal, Opf., Frank. Alb. und seine Bedeutung für die Korrelation und Gliederung der Orbis-Zone, *Stuttgarter Beitr. Naturk. Ser. B.* 1988, no. 142, pp. 1–31.
- Douville, H., Note sur le bathonien des environs de Toul et de Neufchâteau, *Bull. Soc. geol. France*, 1878, vol. 6, pp. 568–577.
- Ershova, E.S., *Ob'yasnitel'naya zapiska k biostratigraficheskoi skheme yurskikh i nizhnemelovykh otlozhenii arhipelaga Shpitsbergen* (Explanatory Note to Biostratigraphic Scheme of the Jurassic and Lower Cretaceous of the Spitsbergen Archipelago), Leningrad: Sevmoregeologiya, 1983.
- Gerasimov, P.A., Mitta, V.V., Kochanova, M.D., and Tesakova, E.M., *Iskopaemye kelloveiskogo yarusa Tsentral'noi Rossii* (Fossils of the Callovian Stage in Central Russia), Moscow, 1996.
- Gulyaev, D.B., Macrocephalites and Govericeratines (Ammonoidea) of the *Elatmae* Zone and the Lower Callovian Stratigraphy of Central Regions of the Russian Platform, *Problemy stratigrafii i paleontologii mezozoya* (Problems of the Mesozoic Stratigraphy and Paleontology), St. Petersburg: Vses. Nauchn.-Issled. Geol.-Razved. Inst., 1999, pp. 63–85.
- Gulyaev, D.B. and Kiselev, D.N., Boreal Upper Bathonian in the Volga River Middle Courses (Ammonites and Stratigraphy), *Stratigr. Geol. Korrelyatsiya*, 1999, vol. 7, no. 3, pp. 279–293.
- Kamysheva-Elpat'evskaya, V.G., Nikolaeva, V.P., and Troitskaya, E.A., *Opredelitel' yurskikh ammonitov Saratovskogo Povolzh'ya* (Guide to Jurassic Ammonites from the Volga Region near Saratov), Moscow: Gosgeoltekhizdat, 1956.
- Kamysheva-Elpat'evskaya, V.G., Nikolaeva, V.P., and Troitskaya, E.A., Ammonite Stratigraphy of Jurassic Sediments near Saratov, the Volga River Right-Bank Region, *Stratigrafiya i fauna yurskikh i melovykh otlozhenii Saratovskogo Povolzh'ya* (The Stratigraphy and Fauna of Jurassic and Cretaceous Sediments of the Volga River Region near Saratov), Leningrad: Gostoptekhizdat, 1959, pp. 3–265.
- Kopik, J. and Wierzbowski, A., Ammonites and Stratigraphy of the Bathonian and Callovian at Janusfjellet and Wimanfjellet, Sassenfjorden, Spitsbergen, *Acta Palaeontol.*, 1988, vol. 33, no. 2, pp. 145–168.
- Laguzen, I., Fauna of the Jurassic Sediments in Ryazan District, *Tr. Geol. kom-ta*, 1883, vol. 1, no. 1.
- Meledina, S.V., Zonation of the Lower Callovian in the Russian Platform, *Izv. Akad. Nauk SSSR., Ser. Geol.*, 1986, no. 7, pp. 66–74.
- Meledina, S.V., *Ammonity i zonal'naya stratigrafiya kellovaya subboreal'nykh raionov SSSR* (Ammonites and Callovian Zonation in Subboreal Regions of the Soviet Union), Moscow: Nauka, 1987.
- Meledina, S.V., Zonation Scheme for the "Boreal Bathonian" (Lower Callovian of Siberia), *Detal'naya stratigrafiya i paleontologiya yury i mela Sibiri* (Detailed Stratigraphy and Paleontology of the Jurassic and Cretaceous of Siberia), Novosibirsk: Nauka, 1991, pp. 125–154.
- Meledina, S.V., *Boreal'naya srednyaya yura Rossii (ammonity i zonal'naya stratigrafiya baioisa, bata i kellovaya)* (The Boreal Middle Jurassic of Russia: Ammonites and Zonal Stratigraphy of the Baurasian, Bathonian, and Callovian), Novosibirsk: Nauka, 1994.
- Nikitin, S.N., Ammonites from the Group of the *Amaltheus funiferus* Phill., *Bull. Soc. Nat. Moscou*, 1878, vol. 53, no. 2, pp. 81–160.
- Nikitin, S.N., Der Jura der Umgegend von Elatma, *Mem. Soc. Natur. Moscou*, 1881, vol. 15, Hf. 1, pp. 1–51.
- Nikitin, S.N., Der Jura der Umgegend von Elatma, *Mem. Soc. Natur. Moscou*, 1885, vol. 15, Hf. 2, pp. 43–66.
- Oppel, A., Die Juraformation Englands, Frankreichs und des sudwestlichen Deutschlands, *Jh. Ver. Vaterl. Naturk. Wurt. Stuttgart*, 1856–1858, vols. 12–14.
- Oppel, A., Über jurassische Cephalopoden, *Palaeontol. Mitt. Mus. Bayer. Staat. Stuttgart*, 1862–1863, vol. 3, pp. 127–266.
- Orbigny, A., *Paleontologie Francaise: Terrains jurassiques. I. Cephalopodes*, Paris, 1842–1851.
- Page, K.N., A Stratigraphical Revision for the English Lower Callovian, *Proc. Geol. Ass.*, 1989, vol. 100, no. 3, pp. 363–382.
- Page, K.N., Biohorizons and Zonules: Intra-Subzonal Units in Jurassic Ammonite Stratigraphy, *Palaeontology*, 1995, vol. 38, Pt. 4, pp. 801–814.
- Postanovleniya Mezhdedomstvennogo stratigraficheskogo komiteta i ego postoyannykh komissii: Komissiya po yurskoi sisteme* (Resolutions of Interdepartmental Stratigraphic Committee and its Permanent Commissions: Commission on the Jurassic System), Leningrad: Nedra, 1978, no. 18, pp. 32–34.
- Poulton, T.P., Zonation and Correlation of Middle Boreal Bathonian to Lower Callovian (Jurassic) Ammonites, Salmon Cache Canyon, Porcupine River, Northern Yukon, *Bull. Geol. Surv. Canada*, 1987, no. 358.
- Quenstedt, F.A., *Petrefaktenkunde Deutschlands, Bd. 1: Cephalopoden*, Tübingen: Fues, 1845–1849.
- Quenstedt, F.A., *Die Ammoniten des schwabischen Jura, Bd. II: Der Braune Jura*, Stuttgart: Schweizerbart, 1886–1887, pp. 441–815.
- Repin, Yu.S. and Rashvan, N.Kh., *Kelloveiskie ammonity Saratovskogo Povolzh'ya i Mangyshlaka* (Callovian Ammonites from the Mangyshlak and Volga River Region near Saratov), St. Petersburg: Mir i sem'ya-95, 1996.
- Resheniya Vsesoyuznogo soveshchaniya po razrabotke unifikirovannoi skhemy stratigrafii mezozoiskikh otlozhenii Russkoi platformy* (Resolutions of All-Union Conference on the Development of a Unified Scheme for the Mesozoic Stratigraphy of the Russian Platform), Leningrad: Gostoptekhizdat, 1955, tabl. 10.
- Resheniya Vsesoyuznogo soveshchaniya po utochneniyu unifikirovannoi skhemy stratigrafii mezozoiskikh otlozhenii Russkoi platformy* (Resolutions of All-Union Conference on Refinement of the Unified Stratigraphic Scheme of Mesozoic Deposits in the Russian Platform), Leningrad: Gostoptekhizdat, 1962, 15 tabl.
- Sazonov, N.T., Stratigraphy of Jurassic and Lower Cretaceous Sediments in the Russian Platform and Dnieper-Donets and Caspian Depression, *Byul. Mosk. O-va Ispyt. Prir., Otd. Geol.*, 1953, vol. 28, no. 5, pp. 71–100.
- Sazonov, N.T., *Yurskie otlozheniya tsentral'nykh oblastei Russkoi platformy* (Jurassic Sediments in Central Regions of Russian Platform), Leningrad: Gostoptekhizdat, 1957.
- Sazonov, N.T., New Data on Callovian, Oxfordian, and Kimmeridgian Ammonites, *Fauna mezozoya Evropeiskoi chasti SSSR i Srednei Azii* (Mesozoic Fauna from the European Part of the Soviet Union and Central Asia), Moscow: Nedra, 1965, pp. 3–49.

- Sei, I.I. and Kalacheva, E.D., The Bathonian–Callovian Boundary in Boreal and Subboreal Regions of Russia, *Otech. Geol.*, 1992, no. 10, pp. 47–52.
- Shishkin, M.A., Evolution As an Epigenetic Process, *Sovremennaya paleontologiya (Modern Paleontology)*, Moscow: Nedra, vol. 2, 1988, pp. 142–169.
- Shmal'gauzen, I.I., *Faktory evolyutsii (teoriya stabiliziruyushchego otbora) (The Evolution Factors: Theory of Stabilizing Selection)*, Moscow: Nauka, 1968.
- Sokolov, D.N., To the Ammonoid Fauna in the Jurassic of the Pechora Region, *Tr: Geol. kom-ta., Nov. Ser.*, 1912, no. 76.
- Sowerby, J. and Sowerby, J.C., *The Mineral Conchology of Great Britain*, London: B. Meredith, 1812–1846, vols. 1–7.
- Spath, L.F., The Invertebrate Faunas of the Bathonian–Callovian Deposits of Jameson Land (East Greenland), *Medd. Groenland*, 1932, vol. 87, no. 7, pp. 1–158.
- Tintant, H., Les Kosmocerotides du Callovien inferieur et moyen d'Europe occidentale, *Publ. Univ. Dijon*, 1963, vol. 29.
- Zony yurskoi sistemy (Zones of the Jurassic System)*, Leningrad: Nauka, 1982.