ISSN 0869-5938, Stratigraphy and Geological Correlation, 2013, Vol. 21, No. 2, pp. 189–214. © Pleiades Publishing, Ltd., 2013.
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Belemnites in the Jurassic–Cretaceous Boundary Interval of the Mauryn'ya and Yatriya River Sections, Western Siberia: Biostratigraphic Significance and Dynamics of Taxonomic Diversity

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Received October 5, 2011; in final form, February 22, 2012

Abstract—The stratigraphic distribution and taxonomic diversity of belemnites from the Volgian and Ryazanian deposits exposed in the eastern foothills of the North and Subpolar Urals, are studied and analysed. Studies of new collections from the Mauryn'ya and Yatriya rivers have revealed within the Laugeites groenlandicus–basal Surites analogus ammonite zones, the East Siberian Lagonibelus napaensis, Cylindroteuthis knoxvillensis, and Liobelus russiensis belemnite zones (the latter in the beds' rank), the Lagonibelus gustomesovi and Arctoteuthis porrectiformis Beds, and local beds with Boreioteuthis explorata and Simobelus compactus. Since in the boundary beds of the Volgian and Ryazanian stages a great number of belemnite species known from the Tordenskjoldberget Member, Kong Karls Land, Svalbard, were found, it is inferred that the accumulation of the member started not in the Valanginian as many researchers believe but immediately at the beginning of the Cretaceous. The dynamics of belemnite species diversity in the northwestern margin of the West Siberian marine basin correlates well with climatic events. An increase of species number in the terminal Volgian–beginning of the Ryazanian corresponds to a temperature elevation in the Siberian paleoseas, and the subsequent reduction of species diversity in the second half of the Ryazanian is correlated with a gradual cooling. The peak of belemnite taxonomic diversity falls at the beginning of the Cretaceous when up to 15 species belonging to eight Cylindroteuthididae genera occurred concurrently. The new species *Cylindroteuthis ornata* sp. nov., *Acroteuthis pseudoconoides* sp. nov., *Pachyteuthis eximia* sp. nov., and *Simobelus compactus* sp. nov. are described.

Keywords: Belemnites, Cylindroteuthididae, biostratigraphy, biodiversity, Volgian and Ryazanian stages, Western Siberia

DOI: 10.1134/S0869593813020020

INTRODUCTION

This work continues research on the boreal belemnite family Cylindroteuthididae in Jurassic and Cretaceous boundary sediments. The preceding paper (Dzyuba, 2012) included the results of paleontological and stratigraphic studies of new belemnite collections from northern Eastern Siberia. This paper considers the new data on belemnite rostra collected in the Volgian and Ryazanian (=Boreal–Berriasian) deposits in the northwestern margin of Western Siberia.

The Jurassic–Cretaceous boundary sediments in Western Siberia are outcropped in the foothills of the North and Subpolar Urals. They are exposed in bank escarpments of the streams belonging to the Vol'ya and Lyapin river basins, two large tributaries of the Severnaya Sos'va River. The well-exposed sections along the Tol'ya and Yany-Man'ya rivers of the Vol'ya River basin yield remains of ammonites, bivalves, and brachiopods. In the Upper Volgian and Ryazanian deposits the occurrence of belemnites is mainly evidenced by holes from dissolved belemnite rostra, whereas the rostra themselves are very scarce. In this stratigraphic interval belemnites are numerous in the sodded bank escarpments of the Mauryn'ya (the Tol'ya tributary) and Yatriya (Lyapin River basin) rivers. The most complete section of Volgian and Ryazanian boundary strata is recorded on the Mauryn'ya River (Mesezhnikov and Braduchan, 1982; Alifirov et al., 2008).

Studies of belemnite collections from the Mauryn'ya and Yatriya rivers (Fig. 1) made it possible to supplement the taxonomic characteristics of the Volgian and Ryazanian stages, to reveal the interregional correlation intervals, and to evaluate changes of taxonomic diversity of Siberian belemnites at the Jurassic–Cretaceous boundary.[1]

[1] The Jurassic–Cretaceous boundary in this paper is accepted within the Craspedites taimyrensis Zone according to magnetostratigraphic data (Houša et al., 2007).

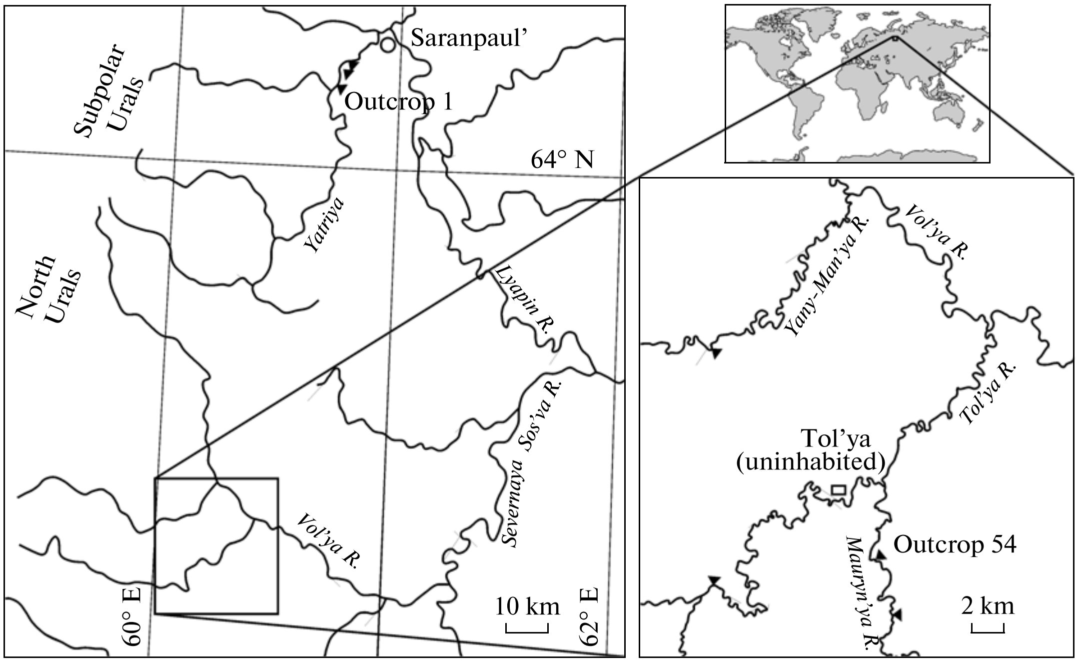


Fig. 1. Location of major sections of the Volgian and Ryazanian stages in the eastern foothills of the North and Subpolar Urals (Western Siberia).

ANALYSIS OF THE PRECEDING RESEARCH OF BELEMNITE TAXONOMIC COMPOSITION

The available published information on taxonomic composition and distribution of belemnites in the Volgian and Ryazanian stages in the northwestern margin of Western Siberia is significantly confusing and contradictory. Therefore it is necessary to take a close look at the history of their study.

The first data on belemnites of this region were obtained in the expedition of N.I. Strazhevskii in 1833 and 1834, which permitted Eichwald (1865–1868) to identify *Belemnites mamillaris* sp. nov. in the collection from the Tol'ya River. This species, typical of the Volgian Stage was considered to be Neocomian by Eichwald, since he assigned most of the Jurassic sediments to the Neocomian (*Geologiya*..., 1944). In the next century belemnites were repeatedly cited in the scientific literature in the lists of fossils characterizing certain parts of the Volgian. Results of identification of new material obtained in the expeditions were reported by Ilovaiskii (1917), Bodylevskii (*Geologiya*..., 1944), Krymgol'ts (1949), Lider (1957), Mikhailov (1957, 1964), Mesezhnikov (1959 and others), and Teslenko (1962). Information on belemnites from the Ryazanian Stage became available later. During the period under discussion only a single paper with a description and images of the new finds was published. Among rostra collected by N.P. Mikhailov in 1950–1953 from the lower Volgian Stage (=Lower and Middle Volgian substages) on the Yatriya River, Gustomesov (1960) identified *Cylindroteuthis (Lagonibelus) michailovi* sp. nov. In the same work, Transuralian rostra are mentioned in the description of *C. (L.) rosanovi* sp. nov. and *Pachyteuthis (Pachyteuthis) cuneata* sp. nov., species characteristic of the Russian Platform. The latter identification, judging from a more recent paper (Gustomesov, 1964), the author considered to be a mistake.

The beginning of systematic study and monographic description of the Volgian and Ryazanian belemnite collections from the eastern foothills of the Urals are associated with the V.N. Saks and T.I. Nal'nyaeva. Results of the study of new collections numbering about 100 specimens from the Yatriya (collected by T.A. Vereninova in 1960 and 1961), Tol'ya, Yany-Man'ya, and Mauryn'ya (collected by Nal'nyaeva in 1962) rivers, were included in two monographs published by them in 1964 and 1966 under the general title "Upper Jurassic and Lower Cretaceous belemnites of the northern USSR".

On the Yatriya River *Acroteuthis (Microbelus) russiensis* (d'Orb.) was described from the lower Volgian Stage (=Lower and Middle Volgian substages).

Five species were recorded in the collection from the Tol'ya River, namely, *Pachyteuthis (Simobelus) mamillaris* (Eichw.) and *P. (S.) subbreviaxis* sp. nov. from the lower substage of the lower Volgian Stage; *Lagonibelus (Lagonibelus) sibiricus* sp. nov. from the upper substage of the lower Volgian Stage–Berriasian; *Acroteuthis (Microbelus) mosquensis* (Pavl.) from the (?) upper Volgian Stage–Berriasian; and *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.) from the Berriasian–Valanginian. The following species were also recorded in the sequence referred to the Upper Berriasian (*Tolli* ammonite zone (a-Zone))–Valanginian: *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), *A. (A.) arctica* (Blüthg.), *A. (A.) bojarkae* sp. nov., *A. (A.) lateralis* (Phill.), *A. (A.) sublateralis* Swinn., and *A. (Boreioteuthis) hauthali* Blüthg. (Saks and Nal'nyaeva, 1966). Many of them are illustrated. However, the true origin of the material remains a mystery, since the Berriasian Tolli a-Zone is not recorded on the Tol'ya River and considerably different belemnite assemblages were subsequently revealed there in the Valanginian (Saks and Klimova, 1967; Gol'bert et al., 1972a, and others). According to these papers, the most similar belemnite taxonomic composition is characteristic of the Lower Valanginian part of the Leshaka-Shchel'e outcrop on the Yatria River.

Five species are identified in the collection from the Yany-Man'ya River; they are *Pachyteuthis (Simobelus) insignis* sp. nov. from the upper substage of the lower Volgian; *Lagonibelus (Lagonibelus) sibiricus* sp. nov. from the upper substage of the lower Volgian–Berriasian; *Acroteuthis (Microbelus) mosquensis* (Pavl.) and *A. (Boreioteuthis) explorata* sp. nov. from the (?) upper Volgian–Berriasian; and *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.) from the Berriasian–Valanginian.

The greatest number of species, eleven, were recognized in the collection from the Mauryn'ya River (Outcrop 54), namely, *Acroteuthis (Microbelus) mosquensis* (Pavl.), *A. (M.) uralensis* sp. nov., *A. (Boreioteuthis) explorata* sp. nov., and *Pachyteuthis (Pachyteuthis) acuta* (Blüthg.) from the (?) Upper Volgian–Berriasian; *Cylindroteuthis (Arctoteuthis) porrectiformis* And. from the (?) Lower Berriasian; *C. (A.)* aff. *subconoidea* sp. nov., *C. (A.) repentina* sp. nov., and *C. (Cylindroteuthis) lepida* sp. nov. from the Upper Berriasian; and *Lagonibelus (Lagonibelus) gustomesovi* sp. nov., *L. (L.) sibiricus* sp. nov., and *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.) from the Berriasian.

The taxonomic studies of cylindroteuthids conducted by Saks and Nal'nyaeva (1964, 1966) showed that most of the species names of Uralian belemnites cited in the older literature are not suitable for further use. The research was actually restarted and collecting of additional material was required. One of the problems to be solved was the need for a precise dating of belemnite assemblages that was correlated with the ammonite zonal scale. A reliable determination of stratigraphic distribution of cylindroteuthid species was often hampered by lack of associated findings of ammonites. For instance, a rich belemnite assemblage collected on the Mauryn'ya River was accompanied by only a single find of the ammonite *Subcraspedites (Borealites)* ex gr. *suprasubdidus* (Bogosl.) (*Granitsa*..., 1972). This resulted in a somewhat conditional age estimate of the belemnite assemblages as the (?) Upper Volgian–Berriasian. As a consequence, precisely this dating as far as possible was taken into account in the tables summarizing information on the stratigraphic distribution of the Uralian belemnites (Saks and Nal'nyaeva, 1964, 1966, 1968, 1972; Nal'nyaeva, 1992).

The fieldwork conducted in 1965 and 1966 with the participation of paleontologists V.A. Zakharov, I.G. Klimova, M.S. Mesezhnikov, and V.N. Saks was of great importance for obtaining a new concept of belemnite stratigraphic distribution in the Jurassic–Cretaceous boundary sediments of the northwestern margin of Western Siberia. Owing to the oil and gas productivity of Jurassic and Cretaceous sediments in Western Siberia, considerable attention was focused on biostratigraphy of this region, which resulted in a thorough layer-by-layer collecting of fossils in outcrops. Subsequently in 1967–1969 and 1971 A.V. Gol'bert and I.G. Klimova undertook expeditions in the eastern foothills of the Urals and particularly thoroughly studied the Cretaceous sections. The results of these works were published in a number of papers and monographs.

In the outcrop on the Yatriya River Saks and Klimova (1967) encountered *Acroteuthis (Microbelus) russiensis* (d'Orb.) (Fulgens a-Zone) together with the ammonites *Kachpurites* sp. and *Craspedites* sp. In the overlying strata *Craspedites* sp. was accompanied by *Lagonibelus* sp. (Subditus a-Zone); and, finally, *Garniericeras* sp. was found in association with *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln., *C. (Arctoteuthis) repentina* Sachs et Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln., *L. (L.) elongatus* (Blüthg.), and *Pachyteuthis (Simobelus) insignis* Sachs et Naln. All these three faunal assemblages are considered as Upper Volgian. In the Ryazanian Stage, sediments bearing *Hectoroceras* sp. and *Garniericeras* sp. and slightly higher, *Hectoroceras* sp. with *Surites* sp., also included *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln., *C. (Arctoteuthis) porrectiformis* And., *C. (A.) repentina* Sachs et Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln., and *L. (L.) luljensis* Sachs sp. nov. (in litt.)[2] (Kochi a-Zone). Along with *Surites* sp. and *Subcraspedites* sp. the same species as in the underlying a-Zone were found, as well as *Cylindroteuthis (Arctoteuthis)* aff. *subconoidea* Sachs et Naln., *Lagonibelus (Lagonibelus) elongatus* (Blüthg.), *L. (L.) sibiricus* Sachs et Naln., *Pachyteuthis (Pachyteuthis) subrectangulata* (Blüthg.), *P. (Simobelus) curvula* Sachs et Naln., and *Acroteuthis* sp. nov. (presumably the Analogus a-Zone). *Tollia* sp. juv. was associated with *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln., *C. (Arctoteuthis) repentina* Sachs et Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln., and *L. (L.) luljensis* Sachs sp. nov. (in litt.). In the above deposits *Tollia* cf. *payeri* was encountered together with *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln., *C. (Arctoteuthis) repentina* Sachs et Naln.,

[2] The species was first described as *Cylindroteuthis (Cylindroteuthis) luljensis* Sachs sp. nov. in the monograph "Jurassic–Cretaceous boundary and the Berriasian Stage", V.N. Saks, Ed. (1972).

Lagonibelus (Lagonibelus) gustomesovi Sachs et Naln., *Acroteuthis (Acroteuthis) anabarensis* (Pavl.), and *A. (A.) vnigri* Sachs et Naln. (Tolli a-Zone). On the Tol'ya River after a thorough search in the Upper Volgian Substage deposits holes from dissolved belemnite rostra belonging to *Acroteuthis (Microbelus)* were found and the Ryazanian sediments yielded molds of belemnites of the genus *Cylindroteuthis* in the Kochi a-Zone and of subgenus *Acroteuthis (Acroteuthis)* in the younger strata.

In the uppermost Volgian Gol'bert and Klimova encountered new finds of ammonites that made it possible to recognize the complete section of the Upper Volgian Substage in the Severnaya Sos'va River basin and, along with its two lower a-zones known earlier, to justify the occurrence of two upper a-zones, Taimyrensis on the Yatriya River and Chetae on the Yany-Man'ya River (Gol'bert et al., 1972b). However, the lists of belemnites published in this work with reference to the Saks' record, contradict those reported previously (Saks and Klimova, 1967). For instance, the youngest of the earlier recognized Upper Volgian belemnite assemblages that included *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln., *C. (Arctoteuthis) repentina* Sachs et Naln., *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln., *L. (L.) elongatus* (Blüthg.), and *Pachyteuthis (Simobelus) insignis* Sachs et Naln., was evidently mistakenly specified for all Upper Volgian a-zones. This most likely resulted from an incorrect estimate of the thickness of the Upper Volgian strata. In Gol'bert et al. (1972b) the thickness of the whole substage is evaluated as 2.5 m, whereas in other papers this value is indicated for the beds between Subditus and Kochi a-zones and the total thickness of all Upper Volgian a-zones by various estimates ranges from 10 to 15–17 m (Mesezhnikov, 1959; Saks and Klimova, 1967; *Granitsa...*, 1972; Zakharov and Mesezhnikov, 1974; and other). Among the new taxa are *Pachyteuthis (Pachyteuthis) acuta* (Blüthg.) along with *Craspedites (Taimyroceras)* cf. *taimyrensis* Bodyl. on the Yatriya River and *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln. in the Chetae a-Zone on the Yany-Man'ya River.

A thorough description of major sections of the Ryazanian Stage with layer-by-layer paleontological characteristics was reported by Gol'bert et al. (1972a). In this paper belemnite taxonomic composition in certain a-zones exposed along the Yatriya River almost completely corresponds to that published by Saks and Klimova (1967). An exception is the upper part of the stage with the distinguished Payeri a-Zone. This a-zone is associated with the belemnite assemblage that accompanied finds of *Tollia* cf. *payeri* (see above). In the Ryazanian Stage along the Yany-Man'ya and Tol'ya rivers only traces of dissolved rostra and molds are recorded.

Exposures of the Ryazanian Kochi a-Zone are also recorded in Outcrops 52 and 53 on the Mauryn'ya River (Zakharov and Mesezhnikov, 1972). The following belemnites were identified in this a-zone: *Acroteuthis (Microbelus) uralensis* Sachs et Naln., *A. (M.) mosquensis* (Pavl.), and *Lagonibelus (Lagonibelus) gustomesovi* Sachs et Naln.

The major sections of the Volgian Stage were most completely described by Zakharov and Mesezhnikov (1974). On the Yatriya River the authors based on identifications by Saks and Nal'nyaeva, reported *Pachyteuthis (Simobelus) mamillaris* (Eichw.) and *Cylindroteuthis (Cylindroteuthis) porrecta* (Phill.) in the Magnum and Subcrassum a-zones; *Lagonibelus (Lagonibelus) magnificus* (d'Orb.), *L. (L.) michailovi* Gust., and *L. (Holcobeloides) rosanovi* (Gust.) in the Iatriensis a-Zone; *Acroteuthis (Microbelus) russiensis* (d'Orb.), *Lagonibelus (Lagonibelus) michailovi* Gust., and *L. (L.) nitida* (Dollf.) in the Maximus a-Zone; *Acroteuthis (Microbelus) russiensis* (d'Orb.) and *Lagonibelus (Lagonibelus) elongatus* (Blüthg.) in the Groenlandicus and Fulgens a-zones; and *Acroteuthis (Microbelus) russiensis* (d'Orb.) in the Vogulicus, Subditus, and Taimyrensis a-zones. On the Tol'ya River Saks and Nal'nyaeva identified *Pachyteuthis (Simobelus) mamillaris* (Eichw.) in the Magnum a-Zone; *Cylindroteuthis (Cylindroteuthis)* aff. *obeliscoides* (Pavl.) in the Subcrassum a-Zone; *Pachyteuthis (Simobelus) mamillaris* (Eichw.) and *Lagonibelus (Holcobeloides) rosanovi* (Gust.) in the Maximus a-Zone; *Lagonibelus (Lagonibelus) sibiricus* Sachs et Naln. in the Groenlandicus a-Zone; and *Acroteuthis (Microbelus) mosquensis* (Pavl.) in the Subditus a-Zone. On the Yany-Man'ya River in the uppermost Middle Volgian Substage *Laugeites borealis* Mesezhn. and *L.* aff. *borealis* were found together with *Lagonibelus (Lagonibelus) sibiricus* Sachs et Naln. and in the Upper Volgian Substage, with *Pachyteuthis (Simobelus) insignis* Sachs et Naln. and *Acroteuthis (Microbelus) mosquensis* (Pavl.) were recognized. Finally, on the Lopsiya River (left tributary of the Severnaya Sos'va) the Subcrassum a-Zone included *Pachyteuthis (Simobelus) mamillaris* (Eichw.); the Fulgens a-Zone included *Cylindroteuthis* sp.

The papers that focus on detailed descriptions of sections unfortunately lack images of the belemnites encountered (except for new species). This inevitably raises taxonomic questions. What is, for example, *Cylindroteuthis (Cylindroteuthis)* aff. *obeliscoides* (Pavl.), found in the Subcrassum a-Zone on the Tolya River? In the light of the author's recent revision of Cylindroteuthididae, there are doubts concerning the identifications of *C. (C.) porrecta* (Phill.) and *Lagonibelus (Lagonibelus) nitida* (Dollf.) in the Volgian, *Acroteuthis (Microbelus) russiensis* (d'Orb.) in the Maximus a-Zone, and of *Cylindroteuthis (Cylindroteuthis) lepida* Sachs et Naln. in the uppermost Upper Volgian Substage (Dzyuba, 2004, 2012). Despite repeated mentions in the literature, there are so far no images of *Lagonibelus (Lagonibelus) magnificus* (d'Orb.) and *L. (Holcobeloides) rosanovi* (Gust.) rostra from the northwestern margin of the Western Siberia.

The data available by the early 1970s on the belemnite taxonomic composition in the Volgian sediments of the region under discussion were revised and supplemented (Dzyuba and Glushkov, 2000; Dzyuba, 2004) after the monographic studies of two collections, from the Lower and Middle Volgian Substages on the Yatriya River (collected by O.V. Shenfil in 1991 and 1992) and from the Lower Volgian Substage on the Lopsiya River (collected by the author in 1997). According to Dzyuba and Glushkov (2000), *Pachyteuthis (Simobelus) subbreviaxis* Sachs et Naln. is a junior subjective synonym of *P. (S.) mamillaris* (Eichw.). Rostra identified by Saks and Nal'nyaeva as *Lagonibelus (Lagonibelus) elongatus* (Blüthg.) are assigned to *L. (L.) napaensis* (And.) (Dzyuba, 2004). In the Lower Volgian Magnum and Subcrassum a-zones on the Lopsiya River the following taxa were recognized: *Simobelus (Simobelus) mamillaris* (Eichw.), *S. (S.) insignis* (Sachs et Naln.), *S. (S.) intortus* (Sachs et Naln.), *Pachyteuthis (Pachyteuthis) panderiana* (d'Orb.), *P. (P.) apiculata* Sachs et Naln., *P. (Boreioteuthis) explanata* (Phill.), and *P. (B.) troslayana* (d'Orb.). All the species except the first one were defined here for the first time. On the Yatriya River *Simobelus (Simobelus) mamillaris* (Eichw.) was recorded in the Subcrassum a-Zone; *S. (S.) mamillaris* (Eichw.), *S. (S.) insignis* (Sachs et Naln.), *S. (Liobelus) praecorpulentus* (Geras.), and *Lagonibelus (Lagonibelus)* cf. *michailovi* (Gust.) in the Iatriensis a-Zone; and *Simobelus (Simobelus) mamillaris* (Eichw.), and *S. (Liobelus) praecorpulentus* (Geras.) in the Maximus a-Zone. The latter species was found east of the Ural Mountains for the first time. It should be emphasized that compared to the previous data (Zakharov and Mesezhnikov, 1974), in the ammonite Iatriensis and Maximus a-zones a significantly different belemnite composition was detected, to which the author has already drawn attention (Dzyuba, 2004). The reasons of these differences are unclear.

Belemnites from the Ryazanian Stage were studied by O.V. Shenfil (Beizel' et al., 1997). On the Yatriya River in the Kochi a-Zone in 1991 he first found *Cylindroteuthis (Cylindroteuthis) knoxvillensis* And. and *Lagonibelus (Lagonibelus) sibiricus* Sachs et Naln.

It can be concluded that previous research revealed in the Volgian and Ryazanian stages of the northwestern margin of Western Siberia a taxonomically diverse belemnite assemblage of the family Cylindroteuthididae.[3] Views on stratigraphic distribution of species of this family are often contradictory in various literary sources. The most poorly studied are belemnites of the Lower Volgian Pectinatus a-Zone, Middle Volgian Ilovaiskii and Crendonites spp. a-zones, Upper Volgian Maurynijensis ammonite beds (age analog of the Chetae a-Zone), and of the Ryazanian Sibiricus a-Zone. The least ordered are the data on belemnites from Outcrop 54 on the Mauryn'ya River, in which, according to available data (Mesezhnikov and Braduchan, 1982), four a-zones, from Taimyrensis to Kochi inclusive are represented. During fieldwork in 1978 when these results were obtained, belemnites were not systematically studied.

[3] Hereinafter for all genera and subfamilies of cylindroteuthids a recently proposed updated system (Dzyuba, 2011) is used.

MATERIAL

This research is based on a new collection of cylindroteuthid rostra collected by the author in 2007 from the Volgian–Ryazanian transitional strata in Outcrop 54 on the Mauryn'ya River. The author also had at her disposal several rostra from the collection of Zakharov collected in 1966 from the Kochi a-Zone in Outcrop 52 on the Mauryn'ya River. In addition, the belemnites collected by O.V. Shenfil in 1991 from the Ryazanian Stage in Outcrop 1 on the Yatriya River and provided to the author for examination, were used. In general, the paleontological material studied comprises more than 300 specimens. Moreover, the Siberian monographic belemnite collections of Saks and Nal'nyaeva nos. 83, 84, 86, 88 deposited in the Central Siberian Geological Museum (CSGM) at the Sobolev Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences, were studied.

Outcrop 54 is located on the right bank of the Mauryn'ya River, 7 km from the mouth, and represents a bank slope covered with vegetation, about 7 m high and 20 m wide. The Volgian–Ryazanian boundary sediments are mainly represented by silty and sandy deposits with a total thickness of about 6 m, bluish-gray in the lower part (about 2.5 m thick) and greenish- gray in the upper portion (about 3.5 m thick) (Alifirov et al., 2008). An uninterrupted succession of the following ammonite zonal units is recognized in the section: Taimyrensis a-Zone, Maurynijensis a-Beds[4] (analog of the Chetae a-Zone), and Sibiricus and Kochi a-Zones (Mesezhnikov and Braduchan, 1982). The section exposed in Outcrop 54 is built up 3 km upstream on the Mauryn'ya River, where, according to Zakharov and Mesezhnikov (1972), on the right bank in the bedrock exposures (Outcrop 52) and talus (Outcrop 53) of brown sandy rocks, the younger beds of the Kochi a-Zone are represented. Thickness of the bedrock exposure is about 4 m.

Outcrop 1 on the Yatriya River is located on the right bank, 34 km from the mouth and 2 km below the Bol'shaya Lyul'ya River mouth. It represents a gently sloping, mostly sodded bank escarpment of the II river terrace, about 800 m long and up to 12 m high (Gol'bert

[4] Instead of the Maurynijensis and Pulcher beds distinguished by Mesezhnikov (Mesezhnikov and Braduchan, 1982), following Alifirov et al. (2009) this stratigraphic interval is designated as the Maurynijensis beds, since *Subcraspedites pulcher* Casey, Mesezh., Schulg. is unknown in this section.

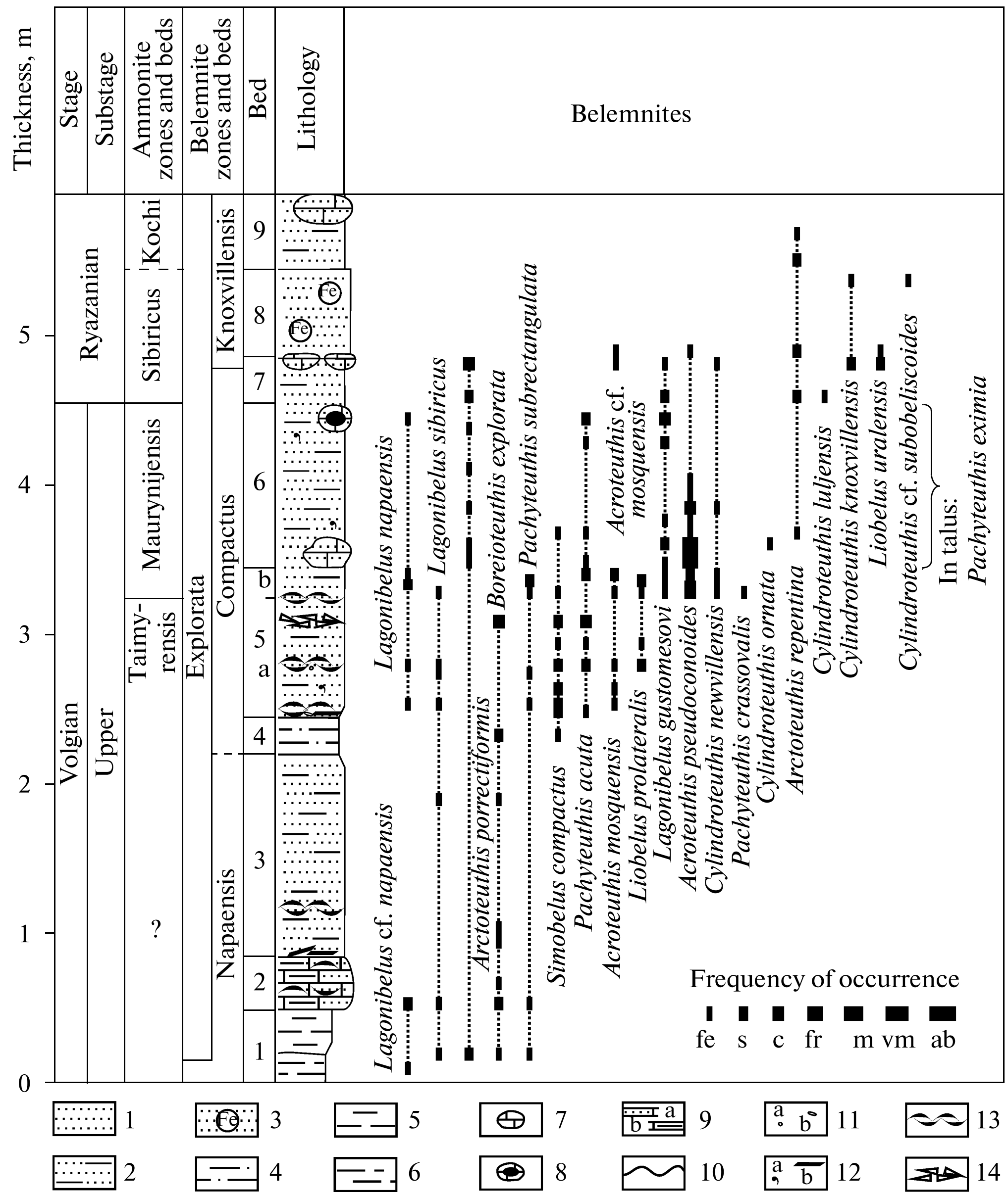


Fig. 2. Distribution of belemnites in the Volgian and Ryazanian boundary sediments outcropped on the right bank of the Mauryn'ya River (Outcrop 54): (1) sandstone; (2) silty sandstone; (3) ferruginous sandstone; (4) sandy siltstone; (5) siltstone; (6) clayey siltstone; (7) carbonate concretions; (8) carbonate-phosphatic concretions; (9) compact calcareous beds of sandstone (a) and siltstone (b); (10) erosional boundary; (11) gravel (a) and pebble (b); (12) glauconite (a), coalificated wood (b); (13) oyster accumulation; (14) belemnite accumulation. Frequency of fossils (*Opornyi*..., 1969): (fe) few (1–2 specimens); (s) scarce (3–5 spec.); (c) common (6–10 spec.); (fr) frequent (11–15 spec.); (m) many (16–29 spec.); (vm) very many (30–99 spec.); (ab) abundant (>100 spec.).

et al., 1972a). The section is composed of Upper Volgian, Ryazanian, Valanginian, and Hauterivian sediments. The Upper Volgian Substage is made up of greenish-gray siltstone with a visible thickness of 12 m. The Volgian–Ryazanian boundary represents a wavy erosional surface (the Chetae and Sibiricus a-zones are missing), above which a basal bed of grayish-green gravelly sandstone is recorded. The Ryazanian Stage as a whole is mainly composed of bluish-gray silty and sandy deposits of the total thickness 12 m.

NEW DATA ON BELEMNITE TAXONOMIC COMPOSITION AND BIOSTRATIGRAPHIC INFERENCES

A detailed study of Outcrop 54 on the Mauryn'ya River revealed the belemnite species distribution in certain beds of the section and provided the correlation of belemnite finds with the ammonite zonation (Fig. 2). In the lower part of the section (Beds 1–4) ammonites were not found (Alifirov et al., 2008). Judging from the position in the section and belemnite assemblage, the sequence should be referred to the Upper Volgian Substage, as it yields *Boreioteuthis explorata* (Sachs et Naln.) and *Pachyteuthis subrectangulata* (Blüthg.) that are missing in the older deposits. The bivalves encountered concurrently with the belemnites do not contradict this conclusion (Urman, 2010). *P. subrectangulata*, widely distributed in the Arctic, was formerly considered to be a typical Cretaceous species (Saks and Nal'nyaeva, 1966, 1972). *B. explorata* beyond the eastern slope of the Urals is known only from the other side of the Uralian Mountains, in the Pechora River basin, where it is found in the Upper Volgian Substage–Ryazanian Stage and first occurs in the Subditus a-Zone (Nal'nyaeva, 1984). It can be assumed that in the section on the Mauryn'ya River its finds indicate not older interval than this a-zone. Only the lower 20 cm of the recovered section yielding solely *Lagonibelus* cf. *napaensis* (And.) and associated astartids (bivalves), can be referred to older strata of the Volgian.

A number of taxa in the section on the Mauryn'ya River were found for the first time. They are *Cylindroteuthis knoxvillensis* And., *C. luljensis* Sachs, *C. newvillensis* And., *C.* cf. *subobeliscoides* Voron., *Lagonibelus napaensis* (And.), *Liobelus prolateralis* (Gust.), and *Pachyteuthis crassovalis* (Blüthg.). *Cylindroteuthis newvillensis* (Plate I, fig. 2), *C.* cf. *subobeliscoides* (Plate II, fig. 3), *Liobelus prolateralis* (Plate II, fig. 4; Plate III, figs. 3 and 4), and *Pachyteuthis crassovalis* (Plate IV, fig. 3) were not previously identified in Western Siberia. The Siberian species *C. lepida* Sachs et Naln., which holotype was derived from the Mauryn'ya River (Saks and Nal'nyaeva, 1964, Plate 6, fig. 1), was recently reported as a junior subjective synonym of *C. knoxvillensis* (Dzyuba, 2012). It is conceivable that *C. newvillensis* And. rostra were also identified in Siberia as *C. lepida*. Both species distinguished by Anderson (1945), quite similar and undoubtedly being in a close genetic relationship, occur consecutively in the stratigraphic column. Judging from the new age estimate of localities of the type material and distribution maps of Buchiazones in northern California (Jones et al., 1969; Imlay and Jones, 1970), the *C. newvillensis* rostra originate from the uppermost Fischeriana Subzone of the Piochii Buchiazone and *C. knoxvillensis*, from the overlying aff. Okensis Buchiazone. In northern Eastern Siberia in the uppermost Volgian Stage (top of the Taimyrensis a-Zone–Chetae a-Zone) *C.* cf. *newvillensis* was identified, and in the Ryazanian Stage (Sibiricus–Mesezhnikowi a-zones), *C. knoxvillensis* was recorded (Dzyuba, 2012). These species are similarly distributed on the Mauryn'ya River (Fig. 2). A very rare species *Cylindroteuthis subobeliscoides* was previously found only in the Nordvik Peninsula, along with the ammonite *Tollia tolli* Pavl. (Voronets, 1962). *Pachyteuthis crassovalis* is known from the Lower Cretaceous of the Kong Karls Land, Svalbard (Doyle and Kelly, 1988). *Liobelus prolateralis* is distributed both west and east of the Urals, i.e. in the Russian Platform and northern Eastern Siberia, and is characteristic of the Middle–Upper Volgian boundary deposits (Gustomesov, 1964; Saks and Nal'nyaeva, 1966; Dzyuba, 2004, 2012). New finds fill gaps in our views on the distribution areas of the species discussed. Additionally, four new species *Acroteuthis pseudoconoides* sp. nov., *Cylindroteuthis ornata* sp. nov., *Pachyteuthis eximia* sp. nov., and *Simobelus compactus* sp. nov. are distinguished.

In the paleontological collection of Zakharov, derived from Outcrop 52 on the Mauryn'ya River, in addition to the species previously recognized in the Kochi a-Zone (Zakharov and Mesezhnikov, 1972), *Pachyteuthis subrectangulata* (Blüthg.) and *Simobelus compactus* sp. nov. are identified. In the collection provided by Shenfil from Outcrop 1 on the Yatriya River, *Arctoteuthis tehamaensis* (Stant.), *Cylindroteuthis* cf. *subobeliscoides* Voron., *Acroteuthis mosquensis* (Pavl.), and *Pachyteuthis eximia* sp. nov. were recognized for the first time in the Kochi a-Zone; and *Lagonibelus napaensis* (And.), in the Kochi and Analogus a-zones. In addition to the species discovered on the Mauryn'ya River, a new find for Western Siberia is *Arctoteuthis tehamaensis* (Plate I, fig. 1) characteristic of the synchronous and older sediments in northern Eastern Siberia (Dzyuba, 2012) and northern California (Stanton, 1895; Anderson, 1945).

In the section on the Mauryn'ya River four biostratigraphic belemnite units are suggested to distinguish, namely, the Explorata Beds, Napaensis Zone, Compactus Beds, and Knoxvillensis Zone (Fig. 2). The Napaensis and Knoxvillensis belemnite zones (bl-zones) are traced from the northern Eastern Siberia (Dzyuba, 2012) but they are not fully represented on the Mauryn'ya River. In the northwestern margin of Western Siberia these bl-zones are built up on the Yatriya River, where almost complete Napaensis bl-Zone and the upper part of the Knoxvillensis bl-Zone are recorded (Fig. 3). Both bl-zones are recognized there along with the Russiensis belemnite beds (bl-beds) and Gustomesovi and Porrectiformis bl-beds that also extend from northern Eastern Siberia (Dzyuba, 2004, 2012). The sediments corresponding to the Compactus bl-beds (age analog of the Tehamaensis bl-Zone) in this area were eroded. In the uppermost Ryazanian on the Yatriya River the East Siberian Curvulus bl-Zone is recognized (Beizel' et al., 1997). *Simobelus curvulus* (Sachs et Naln.) occurs in the Yatriya River section in Bed 3 at the base of the Analogus a-Zone. In this connection the bases of the Analogus a-Zone and Curvulus bl-Zone were shown by Shenfil at the same level (Beizel' et al., 1997) contradicting previously available data on northern Eastern Siberia, where the first occurrence of *S. curvulus* was recorded in the mid-Analogus a-Zone on the Boyarka River (Shenfil, 1992). On the Yatriya River, ammonites in Bed 3 and underlying Bed 2 are very scarce. The lower boundary of the Analogus a-Zone is established in the section conditionally according to first finds of *Surites* species

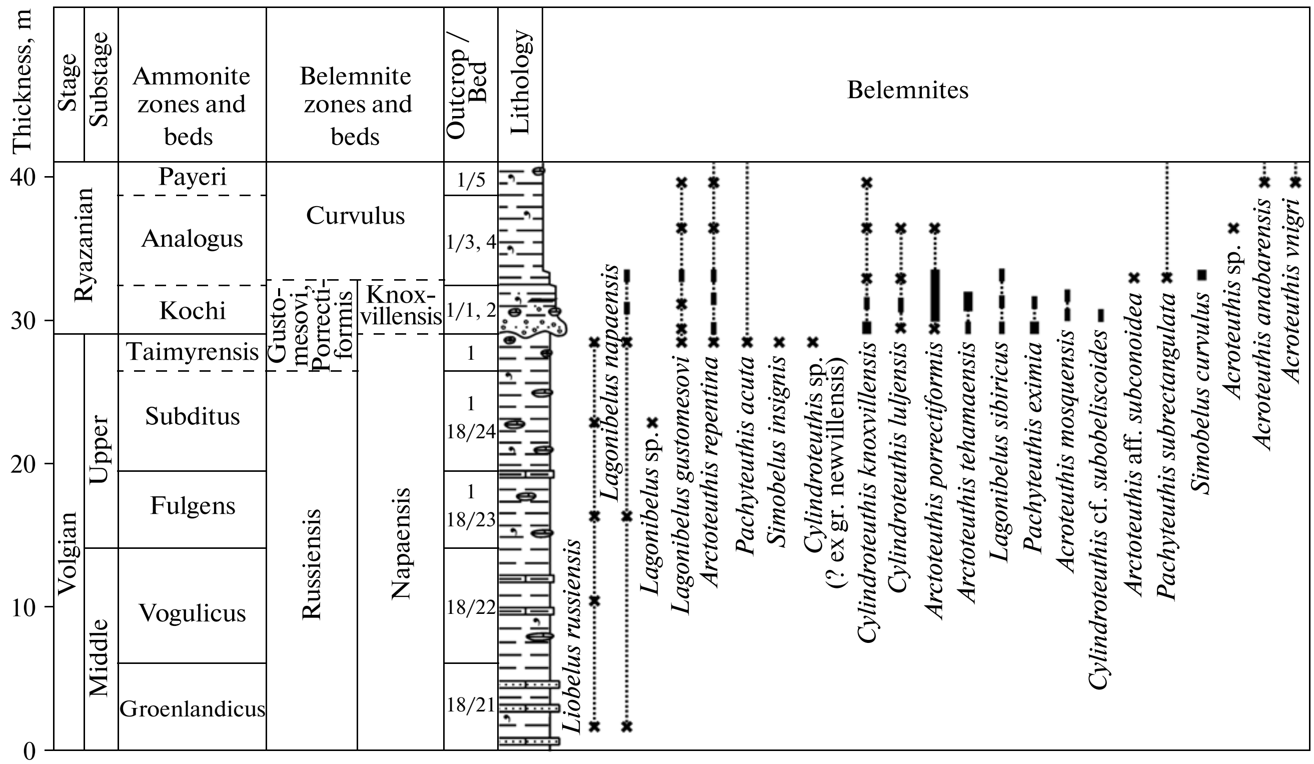


Fig. 3. Distribution of belemnites in the uppermost Volgian and Ryazanian stages outcropped on the right bank of the Yatriya River (Outcrop 1).

Data from literary sources (see the text) are marked by crosses. Stratigraphic scheme and lithology are after (Gol'bert et al., 1972a; Zakharov and Mesezhnikov, 1974; Mesezhnikov et al., 1977). Symbols as in Fig. 2.

(Gol'bert et al., 1972a). The index species of the a-zone is not found there. Accordingly, it is still impossible in this section to show an exact relationship between lower boundaries of the Analogus a-Zone and Curvulus bl-Zone. Consequently in this paper the lower boundary of the bl-zone is not coincident with the base of the a-zone but is shown slightly higher, as in the East Siberian sections where it was first drawn.

The Upper Jurassic and Lower Cretaceous sections in the eastern foothills of the Urals are reference for elaboration of belemnite zonations for the whole Western Siberia (Dzyuba, 2004; *Reshenie*…, 2004) and belemnites from these sections have long been used for solving biostratigraphic questions. In the Jurassic–Cretaceous boundary interval their assemblages with characteristic index species were described by Saks and Klimova (1967) and Nal'nyaeva (1992). The zonations are suggested by Shenfil (Beizel' et al., 1997) and the author (Dzyuba, 2004). The data reported in this paper permit an improvement of the present biostratigraphic subdivision and make it more detailed and correlative to that in the adjacent East Siberian territory (Fig. 4).

The Jurassic–Cretaceous boundary sediments in the northwestern margin of Western Siberia contain a belemnite assemblage most similar to the Pechora and East Siberian associations. A high-resolution belemnite zonation for the Pechora River basin has yet to be developed. In the uppermost Middle Volgian–Ryazanian interval in this region the united Russiensis–Mosquensis bl-beds are recognized (*Unifitsirovannaya*…, 1993; *Unifitsirovannye*…, 1993; Repin et al., 2006). Both species were identified in the studied area as well. The East Siberian high-resolution successions of belemnite zones and beds are recorded in the West Siberian sections almost completely, excluding the Tehamaensis bl-Zone. *Arctoteuthis tehamaensis* (Stant.) on the Mauryn'ya River was not found. On the Yatriya River it was encountered above the erosional surface, in the Kochi a-Zone, i.e. slightly higher the homonymous bl-zone that embraces the uppermost Taimyrensis–lowermost Sibiricus a-zones.

Studies of the new belemnite collections revealed that the Volgian–Ryazanian transitional strata in the region under discussion yield a good many species known from the Tordenskjoldberget Member of the Kong Karls Land, Svalbard. Among them are *Pachyteuthis acuta* (Blüthg.), *P. subrectangulata* (Blüthg.), *P. crassovalis* (Blüthg.), and *Simobelus curvulus* (Sachs et Naln.). In addition, *Acroteuthis (Acroteuthis) conoides* Swinnerton (Doyle and Kelly, 1988) identified from this member, is assigned in the present paper to *Acroteuthis pseudoconoides* sp. nov. (see "Taxonomic description"). As a whole Blüthgen (1936) and Doyle

(Doyle and Kelly, 1988) described from the Tordenskjoldberget Member a rich belemnite assemblage bearing in total over 20 species. Both papers consider the age of the member to be no older than Valanginian, though Doyle noted the occurrence of typical Berriasian *Simobelus curvulus*. The distribution of belemnites throughout the section was not elucidated since rostra were mostly collected in the so-called "belemnite mounds" (Belemnitenhügeln). According to belemnite, bivalve, nannofossil, and palynomorph assemblages, the stratigraphic range of the member is estimated as Valanginian–Hauterivian (Doyle and Kelly, 1988; Smelror et al., 1998; and other), however, in some papers the Upper Berriasian is not excluded (Dallmann, 1999; and other). The Tordenskjoldberget Member actually contains certain typical Valanginian and Hauterivian belemnites, namely, *Acroteuthis acmonoides* Swinn., *A. arctica* Blüthg., *Boreioteuthis hauthali* (Blüthg.), *B. johnseni* (Blüthg.), and *Hibolithes jaculoides* Swinn. Nevertheless, the occurrence in the member of three species characteristic exclusively of older deposits, i.e. *A. pseudoconoides, P. crassovalis*, and *S. curvulus*, enables us to infer that its accumulation started prior to the beginning of the Valanginian and likely occurred with the advent of the Cretaceous.

DYNAMICS OF SIBERIAN BELEMNITES DIVERSITY IN THE TERMINAL JURASSIC AND INITIAL CRETACEOUS

In the history of Mesozoic boreal seas, the Late Jurassic and beginning of the Early Cretaceous are believed to be periods of high biodiversity (Zakharov et al., 1994). The oxygen isotope data reported in the literature on the shell material of boreal belemnites indicate a gradual climatic warming during the Late Jurassic (Price and Rogov, 2009; Žák et al., 2011; and other) and a relatively warm phase in the initial Cretaceous (Price and Mutterlose, 2004). The increase of taxonomic diversity at that time occurred in waves. According to various groups of North Siberian mollusks (cephalopods and bivalves), the studied interval included three large stages of taxonomic diversity growth, the Kimmeridgian, Middle Volgian, and Early Valanginian (Saks and Nal'nyaeva, 1979; Zakharov et al., 1994). In the intermediate periods the number of taxa in all mollusk groups was temporarily reduced. Judging from the previously compiled diversity curve of belemnites (Saks and Nal'nyaeva, 1979), their species abundance in the North Siberian seas was significantly reduced in the Late Volgian–Ryazanian, especially at the beginning of the Ryazanian Stage when the diversity constituted 60% of the Middle Volgian. It

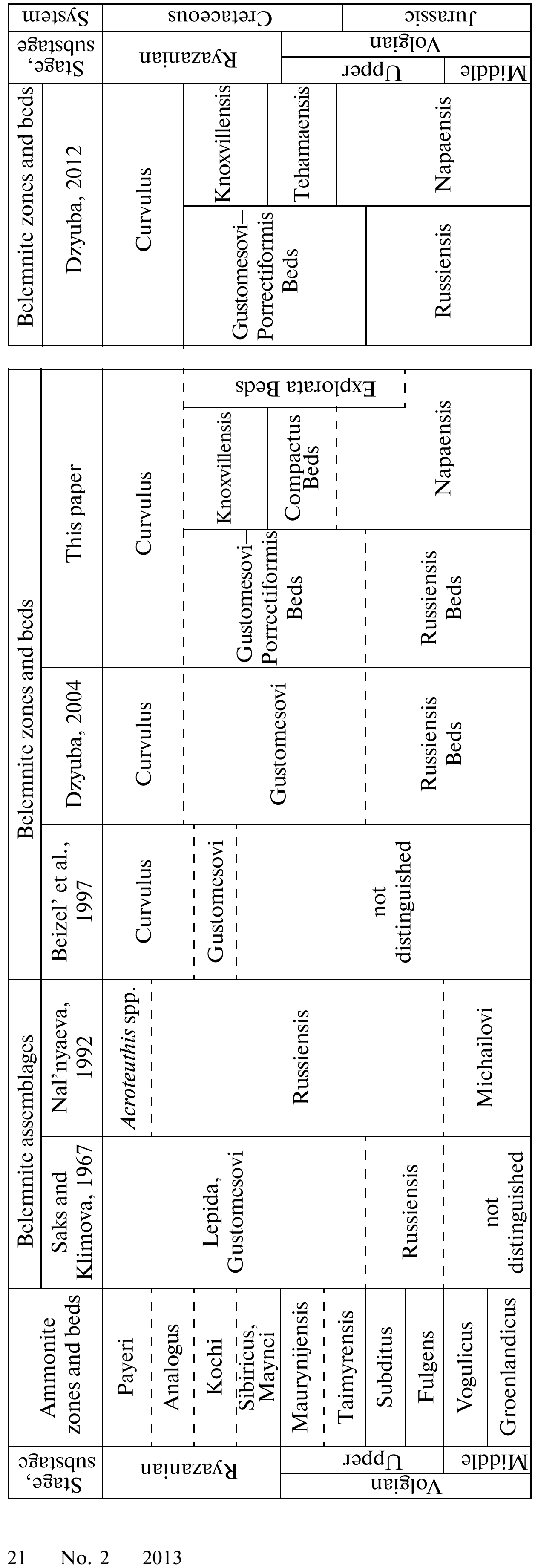


Fig. 4. Development of views on belemnite biostratigraphy of the Jurassic–Cretaceous boundary sediments of the northwestern margin of Western Siberia.

is uncertain whether these data demonstrate the situation with the boreal biota as a whole, or are just regional. The results obtained in the present study support the latter assumption.

To assess the biotic events in the Boreal Mesozoic, researchers commonly use the data on the fauna of northern Eastern Siberia as one of the most typical boreal regions. All Mesozoic stages and almost all the zones distinguished in the boreal sections, as well as all bionomic zones known on the shelf and a great diversity of marine facies, are recognized there (Zakharov et al., 1984, 1997; Shurygin et al., 2000; etc.). Nevertheless, the problem of unequally examined different stratigraphic intervals still remains. For instance, in the Upper Jurassic reference sections (Kheta River basin, Nordvik Peninsula) a significant part of the Volgian ammonite zones is missing and there are few data on belemnites in other East Siberian sections of this stage. Belemnites of the Volgian–Ryazanian transitional interval are best studied in the Nordvik Peninsula. However, at the Volgian–Ryazanian boundary the Khatanga marine strait that occurred in northern Eastern Siberia, was considerably deepened (Zakharov and Yudovnyi, 1974; etc.). Away from the paleoshore, where the sediments of the Nordvik section were accumulated, the depth at that time was about 150 to 200 m or over (Zakharov and Yudovnyi, 1974), which resulted in a scarce occurrence of belemnites. Consequently, even with regard to the data recently obtained from new collections of rostra from the Nordvik Peninsula (Dzyuba, 2012), there is a "sag" in the species diversity of East Siberian belemnites at the Volgian–Ryazanian boundary (Fig. 5).

The Upper Jurassic and Lower Cretaceous sections discussed in this paper were formed slightly south of the outcrops in northern Eastern Siberia. The accumulation occurred in a marginal area of the inner epicontinental West Siberian marine basin, in shallow and moderately deep environments of the Lyapin Bay (Gol'bert et al., 1972a; Zakharov and Mesezhnikov, 1974; etc.). As for the Volgian and Ryazanian stages, they are completely represented in the area and were intensely studied.

As the investigation showed, the Volgian–Ryazanian transitional interval contains an extremely rich and diverse belemnite assemblage of the family Cylindroteuthididae. The Upper Volgian Substage and lowermost Ryazanian Stage (Sibiricus and Kochi a-zones) yield in total 23 species and 8 genera of cylindroteuthids. Such a high belemnite diversity at the Volgian–Ryazanian boundary was in no case recorded in other boreal basins. Evidently at that time the Lyapin Bay was characterized by very favorable conditions for belemnites. For the whole Late Jurassic a similar diversity occurred there only in the Kimmeridgian (Fig. 5) when as a result of transgression recorded in many boreal regions, a significant part of the land in northwestern West Siberia was flooded by the sea (*Paleogeografiya*..., 1983). Isotope and paleoecological data indicate high water temperatures in the Lyapin Bay in the Kimmeridgian (Zakharov et al., 2005). However, that time was characterized by increased taxonomic diversity not only of belemnites but of ammonites and bivalves as well. This occurred concurrently in the West Siberian and East Siberian paleobasins (Zakharov et al., 1994; Dzyuba et al., 2006). Owing to improved connections between high- and low-boreal seas, the Boreal-Atlantic belemnites became widespread in the Arctic, giving rise to a series of new taxa. An increased proportion of thermophilic immigrants in the Arctic seas was also recorded in the Kimmeridgian among other mollusk groups (Zakharov and Rogov; 2003; Rogov et al., 2009; etc.). In contrast, in the terminal Volgian the increased disconnection between seas at the junction of the Arctic and Paleoatlantic resulted in formation of strongly differentiated faunas in both Boreal and Tethyan basins. Therefore, the Kimmeridgian pattern of the biodiversity growth is not suitable for this case.

A gradual increase in number of belemnite species that culminated in the unusually high diversity at the Volgian–Ryazanian boundary, took place in the Lyapin Bay starting from the terminal Middle Volgian. The peak of diversity fell on the Taimyrensis–Kochi a-phases approximately corresponding to the beginning of the Cretaceous, and was followed by a significant reduction of belemnite species number (Fig. 5). The peak corresponds to a sharp decline on the species diversity curve of the East Siberian belemnites. Belemnite assemblages in the adjacent European boreal paleobasins in the terminal Volgian–beginning of the Ryazanian did not experience any peculiar diversity changes, either positive or negative, as evidenced by records from the Russian Platform (Gustomesov, 1964, 1979; Saks and Nal'nyaeva, 1964, 1966, 1972; Mesezhnikov et al., 1979; Nal'nyaeva, 1984; Gerasimov et al., 1995; Dzyuba, 2007; etc.) and northwestern Europe (Swinnerton, 1936–1955; Casey, 1973; Pinckney and Rawson, 1974; etc.). It is remarkable that the total number of species in any time span within this interval in the European sections is less than in northern Eastern Siberia. On average, 5–6 species are recorded in each time span and only in the Pechora River basin in the upper strata of the Ryazanian (Peregrinoceras, Bojarkia, and Surites cf. tzikwinianus a-beds) the diversity slightly increased and became comparable to that of Eastern Siberia. Consequently, using the example of paleobasins discussed, one can infer that at the Volgian–Ryazanian boundary three different trends occurred in the dynamics of belemnite species diversity.

The belemnite assemblages were undoubtedly influenced by transgressive–regressive (T–R) events. It is known that changes in basin size and depth not only led to migration of certain species and groups but could initiate morphogenesis as a result of adaptation of belemnites to a new environment (Gustomesov, 1976; etc.). Meanwhile, the correlation between

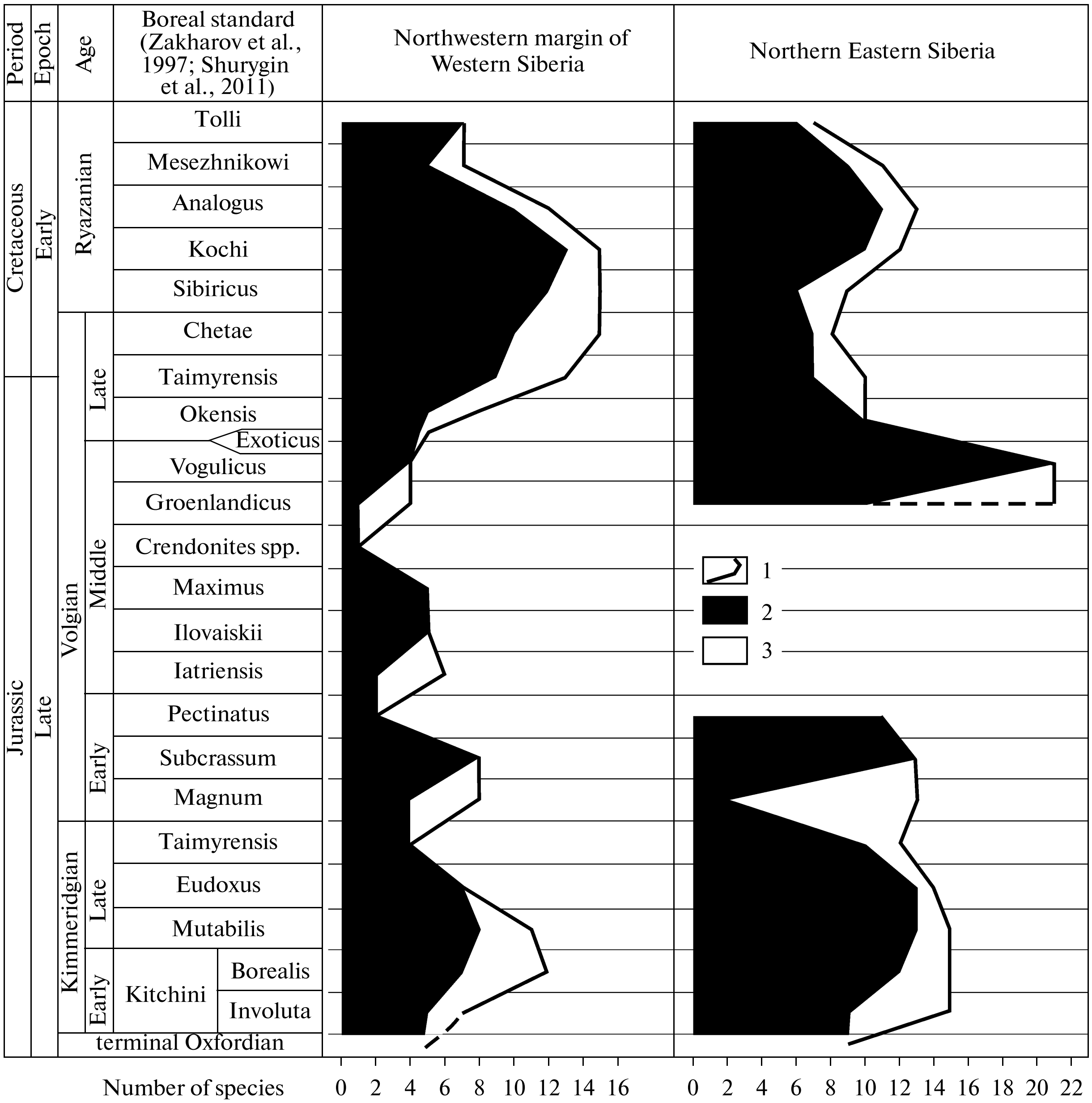


Fig. 5. Dynamics of species diversity of West and East Siberian belemnites in the Kimmeridgian, Volgian and Ryazanian ages (generalized to an ammonite zone).
Additional data on belemnites summarized in (Dzyuba, 2004, 2012) are used: (1) total number of species; (2) number of passing species; (3) number of new species.

belemnite diversity curves and T–R curves is often not recorded. For instance, there is no such relation in comparing curves plotted for the northwestern margin of Western Siberia and northern Eastern Siberia (Fig. 6). The exceptions are the Kimmeridgian and beginning of the Volgian for both regions and, perhaps, the terminal Ryazanian for northern Eastern Siberia. Previously the absence of correlation between dynamics of belemnite diversity and T–R events was illustrated using the example of Jurassic belemnites in the Caucasian paleobasin (Ruban, 2007). Volgian belemnites of the Central Russian sea also showed a rather weak association between these factors (Yanin, 2001a, 2001b). This can probably be attributed to the complicated character of this relationship; a decrease (or increase) in belemnite diversity can be linked to by either shallowing or deepening of their habitat. For example, the Kimmeridgian eustatic and transgressive events obviously favored a rise in biodiversity in Siberian seas; however, the further deepening of the West Siberian sea in the Volgian led to the formation of pseudoabyssal depths (down to 500 m and below) in its

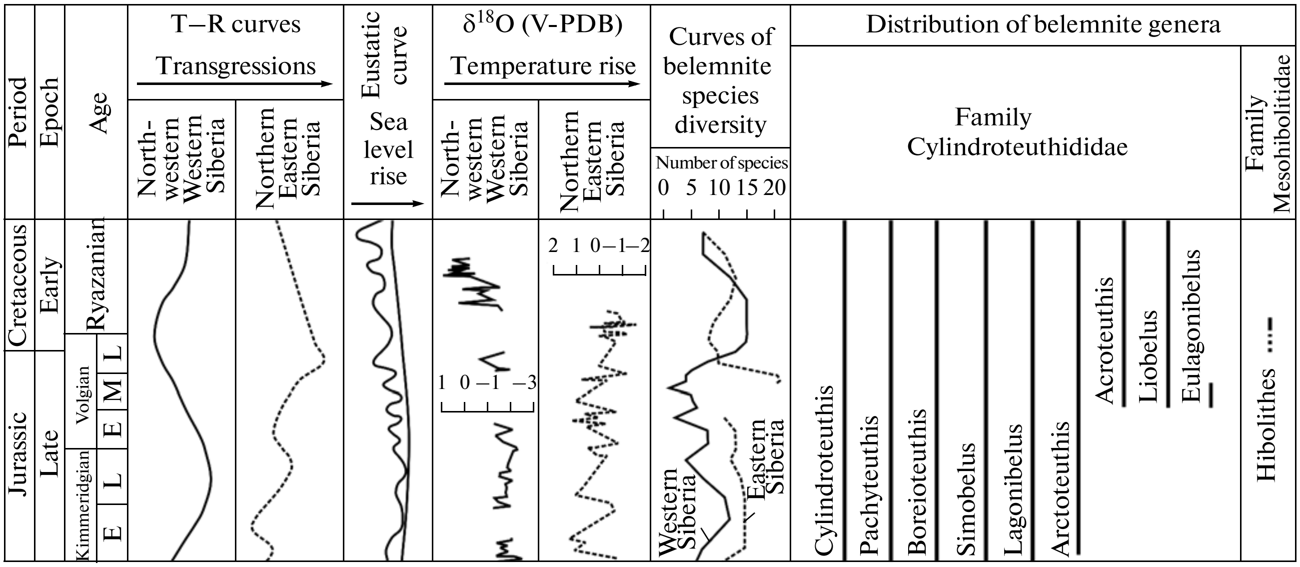


Fig. 6. Major abiotic events and changes in belemnite taxonomic diversity in the Kimmeridgian, Volgian and Ryazanian ages in Siberia.

For reconstruction of transgressive-regressive (T–R) events in the northwestern margin of Western Siberia the data by (Gol'bert et al., 1972a; Zakharov and Mesezhnikov, 1974; Mesezhnikov, 1984; Zakharov et al., 2005) are used; for northern Eastern Siberia the T–R curve plotted by (Zakharov et al., 1994) is given. The eustatic curve is after (Haq and Al-Qahtani, 2005). Oxygen isotope curves for the northwestern margin of Western Siberia are given after (Price and Mutterlose, 2004; Zakharov et al., 2005); for northern Eastern Siberia, after (Žák et al., 2011).

central part and an almost complete absence of belemnites, excluding juveniles transported by currents (Marinov et al., 2006). In northern Eastern Siberia with the increased transgression and deepening of the basin down to 200 m and over in the area of the modern Nordvik Peninsula, the number of belemnites was reduced (Zakharov et al., 1983; Dzyuba, 2012). In the open-sea deep-water facies of Jurassic–Cretaceous transitional time, best studied in the Stolbovoi Island (Kuz'michev et al., 2009) and in the low reaches of the Lena River (Rogov et al., 2011), belemnites are missing despite the occurrence of ammonites and numerous Buchias. A subsequent shallowing of deep areas invariably led to the inverse process when belemnites returned to faunal communities and their taxonomic diversity gradually increased. However, an extreme shallowing of the basins in turn negatively influenced the species diversity. In the terminal Volgian the Central Russian sea became a shallow basin with highly abundant belemnites against the background of very low species and generic diversity (Yanin, 2001a). By the terminal Middle Volgian in the Boreal-Atlantic realms Cylindroteuthidinae, Lagonibelinae, and the genus *Pachyteuthis* disappeared sequentially, and temporarily the genera *Boreioteuthis* and *Simobelus* (reoccurred in the Early Cretaceous). In the Arctic seas these taxa continued to exist and generated a number of new species. In the Central Russian sea, as well as in shallow seas of northwestern Europe, at the Volgian–Ryazanian boundary only *Acroteuthis* and *Liobelus* with dorso-ventrally depressed and flattened on the ventral side rostra occurred as the most adapted to shallow environment.

In interpreting the relations between eustasy, T–R events, and dynamics of biodiversity, it should be considered what kind of a basin the investigated area represented, i.e. inner or marginal sea, bay, strait, etc. For instance, depths in the Lyapin Bay during the Volgian and initial Ryazanian decreased (Zakharov and Mesezhnikov, 1974; Gol'bert et al., 1972a), however, in contrast to the northwestern margin, the West Siberian sea as a whole was at that time the deepest within the span of its Mesozoic history. Probably because of this and since most of belemnites are characterized by the nektonic way of life, the regressive stage of the Lyapin Bay had no effect on dynamics of belemnite assemblages diversity.

Changes in species diversity of West Siberian belemnites during the Jurassic–Cretaceous transitional time are best correlated with the $\delta^{18}O$ variation curves plotted for Siberian sections (Price and Mutterlose, 2004; Žák et al., 2011; Izokh et al., 2011) and reflecting climatic variations. The increased species number in the terminal Volgian–initial Ryazanian corresponds to a temperature rise in Siberian marine basins and the subsequent decline in species diversity in the second half of the Ryazanian is correlated with their gradual cooling (Fig. 6).

At the superspecific level changes in Siberian belemnites in the terminal Jurassic–initial Cretaceous are comparatively weak. In this regard they substantially rank below ammonites, in which over the same time families and subfamilies disappeared and originated and numerous genera were replaced (Shul'gina, 1985; Rogov et al., 2010). The most perceptible change in the generic composition of belemnites took place at the beginning of the Middle Volgian when in the Lyapin Bay three cylindroteuthid genera, *Acroteuthis (Pachyteuthidinae), Liobelus (Simobelinae)*, and *Eulagonibelus (Lagonibelinae)* first occurred (Fig. 6). During the Kimmeridgian, Volgian, and Ryazanian ages none of the taxa superspecific in rank disappeared from the Siberian belemnite assemblages, with the exception of southern migrants that penetrated into the western West Siberian sea for a short time. For instance, the Middle Volgian Iatriensis and Maximus a-zones on the Yatriya and Tol'ya rivers yielded the member of Boreal-Atlantic genus *Eulagonibelus*, namely, *E. rosanovi* (Gust.) (Zakharov and Mesezhnikov, 1974). In Well 157 drilled in the Salym area, in the intervals 2874–2881 and 2867.3–2874 m recovering the upper part of the Bazhenovo Formation, Nal'nyaeva identified two rostra of *Hibolithes* sp. ind. (Braduchan et al., 1986) which indicate the penetration of the Tethyan family Mesohibolitidae. The underlying sediments of the well contained an ammonite of the Upper Volgian genus *Kachpurites*, and in the interval 2867.3–2874 m a *Borealites* member was recorded together with one of *Hibolithes* (Braduchan et al., 1986). Thus the Tethyan belemnites appeared in the West Siberian marine basin at the Volgian–Ryazanian boundary (Fig. 6). According to oxygen isotope data (Price and Mutterlose, 2004; Izokh et al., 2011; Žák et al., 2011), this time in the boreal seas corresponded to a temperature maximum. Finds of the same species of belemnites in Siberia and California indicate wide connections between the Arctic seas and the northeastern Paleopacific including the areas inhabited by mixed Boreal and Tethyan assemblages, among them belemnites of the genus *Hibolithes* (Anderson, 1945).

TAXONOMIC DESCRIPTION

The terminology and designation of morphological elements of rostra used in this work were proposed in (Gustomesov, 1964; Saks and Nal'nyaeva, 1964). Figure 7 illustrates the system of measurements. The following relative values were calculated: PA (%) = PA (mm) × 100/DV (mm); LL (%) = LL (mm) × 100/DV (mm); AR (%) = AR (mm) × 100/PA (mm); ll (%) = ll (mm) × 100/dv (mm). The taxonomy of the family is given after (Dzyuba, 2011).

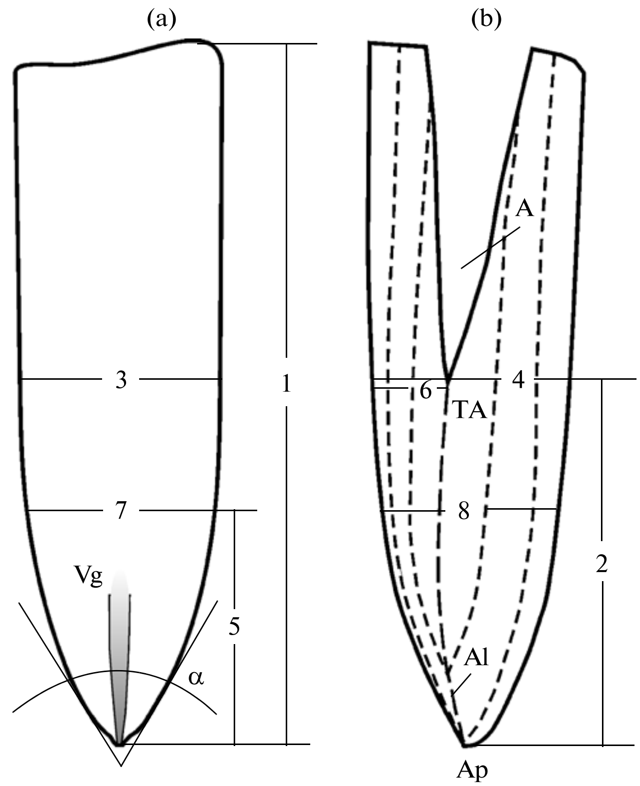


Fig. 7. Scheme of measurements and elements of morphology in belemnite rostra.

(a) ventral side; (b) longitudinal section in the dorso-ventral plane. Elements of morphology: (A) alveolus; (Ap) apex; (TA) tip of alveolus; (Vg) ventral groove; (Al) apical line. Measured parameters: (1) total preserved length (R); (2) length of the postalveolar part of the rostrum (PA); (3) lateral diameter near the tip of the alveolus (LL); (4) dorso-ventral diameter near the tip of the alveolus (DV); (5) length of the apical region of the rostrum (AR); (6) ventral radius near the tip of the alveolus (Rv); (7) lateral diameter in the apical region of the rostrum (ll); (8) dorso-ventral diameter in the apical region of the rostrum (dv); (α) apical angle in the lateral plane.

FAMILY CYLINDROTEUTHIDIDAE STOLLEY, 1919

SUBFAMILY CYLINDROTEUTHIDINAE STOLLEY, 1919

Genus *Cylindroteuthis* Bayle, 1878

***Cylindroteuthis ornata* sp. nov.**

Plate I, fig. 3

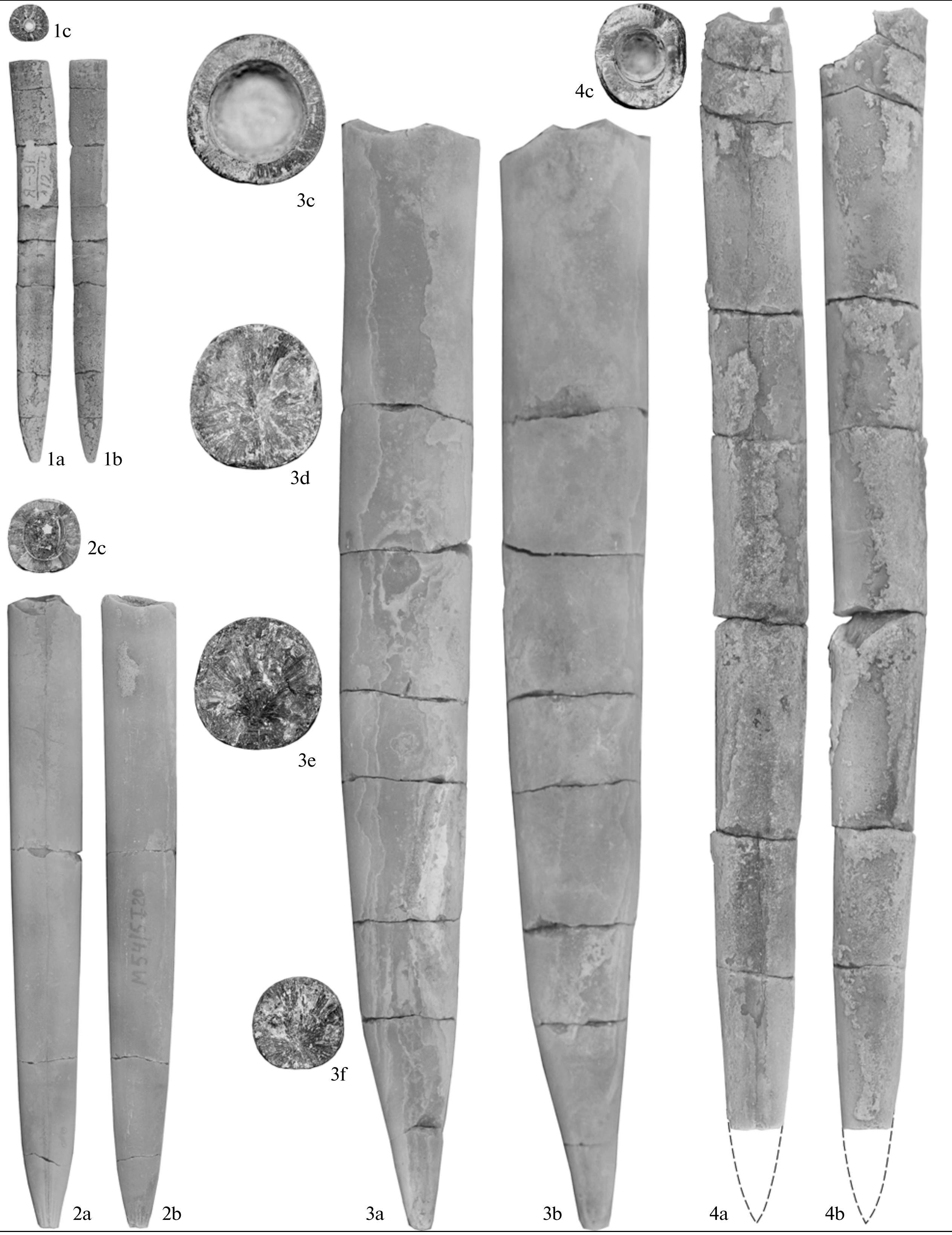
? *Cylindroteuthis (Cylindroteuthis) glennensis*: Saks and Nal'nyaeva, 1964, p. 61, Plate 7, figs. 1 and 2, Fig. 12.

S p e c i e s n a m e: from ornata (Latin) meaning elegant, graceful.

H o l o t y p e: No. 2034/22, CSGM in IGM SB RAS, Novosibirsk, Russia; eastern slope of northern Urals, Mauryn'ya River, Outcrop 54, Bed 6, 0.15 m above the base; Volgian Stage, Upper Substage, Maurynijensis a-Beds; Plate I, fig. 3.

D i a g n o s i s. Rostrum large, strongly elongated, subcylindrical in the anterior and subconical in the posterior half. Profile of the apical region is asymmet-

Plate I



rical. Apex is slightly offset towards the ventral side. Transverse section is oval, laterally compressed. Ventral groove is weakly pronounced.

D e s c r i p t i o n. Rostrum is large, strongly elongated, subcylindrical in the anterior and subconical in the posterior half. At some distance from the apex, within the apical region, a strongly flattened ventral side and at the same time a convex dorsal contour are observed, giving the rostrum an asymmetrical profile. The apex is eccentric, apical angle acute. Except for the apical region, the ventral side is slightly flattened, dorsal side is convex. Lateral sides in the upper half of the rostrum display wide flattened areas, the planes of which are parallel. The ventral groove is hardly visible near the apex. The transverse section in the anterior half of the rostrum is oval to slightly trapezoid, strongly laterally compressed; closer to the apex it becomes more rounded.

Alveolus is shallow with the apex displaced toward the ventral side. Judging from the transverse splits representing different sections of the post-alveolar part of the rostrum (Plate I, figs. 3d–3f), the apical line is eccentric, approximated to ventral side.

S i z e a n d p r o p o r t i o n s.

Specimen	R, mm	PA, mm	PA, %	DV, mm	LL, mm	LL, %	AR, mm	AR, %	α°	dv, mm	ll, mm	ll, %
2034/22	194.0	157.5	620	25.4	22.7	89	65.0	41	19	21.4	20.4	95

C o m p a r i s o n. In comparison with the most closely related species *C. luljensis* Sachs and *C. occidentalis* And. (=*C. glennensis* And.) known from the Ryazanian sediments, the new species is characterized by the better pronounced conical shape, strongly asymmetrical apical region, and almost invisible ventral groove. It differs from the latter in less elongated post-alveolar part of the rostrum. It is considerably larger than the co-occurring *C. newvillensis* And., from which also differs in shape.

R e m a r k s. Rostra similar to the species described are very scarce in the Middle and Upper Volgian substages in northern Eastern Siberia. Saks and Nal'nyaeva (1964) identified them as *Cylindroteuthis (Cylindroteuthis) glennensis* And. Four rostra were found in the Kheta River basin and three, in the Anabar River basin. From the holotype of *C. glennensis* derived from northern California (Anderson, 1945) the East Siberian specimens differ in less developed ventral groove. In addition, the rostrum from the Anabar River illustrated in Plate 7, fig. 1 (Saks and Nal'nyaeva, 1964), is less elongated and its shape is close to subconical. Since its apical region is not asymmetrical as in the species described, it is assigned to it presumably. However, it should be noted that this character may be subjected to intraspecific variability.

M a t e r i a l. The holotype.

SUBFAMILY PACHYTEUTHIDINAE STOLLEY, 1919

Genus *Acroteuthis* Stolley, 1911

***Acroteuthis pseudoconoides* sp. nov.**

Plate III, figs. 1, 2, 5–7

Acroteuthis (Acroteuthis) conoides: Doyle, Kelly, 1988, p. 36, pl. 8, figs. 10–12.

S p e c i e s n a m e: from similarity with *Acroteuthis conoides* Swinnerton.

H o l o t y p e: No. 2034/23, CSGM in IGM SB RAS, Novosibirsk, Russia; North Urals, Mauryn'ya River, Outcrop 54, Bed 6, 0.6 m below the top; Volgian Stage, Upper Substage, Maurynijensis a-Beds; Plate III, fig. 6.

D i a g n o s i s. Rostrum large, elongated, intermediate between subconical and subcylindrical in shape. Apex acute, weakly eccentric. Ventral groove is shallow and short. Transverse section rounded subquadrate, slightly dorso-ventrally depressed.

D e s c r i p t i o n. Rostrum is large, elongated (PA 340–440% with DV > 16.8 mm). The rostrum width varies slightly in the alveolar region and gradually decreases in the post-alveolar part. The apex is acute (α 28°–36°), weakly eccentric. The ventral side is slightly flattened, lateral and dorsal sides are weakly convex. A narrow and shallow ventral groove extends from the apex,

Plate I. Belemnites from Volgian and Ryazanian boundary sediments recovered on the Yatriya and Mauryn'ya rivers. Here and in plates II–V the specimens are illustrated in natural size; they are stored in the Central Siberian Geological Museum (CSGM) at the Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences, Novosibirsk (collection no. 2034). Specimens 1 and 4 originate from the Yatriya River; specimens 2 and 3, from the Mauryn'ya River.

(1) *Arctoteuthis tehamaensis* (Stanton), Specimen 2034/40, Outcrop 1, Bed 2, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (2) *Cylindroteuthis newvillensis* Anderson, Specimen 2034/41, Outcrop 54, Bed 5, 0.2 m below the top, Maurynijensis a-Beds: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (3) *C. ornata* sp. nov., holotype, Specimen 2034/22, Outcrop 54, Bed 6, 0.15 m above the base, Maurynijensis a-Beds: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d–f) transverse sections at different levels of the postalveolar part; (4) *C. knoxvillensis* Anderson, Specimen 2034/42, Outcrop 1, Bed 1, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end.

Plate II

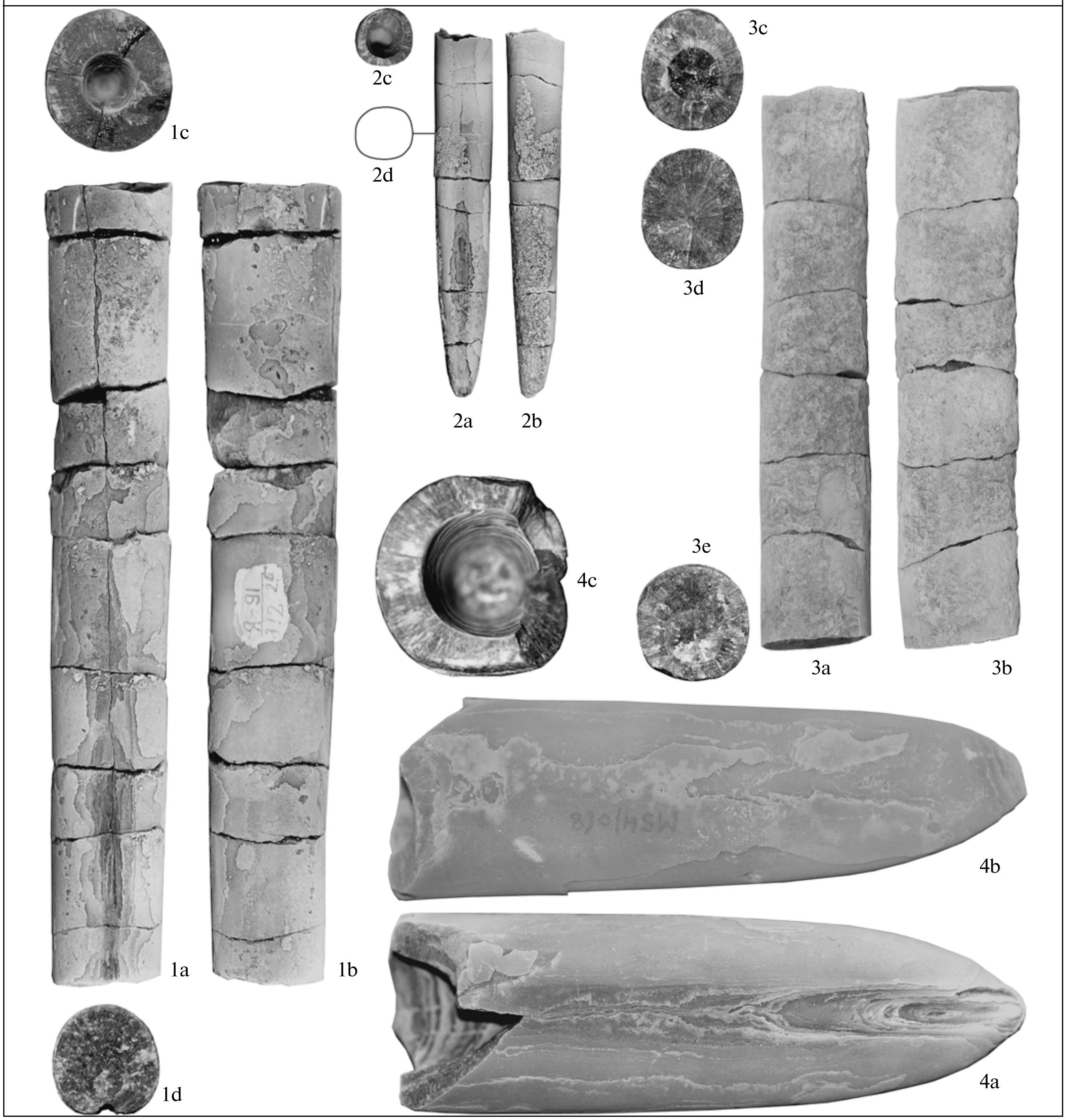


Plate II. Belemnites from Volgian and Ryazanian boundary sediments recovered on the Yatriya and Mauryn'ya rivers. Specimens 1 and 2 originate from the Yatriya River; specimens 3 and 4, from the Mauryn'ya River.

(1) *Cylindroteuthis* cf. *subobeliscoides* Voronetz, Specimen 2034/43, Outcrop 1, Bed 2, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d) transverse section near the posterior end; (2) *Acroteuthis mosquensis* (Pavlow), Specimen 2034/44, Outcrop 1, Bed 2, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d) sketch of transverse section near the tip of the alveolus; (3) *Cylindroteuthis* cf. *subobeliscoides* Voronetz, Specimen 2034/45, Outcrop 54, Bed 8, top, transitional interval between Sibiricus and Kochi a-zones: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d) transverse section near the tip of the alveolus, (e) transverse section near the posterior end; (4) *Liobelus prolateralis* (Gustomesov), Specimen 2034/46, Outcrop 54, talus: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end.

then widens and disappears within the apical region. The transverse section is rounded subquadrate, mostly dorso-ventrally depressed (LL 98–109%, ll 100–110%).

Alveolus is slightly curved, shallow, with the tip offset to the ventral side (Rv 34–39%). The apical line comes close to the ventral margin (Plate III, fig. 1). Thin young rostra relatively thicken in the ontogeny: PA constitutes 500–600% with DV 10–13 mm, 365–440% with DV 16.8–18.5 mm, and 340–353% with DV 20–22 mm. The transverse section of juvenile rostra is nearly rounded, in the ontogeny becomes subquadrate (Plate III, fig. 2).

Size and proportions.

Specimen	R, mm	PA, mm	PA, %	DV, mm	LL, mm	LL, %	AR, mm	AR, %	α°	dv, mm	ll, mm	ll, %
2034/23	113.5	74	441	16.8	17.6	105	43	58	29	15.4	16.0	104
2034/24	100.5	70	409	17.1	17.4	102	40	57	36	15.8	15.6	99
2034/25	99	68	384	17.7	18.6	105	38	56	36	15.8	16.1	102
2034/26	87.5	–	–	21.0	21.5	102	–	–	–	17.9	18.6	104
2034/27	76.5	64	508	12.6	13.2	105	29	45	28	10.7	11.2	105

Variability. Most of rostra are intermediate in shape between subconical and subcylindrical but there are varieties distinctly subconical (Plate III, fig. 5). Magnitude of the dorso-ventral compression is substantially variable. In most of the rostra LL ranges within 100–105% (ll within 102–107%) and only few specimens display deviation up to 98 and 109% (ll up to 99 and 110%, respectively). The most numerous in the collection are rostra with diameters from 10 to 18.5 mm corresponding to juvenile and adult stages of the ontogeny. There are also three rostra of gerontic stage; their diameter exceeds 20 mm.

Comparison. The new species differs from *A. conoides* Swinn. known in the Upper Valanginian and Lower Hauterivian, in thinner and more elongated rostrum, weaker dorso-ventrally depressed. It is more closely related to *A. explanatoides* (Pavl.) widespread in the Lower Cretaceous deposits and to *A. mosquensis* (Pavl.) and *A. festucalis* Swinn. characteristic of the Jurassic–Cretaceous boundary strata. Compared to the two former species, it is considerably less flattened from the ventral side and less dorso-ventrally depressed. From the Arctic *A. explanatoides polaris* Sachs et Naln. it also differs in less relative length of the postalveolar part. The new species is noticeably larger than *A. festucalis* Swinn. and is generally more conical in shape.

Remarks. The *A. (A.) conoides* Swinn. rostra described by Doyle (Doyle and Kelly, 1988) from the Tordenskjoldberget Member in the Kong Karls Land, Svalbard, are assigned to the species discussed. They differ from the *A. conoides* holotype (Swinnerton, 1937, pl. VI, fig. 2) in a lesser dorso-ventral compression and stronger elongation.

Distribution. Volgian–Ryazanian boundary layers (Maurynijensis a-Beds, Sibiricus a-Zone) in the North Urals and the Tordenskjoldberget Member, the Kong Karls Land, Svalbard.

Material. Twelve well-preserved specimens and 14 incomplete specimens from the Mauryn'ya River, Outcrop 54: Bed 5b (8 specimens), Bed 6 (16 specimens), Maurynijensis a-Beds; base of Bed 8, Sibiricus a-Zone (2 specimens).

Genus *Pachyteuthis* Bayle, 1878

Pachyteuthis eximia sp. nov.

Plate IV, figs. 1, 2, 4, 5

Species name: from eximia (Latin) meaning peculiar, extraordinary.

Holotype: No. 2034/28, CSGM in IGM SB RAS, Novosibirsk, Russia; Subpolar Urals, Yatriya River, Outcrop 1, Bed 1; Ryazanian Stage, Kochi a-Zone; Plate IV, fig. 1.

Diagnosis. Rostrum large, moderately elongated, subconical. Profile of the apical region strongly asymmetrical. Apex is drawn-out and brought closer to the ventral side. Ventral groove is wide and deep, not going far beyond the apical region. Transverse section nearly rounded, with flattened ventral side.

Description. The rostrum is large, moderately elongated (PA 365–394% with DV > 20 mm). Lateral sides in the anterior half of the rostrum are parallel, in the posterior half they gradually converge to the apex. The rostrum is subconical in profile. Within the apical region, at some distance from the apex the ventral side is flattened and dorsal contour is strongly convex, which makes the profile asymmetrical in shape. The apical angle is acute (α 26°–30°), the apex is drawn-out and brought closer to the ventral side. The ventral side is flattened, other sides are slightly convex. A wide and deep ventral groove extends 2/5–1/3 of the rostrum length. Transverse section is rounded-subquadrate to rounded in the anterior half of the rostrum, towards the apex the dorso-ventral depression increases (LL 96–102%, ll 101–107%).

Alveolus is slightly curved, occupies less than a half of rostrum, its tip is offset to the ventral side (Rv about 35%). The apical line comes close to the ventral margin (Plate IV, fig. 4). Shape of the transverse section is almost unchanged in the ontogeny (Plate IV, fig. 2). In relative length of the postalveolar part the juvenile rostra are similar to adults.

S i z e a n d p r o p o r t i o n s.

Specimen	R, mm	PA, mm	PA, %	DV, mm	LL, mm	LL, %	AR, mm	AR, %	α°	dv, mm	ll, mm	ll, %
2034/28 (Ya)	163	115	394	29.2	27.9	96	59.5	52	28	23.9	24.8	104
2034/29 (M)	130	90	366	24.6	24.5	100	50	56	26	21.2	21.4	101
2034/30 (Ya)	98	89.8	365	24.6	25.1	102	43.5	48	30	19.6	19.7	101
2034/31 (Ya)	66	~49	~380	12.9	13.1	102	–	–	–	10.6	11.3	107

Note: M—Mauryn'ya River; Ya—Yatriya River.

V a r i a b i l i t y. Length of the apical region (AR 48–56%) is most variable in the studied specimens.

C o m p a r i s o n. None of the known Volgian or Ryazanian member of *Pachyteuthis* is so large. From the most similar *P. acuta* (Blüthg.) the new species differs in better pronounced subconical form of the rostrum and in asymmetric profile. Compared to *P. obliquespinata* (Blüthg.), it is less laterally compressed and has a thicker apical region and the apex offset toward the ventral side.

D i s t r i b u t i o n. Volgian–Ryazanian boundary layers (Maurynijensis a-Beds–Kochi a-Zone) of the North and Subpolar Urals.

M a t e r i a l. One well-preserved specimen from the Mauryn'ya River, Outcrop 54: talus Bed 6, Maurynijensis a-Beds; 2 well-preserved and 3 incomplete specimens from the Yatriya River, Outcrop 1: Bed 1 (3 specimens), Bed 2 (2 specimens), Kochi a-Zone.

SUBFAMILY SIMOBELINAE DZYUBA, 2011

Genus *Simobelus* Gustomesov, 1958

***Simobelus compactus* sp. nov.**

Plate V, figs. 1–8

S p e c i e s n a m e: from compactus (Latin) meaning tight, compact.

H o l o t y p e: No. 2034/32, CSGM in IGM SB RAS, Novosibirsk, Russia; North Urals, Maurynya River, Outcrop 54, Bed 6, 0.2 m above the base; Volgian Stage, Upper Substage, Maurynijensis a-Beds; Plate V, fig. 6.

D i a g n o s i s. Rostrum large, robust, subcylindrical. The apex is sharpened, slightly offset to ventral side. Ventral groove shallow and short. Transverse section from rounded-subquadrate to slightly trapezoid.

D e s c r i p t i o n. The rostrum is large, robust (PA 176–225% with DV > 20 mm), of subcylindrical or transitional to subconical form. The apical region is short, with a sharpening at the end that is slightly offset to ventral side. The apical angle in the lateral plane with DV over 20 mm is 53°–56°. The ventral and lateral sides are flattened, dorsal side is convex. Flattenings on the lateral sides look like wide planes, parallel or obliquely arranged and slightly pulled together on the dorsal side. Near the apex a narrow and shallow ventral groove is observed. The transverse section varies from rounded-subquadrate to slightly trapezoid (LL 96–103%, ll 97–105%).

Alveolus is deep, slightly curved, with the tip offset to the ventral side (Rv about 30%). The apical line comes close to the ventral margin, especially in the lower half of the postalveolar part (Plate V, fig. 5). Rostra are strongly thickened in the ontogeny, PA constitutes 328–358%

Plate III. Belemnites from the Upper Volgian Substage on the Mauryn'ya River, Outcrop 54.

(1, 2, 5–7) *Acroteuthis pseudoconoides* sp. nov., all specimens originate from Maurynijensis a-Beds: (1) Specimen 2034/26, Bed 6, base, longitudinal section, (2) Specimen 2034/25, Bed 6, 0.2–0.4 m above the base: (a) transverse section near the tip of the alveolus, (b) transverse section in the apical region, (5) Specimen 2034/27, Bed 6, 0.0–0.3 m above the base: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (6) holotype, Specimen 2034/23, Bed 6, 0.6 m below the top: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d) transverse section slightly above the tip of the alveolus, (7) Specimen 2034/24, Bed 5, the top: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (d) transverse section near the tip of the alveolus; (3, 4) *Liobelus prolateralis* (Gustomesov): (3) Specimen 2034/47, Bed 5, 0.5 m above the base, Taimyrensis a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (4) Specimen 2034/48, talus: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end.

Plate III

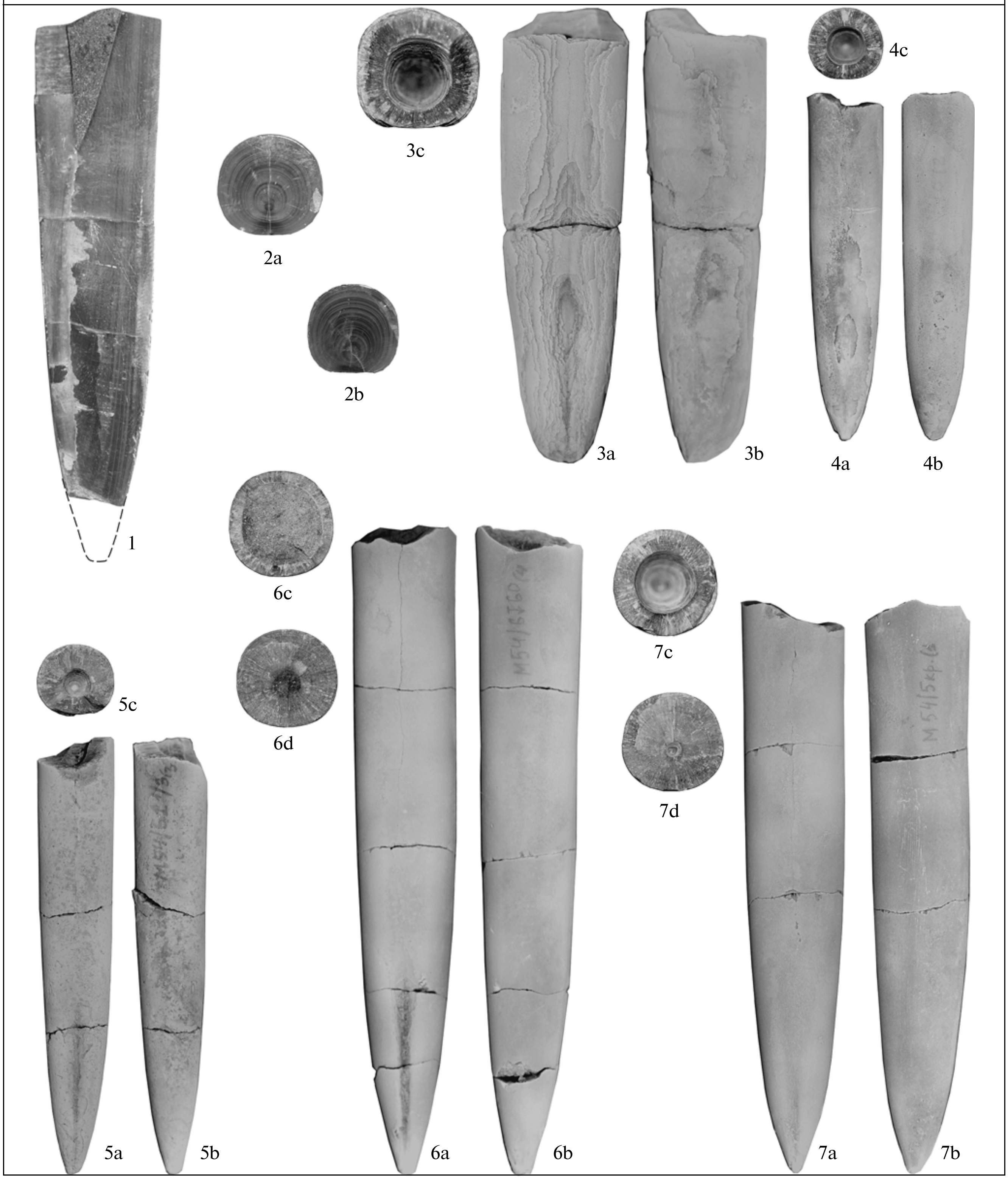
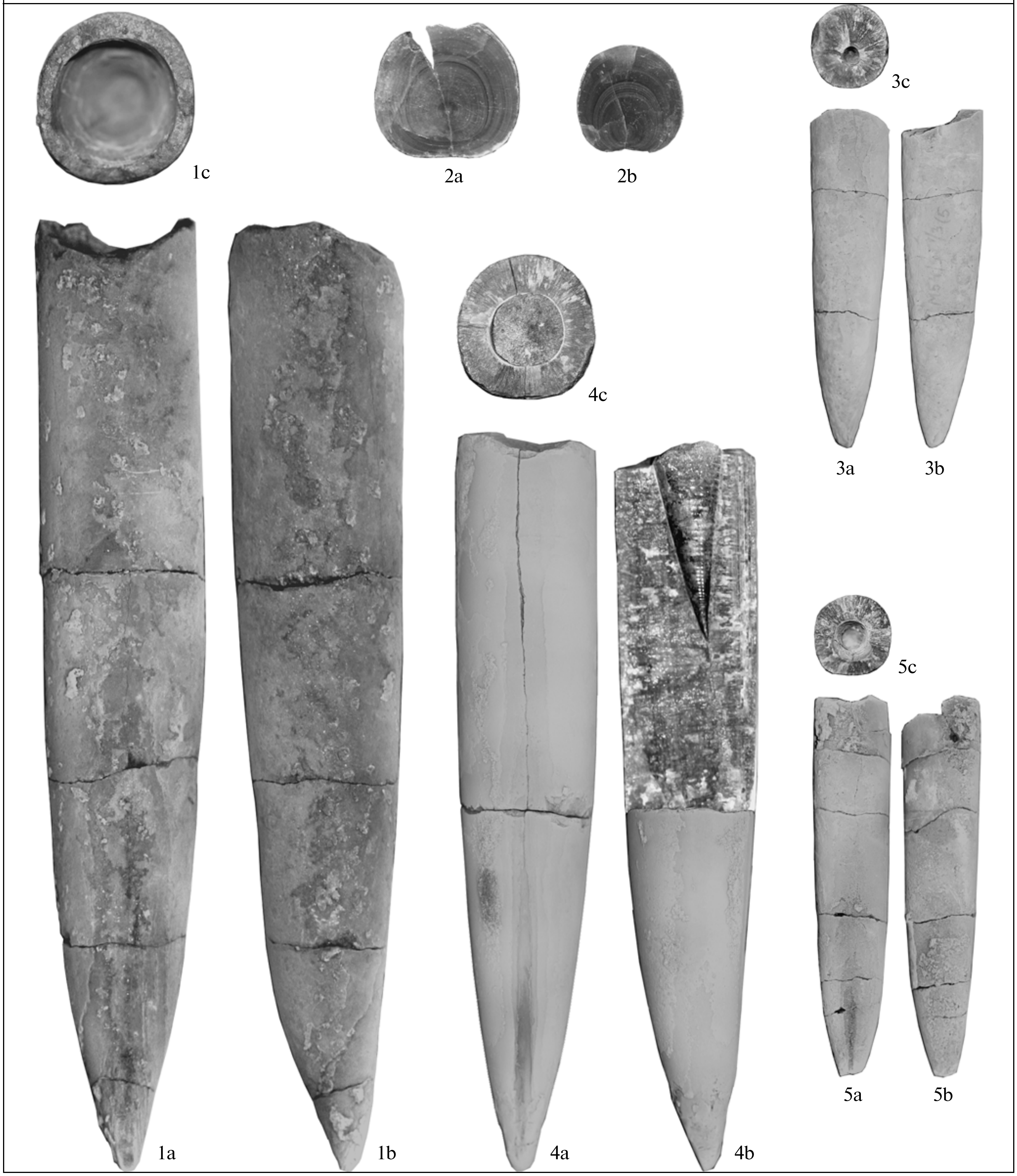


Plate IV



with DV 8.8–12.2 mm, 225–278% with DV 16.2–20 mm, and 176–225% with DV 24.5–30.7 mm. Judging from transverse sections, the lateral flattening increases in the ontogeny (Plate V, fig. 4).

S i z e a n d p r o p o r t i o n s.

Specimen	R, mm	PA, mm	PA, %	DV, mm	LL, mm	LL, %	AR, mm	AR, %	α°	dv, mm	ll, mm	ll, %
2034/32	111	64	225	28.5	28.5	100	31	48	56	25.0	25.5	102
2034/33	103.5	56	209	26.7	26.8	100	31	55	53	23.4	23.4	100
2034/34	67.5	45	278	16.2	16.3	101	20.5	46	43	14.0	14.3	102
2034/35	59	40	328	12.2	12.1	99	19	47.5	37	10.7	10.7	100
2034/36	51.5	36.5	341	10.7	10.5	98	15.5	43	36	9.5	9.9	104
2034/37	48.5	31.5	358	8.8	9.0	102	11.5	37	45	8.0	8.0	100
2034/38	85	47	184	25.5	26.2	103	24	51	56	22.5	23.1	103
2034/39	86	55	179	30.7	30.2	98	29	53	–	27.3	26.9	99

V a r i a b i l i t y. Most of rostra are subcylindrical. However, in some varieties the dorso-ventral plane is nearly subconical in shape (Plate V, fig. 7b). In certain specimens, especially those found in talus, ventral groove is deepened owing to secondary destruction of layers. The collection yields rostra ranging from 6.9 to 31 mm in diameter corresponding to different ontogenetic stages, from juvenile to gerontic, but adult and senile specimens with diameter exceeding 20 mm, dominate.

C o m p a r i s o n. The new species is similar to the Volgian *S. mamillaris* (Eichw.) and *S. insignis* (Sachs et Naln.) in the shape of rostrum and transverse section and in peculiarities of ventral groove, but differs from them in a wider flattening of lateral sides. Compared to the former, it is characterized by a longer postalveolar part; compared to the latter, it is larger and has a subcylindrical or less pronounced subconical shape of the rostrum in the dorso-ventral section. From the Berriasian *S. curvulus* (Sachs et Naln.) the new species differs in less deep alveolus, longer postalveolar part, flattening of lateral sides, and in the apex less offset to the ventral side.

R e m a r k. It is not excluded that the new species is identical to *S. eocretacicus* (Crickmay) known from the Berriasian of British Columbia. Visual comparison with this species is possible only by transverse and longitudinal sections of the rostra illustrated by the author (Crickmay, 1930, pl. 22, fig. 4; pl. 23, fig. 5). In the form of transverse section and inner morphology the differences between species are not visible. According to description, *S. eocretacicus* is characterized by very short and thick rostrum. This information is not enough to compare the species.

D i s t r i b u t i o n. Volgian–Ryazanian boundary layers (Taimyrensis–Kochi a-zones) of the North Urals.

M a t e r i a l. Sixteen well-preserved and 3 incomplete specimens from the Mauryn'ya River, Outcrop 54: Bed 4 (1 specimen), Bed 5a (15 specimens), Taimyrensis a-Zone; Bed 5b (1 specimen), Bed 6 (1 specimen), Maurynijensis a-Beds; Outcrop 52: Bed 1, Kochi a-Zone (1 specimen).

CONCLUSIONS

In the Jurassic–Cretaceous boundary sediments of the northwestern margin of Western Siberia a rich and diverse belemnite assemblage including the genera *Cylindroteuthis*, *Arctoteuthis, Lagonibelus, Pachyteuthis, Boreioteuthis, Acroteuthis, Simobelus*, and *Liobelus* (family Cylindroteuthididae), was recognized. A total of 23 belemnite species were identified in the Upper Volgian Substage and lowermost Ryazanian Stage (Sibiricus and Kochi a-zones), nine species more than previously reported. Such a high diversity of

Plate IV. Belemnites from Volgian and Ryazanian boundary sediments recovered on the Yatriya and Mauryn'ya rivers.
Specimens 1, 2 and 5 originate from the Yatriya River; specimens 3 and 4, from the Mauryn'ya River.
(1, 2, 4, 5) *Pachyteuthis eximia* sp. nov.: (1) holotype, Specimen 2034/28, Outcrop 1, Bed 1, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (2) Specimen 2034/30, Outcrop 1, Bed 1, Kochi a-Zone: (a) transverse section near the tip of the alveolus, (b) transverse section near the apical region, (4) Specimen 2034/29, Outcrop 54, Bed 6, talus, Maurynijensis a-Beds: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end, (5) Specimen 2034/31, Outcrop 1, Bed 2, Kochi a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (3) *Pachyteuthis crassovalis* (Blüthgen), Specimen 2034/49, Outcrop 54, Bed 5b, Maurynijensis a-Beds: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end.

Plate V

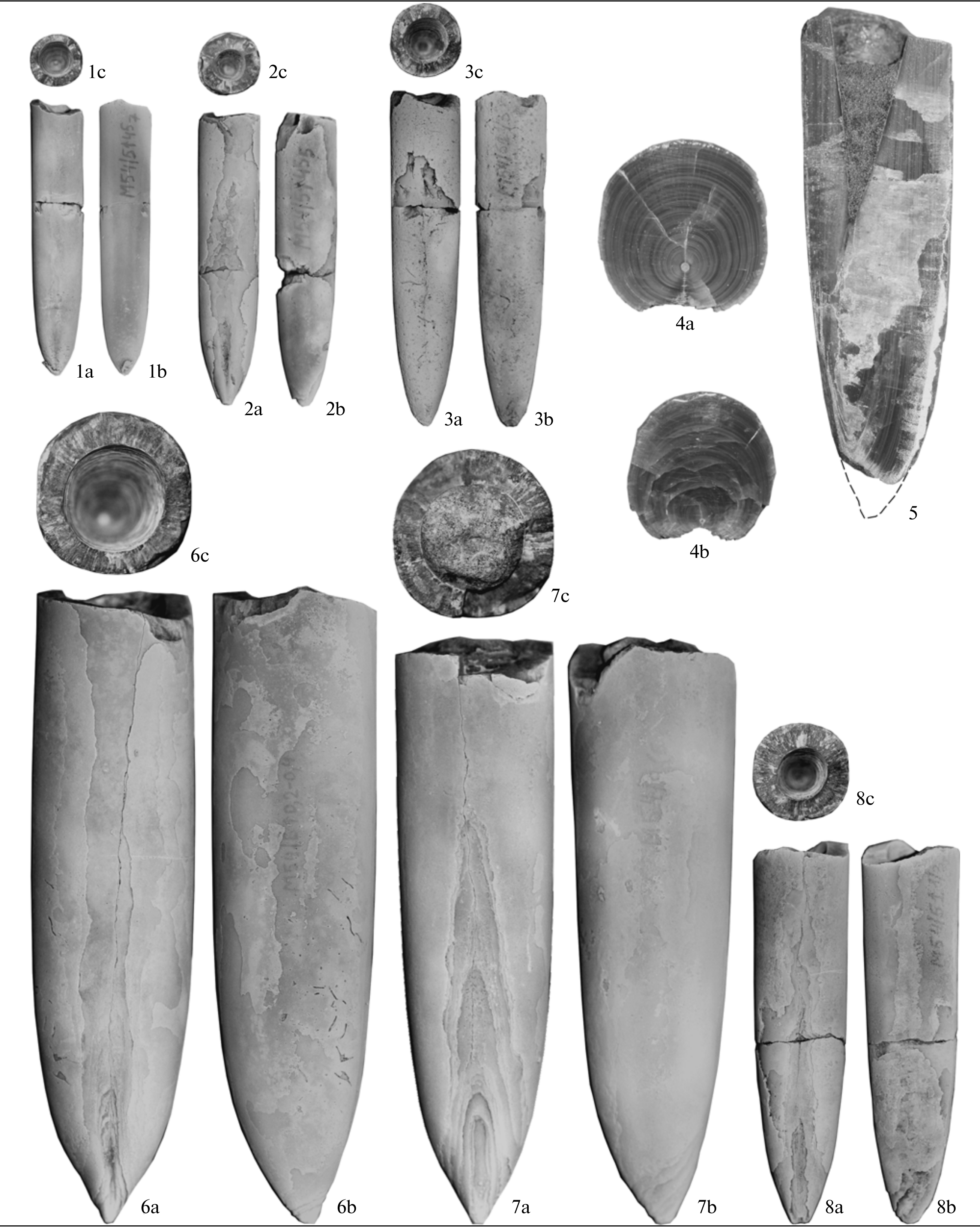


Plate V. The species *Simobelus compactus* sp. nov. from the Upper Volgian Substage on the Mauryn'ya River, Outcrop 54.
(1) Specimen 2034/37, Bed 5, 0.45 m above the base, Taimyrensis a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (2) Specimen 2034/36, Bed 5, 0.45 m above the base, Taimyrensis a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (3) Specimen 2034/35, Bed 5, 0.0–0.3 m above the base, Taimyrensis a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (4) Specimen 2034/39, talus: (a) transverse section near the tip of the alveolus, (b) transverse section near the apical region; (5) Specimen 2034/38, talus, longitudinal section; (6) holotype, Specimen 2034/32, Bed 6, 0.2–0.4 m above the base, Maurynijensis a-Beds: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (7) Specimen 2034/33, talus: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end; (8) Specimen 2034/34, Bed 5, 0.0–0.3 m above the base, Taimyrensis a-Zone: (a) ventral view, (b) right lateral view, (c) transverse section near the anterior end.

belemnites at the Volgian–Ryazanian boundary has not been recorded so far in any other boreal basin.

In the Lyapin Bay that occurred in the northwestern margin of the West Siberian marine basin the growth of belemnite diversity began at the end of the Middle Volgian and significantly increased in the Late Volgian. The peak of the belemnite taxonomic diversity occurred in the terminal Volgian–beginning of the Ryazanian when up to 15 species of the eight Cylindroteuthididae genera concurrently occurred, i.e. it falls on the beginning of the Cretaceous. At this time the genus *Hibolithes* of the Tethyan family Mesohibolitidae penetrated to the western West Siberian sea (Braduchan et al., 1986). In the second half of the Ryazanian the number of species substantially decreased. The dynamics of belemnite species diversity correlates well with climatic events. An increase in the number of species in the Lyapin Bay corresponded to a temperature rise in the Siberian paleoseas, and the subsequent reduction of species diversity is correlated with their gradual cooling.

Information on belemnite assemblages from the Volgian–Ryazanian boundary biostratigraphic units Maurynijensis a-Beds and Sibiricus a-Zone, is available for the first time. A high-resolution knowledge of belemnite stratigraphic distribution in the Jurassic and Cretaceous transitional strata in the northwestern margin of Western Siberia made it possible to recognize an almost complete succession of belemnite zones and beds, that has been revealed previously in northern Eastern Siberia and proposed as the new version of belemnite scale in the Boreal zonal standard (Dzyuba, 2012; Shurygin et al., 2011). In the sections studied the intervals correlated by belemnites with synchronous sections of the Kong Karls Land, Pechora River basin, and northern California, are recorded. All this became possible mainly due to detailed examination of Outcrop 54 on the Mauryn'ya River. During fieldwork in 2007, together with belemnites, ammonites, bivalves, gastropods, brachiopods, and samples for micropaleontological and isotope (belemnite rostra) analysis were collected. The results of a comprehensive paleontological, stratigraphic, paleoecological, carbon isotope, and oxygen isotope study of this section will be published in the near future.

ACKNOWLEDGMENTS

The expeditions in the Vol'ya River basin were actively supported by the State Museum of Nature and Man (Khanty-Mansiisk) represented by A.S. Rezvyi. A.S. Alifirov, S.V. Ivantsov, A.E. Igol'nikov, and O.S. Urman took part in the fieldwork and collecting belemnite rostra. A.L. Beisel' participated in the fieldwork headed by M.S. Mesezhnikov in 1978 in the Vol'ya basin, and kindly provided information from his field diary and advised on the location and structure of the outcrops. Some rostra were given to the author for examination by V.A. Zakharov and O.V. Shenfil. Sections of rostra were prepared by M.A. Serednev and Z.S. Saifulina. Valuable advice and remarks were received from A.P. Ippolitov, I.A. Starodubtseva, and B.N. Shurygin. I am deeply grateful to everyone who has assisted in preparing the publication.

This work was supported by the Russian Foundation for Basic Research (project no. 12-05-00453) and by the Presidium of RAS, Programs no. 23 "Basic problems of oceanology: physics, geology, biology, ecology" and no. 28 "Problems of the life origin and biosphere formation".

Reviewers A.P. Ippolitov and V.A. Zakharov

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