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The Age of the pre-Callovian Jurassic Sequence at the Southwest of Tatarstan (Central Russia, Tarkhanovskaya pristan'—Dolinovka reference section) and the Status of the Upper Bajocian "*Garantiana*-beds", Previously Described from Here

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Abstract—In the present paper we describe and discuss belemnite finds from the basal part of the middle Jurassic sequence at the southwest of the Republic of Tatarstan (Tetyushi district). The belemnites were collected from the outcrops located along a shoreline of the Kuybyshevskoye reservoir (Volga river) between the place Tarkhanovskaya pristan' and the former village Dolinovka. These belemnites indicate that the basal part of the Jurassic sequence is Early Bathonian (Ishmae Zone) or, less probable, Middle Bathonian in age. Such dating triggers a critical review for the age of the middle Jurassic sequence in the region. In particular, poorly preserved ammonites previously collected from the same outcrops higher in the succession and interpreted as members of the Late Bajocian subfamily Garantianinae, are in fact Late Bathonian Gowericeratinae. Consequently, "Beds with *Garantiana*"—nominally the most ancient ammonite-based biostratigraphic unit within the whole Jurassic of European Russia, based on this assemblage,—is invalid.

Keywords: belemnites, Cylindroteuthididae, ammonites, Gowericeratinae, stratigraphy, Bajocian, Bathonian, Volga region, Tatarstan

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INTRODUCTION

One of critical problems for the stratigraphy of the middle Jurassic of Central Russia, is the age of a thick (>20 m) pre-Callovian sequence, exposed along the western bank of Kuybyshevskoye Reservoir near the hills called "Shchuch'i Gory", at the southwest of Republic of Tatarstan (Fig. 1a-c). By the mid-2000s geologists considered these strata as Bathonian, based on the palynological data and scarce microfossils (Didenko and Zorina, 2003; *Unifitsirovannaya*..., 1993; Zorina, 2005a, 2005b, 2007a, 2007b). However, in the last two decades V.V. Mitta discovered poorly preserved marine macrofossils (mainly ammonites and bivalves) in the upper part of the pre-Callovian sequence (Mitta, 2003, 2010). The analysis of this complex brought a real thunderbolt: the assemblage was dated by the middle Late Bajocian (Baculata Subzone of Niortense Zone—Garantiana Zone interval), based on ammonite identifications as the members of subfamily Garantianinae Wetzel (Stephanoceratidae Neumayr) (Mitta and Dietl, 2012; Mitta et al., 2014b). According to such an interpretation, the new biostratigraphic unit—"Beds with *Garantiana*"—was established for the Central Russia. Shortly later, this unit was officially accepted for the actualized edition of the "Unified regional stratigraphic scheme of the Jurassic of East European Platform" (Mitta and Dietl, 2012; *Unifitsirovannaya*..., 2012).

The impact of these data on the regional stratigaphy and palaeogeography can hardly be overestimated. First, prior to the publications by V.V. Mitta and his co-authors, the most ancient Jurassic marine strata in the Volga area were thought to be of latest Bajocian – ?earliest Bathonian age (belonging to so-called Michalskii ammonite Zone); notably, these strata are recorded only ~500 km south of Tatarstan, near Saratov city and southwards of it, while their presence northwards of Saratov has not been ever confirmed. Second, the succession below Mitta's ammonite finds is clearly marine at least at some levels (Milanovsky, 1940; Pavlow, 1884), thus indicating probable ?pre- Late Bajocian marine sedimentation in the Middle Volga area. In particular, based just on its geological position, Mitta et al. (2014b) proposed the (?) Lower Bajocian age for the basal part of the Jurassic sequence. Thus, the discovery of presumably Late Bajocian ammonites in Tatarstan significantly transformed the interpretation of the geological history for the whole Middle Volga region, greatly increasing the age of the earliest phase of the Jurassic marine transgression, reaching here from the Northern Tethys.

However, the Late Bajocian age of the macrofossil assemblage, proposed by V.V. Mitta, had not received the support from other ammonite specialists. In particular, D.B. Gulyaev supposed that ammonite identifications by Mitta are erroneous, and that the whole assemblage should be referred to the Late Bathonian (Infimum Zone), rather than to the Late Bajocian (Gulyaev, "Special opinion" in *Unifitsirovannaya*..., 2012; Gulyaev, 2013). Opinions by other Russian specialists differ: D.N. Kiselev shares the viewpoint of Gulyaev (pers. comm., 2018), while M.A. Rogov considers identification of ammonites impossible due to preservational constraints (pers. comm., 2014–2018).

There are some additional indirect arguments against the Late Bajocian age proposed by Mitta and co-authors—like available data on well log correlations across the Middle Volga area. According to the summary by Zorina (2007b, 2012, 2014), the basal beds of the pre-Callovian succession exposed in SW Tatarstan, to the south **overlie** the clayish Pochinki formation – a well-recognizable unit characterized by multiple macrofossils (ammonites, bivalve, belemnites) and spanning over the Bajocian-Bathonian boundary interval (*Unifitsirovannaya*..., 2012).

In the present paper we provide new data, which allow to settle the dispute about the age of pre-Callovian sequence in the SW of Tatarstan. The principal conclusions were already PUBLISHED IN THE ABSTRACT BOOK of "Paleostrat" Conference in January, 2019 (Ippolitov, 2019).

MATERIAL AND METHODS

The material for the present paper was collected by Alexei Ippolitov during the fieldwork in Shchuch'I Gory area in the October 2018. Considering the existing dispute on the age of the pre-Callovian strata, the main attention was paid to the basal part of the Jurassic sequence, from where "*...unidentifiable bivalves and cavities after dissolved belemnite rostra with alveoli casts*" were previously reported by A.P. Pavlow (1884)[1]. This basal part is represented by brown greywacke sandstone, large- to medium-grained, with gravel and pebbles (=bed 1 of Member I *sensu* Mitta et al., 2014b; see Fig. 1d). From the loose blocks of this layer, abundantly available on the beach near the former Dolinovka village (sections 1 and 2; Fig. 1c), ~30 new belemnite cavities were collected (Figs. 1f, 1g).

These cavities are of different size (ranging in diameter from 4–5 to 20 mm), markedly cylindrical in shape, and usually incomplete—either alveolar, or apical area of the former rostrum is missing. In several cases, strongly leached remains of the rostra with characteristic radial-concentric structure were found inside the cavities, and in one case, surface layers of the rostra were preserved, while the central part was hollow. Among collected samples, 16 cavities were used for making casts with Zhermack Elite Double 16 dental silicone. Those allowed to establish the systematic position of the belemnites, as well as to perform measurements according to the scheme employed previously for the study of related taxa (Ippolitov, 2018c). The alveolar angle of the alveolus in the outline, used for the establishment the approximate protoconch position, was conventionally accepted as equal 21°, following (Ippolitov, 2018c) in order to provide correct comparison with previously published datasets.

[1] Additional mentions of belemnites in the basal beds of the Jurassic in the studied area were provided by Zonov (1939) and Milanovsky (1940), notably, the latter author also mentioned "*rolled ammonite fragments and reptile bones*". Besides, in the reference book "Geology of USSR" (Blom et al., 1967, p. 480) belemnite cavities from Dolinovka were identified as "*Cylindroteuthis beaumonti* Orb.", and a list of bivalves, previously reported from the same strata (Blom, 1955), was repeated. None of these identifications was supported by figures or by descriptions.

SYSTEMATIC PALEONTOLOGY

FAMILY CYLINDROTEUTHIDIDAE STOLLEY, 1919

Genus *Pachyteuthis* Bayle, 1878

Pachyteuthis optima Sachs et Nalnjaeva, 1966

Pl. I, Figs. 1–9

Synonymy and comments on it see Ippolitov, 2018c.

Description. Medium-sized rostrum (maximum diameter is 19 mm at the anterior end among available specimens), moderately elongated, subcylindrical to subconical in shape. The length of the apical part is ~1/2 the rostrum solidum length or slightly less. The cross-section is rounded, in many specimens showing slight lateral compression. Apical ventral groove is present, in most specimens well-defined and extending outside the apical part, in others poorly pronounced, shallow and short.

Measurements and ratios. See Table 1.

Remarks. Six casts represent relatively large specimens (with rostrum diameter exceeding 12 mm), but only two of them allow to establish approximately both the positions of the apex and of the alveolar tip – principal features, together with the rostrum shape allowing the precise species identification. These best preserved rostra can be identified as *P. optima*, while the rest of available material may belong to the same species, too. The former identification of belemnites from the same strata as "*Cylindroteuthis beaumonti* Orb." (Blom et al., 1967, p. 480) is wrong–that latter

Fig. 1. Tarkhanovkskaya pristan'—Dolinovka section and structural features of the basal part of the Jurassic sequence: (a–c) the geographical location of the studied sections; their position on the maps is indicated by arrows; (d) composite lithological log (after Mitta et al., 2014b) and the levels of cephalopod finds in the pre-Callovian strata (level of belemnite finds described in the present paper is marked with an asterisk); (e) general view of the greywacke sandstone outcropping in the base of the Jurassic sequence (section 1; a landslide body with partially preserved original bedding); (f–h) finds of macrofauna from this layer—cavities from dissolved belemnites (f, g) and bivalves (h) (all collected from the section 2). Legend for the log: (1) conglomerate; (2) gravelstone; (3) sands; (4) cross-bedded sands; (5) clayey silt; (6) slightly clayey loess like silt; (7) compact limy clay; (8) flaky limy clay; (9) silt clay; (10) silty clay; (11) clay; (12) marl with ferruginous ooliths; (13) marl; (14) limonite concretions; (15) condensed horizon; (16) silty limy concretions; (17) clayey limy concretions; (18) sand nests; (19) fossils; (20) quartz sand; (21) oligomictic sand; (22) greywacke-like sand; (23) stratigraphic hiatus; (24) erosion boundary; (25) facies boundary; (26) position of belemnite finds described in the present paper.

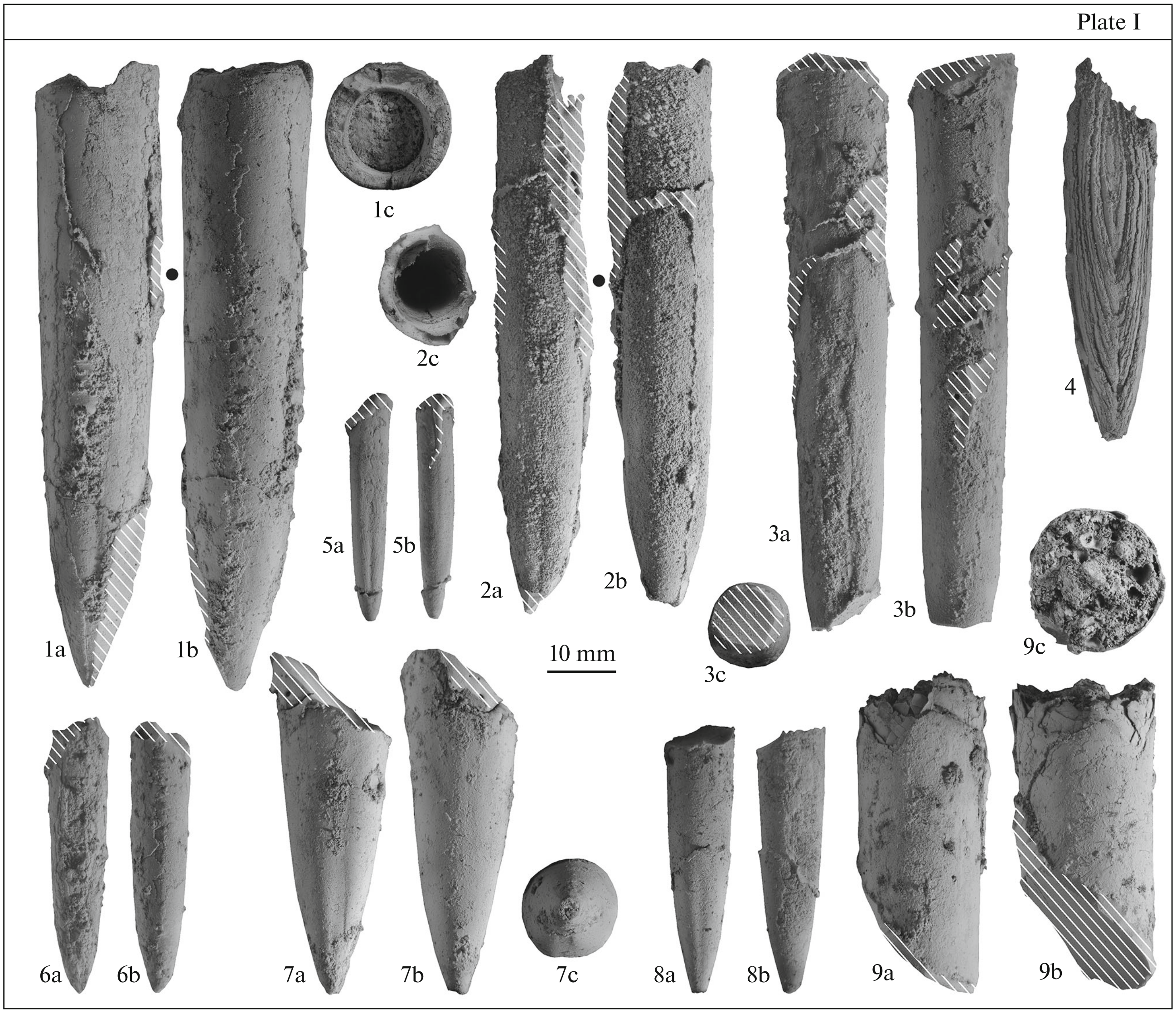

Plate I. *Pachyteuthis optima* from Dolinovka-1 and -2 sections (silicone casts). (1) specimen 01-DOL, the fullest one in our collection; (2) specimen 02-DOL (a cast from the cavity on Fig. 1f); (3) specimen 03-DOL (3c—transverse cross-section at the posterior end); (4) specimen 04-DOL, showing the eroded ventral furrow, typical for Cylindroteuthididae erosion; (5) specimen 05-DOL, juvenile (5b – left side view); (6) specimen 06-DOL (6b – left side view); (7) specimen 07-DOL, specimen with poorly defined ventral furrow (7c—view from the apical side); (8) specimen 08-DOL; (9) specimen 09-DOL, fragment of alveolar part, largest specimen in our collection. All figures are natural size. The specimens are stored in Vernadsky State Geological Museum, Moscow. White hatching shows the areas on the cast, which do not reflect the original surface. Approximate position of the alveolar tip is marked by (●). Except specifically mentioned: a—ventral view; b—right side view; c—alveolar side view.

species[2] has a characterisitc long ventral furrow, clearly absent in our material.

The rostra, described in the present paper, represent the late morphotype of *P. optima*, which differs from more ancient modifications by their principal ratios (see Discussion below). In the future, this morphotype probably can be treated as a separate chronosubspecies/species; however, currently available material is insufficient for describing a new taxon.

Although many casts demonstrate traces of erosional destruction of the rostrum surface (Pl. I, Fig. 4), in no case rostra are likely to had been fragmented prior to burial. Contrary, large fragments representing alveolar area demonstrate fragile anterior part of the *rostrum cavum* as untouched (Fig. 1f; Pl. I, Fig. 9; judging from the outline, the same part of the rostrum was present in the specimen shown in Pl. I, Fig. 3). This allows us to interpret the belemnites as non-redeposited.

M a t e r i a l. 16 casts, reflecting both full rostra and fragments.

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[2] According to the recent system, should be redefined as *Holcobeloides beaumontianus* (d'Orbigny, 1842)—a species, characteristic for the middle Callovian to the lowermost Oxfordian interval.

Table 1. Dimensions and proportions of *Pachyteuthis optima* from Dolinovka

No.	R	PA	LL	DV	$ll^{0.5}$	$dv^{0.5}$	D	LL/DV	$ll^{0.5}/dv^{0.5}$	$dv^{0.5}$/DV	E, %	Figured in
01-DOL	91.9	61.5	*16.7*	16.5	14.5	15.6	16.6	*1.01*	*0.94*	0.93	*370*	Pl. I, Fig. 1
02-DOL	79.3	*49*	13.2	12.9	11.3	11.7	13.0	0.98		0.97	*376*	Pl. I, Fig. 2
03-DOL	83.5				*12.7*	*12.1*			*0.93*			Pl. I, Fig. 3
07-DOL	48.4				*14.6*	*14.6*			*1.05*			Pl. I, Fig. 7
08-DOL	39.5				*8.8*	*8.9*			*1.00*			Pl. I, Fig. 8
06-DOL	39.3	*30.2*	*7.92*	*7.58*	*7.1*	*6.9*	*7.75*	*1.04*	*1.00*	*0.91*	*390*	Pl. I, Fig. 6
05-DOL	32.4	*25.7*	*5.2*	*4.7*	*4.6*	*4.7*	*4.9*	*1.11*	*1.03*	*1.01*	*519*	Pl. I, Fig. 5

All linear dimensions are in mm, Low precision measurements and ratios based on them are shown in italics.

DISCUSSION

Age of the Studied Belemnite Complex

The nominal taxon *P. optima* has an extremely wide stratigraphic range – it spans from the upper lower Bajocian upto the lower Bathonian, and was also recorded from the lower Callovian (see Dzyuba, 2004; Dzyuba and de Lagausie, 2018; Ippolitov, 2018c). But previously it was shown that there are clear morphological trends of the principal ratios – compression (LL/DV) and tapering coefficients ($d^{0.5}$/D; $dv^{0.5}$/DV) (Ippolitov, 2018c), originally traced across the lower Bathonian of the Russian Platform (a single Sokur Quarry reference section). However, there are new, yet unpublished finds from the Bajocian/Bathonian boundary beds of the Izhma river basin (collected ~2 m below the base of sandstone band with *Arcticoceras ishmae*; see Mitta et al., 2015) which perfectly fit the same trends and which can also be considered as an independent chronosubspecies/chronospecies in the future (Fig. 2; "*P. optima* morpha A").

As it can be seen from Fig. 2, by their principal ratios Dolinovka specimens correspond to the rostra found in the upper part of the lower Bathonian sequence of the Sokur quarry (starting from the "belemnite level"), differing from the more ancient morphotypes, first of all, by less conical rostra ($dv^{0.5}$/DV = 0.89–0.94 vs 0.76–0.87 in specimens from the underlying strata). Such an interpretation is supported by the presence of a well-pronounced ventral groove in some specimens from Dolinovka: both *P. optima* morpha A from the Bajocian/Bathonian boundary strata of Izhma and *P. optima* s. str. (=morpha B) from the O. besnosovi zone of the Russian Plate demonstrate poorly defined ventral furrow. The general trend is that upwards the sequence, this ventral apical furrow becomes more and more pronounced. And considering the absence of small megateuthidids of the genus *Barskovisella* Ippolitov, 2018a, which are common in the "belemnite level" of the Sokur Quarry but disappear upwards the section, the basal greywacke sandstone in Dolinovka section should be correlated with the upper part of the Member III (*sensu* Mitta et al., 2014a) of the Sokur Quarry section. In published papers, this upper part of Member III is conventionally correlated with the upper part of the lower Bathonian Ishmae Zone of the Boreal scale (Gulyaev, 2019; Mitta et al., 2014a). However, it is not excluded that near its top Member III off the Sokur Quarry section it should be correlated with the middle Bathonian: at least all the finds of lower Bathonian ammonites derive from the lower levels, while the bivalves *Retroceramus vagt* Kosch. found here are characteristic both for the upper lower Bathonian and middle Bathonian (Nikitenko et al., 2013).

Even if we consider both the identifications of Dolinovka belemnites and previously established morphogenetic trends of *Pachyteuthis optima* as erroneous, the general appearance of the studied belemnite assemblage excludes the pre-Bathonian and, the more so, the early Bajocian (Mitta et al., 2014b) age, since:

• on the Russian Plate, cylindrotheuthidid belemnites were never recorded from the pre-Bathonian strata;

• in Dolinovka, there are no finds of Megateuthididae Sachs et Naln., which are the common elements of the lower Bajocian assemblages in the southern part of Russian platform (Lower Volga region—Ippolitov, 2018b; Donbas—Borissjak, 1908), in the upper Bajocian Garantiana Zone of Donbass (Borissjak, 1908; Nikitin, 1975) and in the lower lower Bathonian of the Volga region (Ippolitov, 2018a). Members of this family are clearly recognizable by their pronouncedly conical shape in early growth stages, while juvenile rostra from Dolinovka are always cylindrical, with a prominent ventral groove, thus being incompatible with Megateuthididae;

• in Dolinovka, there are no finds of the Tethyan family Belemnopseidae Naef. Members of this family are very common within the belemnite assemblage of the Garantiana Zone in Donbass (see Borissjak, 1908; Nikitin, 1975);

• the belemnite assemblage, known from the Bajocian/Bathonian boundary beds of the Russian platform, also has nothing to do with cylindroteuthidids from Dolinovka. This assemblage is represented by endemic forms resembling the genera *Hastites* Mayer-

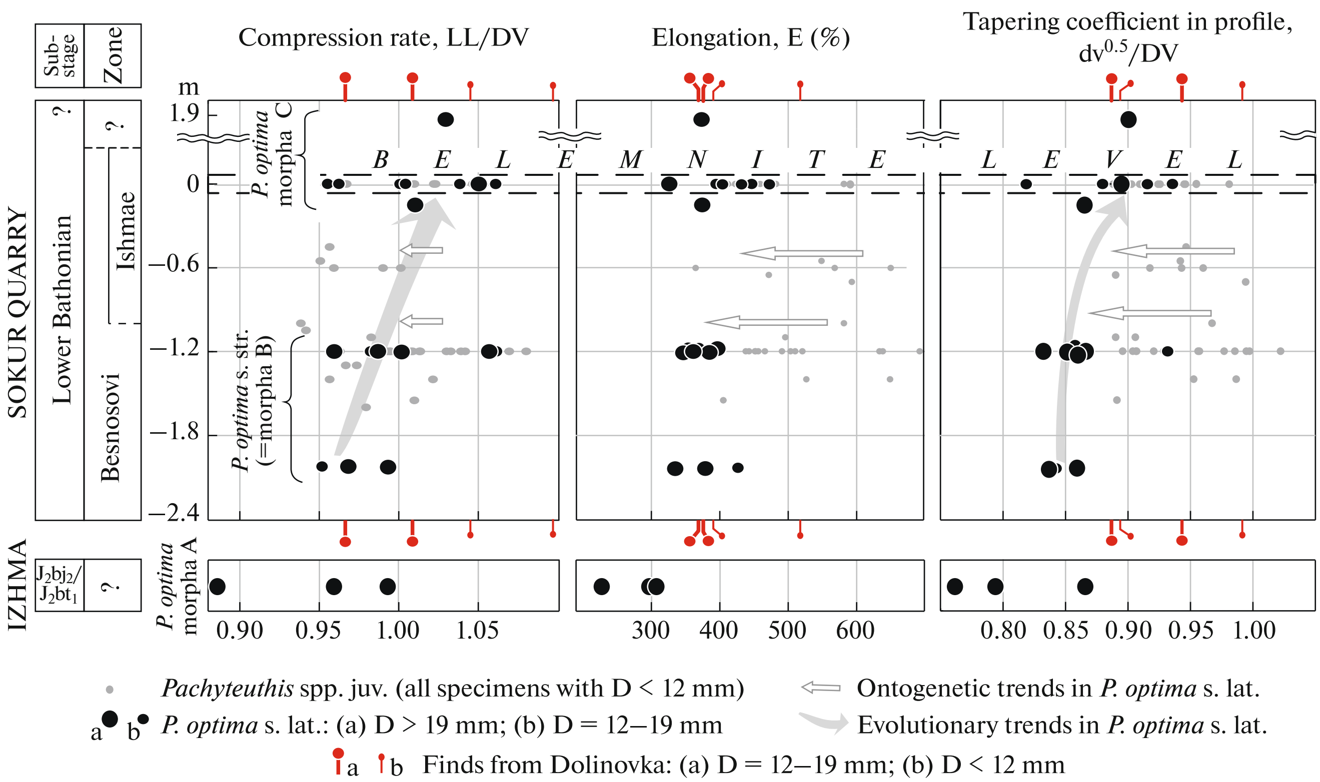

Fig. 2. Evolutionary trends of the main proportions of the rostra of the latest Bajocian?–Bathonian *Pachyteuthis optima* s. lat. (from Ippolitov, 2018c, with changes and additions) and the position of the Dolinovka specimens within the morphogenetic series.

Eymar, 1883 and *Parabrachybelus* Riegraf, 1980 (Ippolitov, 2017, 2018d); these endemics can be easily distinguished from juvenile *Pachyteuthis* by the absence of ventral groove.

On the other hand, the studied complex from Dolinovka is obviously older than the Late Bathonian: the deposits of the latter age in Central Russia contain exclusively elongated rostra belonging to the genus *Cylindroteuthis* Bayle, 1878, while *Pachyteuthis* with shorter rostra, have not yet been found (Ippolitov, 2018d).

Thus, the age of the belemnites, collected in Dolinovka from the basal Jurassic greywacke sandstone, lies within the interval of late Early Bathonian (upper part of the Ishmae Zone) – Middle Bathonian. This conclusion is consistent with the available assumptions on the distributions of belemnite genera across the middle Jurassic of the Russian Plate: monotaxonic communities consisting exclusively of *Pachyteuthis* spp., are known only from the upper lower Bathonian strata (Ippolitov, 2018).

The obtained dating of the basal sandstone as the Early or ?Middle Bathonian is incompatible with the interpretation of any strata above it as Bajocian. On the contrary, our age is consistent with the "classical" assumptions, according to which Member I of the studied section (referred in literature as the "Laishevka unit") is considered to be Bathonian (Didenko and Zorina, 2003; Zorina, 2005a, 2007a, 2007b, etc.). The pre-Callovian sequence of Tarkhanovskaya Pristan'–Dolinovka, indeed, is an important reference section of the middle Jurassic in the central part of the Russian Plate – however, not of the Bajocian age, like it was postulated (Mitta et al., 2014b), but of the Bathonian.

Is it Still Possible That the Belemnites are Bajocian?

The only theoretical "loophole" which could explain the presence of cylindroteutidids in the pre-Early Bathonian strata on the Russian Plate (and, accordingly, allow the Bajocian age of the enclosing strata), is a short-term opening of the meridional strait, connecting the Middle Russian Sea in the Volga region with the Arctic area, in the Bajocian. Cylindroteuthidids in the Arctic area are recorded since the late Early Bajocian (see Dzyuba and de Lagausie, 2018), and thus, hypothetically could penetrate to the Middle Russian sea through a meridional strait, if such opened. The existence of such a strait is reliably established at the moment only for the Early Bathonian, whereas the assumptions of its earlier opening (Dzyuba and de Lagausie, 2018; Mitta et al., 2014a) are based on the erroneous primary cephalopod identifications (see the discussion in Ippolitov, 2018c).

However, such an alternative scenario employing early penetration of cylindroteuthidids through a meridional strait during the Bajocian, looks unlikely.

First, there are no known records of Bajocian cylindroteuthidids in the Arctic Bajocian that would be

Table 2. Re-identification of ammonites previously figured from the upper part of Member II of the Tarkhanovskaya Pristan' section

No. seq.	Reference to published figure	Identification	
		Mitta and Dietl, 2012; Mitta et al., 2014b	present paper
1	Mitta and Dietl, 2012, pl. I, fig. 1a, b (=Mitta et al., 2014b, pl. I, fig. 1)	*Garantiana* sp.	*Toricellites* cf. *pauper* (Spath)
2	Mitta and Dietl, 2012, pl. I, fig. 2 (=Mitta et al., 2014b, pl. I, fig. 6)	*Garantiana* sp.	*Toricellites* sp. ind.
3	Mitta and Dietl, 2012, pl. I, fig. 3	*Garantiana* sp.	Gowericeratinae juv.
4	Mitta and Dietl, 2012, pl. I, fig. 4 (=Mitta et al., 2014b, pl. I, fig. 7)	*Orthogarantiana* cf. *baculata* (Quenstedt)	*Toricellites* sp. ind.
5	Mitta and Dietl, 2012, pl. I, fig. 5	*Garantiana* (*Pseudogarantiana*) sp.	*Toricellites* sp. ind.
6	Mitta and Dietl, 2012, pl. I, fig. 6a, b (=Mitta et al., 2014b, pl. I, fig. 11)	Stephanoceratidae gen. et sp. indet.	*Kepplerites (Kepplerites)* sp. ind.
7	Mitta et al., 2014b, pl. I, figs 2, 3	*Garantiana?* sp. juv.	Gowericeratinae juv.
8	Mitta et al., 2014b, pl. I, fig. 4	*Garantiana* sp.	?Gowericeratinae ind.
9	Mitta et al., 2014b, pl. I, fig. 5	*Garantiana?* sp.	*Kepplerites (Kepplerites)* sp. ind.
10	Mitta et al., 2014b, pl. I, fig. 8a, b	*Orthogarantiana* cf. *densicostata* (Quenstedt)	*Toricellites* sp. ind.
11	Mitta et al., 2014b, pl. I, figs 9,10	*Garantiana* (*Pseudogarantiana*) sp.	*Toricellites* sp. ind.

clearly comparable to the Dolinovka specimens by principal ratios. Nominally, *P. optima* was recorded not only from the upper Bajocian, but even from the upper Lower Bajocian (Cranocephalites gracilis Zone) at northern Siberia (Sachs and Nalnjaeva, 1975), but the material of this age has never been figured. In the recent study of the reference Bajocian sections of Northern Siberia *P. optima* was not recorded below the conventionally upper Bajocian Arctocephalites arcticus Zone (see Dzyuba and de Lagausie, 2018, as "cf."). Considering the morphology of the finds from the Bajocian/Bathonian boundary interval of the Izhma river mentioned above, and the fact that *P. optima*, as accepted in literature, covers the wide range of variability (Ippolitov, 2018c), one should expect the identity of the Bajocian finds from Siberia either to *P. optima* morpha A, or to more ancient modifications of the same lineage.

Secondly, it would be strange to see that only cylindrotheutidids had penetrated into the Central Russian Sea through a hypothetical strait, while megateuthidids of the genus *Paramegateuthis* Gustomesov, 1960, which dominated the Bajocian of Arctic, had not do so. It was previously shown (Ippolitov, 2018a) that the latter were probably more tolerant to reduced salinities, thus having a significantly greater migration potential for spreading over the epicontinental basins and for crossing the stressful environments.

Analysis of the "Garantiana-Beds" Ammonite Assemblage from the Upper Part of the pre-Callovian Sequence

Previous authors (Mitta and Dietl, 2012; Mitta et al., 2014b) figured numerous poorly preserved ammonites, deriving from the upper part of the pre-Callovian strata (Member II, Bed 4^{a-b} *sensu* Mitta et al., 2014b) and collected near the Tarkhanovskaya pristan' place. These ammonites were identified in open nomenclature as members of the Tethyan Late Bajocian subfamily Garantianinae Wetzel (Stephanoceratidae Neumayr) (numerous finds from the interval 0.9–1.5 m below the top of Member II) and "Stephanoceratidae gen. et sp. indet." (a single find 3.2 m below the top of Member II).

A closer look over the available photographs allows to re-interpret the discussed ammonites as Late Bathonian members of the low-Boreal subfamily Gowericeratinae Buckman (Kosmoceratidae Haug) (Table 2). From typical Garantianinae (see Fernandez-Lopez and Pavia, 2016; Howarth, 2017; *Treatise*..., 1957, etc.) these ammonites clearly differ by having more involute shell with narrower whorls, presence of pronounced ventral flattening instead of relatively narrow ventral furrow, higher position of rib branching point and significantly less pronounced distal extension of microconch lappets. The best preserved microconch (Mitta and Dietl, 2012, pl. I, Fig. 1a,b; Mitta et al., 2014b, pl. I, Fig. 1) is almost indistinguishable from *Toricellites pauper* (Spath) previously described from the Late Bathonian Calyx Zone in Eastern Greenland (Spath, 1932, p. 96, pl. XXIV, Fig. 3; Callomon, 1993, p. 94) and from the Late Bathonian Infimum Zone in the Volga region (Gulyaev and Kiselev, 1999, p. 283, 285, pl, II, Figs. 3–5; and others). Similar forms were also figured from the upper Bathonian of the Alatyr' river basin in Central Russia (Mitta, 2008, pl. II, Fig. 2) and from the Bathonian/Callovian boundary strata of Spitsbergen (Kopik and Wierzbowski, 1988, pl. 22, Fig. 3–7). Judging from the dominance of cosmoceratids, the interval with ammonites in the upper part of the pre-Callovian sequence of the Tarkhanovskaya pristan'–Dolinovka

Table 3. Correlation of lithostratigraphic units previously described for the Tarkhanovskaya pristan'–Dolinovka composite section (Mitta et al., 2014b) with those in the Reference Borehole-1 (Zorina, 2007a) and their ages accepted in the present paper

Member no. (thickness, m)		Age			Index fossils, after Zorina (2007a) and present paper
reference Borehole 1 (Zorina, 2005b, 2007a)	Tarkhanovskaya pristan'–Dolinovka (Mitta et al., 2014b)	Zorina, 2007a	Mitta et al., 2014b	accepted in the present paper	
1 (7.6)	I (up to 6.5)	J_2bt	? J_2bj_1	$\mathbf{J_2bt_{1/2}}$	*Pachyteuthis optima* (in the lower part)
2 (12.4)	II (9-14)	J_2bt	J_2bj_2	$\mathbf{J_2bt_{2\text{-}3}}$	Palynofossils; in the upper part – rare Late Bathonian ammonites *Toricellites* cf. *pauper*, *T.* sp. ind., *Kepplerites (K.)* sp. indet., Gowericeratinae juv. and foraminifera indicative of the same age—*Ammodiscus colchicus* Thod., *Glomospirella tsessiensis* Thod.*
3 (7.4)	III (up to 4)	J_2cl_1	? J_2bt	$\mathbf{J_2bt_3/cl_1}$	No finds
4** (30)	–**	J_2cl_1		$\mathbf{J_2cl_1}$	In the middle part—ammonites from the lower part of lower Callovian (*Paracadoceras* ex gr. *elatmae*); in the topmost part—ammonites from the middle-upper parts of the lower Callovian (*Pseudocadoceras* sp. juv., *Toricellites approximatus* Buckman).
5	IV	J_2cl_2	J_2cl_3	$\mathbf{J_2cl_3}$	See Mitta et al. (2014b)

* Foraminifers are found in the Borehole 3, correlated with the Reference Borehole 1 (Zorina, 2007a). ** In the Tarkhanovskaya pristan'–Dolinovka sections analogues of Member 4 of the Reference Borehole are eroded away, and characteristic fossils are redeposited into the base of Member IV.

section should be correlated to the lower part of the Late Bathonian Infimum Zone (see Gulyaev, 2001).

Late Bathonian time was marked by an extensive boreal transgression in the Northern Hemisphere. The marine deposits of the Barnstoni and Infimum Zones, containing boreal ammonites, are widely spread in Central Russia (Gulyaev, 2015, etc.), and thus their presence in the Tarkhanovskaya pristan'–Dolinovka section is not surprising.

Stratigraphic Interpretation of the Middle Jurassic Succession at the Southwest of Tatarstan

During the last 15 years, important data on well logs drilled in south-western part of Tatarstan have been published. They enable us to directly correlate the Jurassic lithostratigraphic units (Members) established for the Tarkhanovskaya pristan'–Dolinovka section by Mitta et al. (2014b) with those in the Reference Borehole-1, located 90 km westwards, near the village Tatarskyie Shatrashany (Zorina, 2005b, 2007a) (Table 3). Comparison of both sequences allows to check our new assumptions about the age of Members established in the Tarkhanovskaya pristan'–Dolinovka section, and also, to clarify the age of some levels by extrapolating the position of index fossils from the Reference Borehole 1.

Members 1 and 2 of the Reference Borehole 1 and members I and II of the composite sequence Tarkhanovskaya pristan'–Dolinovka are almost identical in their lithological characteristics and thickness. Their direct correlation is evident.

Despite there are no microfossils found in Members 1 and 2 of the Reference Borehole 1 itself (Zorina and Startseva, 2010), there are such records from the Borehole 3, located 30 km eastwards and showing the same sequence. Near the top of Member 2, i.e. at about the same level where V.V. Mitta collected his "Late Bajocian" ammonites, G.N. Startseva established the Late Bathonian age based on two foraminifera species—*Ammodiscus colchicus* Thod. and *Glomospirella tsessiensis* Thod. (in: Zorina, 2007a, 2012). Notably, these species were previously identified by the same specialist from the territories of Mordovia and Saratov region, where they are characteristic for the interval "*between the marine formations of the lower Callovian and the middle Bathonian deposits with* Ammodiscus baticus *Dain.*" Startseva in: Zorina, 2012, p. 77. In other words, they are met in the Bathonian–Callovian boundary interval according to recent state of regional stratigraphic knowledge (*Unifitsirovannaya*..., 2012). Contrary, the indication by E.V. Milanovsky (1940; see also Blom et al., 1967, Fig. 74), who reported the presence of a typical Middle–Late Callovian belemnite "*Belemnites beaumonti* d'Orb." [=*Holcobeloides beaumontianus* (d'Orbigny, 1842)] in the Member II near Dolinovka, is probably erroneous. It is highly likely that his rostra were collected loose, deriving from a higher level of the succession – Member IV of Late Callovian age, in which this species is common and seemingly, the only one present (Mitta et al., 2014b).

Member III of the Tarkhanovskaya Pristan' section – Dolinovka section is identical in lithology to the Member 3 of the Reference Borehole 1. So far this unit has not been characterized by fossils that would provide understanding of its age neither in well, nor in exposures, although marine macrofossils were mentioned from it (Pavlov, 1883). V.V. Mitta et al. (2014b) conventionally assigned this Member to "?Bathonian", probably bearing in mind not only its position just above the "Upper Bajocian" strata, but also its lithological similarity to the sediments of the Kamennyi Ovrag Formation—a non-marine middle Bathonian unit, widely extending across the Volga region. The upper part of Member III is transgressively eroded in the Tarkhanovskaya Pristan'–Dolinovka section by the base of the upper Callovian, so that the thickness of Member III varies between 0 and 4 m (Mitta et al., 2014b) against 10 m in the Reference Borehole 1.

Member 4 of the Reference Borehole 1 is characterized by the lower Callovian ammonites: *Paracadoceras* ex gr. *elatmae* (in the middle part), *Pseudocadoceras* sp. juv. and *Toricellites approximatus* (in the upper part). In the Tarkhanovskaya pristan'–Dolinovka sections deposits of this age are absent. But the base of upper Callovian Member IV contains numerous redeposited Early Callovian fossils—and among all, ammonites of the same age as the upper part of Member 4 in the borehole (compare lists of fossils in Zorina, 2007a, p. 271 and Mitta et al., 2014b, p. 34).

Judging from its presumed (Mitta et al., 2014b) geological position (just above the upper Bathonian Infimum Zone, but below the finds of Early Callovian ammonite *Paracadoceras* ex. gr. *elatmae* in Reference Borehole 1), the age of sandy Member III should, therefore, be assigned as belonging to the Bathonian/Callovian boundary interval. It marks the regressive impulse (Zorina, 2005a, 2005b, 2014, Zorina and Startseva, 2010), the geographic and stratigraphic extent of which is yet to be fully assessed in the future.

CONCLUSIONS

(1) The age of the basal greywacke sandstone of the Middle Jurassic sequence in the Tarkhanovskaya pristan'–Dolinovka section, obtained from the examination of belemnites, is the second half of the Early Bathonian, or, less likely, Middle Bathonian.

(2) The fossil assemblage, collected ~20 m higher in the succession by V.V. Mitta and his co-authors (Mitta and Dietl, 2012; Mitta et al., 2014b), was erroneously dated by the Late Bajocian. This complex should be re-dated by the Late Bathonian, apparently, the lower part of the boreal Infimum Zone, as was previously supposed by D.B. Gulyaev (2013). Such a dating is fully consistent with the previously obtained palynological and microfaunistic data (Didenko and Zorina, 2003; Zorina, 2005a, 2005b, 2007a).

(3) At the moment, there is no reliable evidence for the presence of marine sediments of the Late Bathonian Garantiana Chronozone in the Middle Volga region. The marine transgression, apparently, comes into this part of the platform later, reaching the latitude of Saratov during the Michalskii phase of the terminal Bajocian, and the territory of Tatarstan, located ~500 km northwards—only in the late Early or (?) early Middle Bathonian.

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