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Craspeditidae (Ammonoidea) of the Russian Platform at the Jurassic–Cretaceous Boundary. II. Genus *Hectoroceras* Spath

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Abstract—The short geochronological span and wide geographic distribution of the genus *Hectoroceras* in the Boreal Paleogeographic Superrealm make it exceptionally important for correlation of the Volgian–Ryazanian boundary beds. The Ogarkovo Section on the Unzha River (Kostroma Region), which is essential for this correlation, is described. The revised genus *Hectoroceras* includes the type species *H. kochi* Spath, *H. larwoodi* Casey, *H. tolijense* (Nikitin), and its microconch *H. pseudokochi* (Mesezhnikov), the latter two previously assigned to the genus *Shulginites* Casey, 1973 which is here considered as a junior subjective synonym of *Hectoroceras*. The FAD of *Hectoroceras kochi* is an interregional marker for Panboreal correlation, and the coincidence of this event with the invasion of ammonites of Tethyan origin into the Central Russian ecotone improves the prospects for a Boreal – Tethyan correlation of the Jurassic–Cretaceous boundary interval.

Keywords: ammonites, Craspeditidae, *Hectoroceras*, Volgian Stage, Berriasian Stage, Russian platform
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INTRODUCTION

The genus *Hectoroceras* (family Craspeditidae) was established by Spath (1947) based on material from East Greenland, from where other images of its type species *H. kochi* Spath were later published by Surlyk et al. (1973). In the second half of the 20th century, it was shown that *Hectoroceras* had a wide distribution in Boreal regions—central Siberia (Shulgina, 1972b; Klimova, 1972), eastern England (Casey, 1973), Central Russia (Casey et al., 1977; Mesezhnikov et al., 1979, 1983), western Siberia (Mesezhnikov et al., 1983; Braduchan et al., 1986). Taking into account the geographical range of the genus and the restriction of its few species to a narrow stratigraphic interval at the top of the Volgian–basal part of the Ryazanian, *Hectoroceras* is an exceptionally important taxon for Panboreal Jurassic–Cretaceous correlations.

In recent decades, new data were obtained on representatives of *Hectoroceras* (Mitta, 2005, 2007, 2015; Mitta and Sha, 2011), occurring in the Russian Platform at the top of the terminal Volgian *Craspedites nodiger* Zone on the Russian Platform and the basal Ryazanian *Riasanites rjasanensis* Zone. Note that this range coincides with the stratigraphic range in central Russia and the Subpolar Urals of the genus *Praesurites* Mesezhnikov and Alekseev, which I discussed previously (Mitta, 2019). In addition, new data on *Hectoroceras* were published based on material from Siberia (Igolnikov, 2008, 2009, 2015). Below, the entire material on this genus from the Russian Platform and adjacent regions that has recently become available, is analyzed.

MATERIAL

New findings of ammonites of the genus *Hectoroceras* mainly come from two regions, which are the quarries of the Lopatinsky Mine (Voskresensk District of Moscow Region) and riverbank outcrops in the lower reaches of the Unzha River between the villages of Ogarkovo and Efimovo (Makariev District of the Kostroma Region) (Fig. 1a). Thus, ammonites discussed below come from the same sections and the same stratigraphic interval as previously described representatives of *Praesurites*. All the collections were assembled in the recent decades with assistance of A.V. Stupachenko mainly during joint field work; in preparation of this work I used some specimens from his private collection (marked "AS" in figure captions), and also from P.A. Gerasimov's collection housed in the Borissiak Paleontological Institute (PIN). All other specimens used for this paper are from V.V. Mitta's collection housed in the Borissiak Paleontological Institute (PIN, coll. no. 3990).

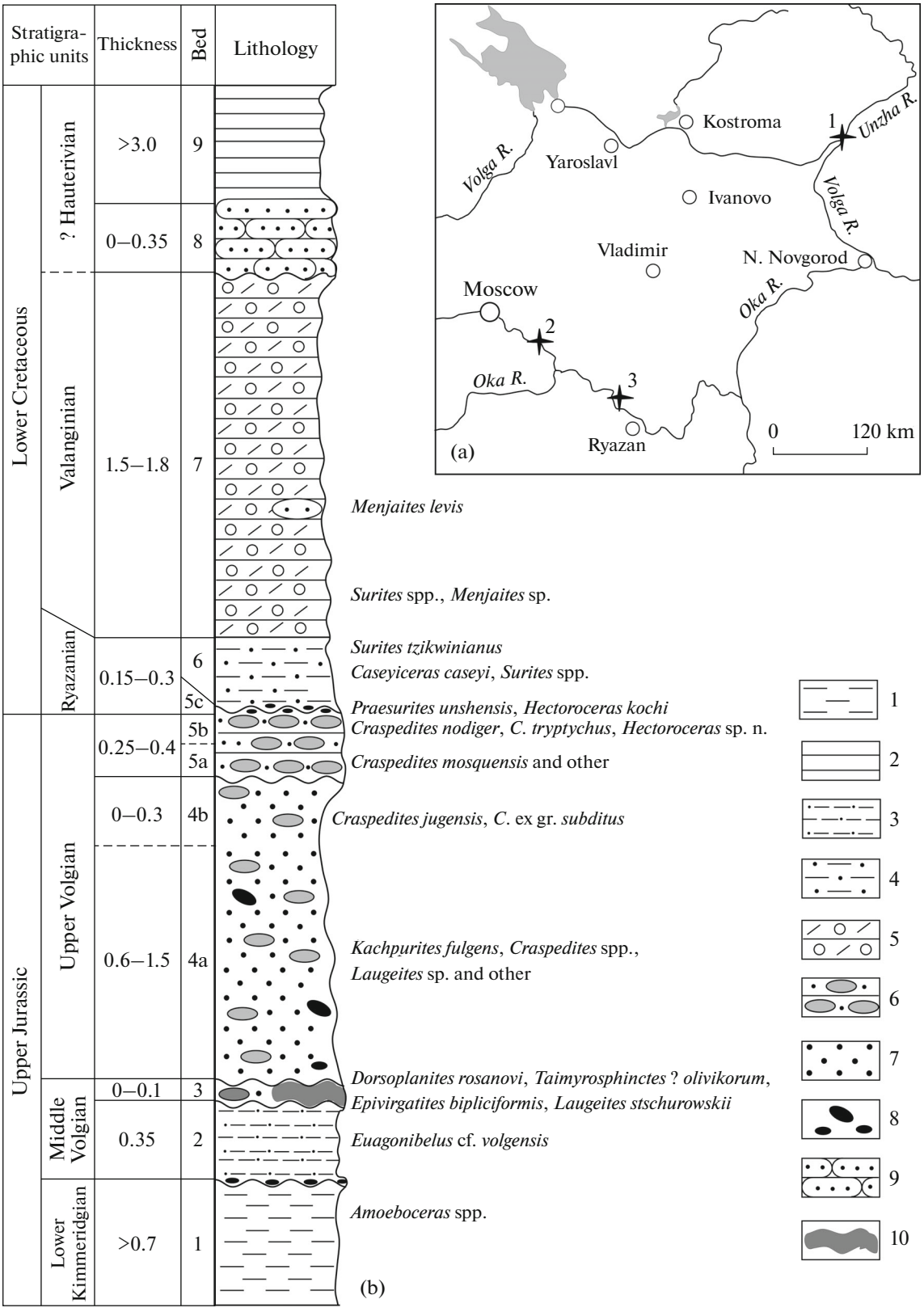


Fig. 1. Ammonite localities with *Hectoroceras* and *Praesurites* (a): (1) Ogarkovo on the Unzha River, Kostroma Region; (2) Lopatinsky Mine, Moscow Region; (3) Kuzminskoe and Kostino on the Oka River, Ryazan Region; (b) section of the Jurassic–Cretaceous in outcrops between the villages of Ogarkovo and Efimovo on the Unzha River. Explanations: (1) calcareous clay, (2) thin-bedded clay, (3) arenaceous clay, (4) argillaceous clay, (5) oolitic sandstone, (6) glauconite-phosphoritic sandstone, (7) glauconitic sand, (8) phosphoritic nodules, (9) gray sandstones, (10) phosphoritic sandstone.

SECTION DESCRIPTION

I have previously described the Jurassic–Cretaceous interval of the Lopatinsky Mine (Mitta, 2005, 2007, 2017). At the same time the modern description of the Jurassic–Cretaceous section in the lower reaches of the Unzha River have previously been published only in conference proceedings (Mitta, 2015) and a shortened description was published by Mitta (2017). Considering its importance to the topic of this paper, its complete updated description is given below.

Nikitin (1885) was the first to describe the Jurassic–Cretaceous deposits in the lower reaches of the Unzha River in the Kostroma Region. Later, these outcrops were visited by many recognized geologists and paleontologists, including A.P. Pavlov, N.A. Bogoslovsky, A.P. Ivanov, A.M. Girmounsky, M.I. Sokolov, P.A. Gerasimov, and others. The importance of these sections is emphasized by the many new species first described from these sections: the ammonites *Olcostephanus tryptychus* Nikitin, *O. unshensis* Nikitin, *Polyptychites craspeditoides* Girmounsky, *Praesurites nikitini* Gerasimov and Mitta, *Praetollia olivikorum* Mitta, the bivalves *Aucella unshensis* Pavlow, *Pseudomonotis subtilis* Gerasimov, the echinoderms *Rhabdocidaris lahuseni* Gerasimov. The biostratigraphic significance of the Mesozoic sections of the lower reaches of the Unzha River is explained by their greatest completeness in the northern margin of the Moscow Syncline. I have systematically studied these outcrops during the last two decades; the ammonite collection amassed from the Volgian and Ryazanian stages in these outcrops comprises over 2000 specimens.

The Upper Jurassic–Lower Cretaceous deposits, often concealed by landslides, crop out on the right bank of the Unzha River (Makariev District of the Kostroma Region) between the villages of Efimovo and Ogarkovo over a stretch of 1 km. The following beds crop out above the waterline from bottom to top (Fig. 1b):

1. [J_3km_1] Clay dark gray, dense, calcareous, with small-sized shell debris, remains of bivalves and gastropods and crushed imprints of *Amoeboceras* spp. Measured thickness 0.7 m.

2. [J_3v_2–vrg] Clay black, arenaceous, at the base a thin bed (0.05 m) of black phosphorite pebbles with a shiny surface; there are also fragments of rostra of *Eulagonibelus volgensis* (d'Orbigny). Thickness 0.35 m.

No ammonites are found; the assignment of this bed to the *Virgatites virgatus* Zone is based on occurrences of a characteristic belemnite species.

3. [J_3v_2–nk] Sandstone greenish-dark-gray and black glauconite-phosphorite hard, platy, laterally becoming interrupted phosphorite nodules and wedging out. Ammonites are represented by phosphorite and less commonly calcite molds: *Epivirgatites biplicitiformis* (Nikitin), *Taimyrosphinctes ? olivikorum* (Mitta) (pl. 8, fig. 5), *Laugeites stschurowskii* (Nikitin) (pl. 8, fig. 6), *Dorsoplanites rosanovi* Gerasimov. Thickness 0.0–0.15 m.

Some ammonites from this bed were for a long time recorded as found in a "phosphorite slab at the top of the Volgian Stage," here Bed 5 (Nikitin, 1885; Sokolov, 1929; Mitta, 2004), which was the basis for their assignment to the genera *Chetaites* and *Praetollia* (Mitta, 2004, 2005; Kiselev et al., 2018). Mistakes in ammonite identification and dating of the host bed were caused by the similarity of rocks and presence of landslides and taluses, largely obscuring Bed 3. Results of field work during the last decade have allowed the recognition in this bed, for the first time in Kostroma Zavolzhye (Trans-Volga area), of an ammonite association characteristic of the *Epivirgatites nikitini* Zone (Mitta, 2015). Accordingly, specimens collected by Nikitin (Nikitin, 1884a (pl. 4, fig. 17), 1884b, 1885,; here Fig. 2) (=*Laugeites* aff. *stschurowskii* (Nikitin)) and Sokolov (Mitta, 2005, pl. 1, fig. 2 (=*Laugeites* sp.)] do not belong to *Chetaites*. New findings of *Laugeites* in situ (pl. 8, fig. 6) fully support that. The ammonites described as *Praetollia olivikorum* (Mitta, 2014) more likely belong to the genus *Taimyrosphinctes* (Rogov et al., 2015). We have also found new specimens of this species (pl. 8,

Explanation of Plate 8

All: Kostroma Region, Makaryev District, right bank of the Unzha River between the villages of Ogarkovo and Efimovo; collected by V.V. Mitta and A.V. Stupachenko, 1998–2015.

Figs. 1, 2. *Kachpurites fulgens* (Trautschold): (1) specimen PIN, no. 3990/467, lateral view, upper part of Bed 4a; *Fulgens* Zone of the Volgian Stage; (2) specimen PIN, no. 3990/466, lateral view, lower third of Bed 4a.

Fig. 3. *Garniericeras catenulatum* (Fischer), specimen PIN, no. 3990/440: (3a) lateral view, (3b) ventral view; Bed 4b, *Subditus* Zone, Volgian Stage.

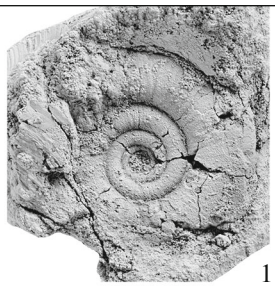
Fig. 4. *Craspedites mosquensis* (Gerasimov), specimen PIN, no. 3990/465: (4a) lateral view, (4b) the same with a partly separated body chamber; Bed 5a, *Mosquensis* Subzone, *Nodiger* Zone of the Volgian Stage.

Fig. 5. *Taimyrosphinctes? olivikorum* (Mitta), phragmocone, specimen PIN, no. 3990/462: (5a) lateral view, (5b) apertural view; Bed 3, *Nikitini* Zone, Volgian Stage.

Fig. 6. *Laugeites stschurowskii* (Nikitin), phragmocone, specimen PIN, no. 3990/463: (6a) lateral view, (6b) apertural view; Bed 3, *Nikitini* Zone, Volgian Stage.

Scale bar 10 mm.

Plate 8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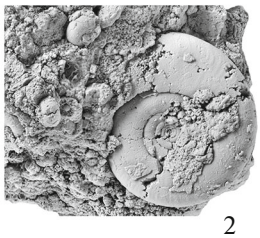
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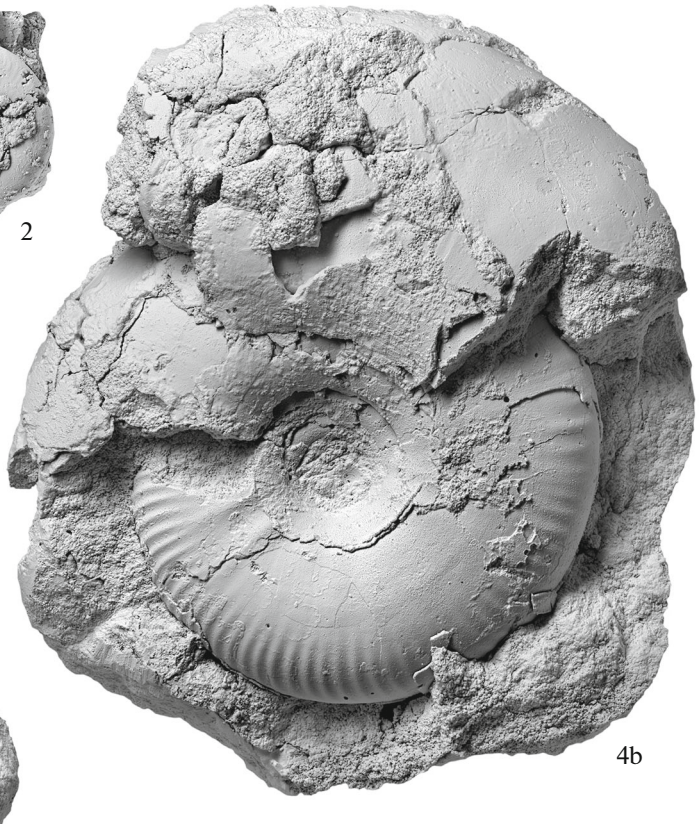

4b


3b


3a


5a


5b


4a


6a


6b

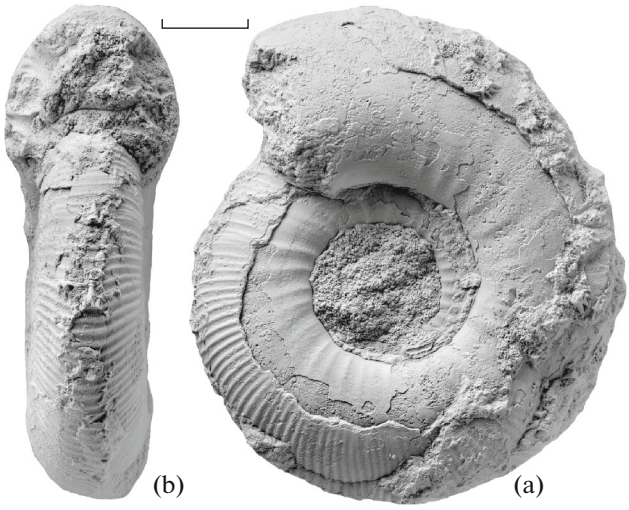


Fig. 2. *Laugeites* aff. *stschurowskii* (Nikitin), phragmocone, specimen GM no. 128/50; Nikitin, 1884 (Nikitin, 1884, pl. 4, fig. 17]: (a) lateral view, (b) apertural view; Kostroma Region, Makaryev District, right bank of the Unzha River between the villages of Kozlovo and Korshunskoe [=Sokornovo]. The photograph is published for the first time; scale bar 10 mm.

fig. 5), but new material is needed for a positive conclusion.

4. [J_3v_3–fg/sb] Sand greenish-dark-gray to black, glauconite, with scattered nodules of phosphatized sandstone (from loosely cemented to very hard), sometimes with abundant rostra of *Liobelis russiensis* (d'Orbigny), and bivalve shells of mainly *Buchia* spp. and *Camptonectes* sp., less commonly with remains of ammonites. Based on ammonites, the bed is readily subdivided into two unequal parts. In the larger lower part (4a, *Kachpurites fulgens* Zone), 0.6–1.5 m thick, with phosphatized shells of *Kachpurites fulgens* (Trautschold) (pl. 8, figs. 1, 2), *Craspedites* spp., *Laugeites* sp., usually fragile, disintegrating when taken out of the rock. The pebbles also contain fragments of redeposited *Laugeites* sp., *Dorsoplanites* cf. *rosanovi* (Gerasimov), *Epivirgatites* cf. *bipliciformis* (Nikitin), *Lomonossovella* sp., in the harder, phosphoritic rock. The upper, often wedging part (4b, *Craspedites subditus* Zone) up to 0.3 m thick, contains phosphatized shells of *Craspedites okensis crassus* Prigorovsky, *C. jugensis* (Prigorovsky), *C.* aff. *subditoides* (Nikitin), *Garniericeras catenulatum* (Fischer) (pl. 8, fig. 3; pl. 9, fig. 5); in the pebbles—*Kachpurites fulgens* (Trautschold).

The presence of the *Kachpurites fulgens* Zone in this section and in Kostroma Zavolzhye in general was established for the first time by Mitta (2015).

5. [J_3v_3–nd/K_1rz–rjs] Sandstone, mottled, yellowish-reddish, gray-brown glauconite-phosphorite, platy, irregularly cemented, basally and laterally becoming glauconitic, argillaceous sand with phosphorite nodules. The lower part (5a, *Craspedites mosquensis* Subzone) contained mostly *Craspedites mosquensis* Gerasimov (pl. 8, fig. 4), *Garniericeras catenulatum* (Fischer) (pl. 9, fig. 4), *G. subclypeiforme* (Milaschewitch) (pl. 9, fig. 6). The upper part (5b, *Craspedites nodiger* Subzone) is characterized by numerous *Craspedites nodiger* (Eichwald) (pl. 9, fig. 8), *C. parakaschpuricus* Gerasimov, *C. okensis* (d'Orbigny), and *Garniericeras subclypeiforme* (Milaschewitch). The interval of 0.1 m contains scarce *Praesurites tryptychus* (Nikitin), and *Hectoroceras* sp. nov. (Fig. 3). The ammonites are represented by phosphatized shells retaining their nacreous layer, with phragmocones frequently replaced by calcite. The unevenly eroded surface of the bed (5c) contains eroded phosphorite molds of *Praesurites unshensis* (Nikitin), less commonly *Hectoroceras kochi* Spath (pl. 9, figs. 2, 3). Thickness 0.25–0.4 m.

The data on the distribution of ammonites in Bed 5 are extremely important for biostratigraphy. The Ogarkovo Section on the Unzha River is the only currently known section, where the *Craspedites nodiger* Zone contains, along with *Garniericeras subclypeiforme*, its ancestral species, *G. catenulatum* (it was previously considered that the latter species became extinct in the *Subditus* Phase). In the same section, the top of the terminal Volgian Zone, contains the species *Praesurites tryptychus,* from which originated a diverse Ryazanian and Valanginian craspeditids evolved; the zone also contains the first representatives of *Hectoroceras*. Finally,

Explanation of Plate 9

Figs. 1–3, 7. *Hectoroceras kochi* Spath: (1) phragmocone, unnumbered, collection of A.V. Stupachenko, lateral view; Lopatinsky Mine, quarry no. 12-2; base of the *Rjasanensis* Zone, Ryazanian Stage; (2) phragmocone, specimen PIN, no. 3990/444, lateral view; (3) phragmocone, specimen PIN, no. 3990/313: (3a) lateral view, (3b) apertural view; (7) phragmocone, specimen PIN, no. 681 (P.A. Gerasimov's collection): (7a) lateral view, (7b) opposite lateral view; Ogarkovo on the Unzha River; (2, 3) top of Bed 5b, condensation horizon of the *Rjasanensis* Zone; (7) from pebbles of Bed 6, *Tzikwinianus* Zone, Ryazanian Stage.

Figs. 4, 5. *Garniericeras catenulatum* (Fischer): (4) specimen PIN, no. 3990/442, lateral view; Bed (5a) *Mosquensis* Subzone, *Nodiger* Zone, Volgian Stage; (5) specimen PIN, no. 3990/441: (5a) lateral view, (5b) apertural view; the same, Bed 4b, *Subditus* Zone, Volgian Stage.

Fig. 6. *G. subclypeiforme* (Milaschewitch), specimen PIN, no. 3990/438: (6a) lateral view, (6b) ventral view; the same locality, Bed 5a, *Mosquensis* Subzone, *Nodiger* Zone, Volgian Stage.

Fig. 8. *Craspedites nodiger* (Eichwald), specimen PIN, no. 3990/464: (8a) lateral view, (8b) apertural view; the same locality, Bed 5b*, Nodiger* Subzone, *Nodiger* Zone, Volgian Stage.

(1–6, 8) collected by V.V. Mitta and A.V. Stupachenko, 1998–2015, (7) collected by P.A. Gerasimov, 1948. Scale bar 10 mm.

Plate 9

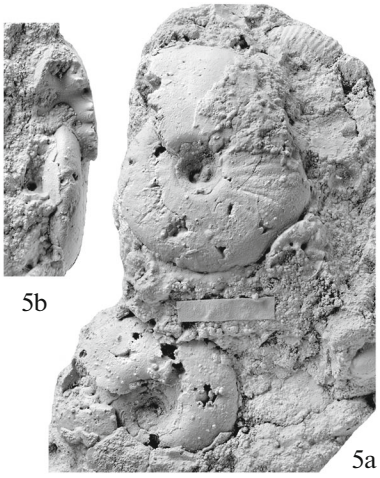

1

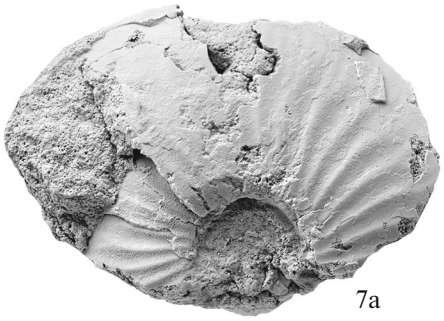

4


6b


6a


2


5b 5a


7a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3b


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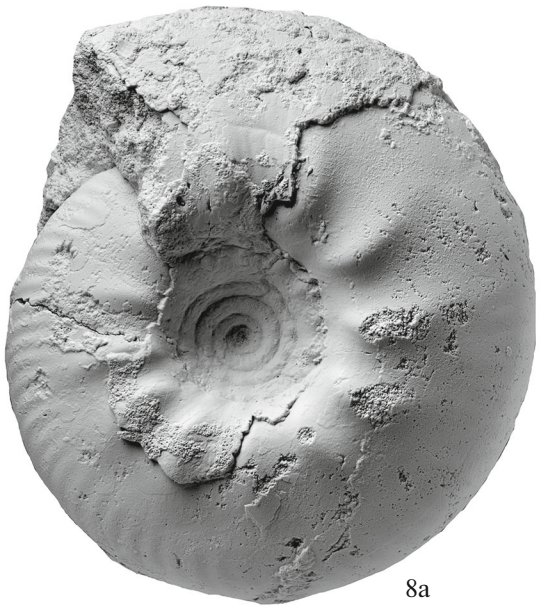
8b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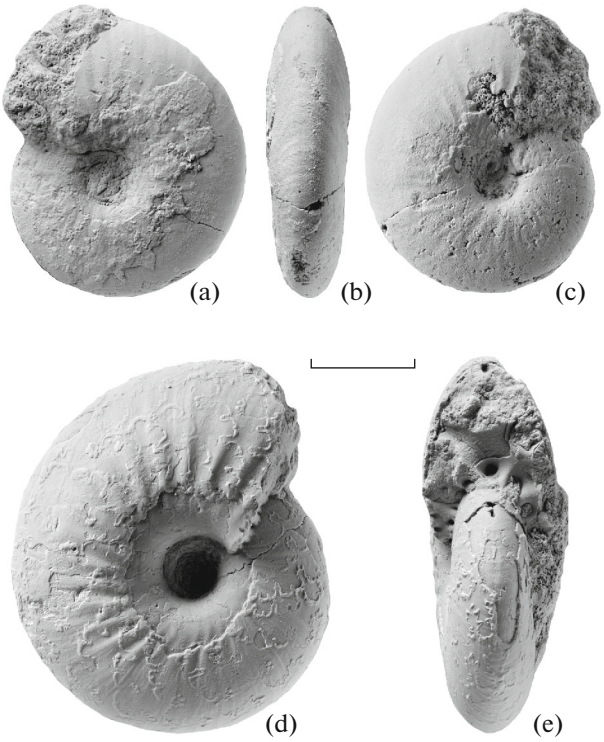

Fig. 3. *Hectoroceras* sp. nov.: (a–c) phragmocone, specimen PIN, no. 3990/410 (a, c) lateral view, (b) ventral view); (d, e) phragmocone, A.V. Stupachenko's collection (d) lateral view, (e) ventral view; Kostroma Region, Makaryev District, right bank of the Unzha River between the villages of Ogarkovo and Efimovo; upper part of Bed 5b, *Nodiger* Subzone of the *Nodiger* Zone of the Volgian Stage, 0.07–0.1 m below the top. Scale bar 10 mm.

the condensation horizon (*Riasanites rjasanensis* Zone of the Ryazanian Stage) at the top of Bed 5 yielded *Hectoroceras kochi* and *Praesurites unshensis*.

Downstream, Beds 1–4 are gradually covered by water, whereas Bed 5 is observed along the Unzha riverbank and in the downstream vicinity of the village of Ogarkovo.

6. [K_1rs–tzk] Clay bluish-gray and brown, dense, arenaceous, laterally becoming argillaceous sand and loosely cemented sandstone. The bed contains clayey molds of *Caseyiceras caseyi* Sasonova, *Surites* spp., including *S. tzikwinianus* (Bogoslowsky), and the pebbles contained phosphorite molds of *Praesurites unshensis* (Nikitin). Thickness 0.15–0.3 m.

A redeposited occurrence of *Hectoroceras kochi* Spath (pl. 9, fig. 7) also comes from this interval judging from the label and the section description (Gerasimov, 1969, p. 21). Bed 6 represents the *Surites tzikwinianus* Zone of the Ryazanian Horizon; the presence of redeposited *Praesurites* and *Hectoroceras* support the former presence of the *Riasanites rjasanensis* Zone, whereas younger deposits of the *Surites spasskensis* are entirely eroded.

7. [K_1vln–und] Sand reddish-yellowish-brown argillaceous, oolitic, in places and beds cemented by loose sandstones becoming arenaceous clay. The rock contains nodules of gray, very hard sandstone. Ammonite: *Surites simplex* (Bogoslowsky), *Menjaites levis* Sasonova, and others. Thickness 1.5–1.8 m.

The above species are characteristic of the Lower Valanginian *Delphinites undulatoplicatilis* Zone.

8. [K_1h?] Sandstone is gray, indistinctly thin-bedded. Thickness 0.0–0.35 m.

9. [K_1h?] Clay gray and dark gray, thin-bedded "scaly," micaceous. The thickness visible under the quaternary rocks and soil is at least 3.0 m.

DISCUSSION

Ammonites are rarely found in the lower part of the Ryazanian Stage of the Russian Platform, and well-preserved ammonites are even less common. Nevertheless for the entire time of the field work, several hundred specimens have been collected from the Ryazanian in this region.

In the Moscow Region, in the quarries of the Lopatinsky and Egorievsky mines, representatives of *Hectoroceras* have been found in a bed of grayish-yellow and brown phosphatized, argillaceous sandstone, with a maximum thickness up to 0.6 m, and immediately below, in a thin (~5 cm) beds of black phosphatized sandstone.

The upper member of sandstone also containing *Riasanites swistowianus* (Nikitin), *R. rjasanensis* (Nikitin) morph α, *Subalpinites* spp., *Malbosiceras* spp., *Mazenoticeras* spp., *Riasanella* spp., *Craspedites ultimus* Mitta and Sha, *Praesurites unshensis* (Nikitin), *Pseudocraspedites bogomolovi* Mitta, belongs to the *Rjasanensis* Zone. Shells of *Hectoroceras*, found in this interval, are characterized by a moderately narrow umbilicus (Figs. 4a, 4b). These ammonites were previously identified as *Hectoroceras* cf. *kochi* (Mitta, 2005, pl. 1, fig. 3; 2007, p. 87, pl. 1, fig. 10) and *Hectoroceras* sp. nov. (Mitta and Bogomolov, 2010, p. 140, text-fig. 2; Mitta and Sha, 2011, p. 31, pl. 4, fig. 2).

The lower sandstone bed in Quarry no. 12-2 contains shells of *Hectoroceras*, with more strongly involute, compressed whorls and a narrow umbilicus (Figs. 4c, 4d; pl. 9, fig. 1). These ammonites were previously identified as *Hectoroceras kochi* (Mitta, 2007, p. 85, pl. 1, figs. 6–8; Mitta and Bogomolov, 2010, p. 140, text-fig. 1; Mitta and Sha, 2011, p. 31, pl. 4, fig. 1). Alongside was only *Praesurites* sp. juv. and *Craspedites* sp. juv.; for some time I assigned the sandstone bed to an "unnamed zone" (Mitta, 2007), and later to the *Kochi* Zone (Mitta and Sha, 2011; Mitta, 2017) recognized in the Greenland, Siberian, and English scales.

It has been suggested that the above differences of whorl thickness and umbilicus width could indicate that they belong to microconchs and macroconchs of

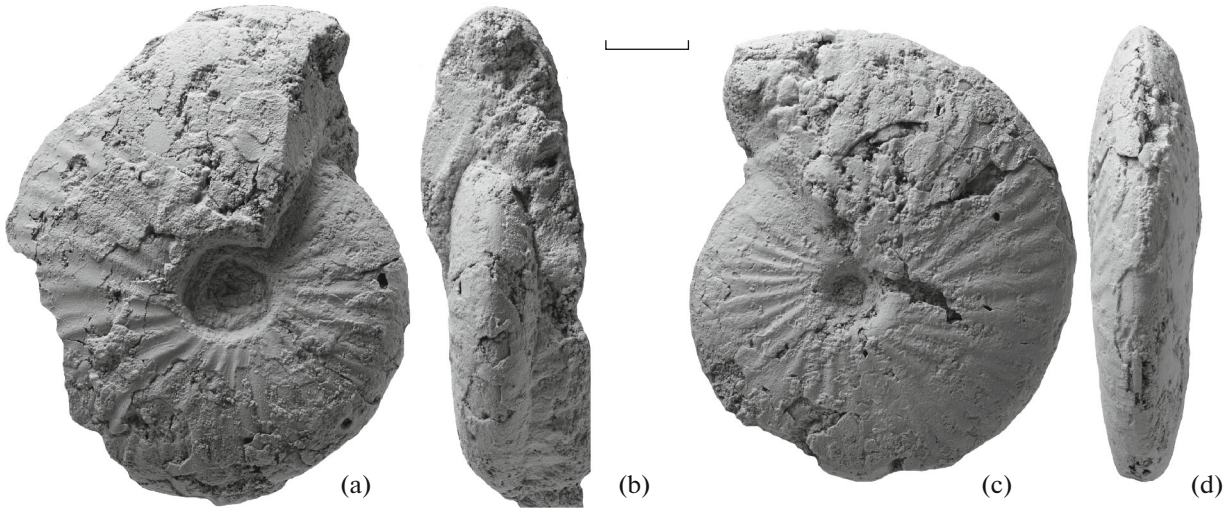

Fig. 4. *Hectoroceras kochi* Spath: (a, b) phragmocone of a microconch, specimen PIN, no. 3990/460 (a) lateral view, (b) apertural view; Moscow Region, Voskresensk District, quarry no. 12-2 of the Lopatinsky Mine; yellowish-brown sandstone of the *Rjasanensis* Zone of the Ryazanian Stage; (c, d) phragmocone of a macroconch, specimen PIN, no. 3990/251 (c) lateral view, (d) ventral view); the same locality, bed of black sandstone at the base of the *Rjasanensis* Zone; coll. by V.V. Mitta and A.V. Stupachenko. Scale bar 10 mm.

the same species, or to two different species (Mitta and Bogomolov, 2008; Mitta and Sha, 2011). The re-examination of the entire material from the bed of black sandstone including imprints and fragments showed that this level also contains shells of *Hectoroceras* with a wider umbilicus. Considering that these widely umbilicate shells possess more prominent ribs, which is characteristic of microconchs of craspeditids, I am inclined to support the former view that the more evolute shells belong to microconchs, and involute shells belong to young macroconchs of the same species, *Hectoroceras kochi* Spath. All our findings are represented by phragmocones. This question can only be positively resolved using material with preserved body chambers.

The description of the Ogarkovo Section on the Unzha River shows that the same level in the condensation horizon at the top of Bed 5, contains *H. kochi* and *Praesurites unshensis* (Nikitin), also found in the Rjasanensis Zone of the Moscow Region (Mitta, 2019). In addition, in some quarries of the Lopatinsky Mine, a bed of black sandstone (assigned to the *Rjasanensis* Zone) contains, apart from *Hectoroceras*, shells of *Riasanites* (Mitta, 2005, p. 53). The combination of these data suggests that the recognition of a separate interval "*Kochi*" between the *Nodiger* and *Rjasanensis* zones cannot now be substantiated because the range of *H. kochi* is within the *Rjasanensis* Zone. This fact opens wide opportunities for Panboreal correlation of the base of the Ryazanian.

Occurrences of *Hectoroceras* on the Russian Platform were first published by a team headed by M.S. Mesezhnikov and come from outcrops on the Oka River in the Ryazan Region north of Ryazan (Fig. 1a). Fragments of small shells identified as *Hectoroceras* sp. indet. and *H. kochi* Spath were illustrated from the Kostino Section (Casey et al., 1977, pl. 1, fig. 4; pl. 9, fig. 6). Larger, but also incomplete shells from the Kuzminskoe Section (Mesezhnikov et al., 1979, pl. 1, figs. 5, 7) were identified as *Hectoroceras* sp. indet. and *H.* cf. *kochi* Spath. All occurrences come from the lower part of the *Riasanites rjasanensis* Zone and occur in association with *Riasanites* spp.; these ammonites can relatively positively be assigned to *H. kochi*.

While discussing *Hectoroceras*, it is necessary to consider ammonites that some authors have identified as *Shulginites* Casey, 1973 (type species *Oxynoticeras tolijense* Nikitin). An incomplete phragmocone reaching ~60 mm in diameter was collected from the Kuzminskoe Section as *Shulginites* sp. ind. (Mesezhnikov et al., 1983, p. 121, pl. 6, fig. 4). It is extremely significant that this specimen comes from the upper part of the "Ryazanian plate" (Mesezhnikov et al., 1983, p. 122), i.e., it was found above the base of the *Rjasanensis* Zone. The same locality yielded ammonites that I described (Mitta, 2007) from A.P. Pavlov's collection as *Hectoroceras tolijense* (Nikitin), with no exact locality details. These are mainly typical representatives of the species *tolijense*: narrowly umbilicate shell, with weakly pronounced ornamentation and a narrow carinate (at Dm= 20–30 mm) venter; with age the umbilicus slightly decreases, the cross-section becomes oval-shaped (Mitta, 2007, pl. 1, figs. 2, 3, 5). The same characters are observed in the type series of this species from the eastern slope of the Subpolar Urals (Nikitin, 1884a, pl. 9, fig. 7 (also see Mitta and Sha, 2011, text-fig. 4c, 4d); Sasonova, 1977, pl. 11,

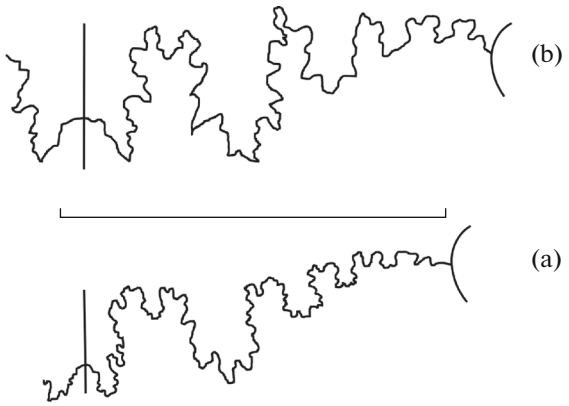

Fig. 5. Sutures: (a) *Hectoroceras* sp. nov., specimen PIN, no. 3990/443 (Figs. 3a–3c) at WH = 9.5 mm; (b) *H. kochi* Spath, specimen PIN, no. 3990/444 (pl. 9, fig. 2) at WH = 10.5 mm.

fig. 3) and topotypes (Casey, 1973, pl. 6, fig. 4). Another ammonite from the Kuzminskoe Section has a similar shape and ornamentation at D = 20 mm (Mitta, 2007, pl. 1, fig. 4a), but sharp and distinct, typically *"Hectoroceras*-like" ribs are present at an older stage (Mitta, 2007, fig. 4b).

Mesezhnikov et al. (1983, p. 118, pl. 4, figs. 1–5; pl. 5, fig. 1) studied the species *tolijense* based on representative material from the type area (Maurynya River, tributary of the Tolya River in the basin of the Severnaya Sosva River. *Shulginites pseudokochi* Mesezhnikov (Mesezhnikov et al., 1983, pl. 5, figs. 2, 4, 5; pl. 6, figs. 1, 2 and *Hectoroceras* kochi (Mesezhnikov et al., 1983, pl. 5, fig. 3) were described and illustrated from the same locality. All ammonites come from a series of outcrops exposing a series of sandstone with sand interbeds, 6.5 m thick in total, subdivided into 10 beds. The ammonites under discussion come from Beds 3–10: Beds 3 and 4 contain only "*Shulginites*," in Bed 6, these are supplemented by *Hectoroceras kochi*, whereas for Beds 8 and 10 *H.* cf. *kochi* was indicated. The distribution of ammonites clearly shows the succession *tolijense* → *kochi*; all authors beginning from Spath (1947), noted the closeness and undeniable relationships of these two species.

I am in complete agreement with Mesezhnikov's identification of the species *tolijense*. The species *pseudokochi* represented by shells with body chambers, with uncoiling of the last whorl beginning as early as 45–50 mm, is in my opinion a microconch of *tolijense*. However, a single illustration of *Hectoroceras kochi* (Mesezhnikov et al., 1983, pl. 5, fig. 3; Bed 6) casts doubt on the identification of this specimen. I mainly retained the shell matrix, with thin, but distinct ribs. Ammonites from the Maurynya River assigned to the *tolijense*, in contrast, are represented mainly by molds with weakly developed ornamentation. However, one specimen of *tolijense* (Mesezhnikov et al., 1983, pl. 4, fig. 1) in the early part of the external whorl retained shell matrix, demonstrating similarly pronounced *Hectoroceras*-like ribs. In contrast, the shell matrix is absent in the umbilical part of "*kochi*" figured in pl. 5, fig. 3, and the shell shows weakly developed "*Shulginites*" ribs – evidently this is another representative of *tolijense*, with a well-developed shell. Hence, all the considered ammonites belong to the dimorph pair *tolijense* [M] and *pseudokochi* [m], whereas the conclusion of the stratigraphic lineage "*Shulginites"* → *Hectoroceras*, based on the succession of taxa on the Maurynya River, does not currently seem justified. Moreover, the above finding of "*Shulginites"* in the Kuzminskoe Section on the Oka River not at the very base of the *Rjasanensis* Zone by Mesezhnikov's team suggests a reversed succession (*kochi* → *tolijense*). Considering that the development (in *tolijense*) in the young whorls of an arrow-like cross-section with a narrow and even angular venter is usually an evolutionary irreversible process, such a succession appears more likely. It is also possible that these two species were formed synchronously, as a divergence of an ancestral taxon.

According to Mesezhnikov et al. (1983, p. 116), the genus *Shulginites* differs from *Hectoroceras* in gently sloping umbilical walls with a rounded shoulder, less pronounced ornamentation and smaller mean size. The above characters are more likely differences of the species level rank, whereas the strength of ornamentation often (as in this case certainly) depends on the state of preservation. Therefore I assign these ammonites to the genus *Hectoroceras* and consider the name *Shulginites* as its junior subjective synonym.

Thus, the Ryazanian Stage of the Russian Platform contains two *Hectoroceras* species, *H. kochi* and *H. tolijense.* Their ancestor from the Volgian Stage (*Nodiger* Zone), is more likely a still undescribed species, known from two complete phragmocones of a small diameter (Fig. 3) and several fragments of shells of a similar and slightly larger size from the Ogarkovo Section on the Unzha River. This species is characteristically represented by shells of medium-size with a high ellipsoid cross-section, with a narrowed but still rounded venter, with a moderately narrow umbilicus with a gently sloping umbilical wall. The ornamentation is represented by relatively thin thread-like long primary ribs subdivided into two–three thinner branches. Unfortunately, there is not sufficient material for the description of a new species. However, illustrations of suture outlines of *Hectoroceras* sp. nov. and *H. kochi* (Fig. 5) show their clear similarity with each other and the sutures of *H. tolijense* (Mesezhnikov et al., 1983, p. 116, text-fig. 6; Shulgina, 1985, p. 96, text-fig. 20).

The origin of *Hectoroceras* is apparently connected with the genus *Kachpurites* Spath, the diversification of which took place in the *Fulgens* Zone (Gerasimov, 1969), and the species of which show a clear trend toward shell compression and umbilical narrowing

(Mitta, 2010). The overlying *Subditus* Zone occasionally contains the last representatives of this genus, showing "proto- *Hectoroceras*" bipartite and tripartite ribs. Figure 6 shows an image of one such specimen represented by a phosphoritic mold with the remains of a nacreous layer.

The species from the *Nodiger* Zone was previously cited by me as *Hectoroceras* sp. nov. aff. *tolijense* (Mitta, 2015, pl. 1, fig. 3), and was recently assigned by Kiselev et al. (2018, pl. 9, fig. 4) to *Volgidiscus pulcher* Casey et al. The latter species is known only from the holotype described from a borehole in the Subpolar Urals (Casey et al., 1977), and its precise stratigraphic level has not been established. Nevertheless, the Central Russian species is readily distinguished from *Volgidiscus* in general, and *V. pulcher* in particular, by the narrower umbilicus and the absence of a clear narrowing of the venter. However, the genus *Volgidiscus* Casey, 1973 is known from very few species and is still poorly studied. For instance, ammonites from the "*Volgidiscus singularis* Zone" assigned to *V. pulcher* (Kiselev et al., 2018, pl. 1, figs. 1–5) clearly differ from one another by the umbilical width and ornamentation and were assigned to several different taxa. Two specimens with a wide umbilicus and well pronounced primary ribs (Kiselev et al., pl. 1, figs. 2, 3), can be assigned to *Craspedites* or *Kachpurites*. To confirm this, it is sufficient to compare these specimens (inner molds in sandstone) with macroconchs of *K. subfulgens* (Nikitin) with a partly preserved shell (Mitta, 2010, pl. 3, figs. 1, 6), considering their different state of preservation.

The following is an emended diagnosis of the genus *Hectoroceras*.

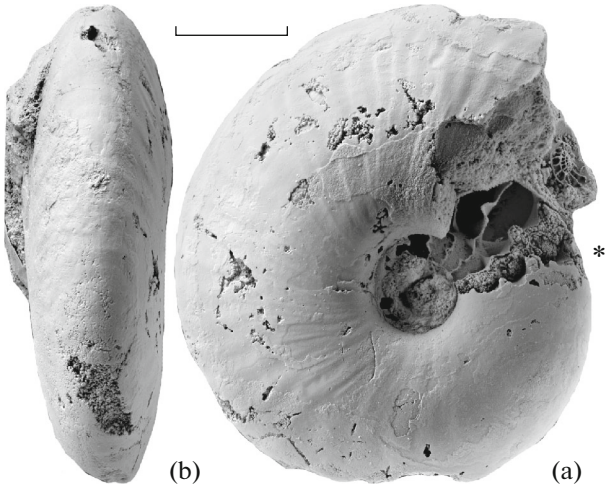

Fig. 6. *Kachpurites* aff. *subfulgens* (Nikitin), specimen with a body chamber, PIN, no. 3990/443: (a) lateral view, (b) ventral view; Yaroslavl Region, Rybinsk District, bank of the Cheremukha River; from phosphorite nodules at the top of the *Fulgens* Zone–lower part of the *Subditus* Zone, Volgian Stage; received from A.V. Stupachenko. The asterisk (*) marks the beginning of the body chamber. Scale bar 10 mm.

SYSTEMATIC PALEONTOLOGY

Superfamily Perisphinctoidea Steinmann, 1890

Family Craspeditidae Spath, 1924

Subfamily Garniericeratinae Spath, 1952

Genus *Hectoroceras* Spath, 1947

Hectoroceras: Spath, 1947, p. 20; Arkell et al., 1957, p. L344; Shulgina, 1972a, p. 135; 1972b, p. 172; Casey, 1973, p. 244; Casey et al., 1977, p. 31; Shulgina, 1985, p. 138; Wright et al., 1996, p. 22.

Shulginites: Casey, 1973, p. 239; Mesezhnikov et al., 1983, p. 115; Shulgina, 1985, p. 140.

Toljaiceras: Shulgina in Saks and Shulgina, 1974, p. 545 (objective synonym of *Shulginites*).

Hectoroceras (Hectoroceras): Wright et al., 1996, p. 22.

Hectoroceras (Shulginites): Wright et al., 1996, p. 22.

Type species. *Hectoroceras kochi* Spath (Spath, 1947, pl. 1, fig. 2); East Greenland, Jameson Land; "Infra-Valanginian" [=Berriasian/Ryazanian], Beds with *Hectoroceras*.

Diagnosis. Shell flattened or medium-wide. Section high-oval to arrow-shaped with narrow, sometimes angular venter. Umbilicus from narrow to moderately narrow, shallow; umbilical wall; umbilical shoulder rounded. Ornamentation represented by densely spaced long thin, weakly bent primary ribs, subdivided into two, less commonly three sickle-shaped branches, sometimes with intercalating ribs in between. Secondary ribs of adult specimens sigmoidally bent backwards.

Macroconchs differing from microconchs by larger sizes. Phragmocones of young macroconchs of similar size to that of microconchs by more strongly compressed whorls with narrow umbilicus directed anteriorad, thinner secondary ribs.

Species composition. Apart from the type species, *H. tolijense* (Nikitin, 1881), its microconch *H. pseudokochi* (Mesezhnikov, 1983), and *H. larwoodi* Casey, 1973 (all from the Ryazanian Stage) and still undescribed species from the *Nodiger* Zone of the Volgian Stage; eastern England, western and Central Siberia, Central Russia.

Remarks. Spath when establishing *H. kochi* recognized its "varieties"—var. *tenuicostata* (Spath, 1947, pl. 1, fig. 1) and var. *magna* (Spath, 1947, pl. 3, fig. 3), connected by transitions to typical *H. kochi*. Evidently, the holotype and one of the paratypes (Spath, 1947, pl. 2, fig. 1) of *H. kochi* are microconchs, and other paratypes, apart from juveniles, are macroconchs.

H. larwoodi was described by Casey (1973) from Norfolk (England) based on a holotype, and according to its author, is distinguished by strongly curved ribs with occasionally bi-dichotomous branching. The validity of this taxon needs to be supported by new material.

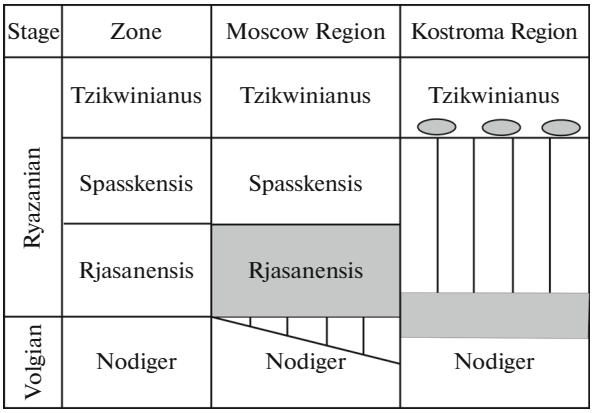

Fig. 7. Intervals of new finds of representatives of the genera *Praesurites* and *Hectoroceras* in the Volgian–Ryazanian boundary beds of the Russian Platform.

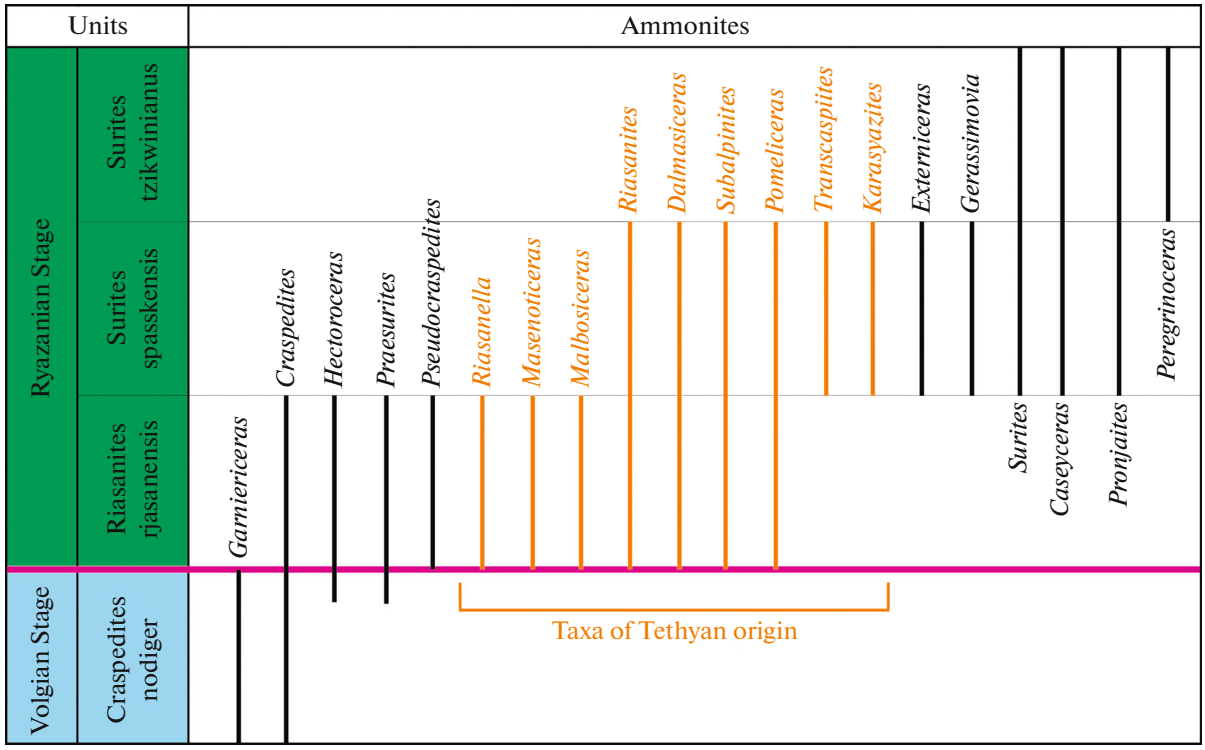

Fig. 8. Distribution of ammonites (taxa of generic rank) at the top of the Volgian and Ryazanian Stages of the Russian Platform (after: Mitta, 2017, modified).

Igolnikov (2015), based on Siberian material, recognized three morphological groups of shells in *Hectoroceras kochi*: microconchs, macroconchs, and "megaconchs." Judging from the description and illustrations, the second group contains young, immature macroconchs, whereas adult macroconchs were misinterpreted as "megaconchs."

CONCLUSIONS

According to the above data, the genus *Hectoroceras* Spath is represented in the Russian Platform by three species—*H. kochi* Spath and *H. tolijense* (Nikitin) in the basal zone (*Riasanites rjasanensis*) of the Ryazanian Stage, and by their ancestor, as yet undescribed species from the terminal zone (*Craspedites nodiger*) of the Volgian Stage. The stratigraphic interval of the distribution of the genus *Hectoroceras* entirely coincides with that of the genus *Praesurites* Mesezhnikov and Alekseev (Fig. 7). The boundary between these stages in the Russian Platform is crossed also only by *Craspedites*, a mainly Late Volgian genus the last representative of which was described from the *Rjasanensis* Zone (Mitta and Sha, 2011). The continuity of this lineage (Fig. 8) shows that there is no gap between the *Nodiger* and *Rjasanensis* zones.

The coincidence of the level of the first appearance of the Panboreal species *Hectoroceras kochi* with the onset of the invasion of Tethyan ammonites to the Central Russian marine basin opens wide prospects for interregional correlation of the Volgian–Ryazanian boundary interval, and for the Boreal–Tethyan correlation of the Jurassic–Cretaceous beds.

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