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New record of *Hesperornis rossicus* (Aves, Hesperornithiformes) in the Campanian of Saratov Province, Russia

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Abstract. New materials of *Hesperornis rossicus* Nessov et Yarkov, 1993 (one complete and one fragmentary tarsometatarsus) from the lower Campanian Karyakino locality in Saratov Province, Russia, show for the first time distal tarsometatarsal morphology for this species and allow reconsideration of its diagnosis. *H. rossicus* is the most derived species of the genus, having the greatest size for the genus and strongly reduced inner fingers, with undivided trochlea on tarsometatarsus for digits II and III and condyle for digit II completely behind that of digit III. Previous records of *Hesperornis* sp. from Rychkovo and Hesperornithidae indet. from Bereslavka (both Volgograd Province, Russia) are referred here to *H. rossicus*.

Key words: *Hesperornis*, Late Cretaceous, Campanian, Russia

Introduction

Hesperornithiforms are a small and compact group of mid- to Late Cretaceous marine toothed, foot-propelled diving birds. Albian-Cenomanian members of the group may have been capable of flight (Tokaryk *et al*., 1997), while more derived Late Cretaceous (mostly Campanian) hesperornithiforms were definitely flightless (Marsh, 1880; Martin and Lim, 2002).

Except for the British mid-Cretaceous *Enaliorinis* Seeley, 1876, the majority of hesperornithiforms were known for a long time only from the New World (hence the name *Hesperornis*, western bird). The first Asiatic hesperornithiform recovered was the baptornithid *Judinornis nogontsavensis* Nessov et Borkin, 1983, based on thoracic vertebra from the Maastrichtian of Mongolia (Nessov and Borkin, 1983). Subsequent Eurasian discoveries include *Asiahesperornis bazhanovi* Nessov et Prizemlin, 1991 from the latest Santonian – early Campanian of northern Kazakhstan (Nessov and Prizemlin, 1991), *Hesperornis rossicus* Nessov et Yarkov, 1993 from the early Campanian of Volgograd Province, Russia and southern Sweden (Rychkovo and Ivö-Klack: Figure 1), *Hesperornis* sp. from the former locality and *Baptornis* sp. nov. from the latter locality (Nessov, 1992; Nessov and Yarkov, 1993; Yarkov and Nessov, 2000), and Hesperornithidae indet. from the late Campanian or ?early Maastrichtian of Volgograd Province, Russia (Bereslavka: Figure 1; Yarkov and Nessov, 2000), referred herein to *H. rossicus* (see below). According to L. A. Nessov (Nessov and Prizemlin, 1991; Nessov, 1992), *Parascaniornis stensioi* Lambrecht, 1933 from the lower Campanian of southern Sweden (Ivö-Klack), originally referred to Phoenicopteri (Lambrecht, 1933), also belongs to Hesperornithiformes. A third, undescribed hesperornithiform from Ivö-Klack was mentioned by Nessov and Prizemlin (1991). A small Baptornithidae indet., reported from the Kushmurun locality in northern Kazakhstan by Nessov and Yarkov (1993: 39), is possibly based on juvenile specimens attributable to *Asiahesperornis*. A new small, possibly volant hesperornithiform was reported from the Maastrichtian of Mongolia (Kurochkin, 1988, 2000).

Here we report a new hesperornithiform locality in Russia: Karyakino in Saratov Province (Figure 1), which produced isolated bones of *H. rossicus* found by Mr. Dmitrii V. Zheglov in 2001 and described below.

The materials described and discussed are housed in the Paleornithological Collection of the Zoological Institute, Russian Academy of Sciences (abbreviated

Figure 1. Localities of *Hesperornis rossicus* in Eastern Europe and Scandinavia: Rychkovo (1), Karyakino (2), Bereslavka (3), and Ivö-Klack (4).

ZIN PO), in Saint Petersburg, Russia and in the Volgograd Regional Museum (abbreviated VRM), in Volgograd, Russia.

Geological setting

The *Hesperornis* bones described herein were found in the Campanian vertebrate locality of Karyakino. The locality is a small occasionally exploited quarry situated 500 m WNW of Karyakino settlement, Tatishchevo District, Saratov Province, near the R-208 motorway (Figure 2A). The quarry is of sandstone of the Campanian Rybushka Formation. This formation is widely distributed in the Khoper monocline of the Voronezh anteclise and in the Murom-Lomov depression of the Volga-Ural anteclise in Saratov and Penza provinces. The stratotype of Rybushka Formation was established near the settlement of Rybushka in Saratov District, Saratov Province (Ivanov, 1995; Pervushov *et al.*, 1999b). This formation, with a maximum thickness of 30 m, is presented by yellowish and greenish-gray sands and sandstones with grains of different size and bioturbations. It contains remains of belemnites *Belemnellocamax mammillatus* (Nilsson, 1827), *Belemnitella mucronata* (Arkhangelsky, 1912), ammonites *Hoplitoplacenticeras* sp., bivalves *Oxytoma psilomonica* A. Ivanov, 1993, *O. tenuicostata* (Roemer, 1841), *Cataceramus balticus* (Boehm, 1907), *C. regularis* (d'Orbigny, 1845), and benthic foraminifers of the regional zone *Brotzenella monterelensis* and subzone *Cibicidoides aktulagayensis* (Yakushin and Ivanov, 2001). Stratigraphically the Rybushka Formation corresponds to the major portion of the lower Campanian (regional molluscan provincial zones *Belemnitella mucronata alpha* and *Belemnellocamax mammillatus*) and to the lowermost upper Campanian (provincial zone (''lona'') *Hoplitoplacenticeras coesfeldiense* / *Belemnitella mucronata mucronata*) (Yakushin and Ivanov, 2001).

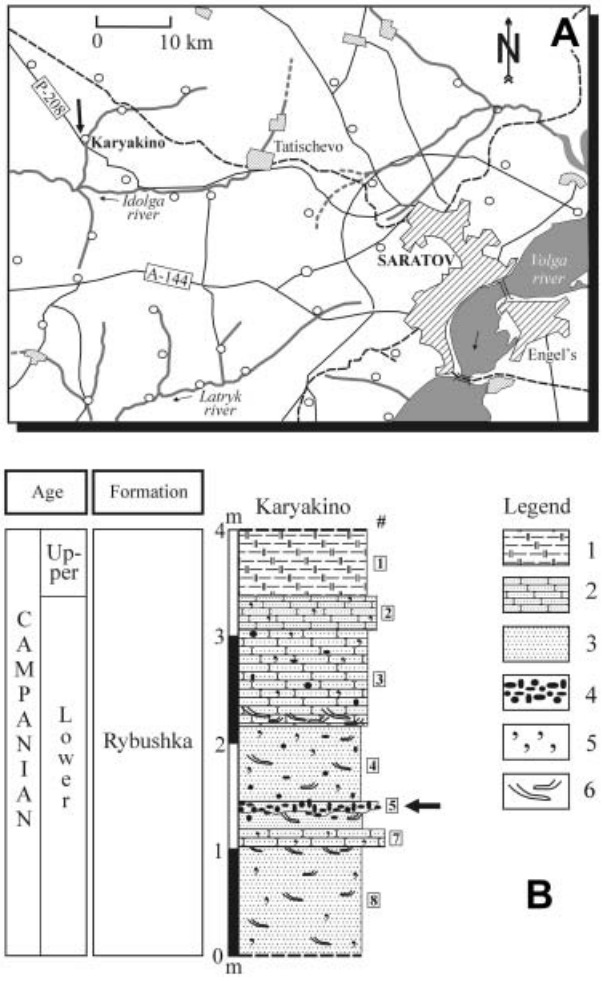


Figure 2. Geographic and geologic settings of *Hesperornis rossicus* remains from Karyakino locality.

A – Map of vicinity of Saratov showing position of Karyakino locality (indicated by vertical arrow).

B – Lithologic section of the Karyakino locality (after Pervushov et al., 1999a). Numerals in rectangles designate number of layer. Position of *Hesperornis rossicus* remains is indicated by horizontal arrow (layer 5). Lithologic designations: 1 – limestone; 2 – clayey opoka; 3 – sandstone; 4 – phosphorite nodules; 5 – glauconite; 6 – bioturbation.

The locality Karyakino was described in detail by Ivanov (1995, 1996) and Pervushov *et al.* (1999a). Its lithologic section is presented on Figure 2B. The bones of *Hesperornis* and other vertebrates come from the 0.1–0.15 m in thickness layer 5, consisting of

quartz-glauconitic medium-grained sand and numerous phosphorite nodules of different size. Besides the *Hesperornis* bones this layer produced the following vertebrate remains: shark teeth identifiable as *Cretolamna appendiculata* (Agassiz, 1843), *Archaeolamna kopingensis* (Davis, 1890), *Pseudocorax laevis* Leriche, 1906, *Cretoxyrhina mantelli* (Agassiz, 1843), *Scapanarhinchus perssoni* Siverson, 1992, *Heterodontus* sp., *Squatirhina* sp., *Squalicorax kaupi* (Agassiz, 1843), *Synechodus* sp., *Paraorthacodus* sp., *Polyacrodus siversoni* Rees, 1999, and *Cederstroemia* sp., dorsal fin spines and tooth plates of chimaeroid fishes *Ischyodus bifurcatus* Case, 1978, *Edaphodon* sp., and *Elasmodus* sp., isolated bones, teeth and jaw fragments of actinopterygian fishes, including Enchodontidae indet., indeterminate sea turtle shell fragments, bone fragments of marine reptiles Elasmosauridae indet., Mosasauridae indet. and ?*Clidastes* sp. (Pervushov *et al*., 1999a), and numerous coprolites, both with spiral structure (chondrichthyan), and structureless cordlike (actinopterygian?). This vertebrate bone-bearing phosphorite horizon can be traced in other sections of Saratov and Penza provinces (Shyrokii Karamysh, Malaya Rybka, Malaya Serdoba; Averianov and Popov, 1995, Pervushov *et al*., 1999a; Yarkov, 2001). The chondrichthyan assemblage from the layer 5 is widely distributed in the Campanian deposits of Eastern and Western Europe, including Scandinavia (Herman, 1977; Siverson, 1992; Rees, 1999; and others).

Among invertebrates the layer 5 produced nuclei of gastropods *Solariella* sp. and bivalves *Monticulina* sp., *Gryphaeostrea* sp., *Chlamys* sp., and phosphatic shells of problematic brachiopod-like marinaculates *Conigalea otschevi* A. Ivanov, 1995, *Lauturria serdobensis* A. Ivanov, 1995, *Inaclypia stabilis* A. Ivanov, 1995 (Ivanov, 1995). In the layer 3 dispersed skeletons of siliceous sponges *Rhizopoterion cervicorne* (Goldfuss, 1833) and *Sororistirps* sp. were found. This sponge association corresponds to the interval between lower and upper Campanian (Pervushov, 2002).

Based on the vertebrate and invertebrate fauna and lithologic correlation with other sections in the region, the layers 2–8 are dated as lower Campanian (Pervushov *et al*., 1999a).

Systematic description

Aves Linnaeus, 1758
Hesperornithiformes Fürbringer, 1888
Hesperornithidae Marsh, 1872
Hesperornis Marsh, 1872

Hesperornis rossicus Nessov et Yarkov, 1993

Figures 3, 4

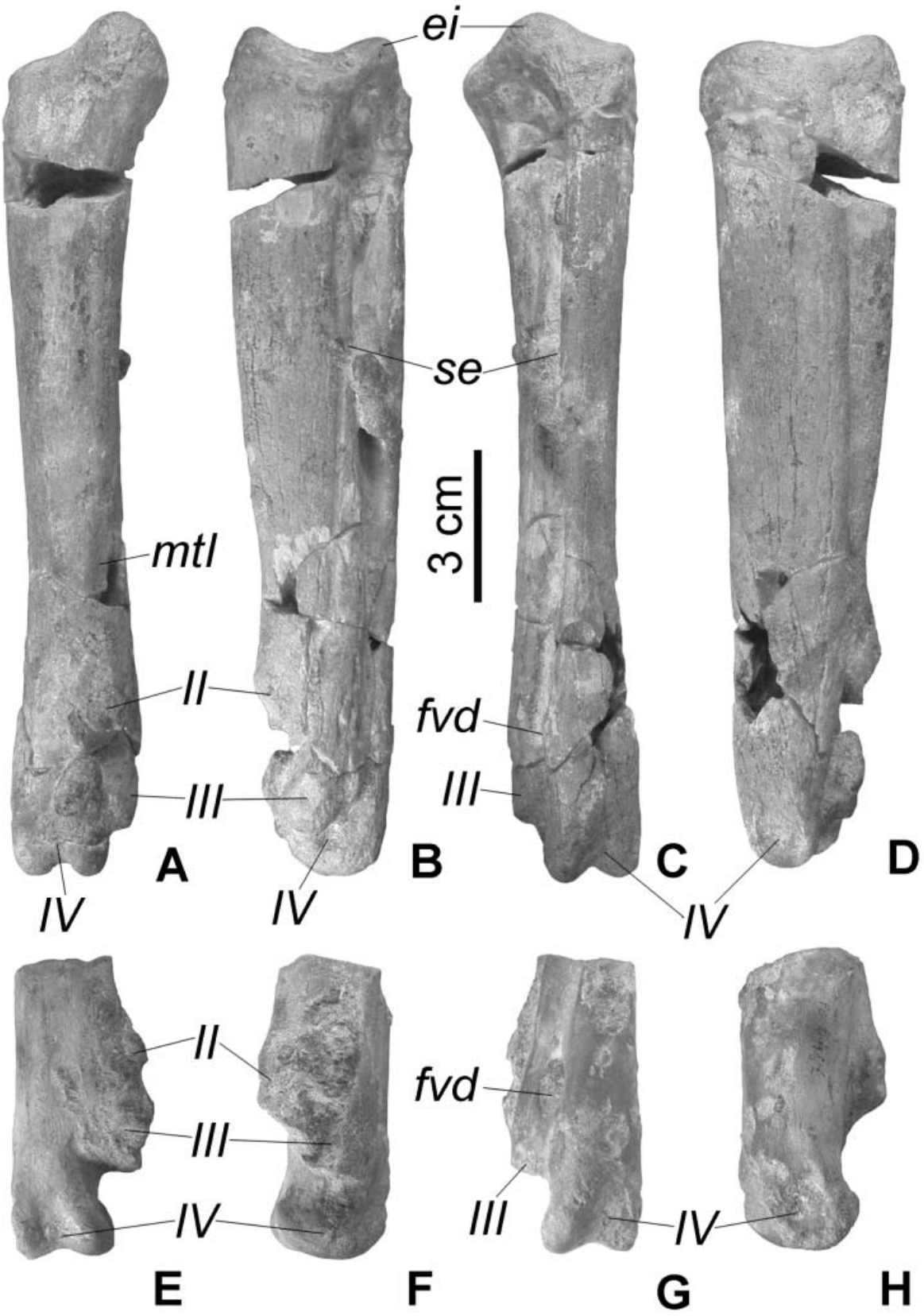
Revised diagnosis.—Size largest for the genus, 20% larger than in *H. regalis*; inner toes strongly reduced; digits II and III with undivided condyle; condyle for digit II completely behind that of digit III.

Material.—ZIN PO 5464, a nearly complete left tarsometatarsus lacking condyle for digit II; ZIN PO 5463, distal portion of the left tarsometatarsus broken at the base of the digit II condyle and lacking condyles for digits II and III.

Locality and horizon.—Karyakino, Tatishchevo District, Saratov Province; Rybushka Formation, Upper Cretaceous (early Campanian).

Note.—The species name is changed from the original ''*rossica*'' due to the masculine gender of the generic name (Kurochkin, 2000, p. 545).

Description.—The tarsometatarsus is large, but relatively slender and narrow, with inner digits (II and III) greatly reduced. Proximal epiphyses strongly diagonally sloping, with the cotyla medialis about twice as large as the cotyla lateralis; both cotylar surfaces are slanting anteriorly. The cotyla medialis is of trapezoid shape with saddle-shaped articulation surface. The lateral cotyle is triangular with concave articulation surface. The intercotylar process (eminentia intercondylaris) is high and rounded in anterior view. The anterior metatarsal groove (sulcus extensorius) is very deep and extending distally to the junction of the condyles for digits III and IV. Another, much smaller and shallower groove extends more medially from the proximal end towards the junction of the condyles for digits III and II. The distal foramen (foramen vasculare distale) is closed in its distal portion by bony roof between the condyles for digits III and IV. Both anterior extensor grooves are separated by a ridge, wide and flat distally, tapering proximally, and almost reaching the proximal end of the anterior metatarsal depression. The lateral anterior metatarsal ridge is more prominent than the medial one. The medial posterior metatarsal ridge is higher and sharper than the lateral posterior ridge. Both ridges are separated by a deep and shallow depression. The facet for metatarsal I is on the medial posterior metatarsal ridge, just above the condyle for digit II. The medial and lateral bone surfaces are gently convex. The condyle for digit II is relatively small and completely confined to the posterior side of the bone, behind the condyle for digit III. The condyle for digit III is of similar size and not trochlea-like, with articulation surface undivided into lateral and medial rims. The condyle for digit IV is more than twice as large as the condyles of inner digits, with articulation surface formed by prominent medial and lateral rims separated by a deep valley. The medial rim is 40%



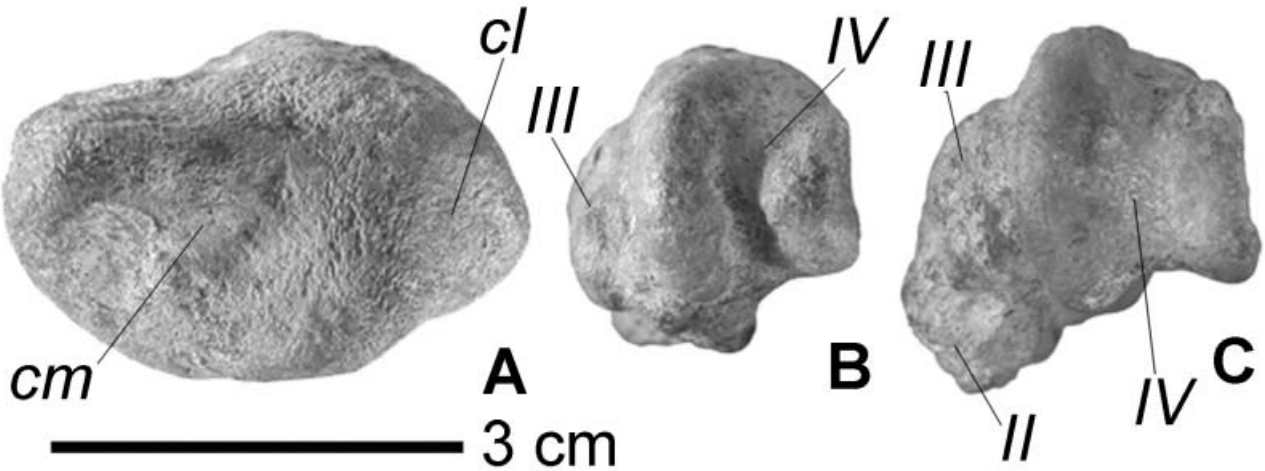


Figure 4. *Hesperornis rossicus*, left tarsometatarsus of a subadult animal (ZIN PO 5464; A, B) and distal portion of left tarsometatarsus of an adult animal (ZIN PO 5463; C) in proximal (A) and distal (B, C) views. Karyakino, Saratov Province; Rybushka Formation, Upper Cretaceous (early Campanian).

Abbreviations: II–IV – condyles for fingers II to IV; cl – cotyla lateralis; cm – cotyla medialis. Scale bar is 3 cm.

larger in the anteroposterior diameter than the lateral rim.

Measurements (in mm).—ZIN PO 5464, tarsometatarsus: maximal length 158.8; anteroposterior diameter of the proximal epiphyses 23.8; width of the proximal epiphyses 40.8; width of the distal epiphyses 24.5; minimal width of the diaphysis 18.0. ZIN PO 5463, tarsometatarsus: width of the distal epiphyses 24.5.

Comparisons.—The tarsometatarsi described possessed at least two characters, unique to the hesperornithiform birds (Martin, 1984): tarsometatarsus elongate and compressed laterally and fourth toe the longest, and thus referred to that order.

The holotype of *H. rossicus* is the proximal portion of the tarsometatarsus from Rychkovo locality in Volgograd Province (Figure 5; VRM 26306/2; Nessov and Yarkov, 1993, fig. 3a-zh). ZIN PO 5464 differs from the holotype by 9% smaller size and by insufficient morphological differentials, all of which can be easily interpreted as ontogenetic variation. ZIN PO 5463 is almost identical with ZIN PO 5464, except being 5% larger and having more developed digital condyles, notably the more anterioposteriorly and proximally projecting medial rim of the condyle for digit IV. These similarities between the two Karyakino specimens and the holotype of *H. rossicus* allow us to attribute the Karyakino materials to the latter species.

Comments.—Distal tarsometatarsus morphology was not previously known for *H. rossicus*. The species was originally diagnosed by its greater size (20% larger than in *H. regalis* Marsh, 1872) and subtle differences in the proximal tarsometatarsal morphology (Nessov and Yarkov, 1993, p. 51; Kurochkin, 2000, p. 545). The new materials revealed more diagnostic characters of *H. rossicus*. In the state of the inner toes reduction it is more derived than the majority of other *Hesperornis* species, approximating the condition of *H. mengeli* Martin et Lim, 2002 from the Campanian of Canada, which also has undivided trochlea for digits II and III and condyle for digit II completely behind that of digit III (Martin and Lim, 2002). *H. rossicus* differs from *H. mengeli* by its more than twice larger size.

Hesperornis sp. from Rychkovo locality is represented by a proximal fragment of left tarsometatarsus (Figure 6; ZIN PO 5099; Nessov and Yarkov, 1993, fig. 4a–d). It differs from the holotype of *H. rossicus* by its smaller size and is identical in size and morphology

⬅ **Figure 3.** *Hesperornis rossicus*, left tarsometatarsus of a subadult animal (ZIN PO 5464; A–D) and distal portion of left tarsometatarsus of an adult animal (ZIN PO 5463; E–H) in posterior (A, E), medial (B, F), anterior (C, G), and lateral (D, H) views. Karyakino, Saratov Province; Rybushka Formation, Upper Cretaceous (early Campanian).

Abbreviations: II–IV – condyles for fingers II to IV; fvd – foramen vasculare distale; ei – eminentia intercondylaris; mtI – facet for the metatarsal I; se – sulcus extensorius. Scale bar is 3 cm.

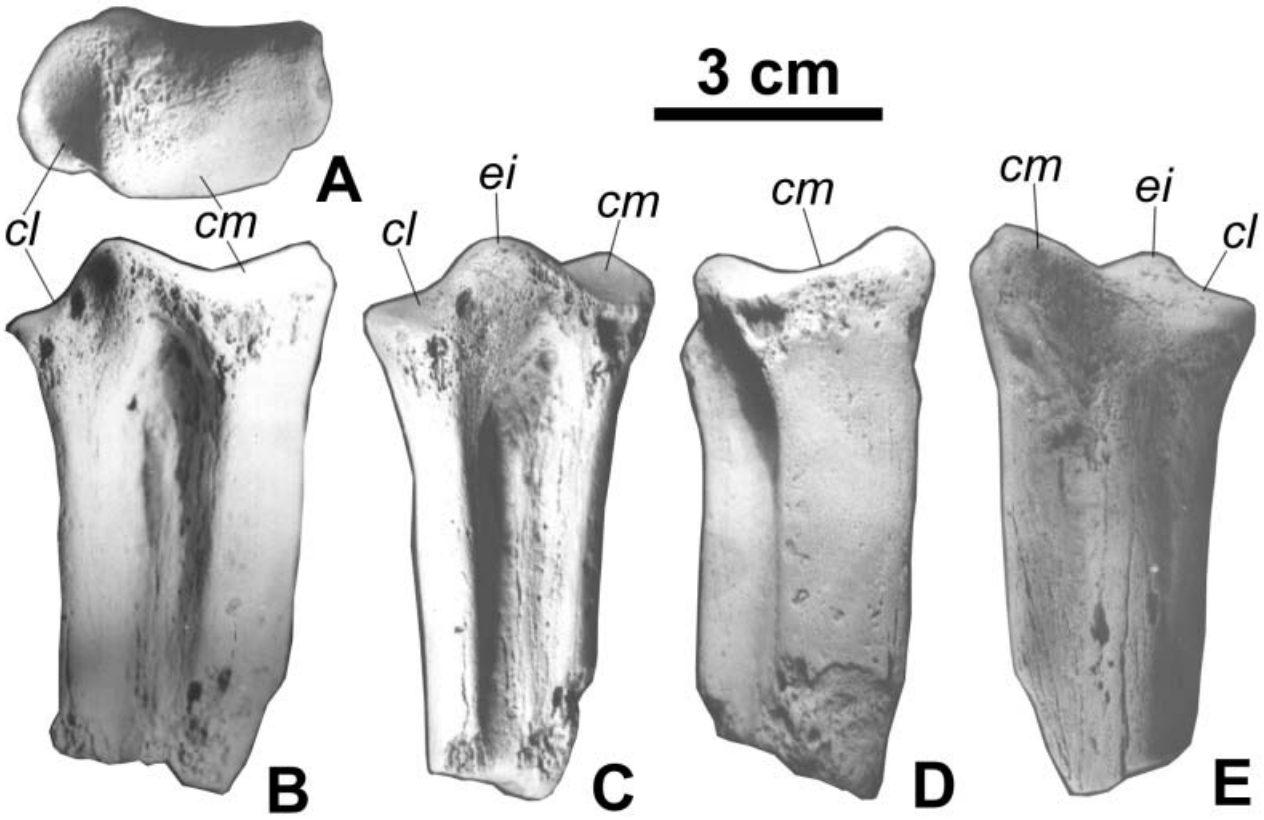


Figure 5. *Hesperornis rossicus*, proximal end of right tarsometatarsus (VRM 26306/2) in proximal (A), anteromedial (B), anterior (C), medial (D), and posterior (E) views. Rychkovo, Volgograd Province; *Belemnellocamax mamillatus* Zone deposits, Upper Cretaceous (early Campanian). Original photographs published by Nessov and Yarkov, 1993.

Abbreviations: cl – cotyla lateralis; cm – cotyla medialis; ei – eminentia intercondylaris. Scale bar is 3 cm.

with ZIN PO 5464 from Karyakino. The subtle morphological differences between ZIN PO 5099 and the holotype of *H. rossicus*, mentioned by Nessov and Yarkov (1993, p. 52) and Kurochkin (2000, p. 545), cannot be confirmed by us. In fact, both specimens are almost identical in morphology, but ZIN PO 5099 is apparently an immature specimen, as indicated by its smaller size and less developed, evidently not com-

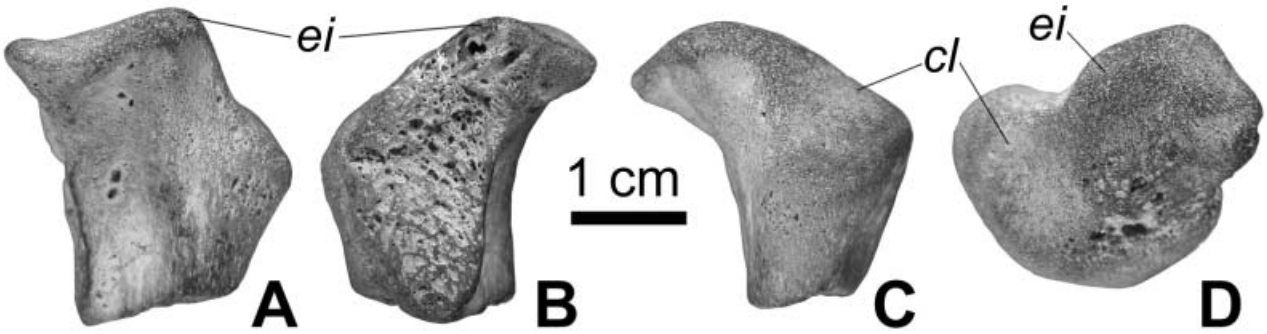


Figure 6. *Hesperornis rossicus*, fragment of the proximal end of left tarsometatarsus (ZIN PO 5099) in anteromedial (A), medial (B), anterior (C), and proximal (D) views. Rychkovo, Volgograd Province; *Belemnellocamax mamillatus* Zone deposits, Upper Cretaceous (early Campanian).

Abbreviations: cl – cotyla lateralis; ei – eminentia intercondylaris. Scale bar is 3 cm.

pletely ossified articular surfaces. It is referred here to *H. rossicus*. Thus, only one hesperornithiform species is currently present at the Rychkovo locality and all hesperornithiform specimens from there can be safely referred to *H. rossicus*.

A distal tarsometatarsus fragment reworked to the Paleogene deposits near Bereslavka, Volgograd Region, Russia and identified as Hesperornithidae indet. (Yarkov and Nessov, 2000, fig. 2zh-i) belongs to an immature individual and is poorly preserved. However, it possesses strongly reduced condyla for digits II and III, the former completely behind the latter, and possibly has undivided articulation surfaces. Based on these characters, the hesperornithiform from Bereslavka is referred here to *H. rossicus*.

In conclusion, *H. rossicus* can be considered as the most derived species of the genus, having the greatest size for the genus (Nessov and Yarkov, 1993) and more reduced inner fingers, related to the specialization for foot-propelled diving, compared with other species of the genus.

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