

An Azhdarchid Humerus (Pterosauria, Azhdarchidae) from the Upper Cretaceous of Saratov Region

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Abstract—A proximal humerus fragment referred to as Azhdarchidae indet. from the Rybushka Formation (Upper Cretaceous, Lower Campanian) of the Beloe Ozero locality in Saratov Region is described. The proximal articular surface is not saddle-shaped, has a weakly convex profile in the frontal section. The most posteriorly projecting part of the proximal articular surface is displaced ventrally. A large pneumatic foramen is located on the anterior surface ventral to the base of deltopectoral crest and close to the proximal articular surface. The humeral head is slightly declined from the diaphysis and only slightly overhangs the diaphysis posteriorly. This proximal humerus fragment possibly belongs to *Volgadraco bogolubovi* Averianov, Arkhangel'sky et Pervushov, 2008, described from the Rybushka Formation of the Shirokii Karamysh 2 locality in Saratov Region.

Keywords: Azhdarchidae, pterosaur, Upper Cretaceous, Campanian, Saratov Region, Russia

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INTRODUCTION

Azhdarchids are the latest and most advanced pterosaur group, which was dominant in the sky in the Late Cretaceous and widespread almost throughout the world (Averianov, 2014). In Russia, azhdarchids were first found at the beginning of the past century in the Campanian the Penza Region (Bogolyubov, 1914). New azhdarchid specimens were found only during the last 10–15 years in the Upper Cretaceous of Volga Region (Averianov, 2004, 2007a, 2008; Averianov and Yarkov, 2004; Averianov et al., 2005, 2008; Averianov and Pantelev, 2009; Averianov and Popov, 2014). Among the recently discovered pterosaur localities in Volga Region, the Campanian Rybushka Formation outcropping in ravines near the village of Beloe Ozero on the left bank the Medveditsa River in the south of the right-bank part of Saratov Region is one of the most promising sites (Pervushov et al., 1999). In particular, these deposits have yielded a toothless rostrum fragment (specimen ZIN PH, no. 14/43), coracoid fragments (ZIN PH, nos. 52 and 53/43), proximal end of the first phalanx of digit IV of wing (ZIN PH, no. 47/43), distal fragment of the first phalanx of digit IV of wing (ZIN PH, no. 51/43), and a dorsal vertebra (ZIN PH, no. 55/43), which were determined as Azhdarchidae indet. (Averianov, 2007a, 2008; Averianov and Pantelev, 2009; Averianov and Popov, 2014).

From this locality, a mandibular symphysis fragment of the plesiosaur Polycotylidae indet. has also been described (Ochev, 1976; Arkhangel'sky et al., 2007). In addition, the Beloe Ozero locality has yielded cartilaginous and bony fishes, sea turtles, plesiosaurs, and mosasaurs, which have not yet been described. The present paper describes a new pterosaur find from Beloe Ozero, a fragment of the proximal humeral part (ZIN PH, no. 59/43). New material also includes a small fragment of the articular surface of an azhdarchid humerus (ZIN PH, no. 60/43), which corresponds in structure to the specimen described. The specimens are housed in the Paleoherpetological collection of the Zoological Institute of the Russian Academy of Science, Saint Petersburg (ZIN PH). The geological characteristics of the Beloe Ozero locality have been provided previously (Averianov and Popov, 2014). In the description, the humerus is positioned as during the flight, with completely spread wings.

DESCRIPTION

Specimen ZIN PH, no. 59/43 is a proximal fragment of a left humerus with completely preserved humeral head, bases of the ulnar and deltopectoral crests, and the proximal part of the diaphysis (Figs. 1, 2i–2l). In proximal end view, the articular surface is semilunar, with a

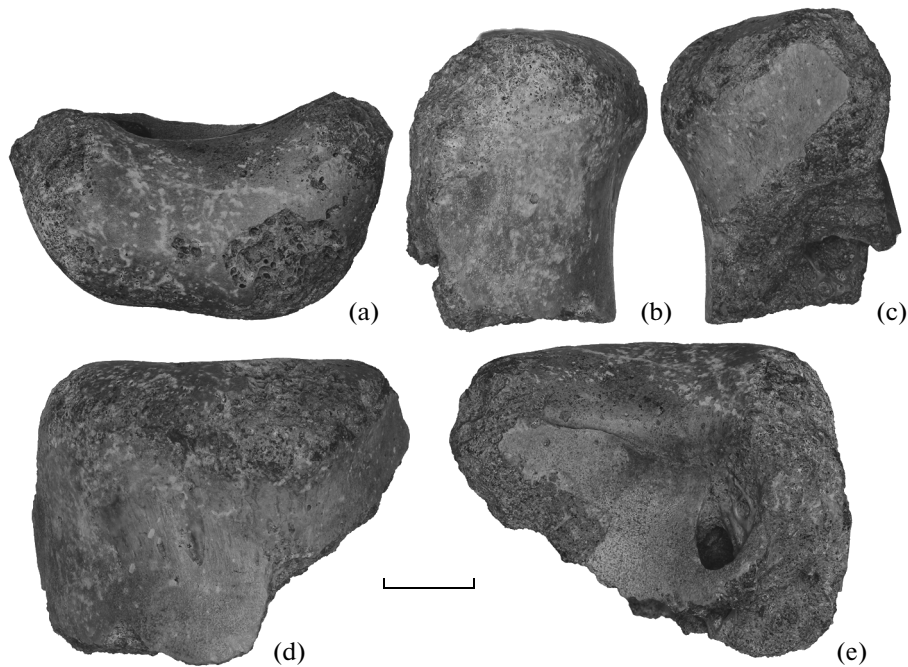


Fig. 1. Proximal fragment of the left humerus of Azhdarchidae indet., specimen ZIN PH, no. 59/43: (a) proximal view, (b) dorsal view, (c) ventral view, (d) posterior view, and (e) anterior view; Saratov Region, Beloe Ozero locality; Rybushka Formation (Lower Campanian, Upper Cretaceous). Scale bar, 1 cm.

relatively short and concave anterior surface and a longer convex posterior one (Figs. 1a, 2i). In general, the convex posterior surface has two convexity maxima (dorsal and more projecting ventral) separated by a slightly concave surface. The maximum dimensions of the articular surface of the humeral head are 40.5×24.4 mm. In anterior view, the articular surface is straight in outline (Figs. 1d, 2j) and slightly convex in posterior view (Figs. 1e, 2k). The humeral diaphysis, like the head, is concave anteriorly and convex posteriorly (in parasagittal plane). In the transverse plane, the posterior surface is slightly concave, with the humeral head only insignificantly overhanging the diaphysis (Figs. 1b, 1c, 2l). The humeral head is inclined to the diaphysis at an angle of more than 30° . Hence, the anterior and posterior expositions of the articular surface differ only slightly. On the anterior surface, ventral to the base of the deltopectoral crest, the diaphysis has a large oval pneumatization foramen ($\sim 7 \times 4.5$ mm) open in a longitudinal anterodorsally directed depression (Figs. 1e, 2k). The surface of this depression is reticulate in structure. The distance between the proximal margin of the pneumatization foramen and articular surface of the humeral head is 6.3 mm. The space between the articular surface and pneumatization foramen is lowered relative to the remaining part of the anterior surface of the diaphysis. The pneumatization foramen opens in a large slitlike cavity inside the diaphysis. Judging from the preserved base, the deltopectoral crest is directed anterodorsally and the ulnar crest extends ventrally.

COMPARISON AND DISCUSSION

The postcranial morphology of azhdarchids is rather conservative. The differences between taxa are mostly manifested in the structure of jaws and cervical vertebrae (Averianov, 2008, 2010, 2014). Therefore, it is particularly surprising that the humeral fragment considered (ZIN PH, no. 60/43) displays significant differences from the previously known humeri of azhdarchids. In the majority of azhdarchids and azhdarchoids, the proximal articular surface of the humerus is saddle-shaped, concave in the frontal plane and convex in the transverse plane (see, e.g., Gilmore, 1928, text-figs. 1a, 1b). In particular, this shape of the proximal articular surface is characteristic of the largest known humerus of the azhdarchid *Quetzalcoatlus northropi* from the Maastrichtian of Texas, United States (Lawson, 1975, text-fig. 1b). A significant part of the curvature is determined by the fact that the proximal articular surface forms the dorsal crest, the proximally projecting dorsal part of the articular surface (Averianov and Ekrt, 2015). However, the articular surface located ventral to this crest is also concave in the frontal plane of the majority of azhdarchids (character 2a in Fig. 2). In specimen ZIN PH, no. 60/43, the dorsal crest is broken off; however, it was probably present, judging from a small proximal eminence of the articular surface at its base. In contrast to the other Azhdarchoidea, in specimen ZIN PH, no. 60/43, ventral to this crest, the articular surface is flat or even slightly convex rather than concave (Figs. 1d, 1e, 2k). The only azhdarchid having a simi-

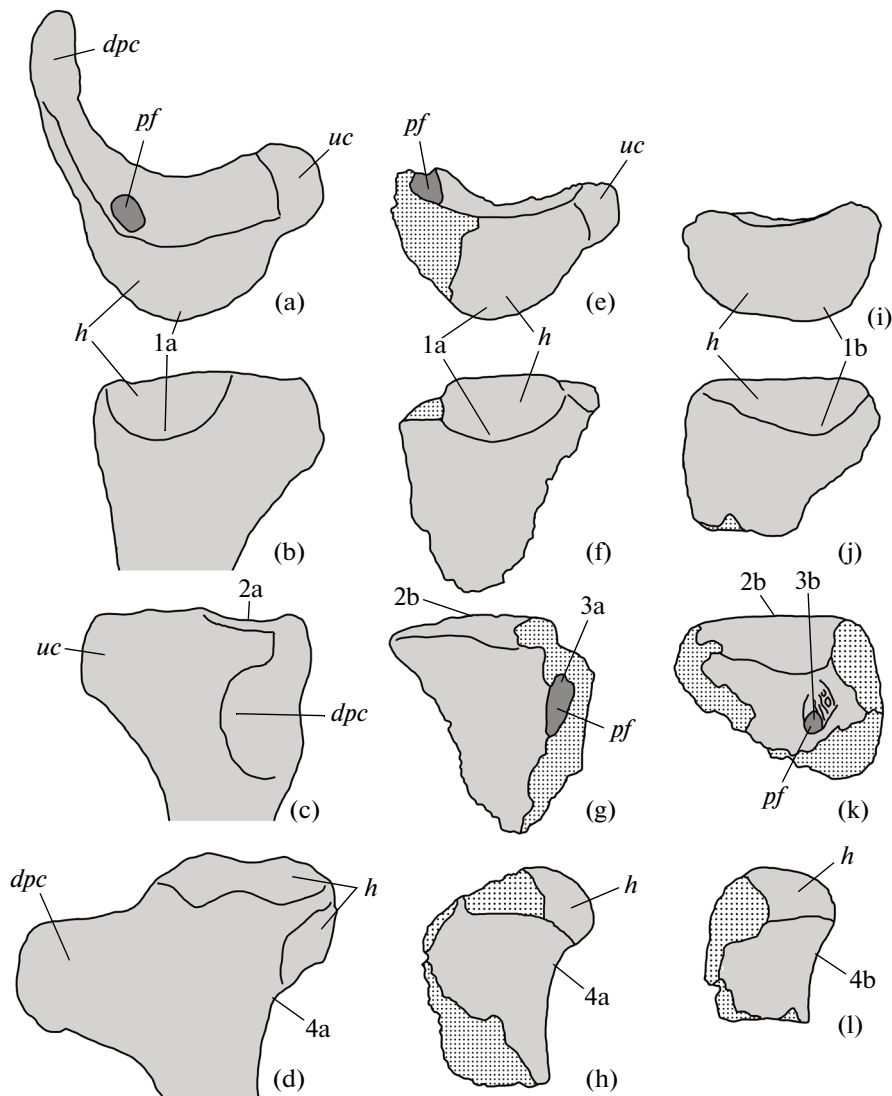


Fig. 2. Comparison of the proximal end of the left humerus in (a–d) *Azhdarchoidea* indet. from the Barremian the Great Britain (after Witton et al., 2009); (e–h) *Aralazhdarcho bostobensis* from the Santonian–Campanian (?) of Kazakhstan (after Averianov et al., 2015); and (i–l) specimen ZIN PH, no. 60/43, *Azhdarchidae* indet. from the Campanian of Volga Region; (a, e, i) proximal end, (b, f, j) posterior, (c, g, k) anterior, and (d, h, l) dorsal views; out of scale. Points designate damaged surface of the bone. Designations: (*h*) humeral head, (*dpc*) deltopectoral crest, (*pf*) pneumatization foramen, and (*uc*) ulnar crest. Morphological characters: (*1*) most convex part of the articular surface, posteriorly: (*1a*) located centrally or (*1b*) displaced ventrally; (*2*) section of the articular surface in the frontal plane: (*2a*) concave or (*2b*) straight or slightly convex; (*3*) pneumatization foramen on the anterior side of the humerus is (*3a*) at the base of the deltopectoral crest, at a significant distance from the articular surface of (*3b*) ventral to the base of the deltopectoral crest, closer to the articular surface; (*4*) humeral head: (*4a*) overhangs the diaphysis strongly posteriorly, with the proximal surface of the diaphysis concave posteriorly in the transverse plane, or (*4b*) only slightly overhangs the diaphysis, with the proximal surface of the diaphysis concave slightly posteriorly.

lar convex proximal articular surface of the humerus (character 2b in Fig. 2) is *Aralazhdarcho bostobensis* from the Santonian–Campanian (?) of western Kazakhstan (Figs. 2e–2h; Averianov et al., 2015). In *A. bostobensis* and other *Azhdarchoidea*, the most posteriorly projecting part of the proximal articular surface is positioned centrally, approximately at the midheight of the humeral head (character 1a in Fig. 2). In specimen ZIN PH, no. 60/43, this most projecting part is displaced onto the ventral part of the humeral head

(character 1b in Fig. 2). Another difference concerns the position of the pneumatization foramen on the anterior side. In specimen ZIN PH, no. 60/43, it is located ventral to the base of the deltopectoral crest and relatively closer to the proximal articular surface (character 3b in Fig. 2). In other *azhdarchids*, this foramen is located at the base of the deltopectoral crest and a greater distance from the proximal articular surface (character 3a in Fig. 2). The last unique character of specimen ZIN PH, no. 60/43 is the small angle

between the humeral head and diaphysis, which is observed in the weak concavity of the posterior surface of the proximal part of the diaphysis in the transverse plane and the humeral head only slightly overhanging the diaphysis (character 4b in Fig. 2). In other azhdarchids, the inclination is greater and the humeral head overhangs the diaphysis to a greater extent (character 4a in Fig. 2).

The above-listed anatomical features show a great morphological peculiarity of the azhdarchid from Beloe Ozero. As noted above, it is highly probable that Azhdarchidae remains from Beloe Ozero belong to *Volgadraco bogolubovi*, which was described from the Rybushka Formation of the neighboring Shirokii Karamysh 2 locality (Averianov et al., 2008; Averianov and Popov, 2015). Specimen ZIN PH, no. 60/43 is closely similar to a fragment of the proximal articular surface of the humerus of an even larger pterosaur from the Campanian Polunino II locality in the Volgograd Region (Averianov and Yarkov, 2004). In the initial description, this fragment was referred to as Ornithocheiridae indet., since at that time, humeri of azhdarchid with a nonsaddle-shaped proximal articular surface were not known. At present, the specimen from Polunino II can be attributed with certainty to Azhdarchidae, possibly, to *Volgadraco bogolubovi*. The similarity in the humeral structure of azhdarchids from the Santonian–Campanian (?) of Kazakhstan and Campanian of the Volga Region suggests a special azhdarchid lineage could have dwelt in the Late Cretaceous on the coasts of the Turgai Strait.

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