

A New Record of an Azhdarchid (Pterosauria: Azhdarchidae) from the Upper Cretaceous of the Volga Region

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Abstract—A distal fragment of a radius of Azhdarchidae indet. from Upper Campanian (Upper Cretaceous) marine deposits of Saratov is described. The bone belongs to a large pterosaur, of about 4.3 m wing span. It differs from the radii of *Azhdarcho*, *Montanazhdarcho*, and cf. *Quetzalcoatlus* in the asymmetrical distal epiphysis and, in addition, from *Montanazhdarcho* and cf. *Quetzalcoatlus* in the absence of a pneumatic foramen on the posterior side. In its geographical and stratigraphical positions, this specimen is close to the azhdarchid *Bogolubovia orientalis* (3–4 m in wing span), known from a fragmentary cervical vertebra from the Campanian of the Penza Region, and may belong to this species.

Key words: Pterosauria, Azhdarchidae, Upper Cretaceous, Volga Region, Russia.

Dedicated to the memory of Vitalii Georgievich Otchev

INTRODUCTION

The first reliable record of a pterosaur from Russia, i.e., a fragment of the posterior part of a cervical vertebra of a relatively large flying reptile referred to a distinct species, *Ornithostoma orientalis* Bogolubov, 1914 (Bogolubov, 1914), was described 90 years ago. The vertebra was found by the geologist V.G. Khimenkov in 1911 in the Campanian coastal beds near the village of Malaya Serdoba (Penza Region) and was accompanied by fossils of marine invertebrates and reptiles (Pervushov *et al.*, 1999). Bogolubov considered this specimen to be close to giant toothless pteranodontids of North America, which were up to 7 m in wing span (Bennett, 2001a, 2001b). For a long time, the eastern "*Ornithostoma*" was thought to belong to pteranodontids (Khozatsky and Yur'ev, 1964; Wellnhofer, 1978). Only much later, it turned out that this vertebra represented the first known specimen of a distinct group, the most evolutionarily advanced group of pterosaurs, the family Azhdarchidae, which was first recognized based on material from Uzbekistan (Nessov, 1984; Padian, 1986). The family comprises long-necked toothless flying reptiles, ranging from 2.5 to 12 m in wing span, including the largest known flying animals, the pterosaurs *Quetzalcoatlus*, *Hatzegopteryx*, and *Arambourgiania*. Azhdarchids first emerged in the Early Cretaceous and reached their acme and became almost cosmopolitan at the end of this period, in the Campanian–Maastrichtian (Fig. 1). Nessov was the first to recog-

nize that the vertebra from Malaya Serdoba belonged to an azhdarchid (Nessov and Yarkov, 1989) and placed "*Ornithostoma*" *orientalis* in a new genus, *Bogolubovia* Nessov, 1989. Bakhurina and Unwin (1995) regarded *Bogolubovia* as a nomen dubium, because they believed that the type material of *B. orientalis* was impossible to identify. The holotype of *B. orientalis* (Bogolubov, 1914, text-figs. 1, 2; the depository of the specimen is not given in the original description, and the specimen is probably lost) is the posterior part of a midcervical vertebra, most likely, vertebra 5. It substantially differs from all known cervical vertebrae of Azhdarchidae in the relatively high position of the spinal canal, the low condyle, and the well-developed postexpophyses. This corroborates that *Bogolubovia* is a valid taxon.

Nessov and Yarkov (1989) and Nessov (1990) mentioned a fragmentary humerus of Azhdarchidae from the Campanian beds near the village of Polunino in the Volgograd Region. However, in actuality, this is most likely a fragmentary proximal epiphysis of a humerus of Ornithocheiridae indet. (Averianov and Yarkov, 2004).

A new (second) azhdarchid specimen from the Volga Region was found by V.B. Sel'tser in 1986 in the Campanian coastal beds (Pudovkino Formation, *Belemnitelletta mucronata mucronata* Zone) in the western area of Saratov (Sed'maya Dachnaya locality, see Pervushov *et al.*, 1999). The specimen is a fragmentary distal part of the left radius of Azhdarchidae indet.

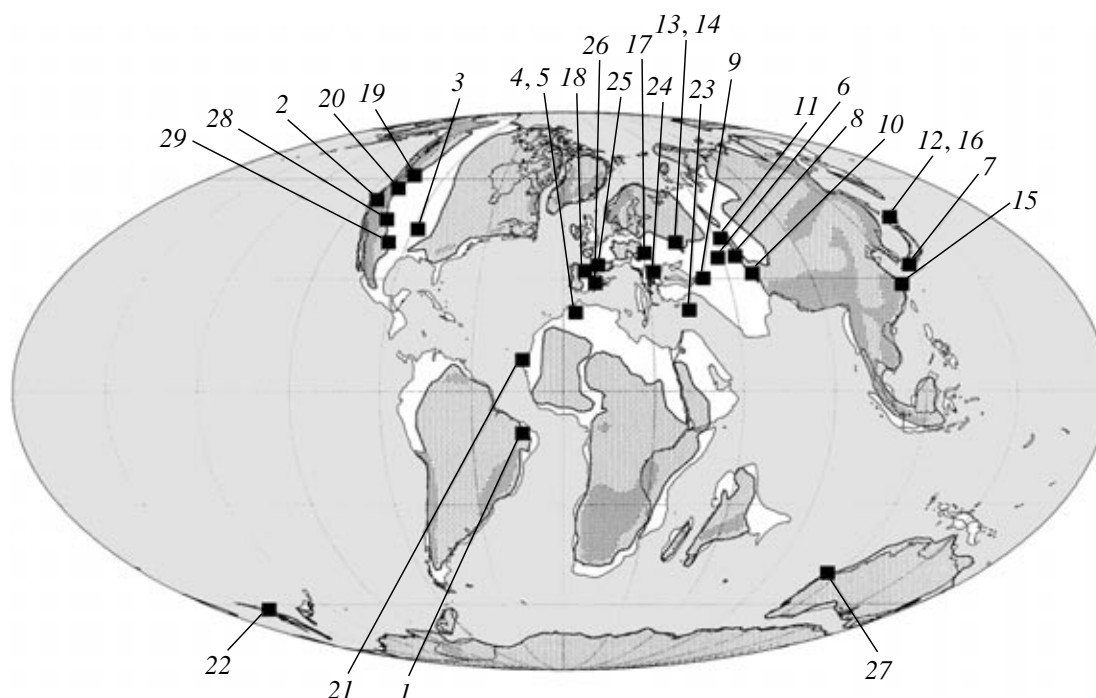


Fig. 1. Occurrences of pterosaurs of the family Azhdarchidae in the paleogeographical map of the Campanian Time (after Smith *et al.*, 1994). Designations: (1) Aptian of Brazil (Martill and Frey, 1999); (2, 3) Albian of the USA (Gilmore, 1928; Murry *et al.*, 1991); (4) Albian–Cenomanian of Morocco (Kellner, 1996); (5) Cenomanian and Maastrichtian of Morocco (Wellnhofer and Buffetaut, 1999; Pereda Suberbiola *et al.*, 2003); (6) Cenomanian of Uzbekistan (Nessov, 1990, 1997); (7) Cenomanian–Turonian of Japan (Ikegami *et al.*, 2000); (8) Turonian of Uzbekistan (Nessov, 1984, 1990, 1991a, 1991b, 1991c, 1997; Nessov and Yarkov, 1989; Bakhurina and Unwin, 1995; Unwin and Bakhurina, 2000); (9) Turonian of Armenia (Averianov and Atabekyan, 2005); (10) Santonian of Tajikistan (Nessov, 1997; Averianov, 2004); (11) Santonian–Campanian of Kazakhstan (Nessov, 1984; Averianov, 2004); (12) Santonian–Campanian of Japan (Obata *et al.*, 1972; Unwin *et al.*, 1997); (13, 14) Campanian of Russia (Bogolubov, 1914; this paper); (15) Campanian of China (Cai and Wei, 1994; Unwin and Lü, 1997); (16) Campanian of Japan (Chitoku, 1996; Unwin *et al.*, 1997); (17) Campanian of Australia (Wellnhofer, 1980); (18) Campanian of Spain (Buffetaut, 1999); (19) Campanian of Canada (Currie and Russell, 1982; Currie and Jacobsen, 1995); (20) Campanian of the USA (Padian, 1984; Padian and Smith, 1992; Padian *et al.*, 1995; McGowen *et al.*, 2002); (21) Campanian–Maastrichtian of Senegal (Monteillet *et al.*, 1982); (22) Campanian–Maastrichtian of New Zealand (Wiffen and Molnar, 1988); (23) Maastrichtian of Jordan (Arambourg, 1954, 1959; Frey and Martill, 1996; Steel *et al.*, 1997; Martill *et al.*, 1998); (24) Maastrichtian of Romania (Buffetaut *et al.*, 2002, 2003); (25) Maastrichtian of France (Buffetaut *et al.*, 1997; Buffetaut, 2001); (26) Maastrichtian of Spain (Company *et al.*, 1999); (27) Maastrichtian of Australia (Bennett and Long, 1991); (28, 29) Maastrichtian of the USA (Estes, 1964; Lawson, 1975; Langston, 1981; Kellner and Langston, 1996).

(specimen SGU, no. 104a/35). This material is described below.

The following abbreviations of institutions are used in the present study: (AMNH) American Museum of Natural History, New York, USA; (MOR) Museum of the Rockies, Bozeman, USA; (NSM) National Science Museum, Tokyo, Japan; (RGM) Nationaal Natuurhistorisch Museum, Leiden, Netherlands; (SGU) Saratov State University, Saratov, Russia; (TsNIGR Museum) Central Research Geological Exploration Museum, St. Petersburg, Russia; (YPM) Yale Peabody Museum, New Haven, USA; (ZIN) Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia.

GEOGRAPHICAL AND GEOLOGICAL POSITION OF THE OCCURRENCE

In the Campanian formations in the right-bank part of the Volga Region, there is a generally uniform phos-

phorite level that often forms a phosphorite horizon in particular sections. This event-driven formation has yielded most of the vertebrate specimens in the Penza, Saratov, and Volgograd regions. This level of phosphorite concentration was dated by complex and detailed paleontological studies as uppermost Lower Campanian–lowermost Upper Campanian ($K_2 \text{ Cmp}_1^3 - \text{Cmp}_2^1$). In the local stratigraphic scheme of the Upper Cretaceous beds, these formations (within connected structural–facies zones) are usually designated as the Pudovkino ($K_2 \text{ pd}$) or Rybushka ($K_2 \text{ rs}$) formations. The azhdarchid radius fragment was found in the western area of the Leninskii Administrative District of Saratov. In the course of geological surveillance and special studies in this area, an extended trench under the pipeline located about 50 m south of the tram line of tram route no. 3, between the stops “Sed'maya Dachnaya” and “Tekhnicheskoe Uchilishche” was repeatedly studied. In this artificial trench, which

existed for a long time, the boundary layers between Santonian and Campanian deposits were exposed. The significance of this locality is related to the extreme rarity of lowermost Campanian outcrops in the Saratov Depression, which is connected with their small thickness and the fact that these particular Upper Cretaceous rocks are usually turf-covered or closed by blocked landslide deposits. In this trench, a section of the terminal Upper Santonian (Mezino-Lapshinovka Formation, $K_2 ml$), glauconitic marl of the upper Lower Campanian and the lower Upper Campanian (Pudovkino Formation $K_2 pd$), and silicified clays of the middle part of the Upper Campanian (Ardym Formation $K_2 ar$) are exposed. The section is described in ascending order.

$K_2 San_2$ 1. Rhythmic alternation of dense bluish gray silicified clays (gaize) (layers 0.4 m thick) and siliceous black clays (layers about 0.2 m thick). The bed contains well-preserved, evenly distributed fine shells of the bivalves *Oxytoma tenuicostata* (Roemer, 1841) and *Liostrea vegmaniana* (d'Orbigny, 1845). Near the roof, there are numerous large (up to 2–3 cm in diameter) and small (1–2 mm) burrows of digging organisms filled with the rock from the overlying layer. Exposed thickness is up to 2 m.

$K_2 Cmp_2^1$ 2. Light gray, sandy, loose marl. The psammitic component is quartz-glauconitic, inequigranular, and mostly fine- and medium-grained. Inclusions of nonuniformly scattered brown phosphorites, irregular in shape and 2–10 cm in size are typical. These inclusions form accumulations at a depth of 0.5 m below the roof. Faunal remains are nonuniformly distributed within this bed and are mostly well-preserved. Fossil remains form accumulations at the same level as abiogenic phosphorite nodules. Skeletons of the sponges *Rhizopoterion cervicorne* (Goldfuss, 1833), *Lepidospongia concavexa* (Pervushov, 1998), and *Ortodiscus* sp.; shell of the oyster *Monticulina vesicularis* (Lamarck, 1809); molds of the bivalve *Inoceramus* cf. *balticus* Boehm, 1907; tests of *Echinocorys* sp.; molds of the ammonites *Pachydiscus* and *Baculites*, rostra of the belemnites *Belemnellocomax mammilatus* (Nilsson, 1827) and *Belemnitella mucronata* (Schlotheim, 1813) were recorded in this bed. The bed is 1.3 m thick.

$K_2 Cmp_2^1$ 3. Gray, with characteristic dark blue spots (tint) caused by nonuniform silicification, sandy marl. The silicified sites are very dense and resonant. Infrequent burrows of silt-feeders, which are filled with relatively loose marl, occur and form accumulations mostly in the roof of the bed. Distorted tests of the sea urchin *Echinocorys* sp., shells of the oysters *Kosmospirella* cf. *similis* (Pusch, 1837) and *Monticulina vesicularis* (Lamarck, 1809), and well-preserved rostra of *Belemnitella mucronata mucronata* (Schlotheim, 1813) are recorded. The bed is 0.6–0.8 m thick.

$K_2 Cmp_2^2$ 4. Rhythmically alternating gray silicified clays (gaize) (interlayers 0.3–0.5 m thick) and dark gray siliceous clays (layers 0.1–0.3 m thick). The bed contains infrequent and mostly poorly preserved rostra of the belemnite *Belemnitella langei* Jelezky, 1924. Exposed thickness is 2.0 m.

The pterosaur bone comes from Bed 3. It is accompanied by a slightly phosphatized tooth crown and a vertebra of Mosasauridae indet.

Vertebrates from the Upper Cretaceous, in particular, from the Campanian of the region considered, were found mostly in the right-bank part of the Volga Region. Localities of marine and coastal-marine vertebrates occur in zones of coastal regions and insular shoals, which resulted from condensed development of elevations. The locality described is situated within the steep southern wing of such an elevation. The reduced thickness and incomplete stratigraphic sequence of the Campanian strata, specific lithologic structure, and unusual oryctocenosis suggest uplifting processes in the Campanian of this area. At a distance of several kilometers south or west of this locality, the taxonomic composition and abundance of Campanian oryctocenoses are sharply reduced.

The burial was formed in conditions of an active bottom regime, with periodic storms. Representatives of the epibenthic fauna occur in subautochthonous burials, forming in places individual accumulations (composed of oyster shells and belemnite rostra). The nearby localities (Lysaya Gora and Polivanovka) with synchronous formations yielded small phosphatized wood fragments. In conditions of periodically mobile substrate, numerous and diverse digging and burrowing organisms developed. Vertebrate remains apparently underwent pronounced spatial scattering, and lateral transport (without clear size differentiation). This vertebrate locality can be assigned to a layered and rarefied type. It is hardly probable that autochthonous or concentrated allochthonous vertebrate burials could have been formed in this area.

DESCRIPTION

Specimen SGU, no. 104a/35 (Fig. 2) is a 45-mm-long distal fragment of the left radius. The greatest (ventrodorsal) width of its distal epiphysis is 31 mm, while the anteroposterior diameter is 24 mm. The bone is asymmetrical in both front and rear views: the ventral edge projects distally and ventrally relative to the dorsal edge. The posterior side adjoining the ulna is flat or slightly concave, with a shallow depression near the border of the distal articular facet. The pneumatic foramen (which is present in some azhdarchids in the center of this depression) is absent. The ventrodorsal corner of the posterior side is formed by a poorly pronounced articular facet (facies articularis ventralis) for a small detached facet on the proximal carpal. On the anterior side, a short but stout crest (“anterior tubercle” after

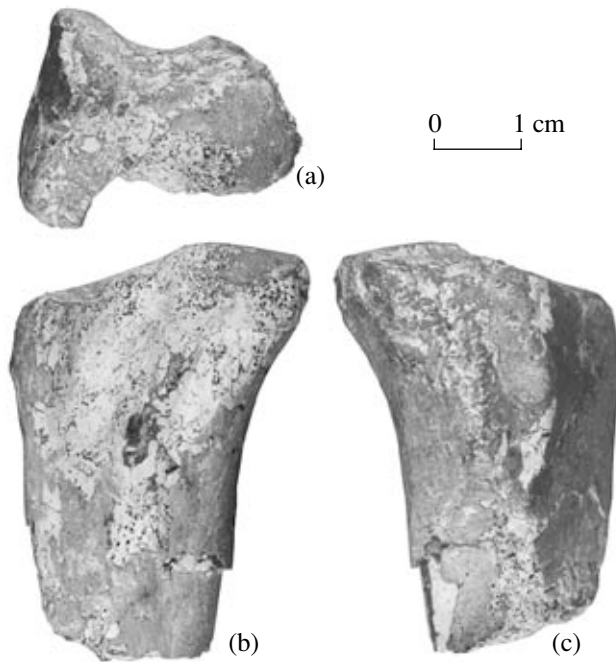


Fig. 2. Azhdarchidae indet., SGU, no. 104a/35, distal fragment of the radius: (a) distal, (b) frontal, and (c) rear views; Sed'maya Dachnaya locality, Saratov, Russia; Pudovkino Formation, *Belemnitella mucronata mucronata* Zone, Upper Campanian, Upper Cretaceous.

Bennett, 2001a) extends obliquely from the ventrodorsal corner in the proximal and somewhat dorsal direction and terminates within the fragment described. The transverse section of the epiphysis is T-shaped; its ventral margin is widened by the “anterior tubercle” projecting strongly anteriorly and by the ventral articular surface projecting posteriorly, which form an axis located at an angle of approximately 80° to the remaining part of the epiphysis, which is elongated ventrodorsally. The surface of the epiphysis is almost entirely occupied by a convex distal articular surface (facies articularis distalis), which is articulated with a large oval concave facet on the proximal carpal.

DISCUSSION

The radius (SGU, no. 104a/35) has a specific T-shaped distal region, since the ventral margin of the epiphysis is widened anteroposteriorly and positioned at a right angle to the narrow remaining part of the epiphysis. The same structure of the radius is characteristic of pterosaurs from the monophyletic group Dsungaripteroidea (Germanodactylidae and Dsungaripteridae) + Azhdarchoidea (Tapejaridae and Azhdarchidae). It is described in dsungaripterids (Young, 1964, text-fig. 4A [the bone was incorrectly determined as the humerus]; Bakhurina, 1982, text-fig. 1c), the tapejarid “*Santanadactylus spixi* Wellnhofer, 1985 (Wellnhofer, 1985, text-fig. 25C), and azhdarchid. The specimen from Saratov is closer to azhdarchids in the short ventrodorsal diameter of the distal epiphysis. Among the azhdarchids, the structure of the distal epiphysis of the radius is known in *Azhdarcho lancicollis* Nessov, 1984 from the Turonian of Uzbekistan (Nessov, 1984, pl. 7, figs. 8a, 8b; 1997, pl. 14, figs. 13a, 13b [the bone was incorrectly determined as ulna]; Averianov and Atabekyan, 2005, text-figs. 2f–2j); *Montanazhdarcho minor* Padian *et al.*, 1995 from the Campanian of the United States (McGowen *et al.*, 2002, text-fig. 2D); and in cf. *Quetzalcoatlus* sp. from the Campanian of the United States (Padian, 1984, text-figs. 1E–1G; Padian and Smith, 1992, text-fig. 2). Specimen SGU, no. 104a/35 differs from *Montanazhdarcho* and cf. *Quetzalcoatlus* in the absence of a large pneumatic foramen on the posterior side. *Azhdarcho* also lacks this foramen (contra McGowen *et al.*, 2002). Only one juvenile (TsNIGR Museum, no. 10/11915; Nessov, 1984, pl. 7, fig. 8b) has a series of small foramina in the distal depression on the posterior side at the border of the distal articular facet. In larger (probably adult) individuals (specimens ZIN PH, nos. 1/44 and 28/44) these foramina are absent. The radius described differs from this bone of other azhdarchids in the asymmetrical distal epiphysis: its ventral edge sharply projects distally and ventrally with reference to the dorsal edge. In other azhdarchids, the distal epiphysis of the radius is almost symmetrical in front or rear views. It is evident that specimen SGU, no. 104a/35 does not

The ratio of the maximum width of the distal epiphysis of the radius (X) to the reconstructed wing span (Y) in large pterodactyloids (in m)

Taxon, specimen	X	Y	Reference
<i>Coloborhynchus santanae</i> , AMNH, no. 22555	0.033	4.15	Wellnhofer, 1991
<i>Coloborhynchus piscator</i> , NSM PV, no. 19892	0.039	5.00	Kellner and Tomida, 2000
<i>Coloborhynchus spielbergi</i> , RGM, no. 401880	0.040	5.90	Veldmeijer, 2003
<i>Pteranodon</i> sp., YPM, no. 42819	0.020	3.35	Bennett, 2001a, 2001b
cf. <i>Quetzalcoatlus</i> sp., YPM PU, no. 22446	0.061	8.25*	Padian, 1984; Padian and Smith, 1992
<i>Montanazhdarcho minor</i> , MOR, no. 691	0.019	2.50	McGowen <i>et al.</i> , 2002

* The mean of reconstructed values, ranging from 7.5 to 9.0 m.

belong to any azhdarchid taxon in which the structure of the radius is known.

The ratio of the greatest width of the distal epiphysis of the radius (X) to the reconstructed wing span (Y) in large pterodactyls is described by the following regression formula (table; correlation coefficient $r = 0.98$, $p < 0.05$):

$$Y = 0.278 + 129.634X \text{ (m)}.$$

Based on the value of the first parameter in specimen SGU, no. 104a/35 ($X = 0.031$ m), the wing span $Y = 4.3$ m. In *A. lancicollis*, the estimated wing span is 3.8 m ($X = 0.027$ in ZIN PH 1/44). This agrees with the value 3–4 m proposed for this species by Bakhurina and Unwin (1995). Nessov (1991a, text-fig. 1) reconstructed this pterosaur and estimated its wing span as 4.8 m (4.4 m after McGowen *et al.*, 2002). Among the specimens of *A. lancicollis* from Uzbekistan, two radii (ZIN PH, nos. 1/44 and PH 28/44) are almost identical in size and probably characterize the maximum size of mature adults (pterosaurs, like birds and mammals and unlike other reptiles, stopped growing at maturity). The majority of other identifiable bones of *A. lancicollis* from Dzharakuduk fall into this size class. Only one zygopophys of a cervical vertebra belongs to a much larger reptile; however, it is impossible to assign it with certainty to the same species or even to pterosaurs. Thus, the maximum wing span of *A. lancicollis* was likely 3.5–4.0 m. Approximately the same wing span (3.5 m) was characteristic of the azhdarchid *Zhejiangopterus* from the Campanian of China represented by complete skeletons (Cai and Wei, 1994; Unwin and Lü, 1997). *Montanazhdarcho* from the Campanian of the United States was substantially smaller, only 2.5 m in wing span of adults (Padian *et al.*, 1995; McGowen *et al.*, 2002). Giant azhdarchids are only represented by the Maastrichtian *Quetzalcoatlus* (up to 11–12 m in wing span: Lawson, 1975; Langston, 1981), *Hatzegopteryx* (12 m or more in wing span: Buffetaut *et al.*, 2002), and *Arambourgiania*, which was probably even larger. The azhdarchid from the Campanian of Saratov (4.3 m in wing span) and *Bogolubovia orientalis* from the Campanian of Malaya Serdoba (3–4 m in wing span: Bakhurina and Unwin, 1995) belong to the same size class and are somewhat larger than *Azhdarcho*. Taking into account the similarity in size, geographical proximity, and occurrence in the same stratigraphic level (Campanian Stage), it is logical to assume that they belong to the same taxon. Gaining a complete understanding of this question will require a find of a complete skeleton that would have cervical vertebrae characteristic of *Bogolubovia* and radius of the same structure as described above. However, this is highly unlikely because of the extreme rarity and fragmentary nature of such finds in the Upper Cretaceous of the Volga Region (only two incomplete bones were found during 100 years). The bone from Saratov is formally determined by us as Azhdarchidae indet.

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