



## A new ctenochasmatid pterosaur from the Lower Cretaceous, western Liaoning, China

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### ABSTRACT

A nearly complete skull of a new ctenochasmatid pterosaur, *Pterofiltus qiui* gen. et sp. nov., from the Lower Cretaceous deposits of Liaoning, China, is described here. The specimen (IVPP V12339), was collected from the shale of the lower Yixian Formation (125 Ma) at the Zhangjiagou locality. It has the following combination of characters: about 112 teeth in total (including the upper and lower jaws); the dentition occupies more than 50% of the skull length; the anterior teeth vary in size; the mandibular symphysis is longer than half of the whole mandible length; in ventral view, an apparent symphyseal trough in the median part of the symphysis.

**Key words:** Lower Cretaceous, Yixian Formation, *Pterofiltus qiui*, Ctenochasmatidae, Liaoning, China.

### INTRODUCTION

The pterosaur record from China has yielded several important new taxa due to the collecting activities done particularly in western Liaoning (e.g., Wang et al. 2009, 2010). The most important deposits are known as the Jehol Biota that comprises numerous articulated fossils, from plants and insects to all kinds of vertebrates, making it one of the most amazing terrestrial Cretaceous ecosystems in the world (Chang et al. 2003, Zhou et al. 2003, Wang et al. 2008, Zhou and Wang 2010).

Since the first description of a pterosaur in 1997 (Ji and Ji 1997), many more pterosaur fossils have been discovered in the Jehol Biota. Among them, four ctenochasmatids play an important role in the pterosaur research: *Beipiaopterus chenianus* (Lü 2003), *Cathayopterus grabaui* (Wang and Zhou 2006), *Gegepterus changae* [nom. correct. Wang and Dong 2008 (pro

*Gegepterus changi* Wang et al. 2007)] and *Elanodactylus prolatus* (Andres and Ji 2008). Most of them come from the Jianshangou Bed of the lower Yixian Formation, except *Cathayopterus* from the Dawangzhangzi Bed of the middle Yixian Formation.

Recently, another interesting specimen of a ctenochasmatid pterosaur was discovered from the Zhangjiagou locality near Beipiao City, Liaoning Province (Fig. 1). In the same locality, there are many other vertebrate fossils such as *Dendrorhynchoides curvidentatus* (Ji and Ji 1998, Wang and Lü 2001), *Protarchaeopteryx robusta* (Ji et al. 1998), *Caudipteryx dongi* (Zhou and Wang 2000), *Caudipteryx zoui* (Ji et al. 1998), and an immature iguanodontian. The specimen V 12339 consists of most part of skull and mandibles and was collected from the Jianshangou Bed of the lower Yixian Formation. It represents a new genus and species, *Pterofiltus qiui*, which is described here. Additionally, we discuss the relationship between the new taxon and other ctenochasmatid pterosaurs.

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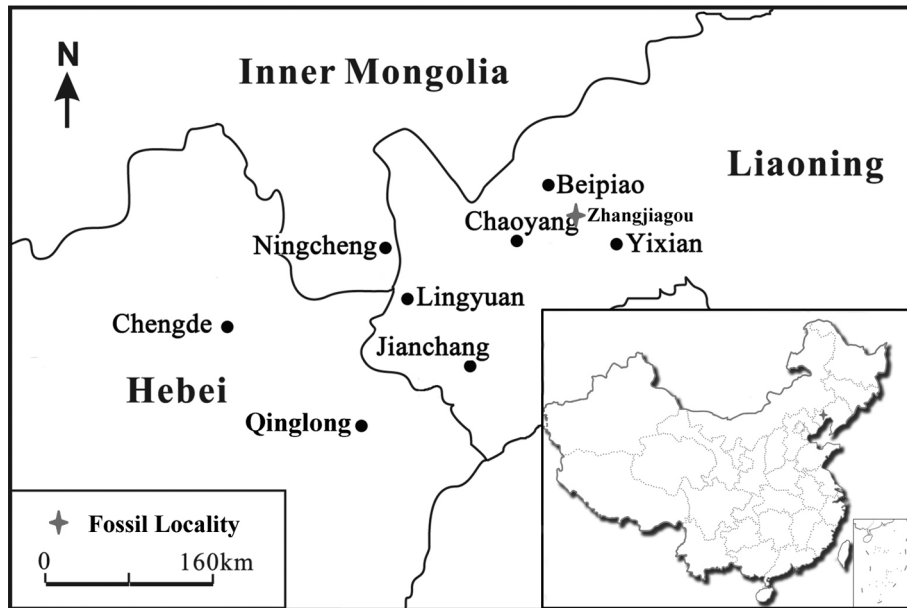


Fig. 1 – Sketch of the map of China with the indication of the fossil locality.

#### SYSTEMATIC PALEONTOLOGY

Pterosauria Kaup, 1834

Pterodactyloidea Plieninger, 1901

Archaeopteroactyloidea Kellner, 2003

Ctenochasmatidae Nopcsa, 1928

*Pterofiltrus* gen. nov.

**Etymology** – *ptero-*, from *pteron* (Greek), means wing; *filtrus*, from *filtrum* (Medieval Latin), means filter.

**Type species** – *Pterofiltrus qiu* gen. et sp. nov.

**Diagnosis** – As for the species.

*Pterofiltrus qiu* sp. nov.

**Etymology** – In honor of Prof. Qiu Zhanxiang, who has made great contributions to the Chinese paleontology.

**Type specimen** – IVPP V12339 (Fig. 2), most part of skull and mandible, and first two cervical vertebrae, housed in the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Chinese Academy of Sciences, Beijing, China.

**Locality and horizon** – Zhangjiagou, Beipiao City, Liaoning Province, China. Jianshangou Bed, lower Yixian Formation, Lower Cretaceous, about 125 Ma (Swisher et al. 2001).

**Diagnosis** – A Ctenochasmatid pterosaur with the following combination of characters that distinguish it from the other members of this clade (autapomorphies are marked with an asterisk): about 112 teeth in total (including the upper and lower jaws); the dentition occupies more than 50% of the skull length; the anterior teeth vary in size; the mandibular symphysis is longer than half of the whole mandible length\*; in ventral view, an apparent symphyseal trough in the median part of the symphysis\*.

#### DESCRIPTION

IVPP V12339 preserves nearly all elements of the skull, but they are not articulated (Fig. 2A, B). The estimated length of the skull is 208 mm. The rostrum and the posterior part of the skull can be observed in both right and dorsal sides, respectively. The mandibles are preserved dorsoventrally flattened. Their posterior and anterior parts are respectively preserved in the dorsal and ventral sides, as the anterior part was turned over (Fig. 2C; showing the relationship of the main elements).

#### PREMAXILLA AND MAXILLA

The premaxilla and maxilla are fused, and the suture between them is unclear (Fig. 2A, B, D). The premaxilla is very long, and it is estimated to extend to the posterior end of the nasoantorbital fenestra. The anterior tip

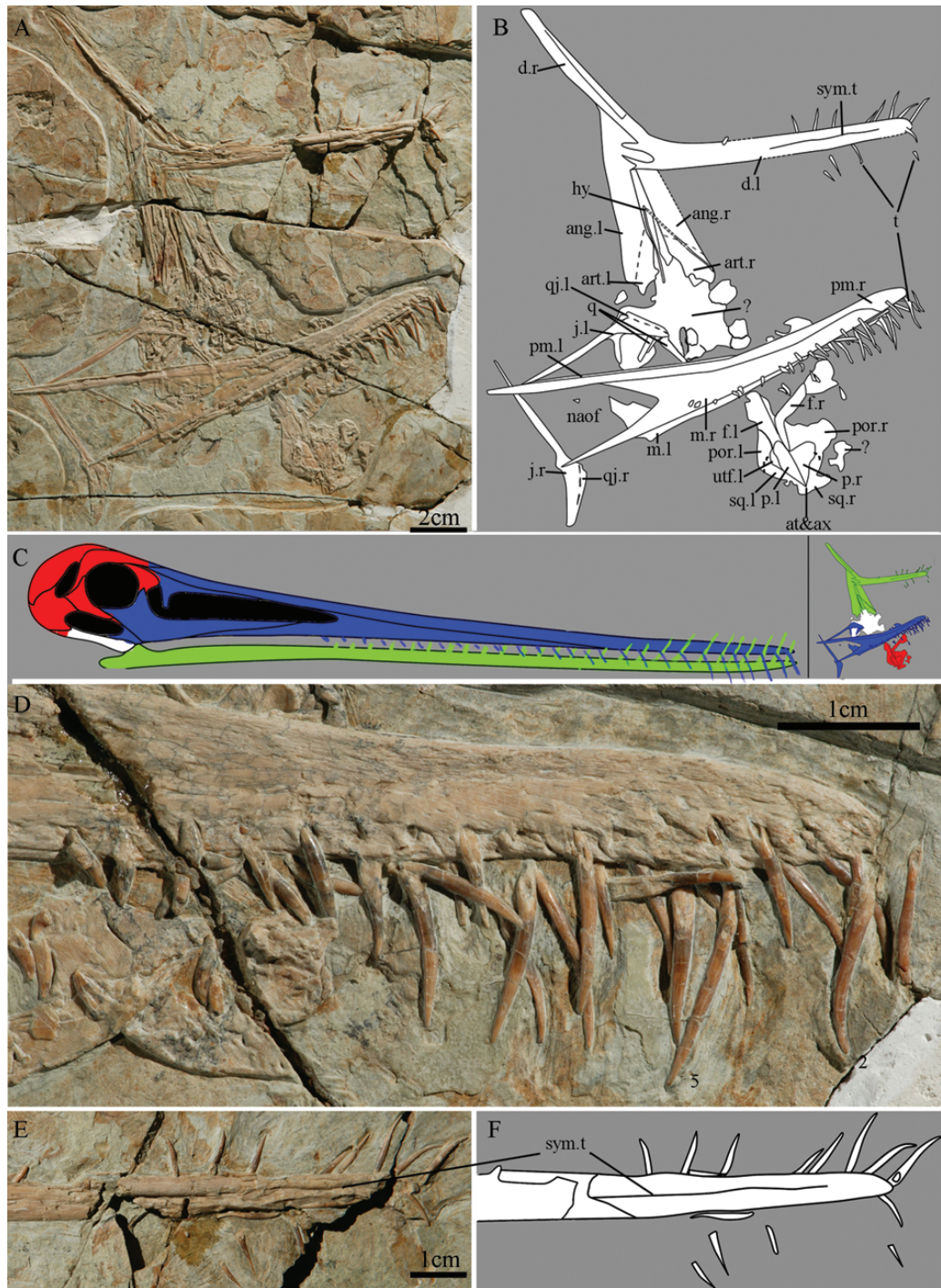


Fig. 2 – *Pterofiltrus qiu* gen. et sp. nov., IVPP V12339; photograph (A); line drawing (B) showing the general position of the elements; their relationship (C), blue, rostrum; green, mandible; red, posterior part of the skull; white, indeterminate; The anterior teeth in the upper jaw, the teeth are numbered based mainly on the presence of the alveoli. The 2<sup>nd</sup> and 5<sup>th</sup> teeth are the longest ones (D); photograph (E) and line drawing (F) of the anterior mandibles, the teeth are directed laterally, and the anterior teeth directed anterolaterally, which is an important feature of Ctenochasmatidae. ang, angular; art, articular; at, atlas; ax, axis; d, dentary; f, frontal; hy, hyoid; j, jugal; m, maxilla; naof, nasoantorbital fenestra; p, parietal; pm, premaxilla; por, postorbital; q, quadrate; qj, quadratojugal; sq, squamosal; sym.t, symphyseal trough; t, tooth; utf, upper temporal fenestra; l, left; r, right.

of the premaxilla is not expanded like in some other ctenochasmatids, such as *Plataleorhynchus* and *Gnathosaurus* (Howse and Milner 1995). There is no crest on the maxilla or premaxilla. The maxilla is separated from the jugal, and exceeds the middle of the nasoant-orbital fenestra, forming the ventral margin of the nasoantorbital fenestra.

There are 29 teeth on each side. The number of the teeth is mainly based on the alveoli on the specimen. The diameter of the anterior alveoli nearly equals the distance between two teeth. The density of them is 3.4 teeth/cm (15 teeth/4.4 cm). The teeth are inclined anteriorly, and the inclination angle becomes smaller from the anterior portion to the posterior portion. The anterior teeth have a 135° angle to the ventral margin of the premaxilla, but the last few ones are nearly vertical. The anterior teeth vary in size. The 2<sup>nd</sup> and 5<sup>th</sup> teeth are the longest ones (Fig. 2D). The alveoli become shallower posteriorly. The teeth also become smaller and vary in shape. The anterior and posterior teeth are slender and triangular, respectively. The whole tooth row is about 116 mm long, 55.8% of the skull length, having a 2.5 teeth/cm density on average.

#### JUGAL, QUADRATOJUGAL AND QUADRATE

Both jugals are preserved, but not in their original anatomic position. The right jugal is complete, and it is a triradiate bone. The anterior process is thin, smooth and very long, nearly 70% of the jugal length. The right dorsal process, which is in contact with the lacrimal, is preserved in a 60° angle with the anterior process. Only some broken process remains on the left jugal. On the ventral side of the left jugal, the posterior process is fused with the quadratojugal, forming the anterior margin of the lower temporal fenestra, which is surrounded by the jugal, quadrate, quadratojugal, squamosal, and postorbital.

The quadratojugal is a V-shaped bone. One end fuses with the jugal without any perceptible suture, and the other one would fuses with the quadrate. However, a small glenoid cavity is found at the bottom of each quadratojugal where it would be in contact with the quadrate. In the specimen, some fragmentary bones are located between the upper and lower jaws. Two stick-like bones may both be quadrates. The putative right quad-

rate has an expanded end, which would connect with the articular. The other end is laid by the premaxilla.

#### FRONTAL, PARIETAL AND SQUAMOSAL

The posterior portions of both frontals are preserved. They are fused together and no suture can be observed. They taper posteriorly and wedge into the middle of the both parietals. There is no crest on the frontals. The right frontal is broken, and the upper temporal fenestra cannot be recognized. The left frontal is well preserved, surrounding the upper temporal fenestra with the parietal, squamosal, and postorbital. Because of the preservation, the posterior part of the eye socket is overlaid, and part of the upper temporal fenestra is visible.

Both parietals are fused together, and have a groove in the middle. The parietal is very smooth, and it is easy to distinguish it from the other bones. There is also no crest on the parietals. The squamosal is not well preserved. Only the outline can be recognized and the details are lost.

#### MANDIBLE

Both mandibles are narrow, with about 174 mm length. Both retroarticular processes are developed. The outlines of the angular and the surangular cannot be recognized. The dentary is the largest bone in the lower jaw. The tip of the dentary is not expanded. The anterior portions fuse together, forming a symphysis, which bears an apparent symphyseal trough in the ventral side (Fig. 2E, F). The symphyseal trough is nearly 5 mm depth and fills 26% of the mandible length. The surface of the symphysis is smooth. The symphysis occupies 58% of the mandible length.

The mandibles also have slender teeth. Because some teeth are lost and the alveoli are not exposed, the number of teeth is not certain. Considering the length of the tooth row, it should nearly subequal that of the upper jaw, so it may have 27 teeth per side. The mandible is preserved dorsoventrally flattened; the teeth are directed laterally, and only the anterior teeth are directed the anterolaterally (Fig. 2E, F).

#### HYOID

Although the anterior part of the hyoid is absent, both posterior rami are preserved. They are separated.

## VERTEBRAE

Only the first two cervical vertebrae, atlas and axis are preserved. They are fused together and their outline is not very clear.

## COMPARISON AND DISCUSSION

The Ctenochasmatidae is part of the clade known as Archaeopterodactyloidea (Kellner 2003). *Pterofiltrus qiui* is assigned to the Ctenochasmatidae based on the extremely elongated rostrum, a large number of slender teeth, and the upper anterior teeth inclined ventro-anteriorly.

There are five genera and species of ctenochasmatids reported in China (Dong 1982, Lü 2003, Wang and Zhou 2006, Wang et al. 2007, Andres and Ji 2008). *Beipiaopterus* and *Elanodactylus* are known only postcranial skeletons, which cannot be compared with the holotype of *Pterofiltrus*, whereas *Huanhepterus*, *Cathayopterus* and *Gegepterus* have partial or nearly complete skulls.

*Cathayopterus* and *Pterofiltrus* share some important features. For example, the amounts of the teeth are similar, and the ratio of rostrum to skull length is more than 50% (Wang and Zhou 2006). However, they have some significant differences. The teeth row of *Pterofiltrus* exceeds the anterior margin of the nasoantorbital fenestra, while that of *Cathayopterus* does not reach the nasoantorbital fenestra. The teeth shapes are different in both pterosaurs. *Cathayopterus* lost the last few teeth, and only the alveoli left. The preserved teeth are slender, and only vary in size from the anterior to the posterior region. In *Pterofiltrus*, the teeth can vary both in size and in shape, from the slender ones in the anterior portion to the triangular ones in the posterior portion.

*Gegepterus* has more complete and articulated skulls than that of *Pterofiltrus* (Wang et al. 2007, Jiang and Wang 2011). It has a very low premaxillary crest, not found in *Pterofiltrus*. Although some authors consider the cranial crests in the skull is considered as sexual dimorphism in some genera (for instance, Lü et al. 2011), this difference may not only related to sexual dimorphism, but also to an interspecific difference (Kellner 2010). The teeth of both pterosaurs are slender, but the posterior teeth of *Pterofiltrus* are triangu-

lar and reach the anterior margin of the nasoantorbital fenestra. The posterior teeth of *Gegepterus* are still slender, and the last tooth has a distance to the anterior margin of the nasoantorbital fenestra.

*Huanhepterus* has a skull (Dong 1982). Most elements of the postcranial skeleton are absent, but left some three dimensional impression in the sandstone. Although *Huanhepterus* is not complete, it is obviously larger than *Pterofiltrus*. *Huanhepterus* has an apparent crest beginning at the anterior portion of the premaxilla, which is absent in *Pterofiltrus*. *Huanhepterus* has about 25 teeth per jaw side, slightly fewer than *Pterofiltrus* (27-29 teeth per jaw side). The density of teeth in *Huanhepterus* (1.6 teeth/cm) is less than that in *Pterofiltrus* (2.5 teeth/cm). All teeth in *Huanhepterus* are similar, and they are not as slender as in other ctenochasmatids.

Compared with other ctenochasmatid pterosaurs, *Pterofiltrus* is unique. *Pterodaustro* from the Lagarcito Formation, Lower Cretaceous of Argentina, is very specialized, with nearly a thousand needle-like teeth on the upper jaws (Chiappe et al. 2000), and it is easy to distinguish it from *Pterofiltrus*. *Ctenochasma* has three species, including *C. roemeri*, *C. elegans* and *C. taqueti* from the Upper Jurassic Solnhofen Limestone of Bavaria, Germany, Upper Jurassic *Calcaires tachetés* of eastern France and Lower Cretaceous "Purbeck" Formation of Deister Hill, Germany. *Ctenochasma* has more than 50 teeth per jaw side (Bennett 2007), and their density is much greater than in *Pterofiltrus*. *Plataleorhynchus* from the Upper Jurassic or Lower Cretaceous Purbeck Limestone of Dorset, England, has only the part of the rostrum preserved, with an estimated skull length of at least 400 mm, nearly twice of that in *Pterofiltrus* (208 mm). Furthermore, *Plataleorhynchus* has an expanded spatulated rostrum (Howse and Milner 1995), which differs from *Pterofiltrus*. *Gnathosaurus*, including *G. subulatus* and *G. macrurus* from the Solnhofen Limestone and Purbeck Limestone, respectively, have expanded anterior tips and maxillary crests, which cannot be found in *Pterofiltrus*. The symphyseal portion of the mandible is about 40% and 58% in *Gnathosaurus* and *Pterofiltrus*, respectively. We observed a symphyseal trough on the dorsal side of the mandible in *Pterofiltrus*, while the symphyseal trough is found on the ventral side in *Gnathosaurus macrurus* (Howse and Milner 1995).

*Boreopterus*, from the Yixian Formation, resembles *Pterofiltus* regarding the very slender teeth of the rostrum tip (Lü and Ji 2005). The most marked difference is the direction of the teeth. In *Boreopterus*, the teeth are inclined anteriorly, while in *Pterofiltus*, they are inclined not only anteriorly but also ventrally, which is a significant character of the Ctenochasmatidae.

#### CONCLUSIONS

Based on a series of combination of characters, the new genus and species *Pterofiltus qiui* is established. The Jehol Biota comprises many pterosaurs and ctenochasmatids play a very important role. The amount of clade members is not big, but this clade has more taxa than many others. This new member provides further information on the global distribution of the ctenochasmatid, in Asia, Europe and America (Rodrigues and Kellner 2010).

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#### RESUMO

Um crânio quase completo de um novo pterossauro ctenochasmatídeo, *Pterofiltus qiui* gen. et sp. nov., de depósitos do Cretáceo Inferior de Liaoning, China é descrito. O exemplar (IVPP V12339) foi coletado de um argilito da parte inferior da Formação Yixian (125 Ma) na localidade Zhangjiagou. A nova espécie possui a seguinte combinação de caracteres: aproximadamente 112 dentes (incluindo ambas as arcadas); dentição ocupando mais de 50% do comprimento do crânio; dentes anteriores de tamanho variado; sínfise mandibular ocupando mais

da metade do comprimento da mandíbula; abertura ventral na parte média da sínfise mandibular.

**Palavras-chave:** Cretáceo Inferior, Formação Yixian, *Pterofiltus qiui*, Ctenochasmatidae, Liaoning, China.

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