New Data on *Shenzhoupterus chaoyangensis,*

an Unusual Lower Cretaceous Pterosaur

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Abstract

A recently described specimen of a new genus of pterosaur from the Lower Cretaceous Jiufotang Formation of northeastern China, *Shenzhoupterus chaoyangensis*, was assigned to the Chaoyangopteridae within the Azhdarchoidea. Originally the posterior skull was traced as an indistinct sheet with only a drop-shaped orbit piercing it at mid-height. That morphology would be atypical for pterosaurs, but a low orbit is found in azhdarchids. A first-hand observation provided new data. Here a new technique, known as Digital Graphic Segregation (DGS), enabled the identification of every bone in the chaotic jumble of the posterior skull and a new reconstruction of the specimen's "face" in which the orbit was very high on the skull and otherwise more in accord with other pterosaurs. Other purportedly missing elements including the pelvis, prepubis, pteroid and sternal complex were also identified. A new reconstruction of Shenzhoupterus demonstrates very few synapomorphies with *Chaoyangopterus,* but several with tapejarids and dsungaripterids.

Keywords Azhdarchoidea. *Shenzhoupterus*. Pterosaur. Lower Cretaceous. China

Introduction

Lü et al. (2008) described and named a new genus of pterosaur from the Lower Cretaceous Jiufotang Formation of northeastern China, *Shenzhoupterus chaoyangensis* (Figs. 1-4). Presently this genus is represented by the holotype, a complete skull and postcranial skeleton (HGM 41HIII-305A, Henan Geological Museum, Zhengzhou, China). Lü et al. (2008) reported, "The skull lies on its right side and is heavily compressed especially the cranium, some elements of which are indistinct and not well preserved, although the orbit and nasoantorbital opening can be identified." They also reported the spinal column was poorly preserved and indistinct (Fig. 1a). They identified the orbit as, "relatively small, pear-shaped and situated well below the dorsal margin of the nasoantorbital fenestra." They reported the scapula was longer and more slender than the coracoid and that the deltopectoral crest of the humerus was "markedly elongate." In the original tracing of these elements (Fig. 1a), the left and right coracoids, scapulae and humeri did not match their counterparts in length, width or overall shape. Lü et al. (2008) did not identify any caudal or pelvic elements and considered the fifth pedal digit absent.

Lü et al. (2008) assigned *Shenzhoupterus* to the Chaoyangopteridae, which they erected within the Azhdarchoidea. According to Lü et al. (2008), "Members of Chaoyangopteridae are distinguished from all other pterosaurs by an unusually slender premaxillary bar bounding the nasoantorbital opening and extension of the nasoantorbital opening posterior to the jaw joint." Lü et al. (2008) reported that *Shenzhoupterus* had distinct limb bone proportions from other chaoyangopterids. The rostral index (length of prenarial rostrum to depth) and the concave upper jaw line were also considered distinct.

An examination of the specimen revealed several overlooked elements and some misidentified bones. Here certain errors and omissions were rectified, shedding new light on this unique pterosaur.

Materials and Methods

The holotype of *Shenzhoupterus* was examined first hand in August 2010 in Beijing during the third Flugsaurier Conference. Several digital photographs of the specimen were taken and later opened in Adobe Photoshop (v. 10.0.1, Knoll et al. 2007), a graphics software program. Using the "layers" palette, colors were applied to identify bones (Fig. 1). This technique is called Digital Graphic Segregation (DGS). These layers of color were later traced with black outlines and the outlines were later moved into typical pterosaur positions to create reconstructions (Figs. 2, 3). Nosotti (2007) also used this method to great advantage.

Redescription

Lü et al. (2008) accurately described most of *Shenzhoupterus*. Wherever they had difficulties the new technique was able to segregate and identify tentative, missing and misidentified elements.

The posterior of the skull (Fig. 2a) was not a solid sheet of bone pierced only by an orbit (contra Lü, et al. 2008; Fig. 1a, 2c). As would be expected in a crushed pterosaur, both sides of the skull were smashed together along with the overlying occipital elements which all fell onto the bedding plane atop one another. Creating more chaos in the lower cheek area there was an underlying sternal complex (fused sternum plus clavicles plus interclavicle, Fig. 2), which was considered absent originally (Lü, et al. 2008). The jugal was correctly identified in Lü et al. (2008), but the purported orbit was misidentified with its upper boundary at the displaced foramen magnum. The actual scleral rings were located high on the skull. The actual orbit was an extremely elongated opening bound by extremely slender processes of the jugal and lacrimal (Fig. 2b, 3). This morphology is similar, but not homologous, to the morphology of the Isle of Wight pterosaur, *Istiodactylus* (Howse, Milner & Martill, 2001). No doubt such a slender morphology was associated with the development of the atypically tall antorbital fenestra. With regard to phylogenetic scoring, such a high orbit would not be considered similar to that of azhdarchids.

Lü et al. (2008) failed to note that *Shenzhoupterus* had a slender elongated premaxilla/frontal crest extending beyond the posterior of the skull, as in dsungaripterids and especially tapejarids. The squamosal created a strong paroccipital process, as in dsungaripterids. The lacrimal sent new processes to the postorbital, dividing the orbit into upper and lower portions, as in dsungaripterids (Figs. 1-3).

Lü et al. (2008) failed to note the three anteriormost cervicals were still in articulation with number four near the jaw joint (Fig. 2). The dorsals were not indistinct, but they were all compressed such that the distance between the scapula and ilium had been reduced to half the length of a scapula. Lü et al. (2008) failed to identify the string of tiny caudal vertebrae (Fig. 1) that curled back toward the torso.

Lü et al. (2008) correctly identified the scapula and coracoid closest to the body, but reversed the true identities of the more distant scapulocoracoid elements. Here (Fig. 1), both elements are identical in size and shape to their counterparts. Lü et al. (2008) correctly identified the right humerus, but the left humerus is probably hidden beneath the vertebral column. What Lü et al. (2008) identified as the left humerus is actually the much more slender left prepubis, along with the right prepubis behind it, plus a broken rectangular unidentified bone. Lü et al. (2008) failed to identify a single pteroid, but both are identified here (Fig. 2). A tiny ungual appears just off the tip of the better-preserved fourth wing phalanx (Fig. 4) which is tipped with a trochlear joint.

Lü et al. (2008) did not identify the left pelvis and prepubis crushed in place. The pelvis is slender in general morphology with a diverging pubis and ischium. The posterior ilium includes an anterior process. The prepubis is deeper than the pelvis and provided with a distal perforation.

In their tracing, Lü et al. (2008) did not attempt to delineate the phalanges or separate one pes from another (Fig. 1a). They described the fifth metatarsal as “short and spur-like” and without any phalanges. Actually the fifth toe is present on both pedes, but it is a slender elongated vestige. Here (Fig. 1d) all the pedal phalanges are identified.

Discussion

A reconstruction of *Shenzhoupterus* (Fig. 3e-i) indicates it was clearly distinct from *Chaoyangopterus* (Fig. 3a). The antorbital fenestra did not extend posterior to the jaw joint. The orbit was not lower than the upper rim of the antorbital fenestra. Manual and pedal phalangeal patterns were not similar. The sternal complex had a distinct shape in each. A complete phylogenetic analysis is beyond the scope of this short report, but is part of another study currently in review. *Shenzhoupterus* does share several synapomorphies with tapejarids including a downturned rostrum, elongated posteriorly-directed crest, a square sternal complex, a short deep torso, distinct manual and pedal phalanx proportions and other traits.

The technique of using digital images to gather data and trace specimens has been widely employed (e.g. Nosotti 2007) and it was again successful here. The technique of Digital Graphic Segregation (DGS) enabled the identification of several previously unidentified and misidentified elements that were nearly matched in sister taxa. Lü et al. (2008) were unable to segregate the elements gathered at the face of *Shenzhoupterus* using visual inspection alone. The visual inspection problem is multiplied in figure 2a by the loss of color and the reduction in resolution that were necessary for publication. Nevertheless, a careful comparison of the map-like tracing in figure 2c with the photo in figure 2a will reveal certain bone outlines that are more prominent than others. The fact that all the bones could be digitally moved into place on the reconstruction and that they all fit together precisely gives certain assurance that the bones were correctly identified. The identification of pelvic, sternal and occipital elements previously ignored or considered missing adds evidence that this was indeed a complete and largely articulated specimen

As in any scientific experiment, the method must be followed using the prescribed instrument(s) in order for results to match. One cannot hope to understand microbes without a microscope and stars without a telescope. The chaotic jumble certain parts of this fossil present can only be understood by picking them apart, piece by piece until no pieces are left. This can only be done using a digital image on a computer screen. The human eye was proven to be incapable, as reported by Lü et al. (2008).

Conclusions

The specimen of *Shenzhoupterus* was reexamined and more data was gleaned from the fossil using the technique of Digital Graphic Segregation (DGS). Several bones were newly identified and a few misidentified bones were correctly identified. The bones of the face were resolved and mapped. A sternal complex was discovered beneath the right cheek. Rather than demonstrating affinities with *Chaoyangopterus*, *Shenzhoupterus* shared more synapomorphies with tapejarids and dsungaripterids.

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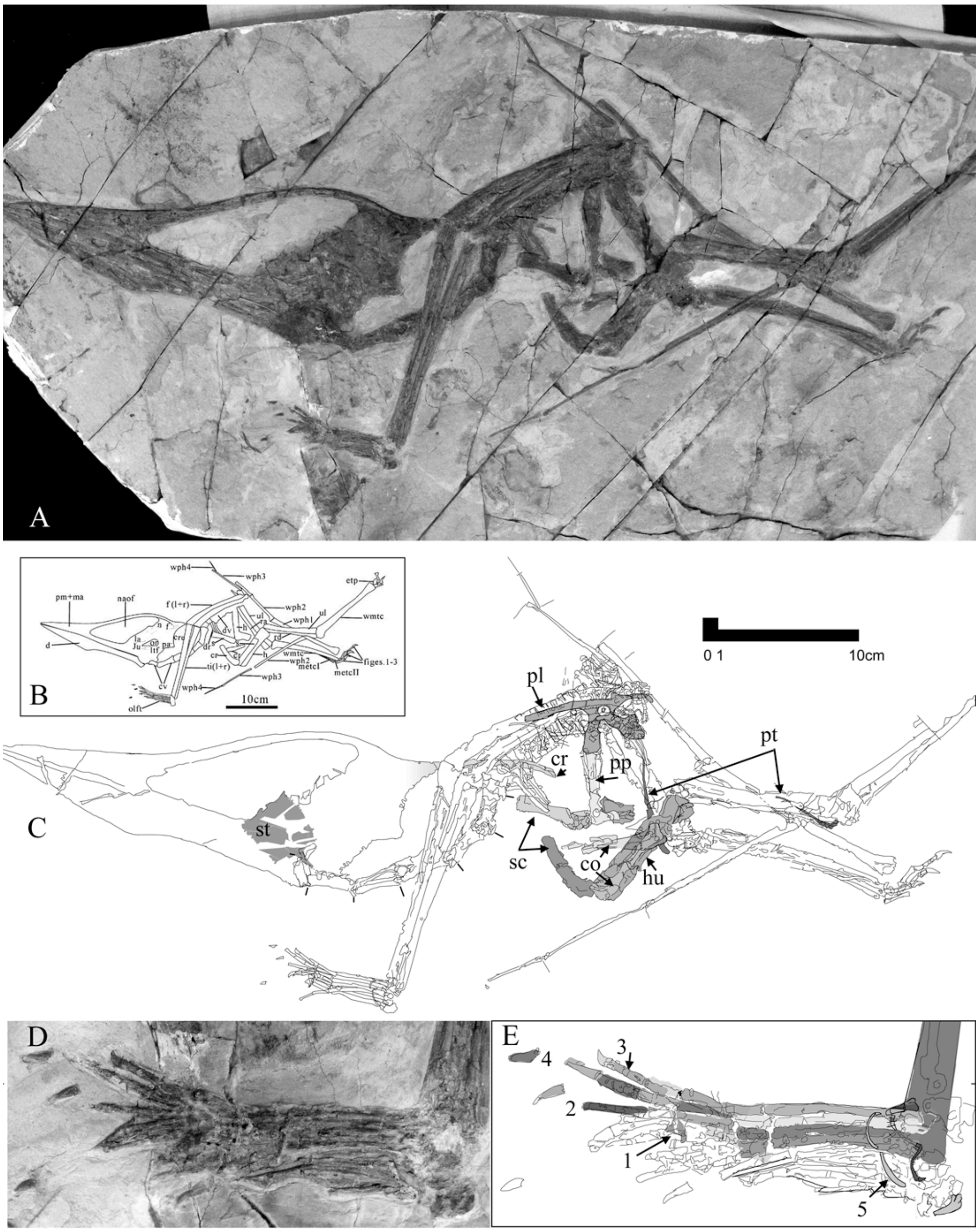

Figure 1. The holotype of *Shenzhoupterus chaoyangensis.* **A** As originally traced in Lü, et al. (2008); **B** Tracing of the specimen in the present study, certain bones colored for clarity; **C** Main slab; **D** Close up of pes; **E** Tracing of same with elements of left pes colored for clarity. Abbreviations: *co* coracoid, *cr* crest, *hu* humerus, *pl* pelvis, *pp* prepubis, *pt* pteroid, *sc* scapula, *st* sternal complex, *1-5* pedal digits. Scale bar equals 10 cm.

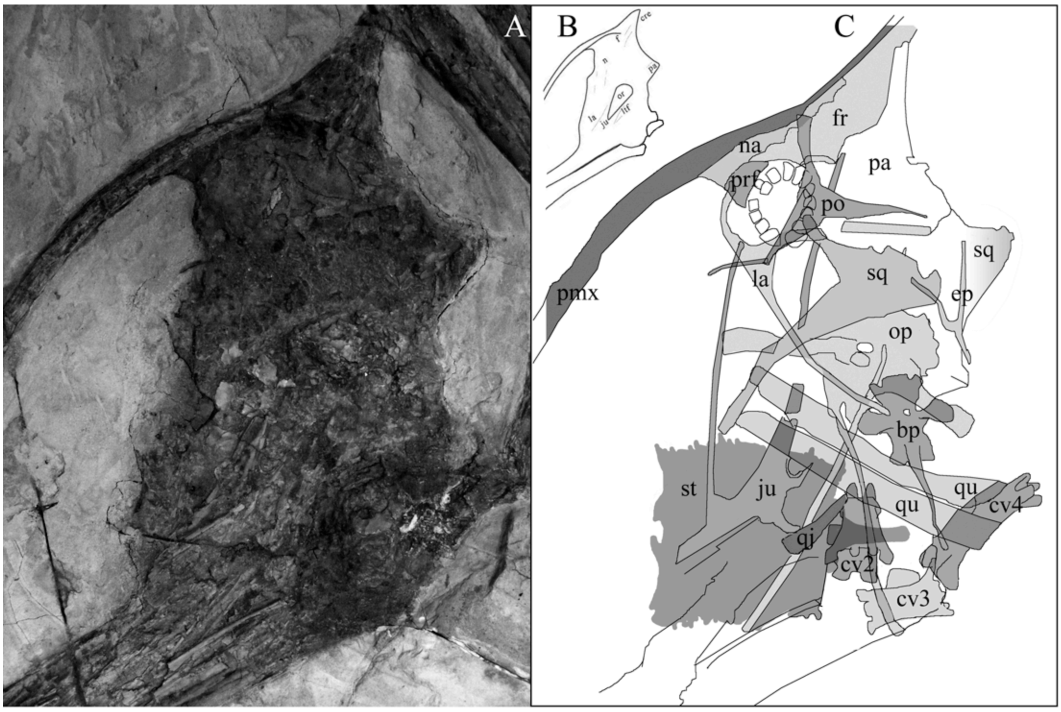

Figure 2. The "face" of *Shenzhoupterus* **A** Close up of the main plate; **B** Original tracing of Lü et al. (2008). **C** Tracing of same indicating left side bones only for clarity (except for squamosal and quadrate duplicates); Abbreviations *bp* basipterygoid, *cv* 2-4 cervical vertebrae, *ep* ectopalatine (fused ectopterygoid + palatine) or possible hyoid, *fr* frontal, *ju* jugal, *la* lacrimal, *na* nasal, *op* occipital plate, *pa* parietal, *prf* prefrontal, *pmx* premaxilla, *qj* quadratojugal, *qu* quadrate, *st* sternal complex (in blue), *sq* squamosal. See figures 1 and 3 for scale.

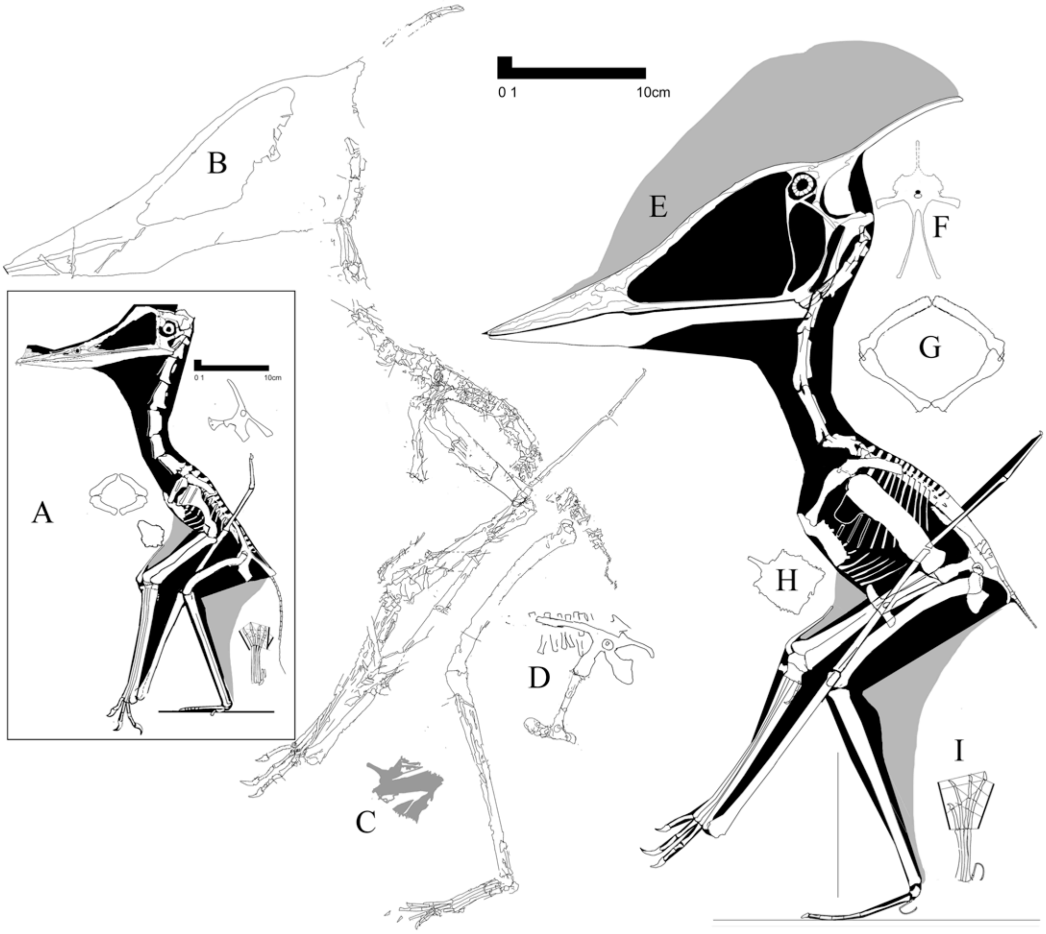

Figure 3. Reconstructions of *Shenzhoupterus* and *Chaoyangopterus* **A** *Chaoyangopterus* including alternate views of scapula/coracoid, sternal complex, pelvis and prepubis and right pes; **B** Relocated bones of *Shenzhoupterus* moved from the tracing on figure 2 into approximate natural positions as a second step prior to the reconstruction; **C** sternal complex of same; **D** pelvis and prepubis of same; **E** Cleaned up reconstruction of *Shenzhoupterus* with imagined soft tissues in gray not present in the original specimen; **F** occipital plate; **G** scapula and coracoid not foreshortened; **H** Sternal complex in ventral view; **I** right pes in dorsal view. Scale bar equals 10 cm.

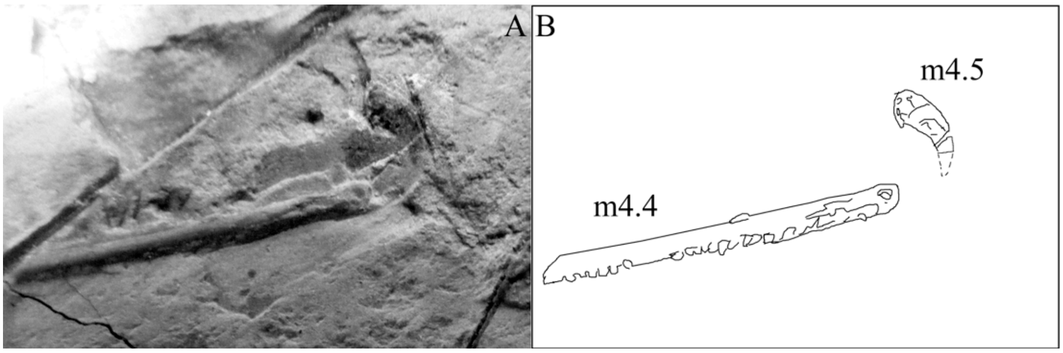

Figure 4. Wing tip of *Shenzhoupterus* **A** Close up photo of main slab **B** Tracing of same Abbreviations *ks* keratin sheath, *m4.4* manual digit four phalanx four, *m4.5* wingtip ungual. See figures 1 and 3 for scale.