

An azhdarchoid pterosaur humerus from the latest Jurassic (Phu Kradung Formation) of Phu Noi, north-eastern Thailand.

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Abstract - A pterosaur humerus from the Phu Kradung Formation at Phu Noi (Kalasin Province, north-eastern Thailand) is described and referred to an azhdarchoid, probably an azhdarchid. The Phu Noi locality is in the lower part of the Phu Kradung Formation and therefore probably latest Jurassic in age. This makes the Phu Noi pterosaur one of the oldest known azhdarchoids.

Keywords: Pterosauria, Azhdarchoidea, humerus, Late Jurassic, Thailand.

1. Introduction

Although the non-marine Mesozoic rocks of Thailand have yielded vertebrate remains in great abundance, pterosaur fossils have so far remained elusive. The only really conclusive specimen so far was an isolated pterodactyloid tooth from the Sao Khua Formation (Barremian) of Phu Phok, on the Khorat Plateau of north-eastern Thailand (Buffetaut *et al.* 2003). The scarcity of pterosaur remains in Thailand may be linked to the detritic nature of most of the vertebrate-bearing formations, which are not conducive to the preservation of fragile specimens such as the hollow, extremely thin-walled bones of pterosaurs. In the present paper, we describe a complete, albeit crushed, pterosaur humerus from the Phu Kradung Formation (latest Jurassic – earliest Cretaceous) of Phu Noi fossil locality in north-eastern Thailand. This specimen is referable to an azhdarchoid and because of its probable latest Jurassic age can be considered as one of the oldest known representatives of that group of pterosaurs.

2. Geographical and geological setting

Specimen n°PRC 64, a pterosaur humerus, was found in the course of systematic excavations conducted by the Palaeontological Research and Education Centre of Mahasarakham University at Phu Noi, a hill close to the village of Ban Dinchi, Kham Muang District, Kalasin

Province. At Phu Noi, grey to green siltstones of the Phu Kradung Formation yield abundant and diverse vertebrate remains, including hybodont sharks (Cuny *et al.*, 2014), ginglymodian fishes (Deesri *et al.*, 2014), turtles (Tong *et al.*, 2015), teleosaurid crocodilians, theropods (including a sinraptorid (Chanthasit, 2011) and a smaller form), sauropods (including a mamenchisaurid) and ornithopods (Buffetaut *et al.*, 2014).

The Phu Kradung Formation has often been considered as Jurassic in age. Its vertebrate assemblage does include various forms, such as teleosaurid crocodilians and mamenchisaurid sauropods, which in China occur in formations usually considered as Jurassic. However, on the basis of palynological evidence, Racey and Goodall (2009) suggested that most of the Phu Kradung Formation should be placed in the Early Cretaceous, with only its basal part possibly being Late Jurassic. On the basis of freshwater sharks, Cuny *et al.* (2014) suggested that some vertebrate localities in the upper part of the Phu Kradung Formation may be Early Cretaceous in age, while others, in the lower part, are probably Jurassic, Phu Noi being among the latter (Cuny *et al.*, 2014, Fig. 1). Similarly, according to Deesri *et al.* (2014), the Phu Noi locality belongs to the lower part of the Phu Kradung Formation, and its age is likely to be Late Jurassic. This conclusion is accepted here.

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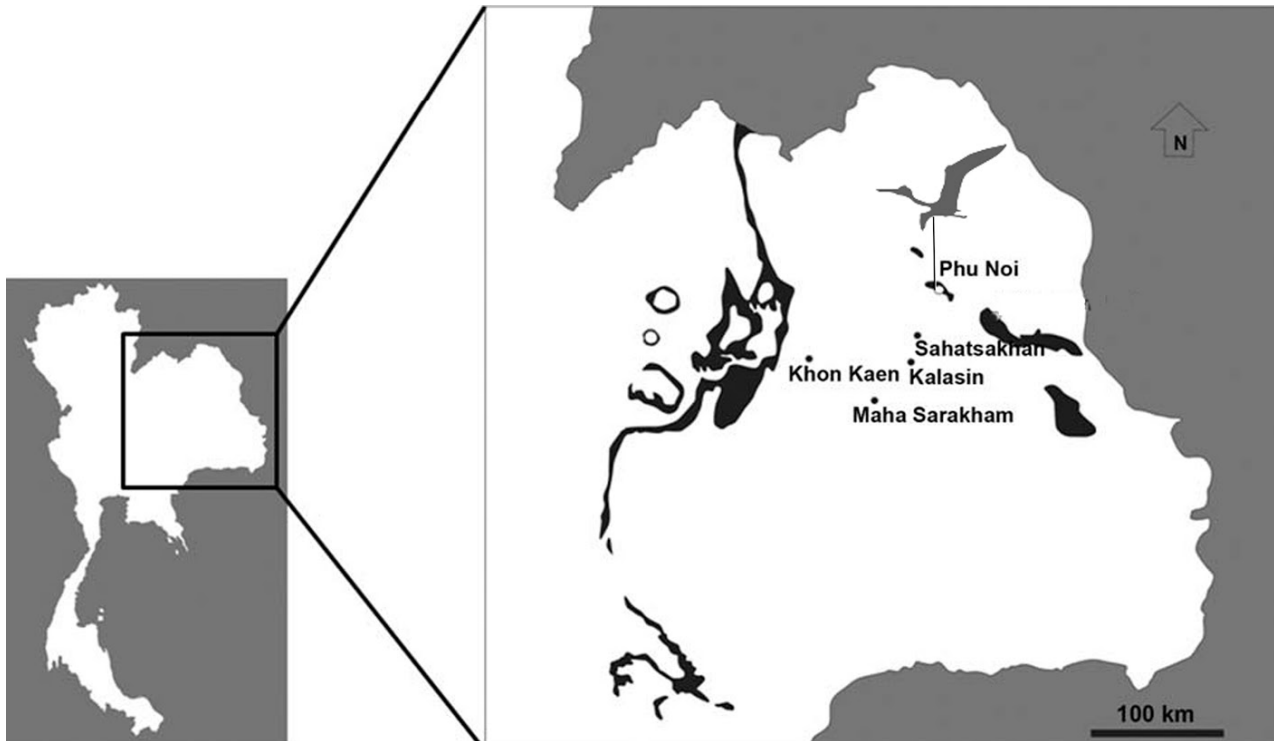


Figure 1. Location map showing the outcrops of the Phu Kradung Formation on the Khorat Plateau of north-eastern Thailand and the Phu Noi locality that has yielded a pterosaur humerus.

3. Results

3.1 Description

Specimen PRC 64 is a complete right humerus (Fig. 2), 112 mm long, that has undergone considerable dorsoventral crushing and some distortion. It is preserved in the palaeontological collection of the Palaeontological Research and Education Centre of Maha Sarakham University.

The crista deltopectoralis is well preserved. It is long (35 mm from its insertion to its tip), parallel-sided, with a rounded and only slightly expanded distal end. It is not warped but inserts on the lateral margin of the bone. When seen in proximal view, it is more or less at right angles to the medial process. The ventral surface shows a short distinct ridge arising from the distal margin of the crista and perpendicular to it, located about 10 mm from its tip. A similar crest was described by Costa and Kellner (2009) in an incomplete humerus from the Late Jurassic of Tendaguru that was referred to a « dsungaropteroid ». According to Costa and Kellner, on the basis of Bennett's study of pterosaur pectoral myology (Bennett, 2003), this crest may be an attachment area for the *Musculus pectoralis*.

The caput humeri is well preserved. It is well rounded dorsoventrally, overhangs the dorsal face of the

shaft and is separated from the ventral face by a step-like sulcus. In proximal view the caput humeri is crescent-shaped, with a concave ventral margin and a convex dorsal margin. Its maximum dorsoventral thickness is 6 mm and its mediolateral length 20 mm.

The processus medialis is distorted dorsally. It is thick and short. No pneumatic foramina are clearly visible in the proximal region of the bone, probably because crushing obscured details.

The shaft is strongly crushed dorsoventrally. It is markedly curved, being concave dorsally and convex ventrally. This curvature may be partly the result of distortion caused by crushing.

The distal end of the bone is poorly preserved, being much distorted by crushing. Both condyles are strongly developed. The lateral condyle is continued proximally by a sharp ridge forming the medial margin of the shaft – this is the tuberculum supracondyloideum laterale of Wellnhofer (1985, 1991), supracondylar process of Bennett (2001) or lateral supracondylar process of Eck *et al.* (2011). According to Bennett (2001), this ridge corresponds to the attachment of the *Musculus supinator*. The medial condyle is continued by a large oval tubercle, the entepicondyle. A transverse bony ridge links the condyles.

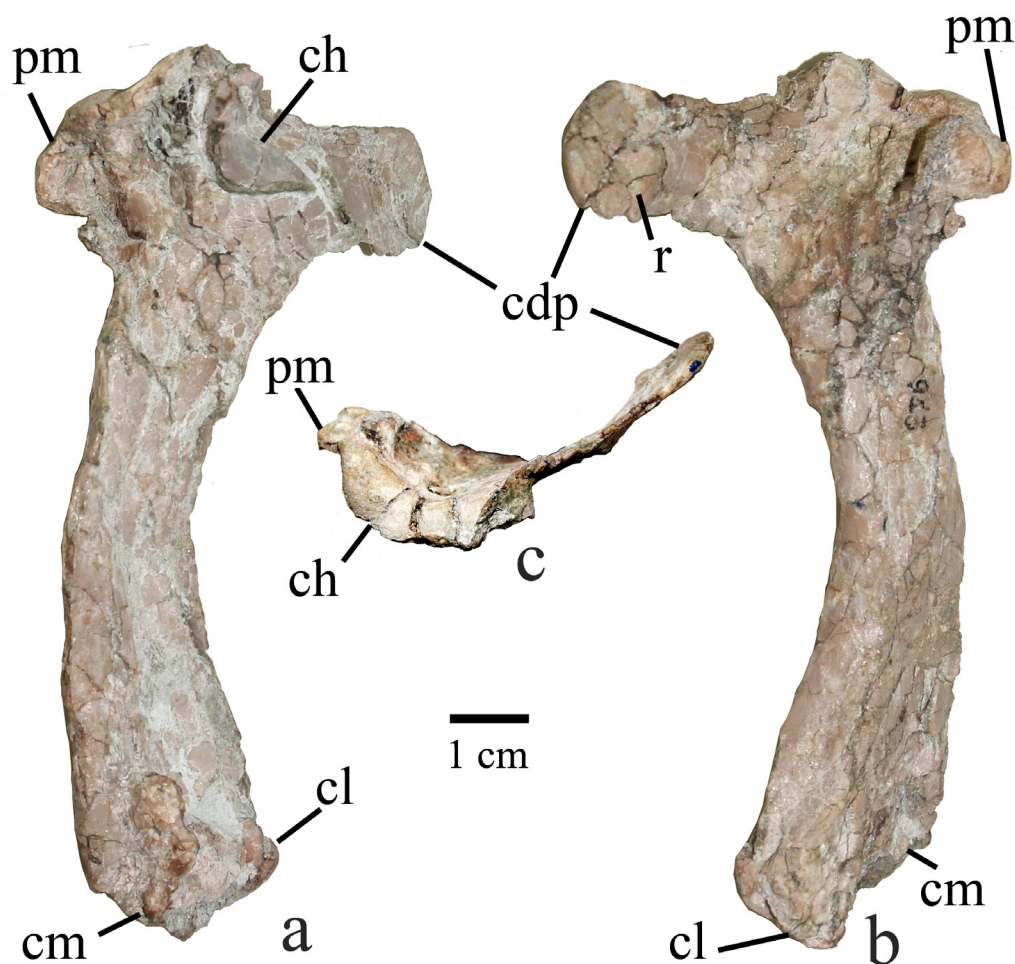


Figure 2. Pterosaur humerus from the Phu Kradung Formation at Phu Noi, north-eastern Thailand in ventral (a), dorsal (b) and proximal (c) views. cdp: crista deltopectoralis; ch: caput humeri; cl: condylus lateralis; cm: condylus medialis; pm: processus medialis; r: ridge (for muscle insertion).

3.2 Identification

With its typical elongate, wing-shaped crista deltopectoralis, this humerus exhibits a typically pterosaurian morphology. On the basis of such an isolated specimen, a very accurate identification is hardly possible. However, the long, parallel-sided crista deltopectoralis differs from that of basal pterosaurs, which is usually shorter and broader proximodistally (see Fig. 10 in Wellnhofer, 1978; Fig. 17 in Unwin, 2003). The more advanced wukongopterids also have a relatively short crista deltopectoralis (Wang *et al.*, 2010; Lü *et al.*, 2010). The crista deltopectoralis of PRC 64 is clearly different from that of rhamphorhynchids, which is « tongue-shaped » (Unwin, 2003), with a constriction at its base. An important character of the crista deltopectoralis of the Phu Noi pterosaur is that it is not warped, which separates it from ornithocheiroids (Unwin, 2003). In dsungaripterids, the crista deltopectoralis appears to be shorter than in the Phu Noi specimen (Young, 1973). The general morphology of the bone, especially its proximal

region, agrees with that of azhdarchoids (*sensu* Witton, 2013). Within that group, humerus morphology is relatively constant, with a fairly long crista deltopectoralis nearly at right angles to the processus medialis. In tapejarids (Eck *et al.*, 2011) and thalassodromeids (Aires *et al.*, 2014), the crista deltopectoralis may be relatively shorter than in PRC 64, which in this regard seems closer to azhdarchids. Similarly, the caput humeri of azhdarchids is thicker dorsoventrally and dorsally overhangs the shaft more sharply than in tapejarids and thalassodromeids (Buffetaut *et al.*, 2011), and in this respect PRC 64 seems to be more reminiscent of azhdarchids than of other azhdarchoids. In another group of azhdarchoids, the Chaoyangopteridae, the humerus shows general azhdarchoid characters, but the detailed structure of that bone is poorly known (Witton, 2013), so that comparisons with PRC 64 are difficult. To sum up, the humerus from Phu Noi shows clear azhdarchoid characters, and may belong to an azhdarchid.

4. Conclusions

Since very few pterosaur specimens are currently known from Thailand, any addition to this limited record is significant. As noted above, the scarcity of pterosaur remains in the otherwise fossil-rich continental Mesozoic of Thailand is probably linked to the predominantly fluvial depositional environment of the formations, which is not conducive to the good preservation of the fragile bones of pterosaurs, unlike the situation in other kinds of environments such as lacustrine or lagoonal deposits (see Buffetaut, 1995, for a discussion of the importance of Lagerstätten for the pterosaur record). The complete humerus from the Phu Kradung Formation described in the present paper shows that relatively well preserved specimens do occur (although in the present case the bone has undergone considerable compression). At the exceptional Phu Noi locality, which has yielded PRC 64, delicate vertebrate fossils sometimes show a remarkably good preservation, and it can be hoped that more pterosaur remains will be found there in the future.

A result of the scarcity and incompleteness of pterosaur remains from the Mesozoic of Thailand is that it is difficult to make useful comparisons with the remarkable pterosaur record from Jurassic and Cretaceous formations in China, from which a large number of taxa, often based on articulated skeletons and reflecting a considerable diversity have been described during the last twenty years (see Witton, 2013, for a recent comprehensive review of pterosaurs, including recent Chinese finds). This is all the more regrettable that there are many similarities between the Mesozoic vertebrate assemblages from Thailand and those from China. Nevertheless, the occurrence of an azhdarchoid in Thailand is not surprising from a palaeobiogeographical point of view, as this group of pterosaurs had a wide geographical distribution, which included China.

Be that as it may, the identification of an azhdarchoid in the Phu Kradung Formation is significant in view of the age of the Phu Noi locality. As mentioned above, the Phu Kradung Formation may straddle the Jurassic-Cretaceous boundary, but Phu Noi is in its lower part and probably latest Jurassic in age. All well attested azhdarchoid pterosaurs hitherto were Cretaceous in age (Witton, 2013), the oldest known specimen being a possible azhdarchid cervical vertebra from the Berriasian of Romania (Dyke *et al.*, 2011). The humerus from Phu Noi, which clearly shows azhdarchoid characters and may belong to an azhdarchid, therefore seems to be among the oldest currently known azhdarchoid specimens.

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