



A pterosaur humerus and scapulocoracoid from the Jurassic Whitby Mudstone Formation, and the evolution of large body size in early pterosaurs

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ABSTRACT

Early Jurassic pterosaurs are rare and display low diversity with only three well known genera for a period of ~21 million years duration. The Hettangian–Pliensbachian *Dimorphodon* reached a wingspan estimated at only 1.3 m, while the Lower Toarcian forms *Dorygnathus* and *Campylognathoides* reached wings spans of 1.8 m. Here we describe a new specimen of Toarcian pterosaur from the north east coast of England that may have achieved an estimated wingspan between 1.6 and 3.2 m.

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1. Introduction

Pterosaurs were first reported from the Lower Jurassic of Britain when William Buckland described '*Pterodactylus*' (= *Dimorphodon macronyx* Buckland, 1835 from the Lower Lias of Lyme Regis, Dorset (see also Buckland, 1836; Owen, 1861). This pterosaur, specimen NHMUK PV R 1034, represented the first discovery of pterosaurs outside of Late Jurassic deposits of Germany and was the first scientifically reported pterosaur specimen from England, although Cretaceous pterosaur bones misinterpreted as bird bones had previously been reported from the English Wealden (Martill, 2010). While several specimens of *Dimorphodon* are now known (Padian, 1983), the record of pterosaurs in the Lower Jurassic globally remains disproportionately low. The Lower Jurassic (Toarcian) Posidonia Shale in Germany has produced dozens of pterosaur specimens (Padian, 2008a,b), but all can be referred to just two genera, *Dorygnathus* Wagner, 1860 and *Campylognathoides* Plieninger, 1895. The Posidonia Shale is a Konservat Lagerstätte, and specimens are often exquisitely preserved, some retaining soft tissues such as that seen in SMNS 9787 (Padian, 2008a,b). Other Lower Jurassic pterosaur remains generally consist of isolated elements (e.g. Buffetaut et al., 2010; Delsate and Wild, 2000). In the UK the only other Lower Jurassic pterosaur material known is *Parapsicephalus Arthaber*, 1919, which is known from a

single near complete skull (GSM 3166) from the *Hildoceras bifrons* ammonite zone (Lower Jurassic, Toarcian) of the Alum Shale Member of the Whitby Mudstone Formation in the Loftus Alum Quarries, near Whitby (Newton, 1888; Lydekker, 1890; Benton and Spencer, 1995). Outside of Europe, Lower Jurassic pterosaurs are even rarer. Padian (1984) described *Rhamphinion jenkinsi* Padian, 1984 from the Kayenta Formation, Arizona, USA, while Barrett et al. (2008) reported on several isolated pterosaur teeth. Jain (1974) identified supposed *Campylognathoides* remains from the Kota Formation, India, but Padian (2008a,b) argued that the specimen is more likely to be a fish.

The rarity of Early Jurassic pterosaurs means there are many gaps in our understanding of Jurassic pterosaur evolution. With only one or two representatives per family, little is known about the morphological disparity between taxa. Therefore, any new or unusual pterosaurs from this period deserve scrutiny. Another reason for close examination of any Early Jurassic pterosaur material is our limited understanding of Jurassic pterosaur diversity. Recent studies (Butler et al., 2009, 2012) argue that for much of the Mesozoic, pterosaur diversity directly correlates to the amount of pterosaur-bearing strata. Thus, any identifiable remains improve our understanding of pterosaur taxonomy and diversity. Here we describe a new specimen of rhamphorhynchine pterosaur (NHMUK PV R36634), consisting of an associated near complete left humerus and scapulocoracoid from the Lower Jurassic Alum Shale Member of Whitby, Yorkshire, England. Along with a description, we discuss its somewhat unusually large size and morphology.

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Institutional abbreviations – AMNH: American Museum of Natural History, New York, USA; NHMUK: Natural History Museum, London, United Kingdom; BNM: Bündner Naturmuseum, Chur, Switzerland; CYGB: Chaoyang Geopark, Chaoyang City, China; GSM: British Geological Survey, Keyworth, United Kingdom; IVPP: Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China; JME: Jura Museum, Eichstätt, Germany; MBR: Humboldt Museum für Naturkunde in Berlin, Germany; MCSNB: Museo Civico di Scienze Naturali, Bergamo, Italy; NSM: National Science Museum, Tokyo, Japan; SMNK: Staatliches Museum für Naturkunde Karlsruhe, Germany; SMNS: Staatliches Museum für Naturkunde, Stuttgart, Germany; YJK: Yizhou Museum, Liaoning, China.

2. Locality and stratigraphy

NHMUK PV R36634 was found by one of the authors (DG) on the 18th October 2011. It was found in a dark grey, calcareous mudstone concretion on the foreshore at Saltwick Bay, East of the Black Nab, an isolated sea stack of Toarcian black shales, North Yorkshire, England (National Grid reference NZ 92596 10461) (Fig. 1). This stretch of the Yorkshire coast is famous for magnificent exposures of the Lower Jurassic which yield a diversity of marine reptiles including ichthyosaurs, plesiosaurs and crocodylomorphs (Benton and Spencer, 1995).

The distinctive concretion comes from the upper Alum Shale Member of the Whitby Mudstone Formation (Lower Toarcian), which consists of ~28 m of alternating layers of shale and calcareous concretions of variable thickness (Simms et al., 2004). Several of these concretion horizons are known from the Alum Shale Member, and that containing the pterosaur specimen

described here is typical of those found in the Cement Shale Beds of the *Hildoceras bifrons* Zone, *Peronoceras fibulatum* subzone (Fig. 2).

3. Methodology

The specimen was discovered when the concretion was hammered at the locality, it being usual for such concretions to split readily to reveal 3D ammonites, resulting in the humeral head breaking away from the diaphysis. At UOP, the specimen was repaired, but the humeral head could not be reattached to the diaphysis because of its fragility. Instead, this element was reconnected to its original place on a concretion fragment which had come loose when the nodule was split. At NHMUK, the humeral head was reattached to the scapulocoracoid half of the nodule. The specimen was photographed and measured using a RAPER Expert digital calliper. Wingspan was estimated using a regression equation derived from the relationship between humeral length and overall wingspan from several rhamphorhynchines ($n > 80$). Data for the regression analysis, as well as that used for the percentage of the wing component of the humerus, was acquired from Colbert (1969), Wellnhofer (1975), Czerkas and Ji (2002), Padian (2008a,b), Andres et al. (2010) and Lü et al. (2012a).

4. Systematic palaeontology

PTEROSAURIA Kaup, 1834

RHAMPHORHYNCHIDAE Seeley, 1870

?*Parapsicephalus purdoni* Arthaber, 1919

Referral of the specimen here to *Parapsicephalus purdoni* is tentative, given that this taxon is known only from a partial skull. Referral is based on stratigraphic and geographical occurrence and

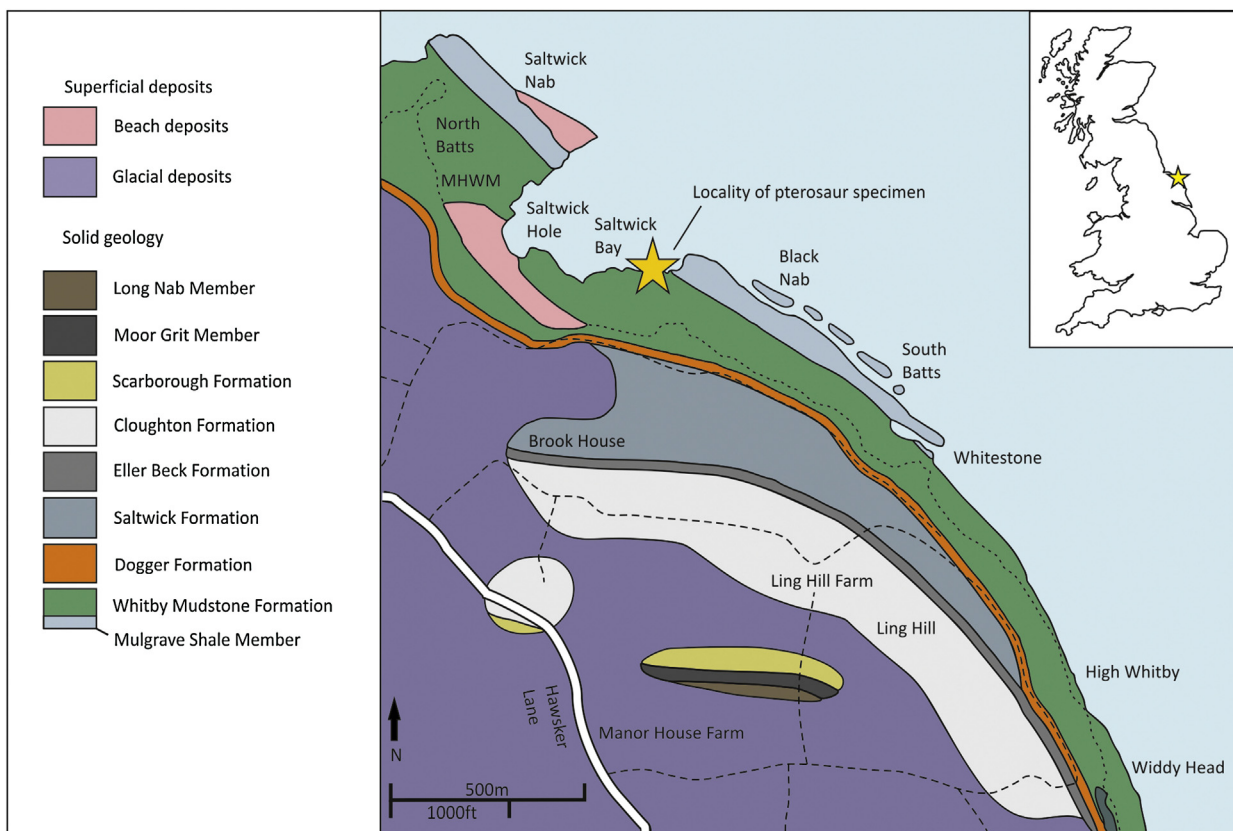


Fig. 1. Map showing Saltwick Bay and Whitby, North Yorkshire, where NHMUK PV R36634 was discovered by one of the authors (DG). Modified from Digimap.

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