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FIRST PTEROSAUR REMAINS FROM THE CRETACEOUS OF POLAND

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Abstract: The first records of pterosaurs from the Cretaceous of Poland are reported, on the basis of fragmentary remains from the marine Upper Albian (Lower Cretaceous) of the Annopol Anticline, central Poland. The new material consists of four bone fragments, tentatively interpreted as: 1) a portion of wing phalanx; 2) a medial element of fused skull bones (parietal crest?); 3) a fragmentary carpal or tarsal; and 4) a distal phalanx of the pes (or a very small fragment of a long cervical vertebra). Previously, only the remains of marine vertebrates have been reported from the Cretaceous of the Annopol area. The pterosaur fossils studied most probably belonged to individuals that died while over the sea. The possibility that they represent remains dropped from floating carcasses, introduced into the marine environment by rivers, is regarded as less probable, as there are no remains of dinosaurs or other terrestrial fauna in the Annopol deposits.

Key words: Pterosauria, Albian, Cretaceous, Poland.

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INTRODUCTION

Pterosaur bones are very fragile due to their thin walls and a general reduction of internal trabeculae (e.g., Elgin and Hone, 2013). The best preserved pterosaur remains occur in fossil Konservat-Lagerstätten (*sensu* Seilacher, 1970), where skeletons may be fully articulated, uncrushed and have associated soft tissues, including wing membranes, preserved. These deposits are exemplified by the lithographic limestones of the Jurassic Solnhofen Formation in Germany, the Early Cretaceous Yixiang Formation of China and the Santana Formation of Brazil (e.g., Wellnhofer, 1991; Unwin, 2006).

Pterosaur remains also occur in fossiliferous deposits of the concentration type (Konzentrat-Lagerstätten), typified by the mass occurrence of organic remains. The best-known pterosaur-bearing deposit of this latter type is the lowermost Cenomanian Cambridge Greensand of eastern England. This Konzentrat-Lagerstätte has yielded hundreds of *remanié* pterosaur fossils of Late Albian age which, though disarticulated and fragmentary, nevertheless provide a valuable source of data on pterosaur taxonomy, phylogeny and diversity (e.g., Unwin, 2001; Buffetaut, 2006; Martill and Unwin, 2012).

Here the authors describe and illustrate rare pterosaur material from another highly-fossiliferous deposit of the concentration type, namely the phosphorite-bearing Upper Albian sands of the Annopol Anticline, central Poland (Fig. 1A, B). The new material is a part of a rich vertebrate assemblage collected from the Annopol area by a team, led by the first author. These collections were made during subterranean exploration of the abandoned phosphorite mine Jan 1 (Machalski *et al.*, 2009) and screen washing of the sediment at the surface locality of Kopiec (see Fig. 1B for location of both settings and Popov and Machalski, in press, for a detailed description of the screen washing procedures).

The material described here, although highly fragmentary, represents the first pterosaur remains from the Polish Cretaceous. The material is now housed at the Institute of Paleobiology of Polish Academy of Sciences, Warszawa, Poland (ZPAL).

GEOLOGIC BACKGROUND

A highly condensed sedimentary succession, ranging from the uppermost Lower Albian to the Lower Turonian, is exposed around the town of Annopol (Fig. 1A, B), along the

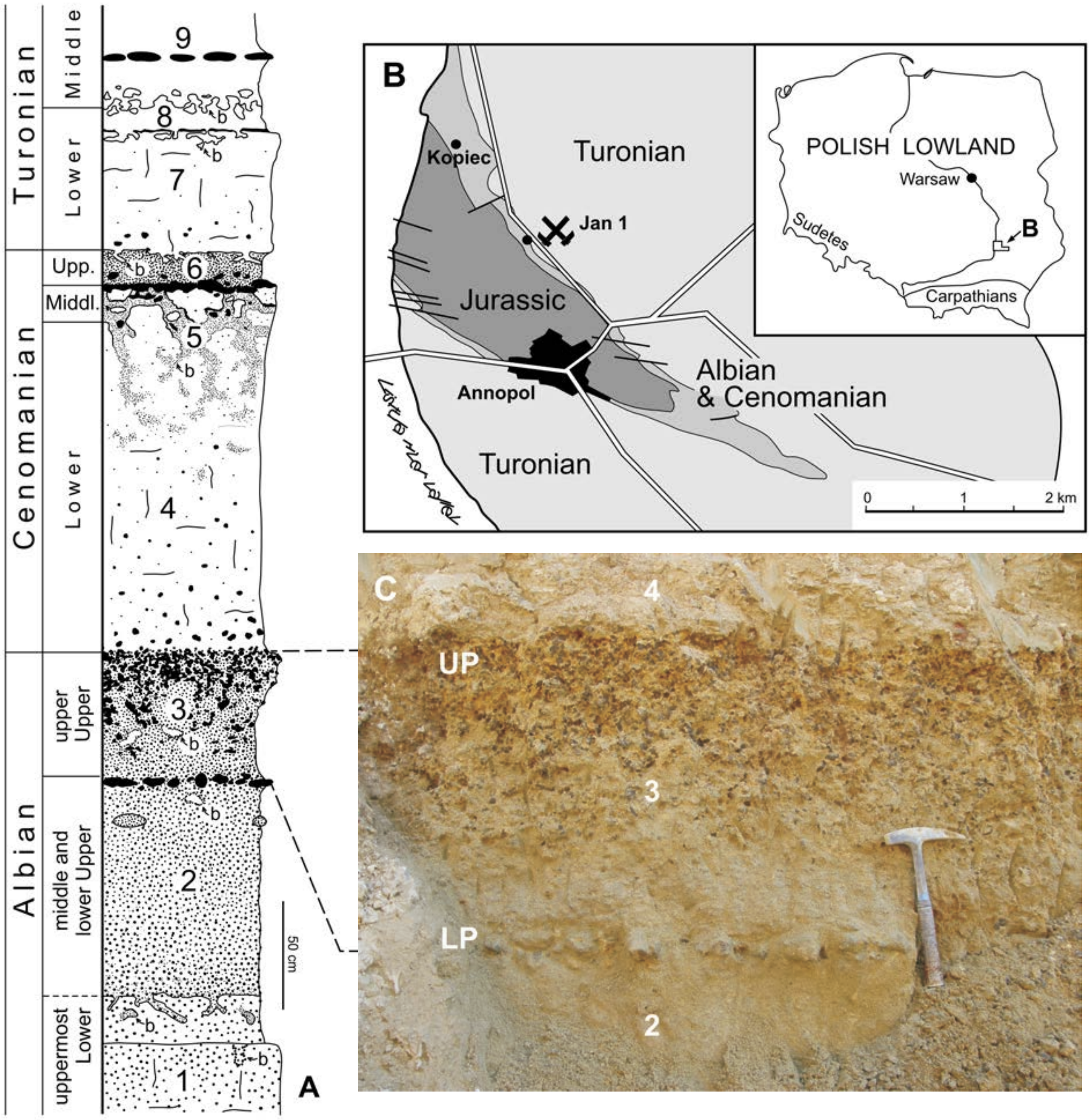

Fig. 1. Geologic background of the pterosaur remains from the Annopol Anticline, **A.** Lithology and stratigraphy of the mid-Cretaceous succession of the Annopol Anticline (modified after Walaszczyk, 1984). 1. A quartzose sandstone replaced upwards by quartz sands truncated by a burrowed surface. 2. Quartz sands with glauconite and sandstone nodules near the top; unit 2 is capped by a phosphorite horizon. 3. Quartz sands with glauconite passing upwards into marly sands with glauconite and phosphates. 4. Quartzose marls with glauconite and phosphates in the lower part. 5. Glauconitic marls infilling burrows in the underlying unit, truncated by a hardground with phosphate and glauconite impregnation. 6. Strongly glauconitic marls with burrowed omission surface at the top. 7. Limestone with rare phosphatic nodules and glauconite, truncated by a hardground with glauconitic mineralization. 8. Marls with burrowed top. 9. Marls with black flint; b – burrows. **B.** Geologic map of the Annopol Anticline (modified after Walaszczyk, 1987) with localities studied and the location of the study area in Poland. **C.** Close-up view of the upper Upper Albian pterosaur-bearing unit 3 at the locality Kopiec. LP – lower part of the Phosphorite Bed, UP – upper part of the Phosphorite Bed. Adapted from Popov and Machalski (in press) with permission from Elsevier

limbs of a small anticline (the Rachów or Annopol Anticline, see Samsonowicz, 1925, 1934; Marcinowski and Radwański, 1983; Walaszczyk, 1984, 1987; Machalski and Kennedy, 2013). The succession records the early phases of the great Cretaceous marine transgression (Marcinowski and Radwański, 1983; Walaszczyk, 1987) and is extremely thin (condensed) in comparison to coeval strata in adjacent areas, due to its location on a submarine high (Cieśliński, 1976).

With reference to the transgressive-regressive model of Juignet (1980) and Hancock (1990), the Annopol succession is interpreted as a series of transgressive units, num-

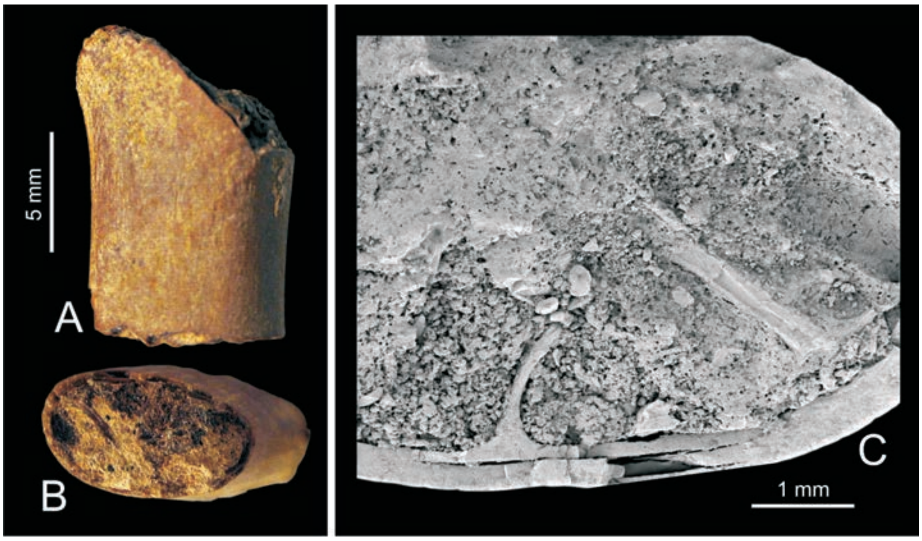

Fig. 2. Specimen ZPAL V. 38/390, fragment of a wing phalanx in lateral view (**A**), cross-section (**B**) and SEM (**C**)

bered 1–9, capped by layers of reworked phosphatic nodules and clasts, hardgrounds and burrowed omission/erosional surfaces, which reflect a series of regression maxima (Fig.1A).

The pterosaur specimens reported herein, four in total, come from unit 3 as exposed at Kopiec (Fig.1A, C). This unit corresponds to the upper part of the so-called Phosphorite Bed, distinguished in the Annopol section by previous authors (see e.g., Samsonowicz, 1925, 1934; Radwański, 1968; Marcinowski and Radwański, 1983, 1989).

Unit 3 (see Fig. 1A, C) is c. 50 m thick and is composed of quartz sand with abundant glauconite, passing gradually upwards into quartz-glauconitic marl. A distinct bed of phosphatic clasts and fossils occurs in the upper part of unit 3. Its upper boundary is sharp, whereas the lower boundary is diffuse due to bioturbation (Marcinowski and Walaszczyk, 1985; Walaszczyk, 1987). The phosphatic clasts are c. 1 cm in diameter, but in the upper part of the layer they commonly form larger aggregates, up to 12 cm in diameter. These aggregates are composed of up to three generations of clasts showing the same matrix, but differing in intensity of phosphatisation, suggesting multi-phase intraformational reworking of the phosphatic material.

The fossil assemblage from unit 3 is dominated by phosphatised sponges, calcitic-shelled bivalves *Aucellina gryphaeoides* and *Pycnodonte vesiculosa*, and rostra of the belemnite *Neohibolites ultimus*. Shells of rhynchonellid and terebratulid brachiopods, serpulid tubes and shrimp remains are subsidiary components of the invertebrate assemblage. Associated vertebrates include relatively common teeth and vertebrae of sharks and bony fishes, less common chimaeroid dental plates (Popov and Machalski, in press), teeth, fragments of jaws and vertebrae of ichthyosaurs and plesiosaurs, as well as remains of marine turtles. The most numerous and best preserved fossils occur in the lower and middle part of the unit, those from its upper portion are commonly poorly preserved, fragmented and overgrown by phosphates.

AGE OF THE PTEROSAUR MATERIAL

The pterosaur-bearing unit 3 of the Annopol succession is dated on the basis of specimens of the ammonite *Mortoniceras* (*Subschloenbachia*) sp., preserved as attachment scars on the left valves of some oysters (Machalski and Kennedy, 2013). These specimens show the closest affinity with those of *Mortoniceras* (*Subschloenbachia*) which are characteristic of the upper Upper Albian *Mortoniceras perinflatum* Zone (for a detailed discussion and zonation of the relevant part of the Albian Stage see Machalski and Kennedy, 2013, table 1).

There is no evidence of any biostratigraphically older fossils within unit 3, and the late Late Albian is taken to be the age of the pterosaur material described herein. This contrasts with the situation from the lowermost Cenomanian Cambridge Greensand as the pterosaur remains contained in the latter unit are thought to represent older, Late Albian, material (e.g., Martill and Unwin, 2012).

DESCRIPTION AND COMPARISONS

Specimen ZPAL V.38/390 (Fig. 2A–C) is the most diagnostic of the present material. It measures16 mm in length, is 10 mm high and 5 mm wide. It has an ultra thin (thinnest 0.3 mm – thickest 0.6 mm) bone wall, and the typical (for pterosaurs) lamellar structure can be seen in SEM (Fig. 2C). There are two prominent trabeculae visible, the remainder of the cross-section surface being filled with sediment (a pneumatic cavity during life) (Fig. 2B, C). The cross-section is an oval with two opposing, slightly flattened sides and is typical of the cross-section found in non-azhdarchid pterodactyloid pterosaur wing-finger phalanges. Assuming this identification to be correct, in dorsal view (as though the wings were outstretched) there is a gentle expansion (slightly more prominent on one side than on the other), suggesting this is a portion of the phalanx diaphysis close to either the distal or proximal termination.

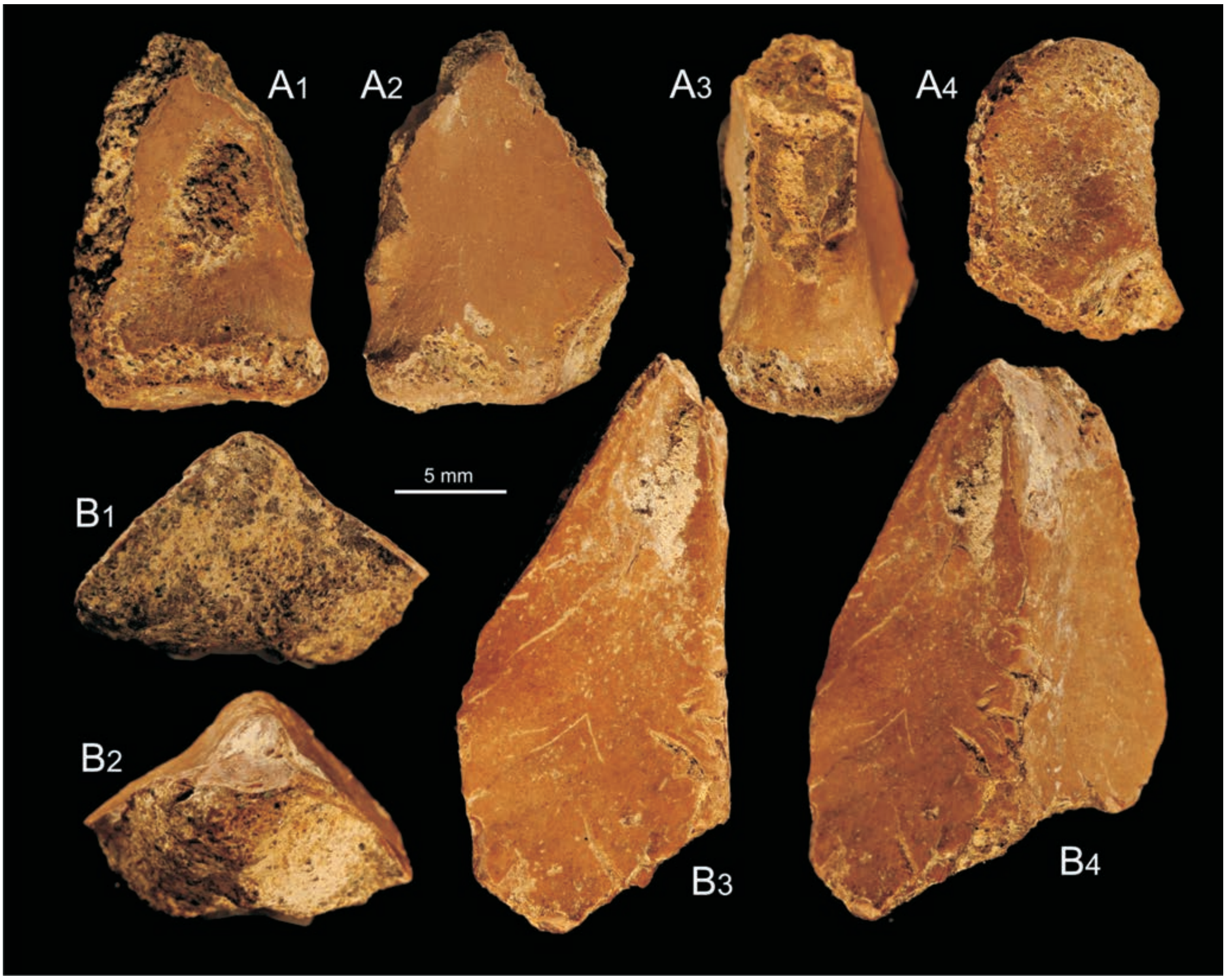

Fig. 3. Pterosaur remains from the Annopol Anticline, **A.** Specimen ZPAL V.38/273 (a fragmentary carpal or tarsal) in four different views (A_1–A_4). **B**. Specimen ZPAL V.38/816 (medial element of fused skull bones, parietal crest?) in four different views (B_1–B_4)

Specimen ZPAL V.38/273 (Fig. 3A_1–A_4) is 15 mm in its maximum dimension. The thin nature of the bone wall of this fragment identifies it as pterosaurian. It has two features that might allow a reasonable attempt at identification of the element. There is a suboval articulatory surface with a slight depression on one margin. The bone is broken in what might be its distal part. It is a rather tabular element and there is a slight inflation on one side. It is possibly a carpal or tarsal.

Specimen ZPAL V.38/816 (Fig. 3B_1–B_4) is 25 mm in its maximum dimension. The thin bone wall of this triangular fragment identifies it as pterosaurian. It has a strongly developed 'median' ridge, from which fascia descend symmetrically to define an angle of 90 degrees. The ridge decreases and disappears toward the apex, and the (presumed) left margin appears entire, while the corresponding margin of the other side is slightly damaged. Nevertheless, the bone probably had a triangular termination in life. It may be a medial element of fused skull bones, such as a parietal crest. This identification is extremely tentative.

Specimen ZPAL V.38/1195 is not illustrated here, because of its very poor preservation. This small fragment (c. 10 mm in its maximum dimension) is also very thin walled, and most likely a pterosaur bone. There are few features to diagnose it, but what appears to be a grooved articulatory surface suggests that it is possibly a distal phalanx of the pes. However, it has a flat face and slightly expanded termination, and as such, could also be a very small fragment of a long, slender cervical vertebra.

Because of the highly fragmentary nature of the material, comparisons with other pterosaurs are difficult. Nevertheless, an affinity with non-pterodactyloid monofenestratans, Rhamphorhynchidae, and all pre-Middle Jurassic pterosaurs can be ruled out, on account of the Cretaceous age of the new material. The thin wall of the bones also rules out affinities with Dsungaripteroidea in which there is a tendency to bone-wall thickening (Martill *et al.*, 2013). Thus the affinities of the new Polish material probably lie within Ornithocheiroidea and/or Azhdarchoidea, all of which are known from the Cretaceous of Europe (Unwin, 2001; Martill *et al.*, 2013).

DISCUSSION AND CONCLUSIONS

In general, the record of pterosaur remains in Poland is poor. Prior to the present study, the sole published body-fossil example was an isolated tooth from the Upper Jurassic (Upper Tithonian) *Corbulomina* horizon of the Kcynia Formation exposed in the Owadów-Brzezinki quarry near the town of Tomaszów Mazowiecki, central Poland (Kin *et al.*, 2013). Foot prints attributable to pterosaurs were described from the topmost part of the Upper Jurassic (Lower Kimmeridgian) Oolites and Platy Limestones (informal lithostratigraphic unit) exposed in the Wierzbica quarry, south of the town of Radom (Pieńkowski and Niedźwiedzki, 2005).

The fossils described here, although fragmentary, are sufficiently diagnostic to demonstrate the presence of pterosaurs in the Polish Cretaceous, and are the first remains of Cretaceous pterosaurs to be recorded from this country. One may hope that further palaeontological exploration of the Upper Albian deposits in Annopol anticline and other parts of Poland will yield more diagnostic pterosaur remains.

The Late Albian pterosaur remains documented here are the only non-marine elements in the vertebrate assemblages recorded from the Annopol anticline (Samsonowicz, 1925, 1934; Marcinowski and Radwański, 1983; Machalski *et al.*, 2009; Popov and Machalski, in press). In view of the absence of any non-marine strata (or their remnants) in the Annopol section, the authors suggest that the pterosaur remains belonged to individuals that died while over the sea. The possibility that they represent remains dropped from floating carcasses introduced into the marine environment by rivers is regarded as less probable as there are no dinosaur or other terrestrial fauna recorded from these deposits. A land area in southern Poland, separating the Polish epicontinental basin from Tethys in Late Albian (e.g., Jaskowiak-Schoeneichowa, 1978) may have been a habitat for the pterosaurs described here.

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REFERENCES

Buffetaut, E., 2006. La “ruée vers les phosphates” du dix-neuvième siècle: une aubaine pour la paléontologie des vertébrés crétacés. *Strata*, 13: 11–23.

Cieśliński, S., 1976. Development of the Danish-Polish furrow in the Góry Świętokrzyskie region in the Albian, Cenomanian and Lower Turonian. *Biuletyn Instytutu Geologicznego*, 295: 249–271. [In Polish, English summary].

Elgin, R. A. & Hone, D. W. E., 2013. Pneumatization of an immature azhdarchoid pterosaur. *Cretaceous Research*, 45: 16–24.

Hancock, J. M., 1990. Sea-level changes in the British region during the Late Cretaceous. *Proceedings of the Geologists' Association*, 100 (for 1989): 565–594.

Jaskowiak-Schoeneichowa, M., 1978. Paläogeographie des Alb und Cenoman in Polen. In: Wiedmann, J. (ed.), *Aspekte der Kreide Europas. IUGS Series A*, 6: 463–471.

Juignet, P., 1980. Transgressions-régressions, variations eustatiques et influences tectoniques de l'Aptien au Maastrichtien dans le Bassin de Paris occidental et sur la Bordure du Massif Armoricain. *Cretaceous Research*, 1: 341–357.

Kin, A., Gruszczyński, M., Martill, D., Marshall, J. D. & Błażejowski, B., 2013. Paleoenvironment and taphonomy of a Late Jurassic (Late Tithonian) Lagerstätte from central Poland. *Lethaia*, 46: 71–81.

Machalski, M., Komorowski, A. & Harasimiuk, M., 2009. Nowe perspektywy poszukiwań morskich kręgowców w nieczynnej kopalni fosforytów w Annopolu nad Wisłą. *Przegląd Geologiczny*, 57: 638–641. [In Polish].

Machalski, M. & Kennedy, W.J., 2013. Oyster-bioimmured ammonites from the Upper Albian of Annopol, Poland: stratigraphic and palaeobiogeographic implications. *Acta Geologica Polonica*, 63 (4): 545–554.

Marcinowski, R. & Radwański, A., 1983. The mid-Cretaceous transgression onto the Central Polish Uplands (marginal part of the Central European Basin). *Zitteliana*, 10: 65–96.

Marcinowski, R. & Radwański, A., 1989. Stratigraphic approach to the mid-Cretaceous transgressive sequence of the Central Polish Uplands. *Cretaceous Research*, 10: 153–172.

Marcinowski, R. & Walaszczyk, I., 1985. Middle Cretaceous deposits and biostratigraphy of the Annopol section, Central Polish Uplands. *Österreichische Akademie der Wissenschaften, Schriftenreiche der Erdwissenschaftlichen Komisssionen*, 7: 27–41.

Martill, D. M., O'Sullivan, M. & Newman, C., 2013. A possible Azhdarchid pterosaur (Pterosauria, Azhdarchidae) in the Durlston Formation (Early Cretaceous, Berriasian) of southern England. *Cretaceous Research*, 42: 26–39.

Martill, D. M. & Unwin, D. M., 2012. The world's largest toothed pterosaur, NHMUK R481, an incomplete rostrum of *Coloborhynchus capito* (Seeley, 1870) from the Cambridge Greensand of England. *Cretaceous Research*, 34:1–9.

Pieńkowski, G. & Niedźwiedzki, G., 2005. Pterosaur tracks from the early Kimmeridgian intertidal deposits of Wierzbica, Poland. *Geological Quarterly*, 49: 339–346.

Popov, E.V. & Machalski, M., (in press). Late Albian chimaeroid fishes (Holocephali, Chimaeroidei) from Annopol, Poland. *Cretaceous Research*, 47: 1–18, http://dx.doi.org/10.1016/j.cretres. 2013.09.011

Radwański, A., 1968. *Ischyodus thurmanni* Pictet & Campiche and other chimaeroid fishes from the Albian–Cenomanian of the Holy Cross Mountains (Poland). *Acta Palaeontologica Polonica*, 13: 315–322. [in Polish, English summary].

Samsonowicz, J., 1925. Esquisse géologique des environs de Rachów sur la Vistule et les transgressions de l'Albien et du Cénomanien dans les sillon nord-européen. *Sprawozdania Państwowego Instytutu Geologicznego*, 3: 45–118 [in Polish, French summary].

Samsonowicz, J., 1934. *Explication de la feuille Opatów (zone 45, colonne 33). Service géologique de Pologne, Carte Géologique Générale de la Pologne au 100.000-e*. Państwowy Instytut Geologiczny, Warszawa, 97 pp.

Seilacher, A., 1970. Begriff und Bedeutung der Fossil-Lagerstätten. *Neues Jahrbuch für Geologie und Paläontologie*, *Monatshefte*, 1970 (1): 34–39.

Unwin, D. M., 2001. An overview of the pterosaur assemblage from the Cambridge Greensand (Cretaceous) of eastern England. *Mitteilungen aus dem Museum fur Naturkunde in Berlin, Geowissenschaftliche Reihe*, 4: 189–221.

Unwin, D. M., 2006. *The Pterosaurs from Deep Time*. Pi Press, New York, 347 pp.

Walaszczyk, I., 1984. *Geologia antykliny Annopola*. Unpublished MSc thesis. Geology Department, University of Warsawa, 72 pp. [in Polish].

Walaszczyk, I., 1987. Mid-Cretaceous events at the marginal part of the Central European Basin (Annopol-on-Vistula section, Central Poland). *Acta Geologica Polonica*, 37: 61–74.

Wellnhofer, P., 1991. *The Illustrated Encyclopedia of Pterosaurs*. Crescent Books, New York, 192 pp.