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Summary of a decade of research at the Owadów–Brzezinki Lagerstätte (Tithonian, central Poland): A review and perspectives for the future

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Abstract. For over ten years, the Lower to Upper Tithonian boundary beds cropping out in the Owadów–Brzezinki quarry have yielded numerous fossils of ammonites, bivalves, brachiopods, xiphosurans, decapods, insects, and vertebrates – including actinopterygian fishes and various reptiles and others, all of which exhibit fine preservation of their anatomical details due to special environmental conditions during their fossilization. The Owadów–Brzezinki section is also important for stratigraphical correlations because it contains ammonite faunas indicative of the NE European and NW European Subboreal zonal schemes, as well as Tethyan calpionellids. The whole faunal assemblage, which represents taxa of many iconic groups of Mesozoic animals, has created the opportunity to establish the 'Owadów–Brzezinki geopark', a geoeducation area where the public, and especially the young, can learn about the beauty of the natural history of the region.

INTRODUCTION

A decade of systematic palaeontological excavation in an active limestone quarry at Owadów–Brzezinki located in central Poland (Łódzkie Voivodeship, Opoczno County), in the north-western margin of the Holy Cross Mountains (51°22′27″N, 20°8′11″E), has finished recently, resulting in numerous spectacular discoveries. The Owadów–Brzezinki Konservat-Lagerstätte crops out in the lower and middle parts of the quarry (Fig. 1). The research at this palaeontological site has contributed to the understanding of the fossil record and evolution of various animal groups, both vertebrates and invertebrates. Furthermore, it has provided valuable insights into palaeoenvironmental conditions and climatic changes that occurred during the Tithonian (Late Jurassic) in Poland (Błażejowski *et al.*, 2023). The Owadów–Brzezinki quarry not only presents a previously unknown detailed record of the evolution of organisms near the Early/Late Tithonian boundary, but also sheds light on the palaeogeography of Central Europe during that time. Additionally, the establishment of the Owadów–Brzezinki geoeducation area has been a significant achievement.

The excavation has been systematically carried out since 2013 by the Institute of Paleobiology PAS in Warsaw as a part of research projects supported by the Polish National Science Centre. It involved amateurs, undergraduate and

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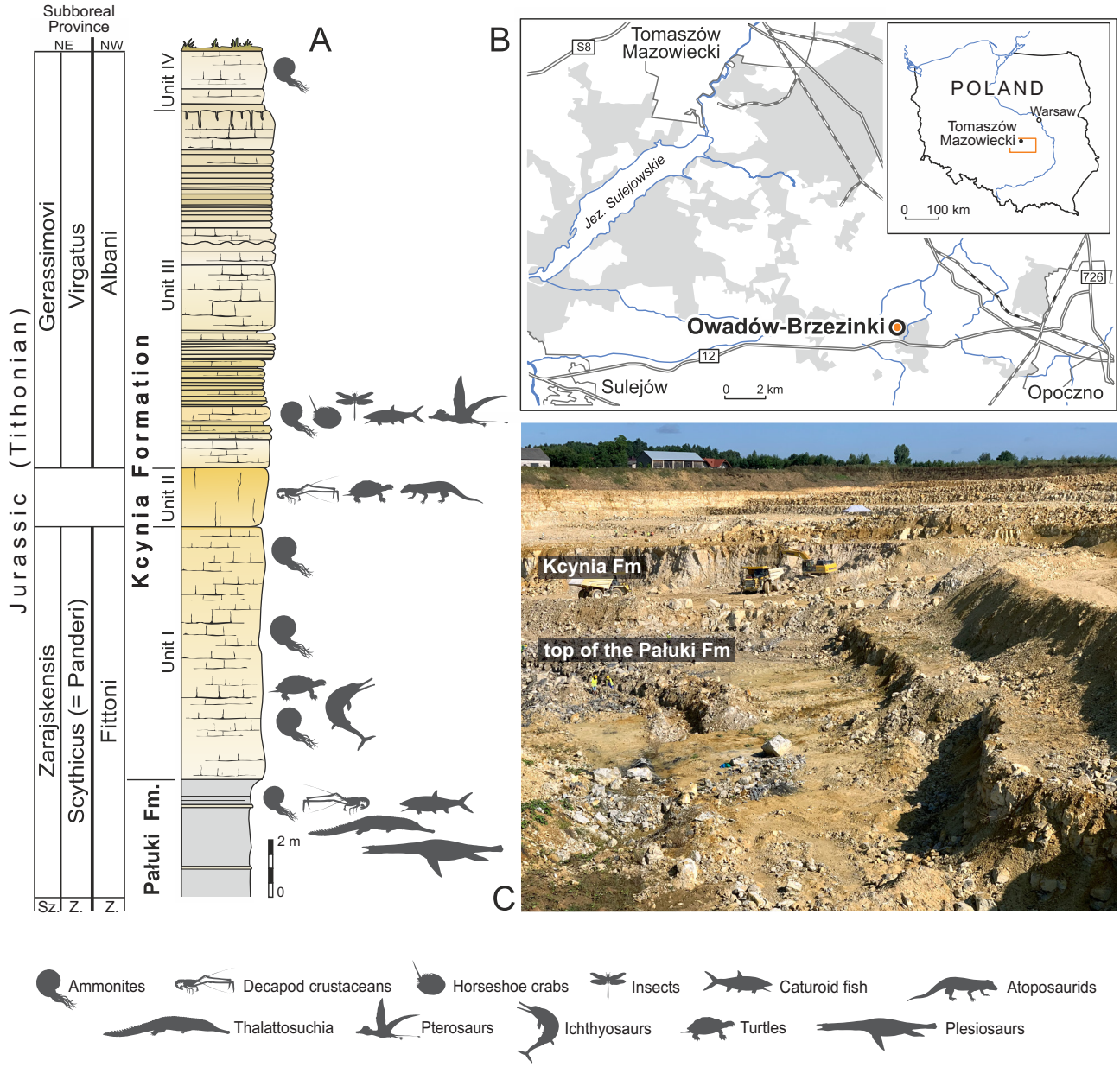

Fig. 1. Owadów–Brzezinki Lagerstätte

A. Lithological succession and ammonite stratigraphy of the Owadów–Brzezinki quarry. The topmost part of the Pałuki Fm and overlying limestones of the Kcynia Fm (Units I–IV); Sz – Subzone, Z – Zone. **B.** Road map with the location of Owadów–Brzezinki quarry in the proximity of Tomaszów Mazowiecki in Central Poland. **C.** Panoramic view of the Owadów–Brzezinki section

PhD students, as well as professional scientists from around the world. The remarkably well-preserved fossils of marine and terrestrial organisms of Tithonian age, many of which are new to science, offer an excellent opportunity to study various aspects of the taphonomy of the ecosystem, including the palaeobiology of the newly discovered organisms, the evolution/migration of taxa, and palaeoenvironmental changes (cf. Błażejowski *et al.*, 2014, 2016, 2019, 2023; Wierzbowski *et al.*, 2016).

The Owadów–Brzezinki Lagerstätte has recently attracted much attention not only because of the quality and quantity of well-preserved fossils, but also due to its palaeogeo-

graphic significance. This site encompasses an important region, situated at the transition of the Boreal/Subboreal and Tethyan realms, where interchange between temperate and tropical faunas occurred (Błażejowski *et al.*, 2023; Fig. 2). The Owadów–Brzezinki Lagerstätte provides important clues for stratigraphical correlation between the NW Europe, Russian and Tethyan domains of the Tithonian (Late Jurassic), linking calpionellid occurrences (a typical Tethyan stratigraphic proxy) with the well-established, British and Russian ammonite zonal schemes (Matyja, Wierzbowski, 2016; Błażejowski *et al.*, 2023).

GEOLOGICAL BACKGROUND

The rocks exposed in the quarry belong to the mid-Tithonian (Upper Jurassic), and are independently correlated with a lower part of the "Middle Volgian", being a local East European Substage. The Owadów–Brzezinki quarry exposes the Brzostówka Marl Member (Mb) of the topmost

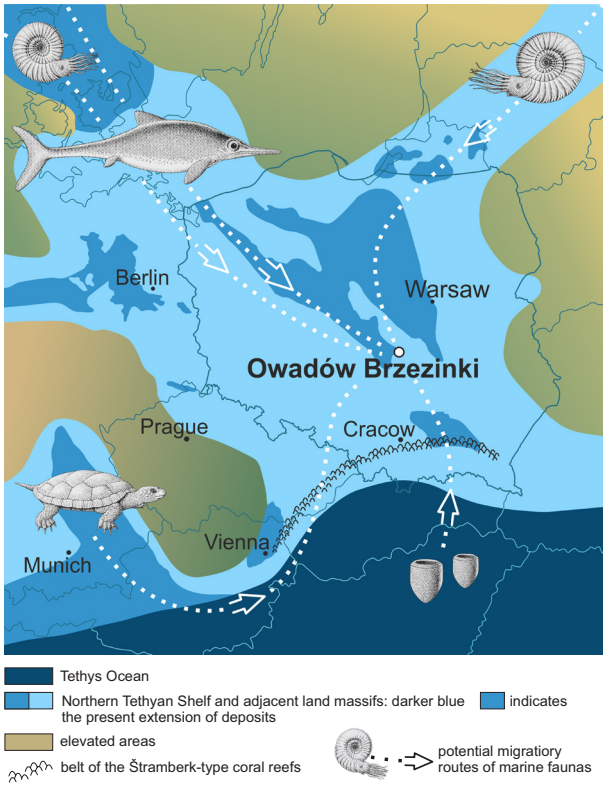

Fig. 2. Palaeogeographical reconstruction for the Middle European areas in the Early/Late Tithonian boundary interval (after an explanation in the palaeontological pavilion in the Owadów–Brzezinki Geopark, acc. B. Błażejowski, A. Hołda-Michalska, B. Matyja, A. Wierzbowski)

part of the Pałuki Formation (Fm) and the overlying limestones of the Kcynia Fm, which belong to the Sławno Limestone Member, "*Corbulomima* limestones" and a horizon of "serpulite beds" (Kutek, 1994; Błażejowski *et al.*, 2016; Matyja, Wierzbowski, 2016; Fig. 1). Chitinoidellids from the uppermost part of the Pałuki Fm in the Owadów–Brzezinki section belong to the topmost part of the Dobeni and lower part of the Boneti subzones of the Chitinoidellidae Zone (Błażejowski *et al.*, 2023). The same part of the succession is correlated to the magnetosubzone M20n.2n. The sedimentary pattern observed in the Owadów–Brzezinki quarry indicates a gradual marine regression, characterized by a transition from offshore to coastal and lagoonal settings. The uppermost part of the section was, however, deposited during a short-term marine transgression, marking the re-appearance of coastal environments (Błażejowski *et al.*, 2016; Wierzbowski *et al.*, 2016, 2019). The geochemical data shows a decreasing intensity of chemical weathering during the earliest Late Tithonian in central Poland, which is linked to the aridification of the latest Jurassic climate (Błażejowski *et al.*, 2023). The same trend is observed in coeval sections of NW and NE Europe (Hesselbo *et al.*, 2009).

The uppermost part of the Brzostówka Marl Mb of the Pałuki Fm from the Owadów–Brzezinki quarry (*ca.* 4 m thick) consists of black, blue-greyish and yellow-bluish marls with the intercalation of thin oyster-bearing and marly limestone beds (*cf.* Błażejowski *et al.*, 2016; Wierzbowski *et al.*, 2016). The marls yielded abundant marine microfossils, bivalves, ammonites, decapod crustaceans and fishes (Błażejowski *et al.*, 2016). The overlying limestones of the Kcynia Fm have been subdivided into four lithological units (Fig. 1). Unit I and unit II belong to the Sławno Limestone Member.

Unit I (*ca.* 9.1 m thick) consists of massive, fine-grained, chalky limestone characterized by a general absence of sedimentary structures. Common faunal elements, especially in the lower part of this unit, are deep-burrowing bivalves *Pleuromya* sp. accompanied by oysters *Deltoideum delta* (Smith) and unidentified trigoniid bivalves (Fig. 3), terebratulid and rhynchonellid brachiopods (Fig. 4), small gastropods, crinoids and ammonites (Fig. 5). Unit I yielded a highly diversified foraminiferal assemblage, except in its uppermost part, as well as low diversity ostracod fauna and echinoid fragments (Wierzbowski *et al.*, 2016). Recently, bones of marine reptiles have been also recovered from Owadów–Brzezinki quarry. These are represented by ichthyosaurs (Fig. 6), turtles (Fig. 7), crocodylomorphs and plesiosauroid teeth (Fig. 8) with remarkably good preservation (Błażejowski *et al.*, 2016; Tyborowski, 2016; Szczygielski *et al.*, 2018; Weryński, Błażejowski, 2023).

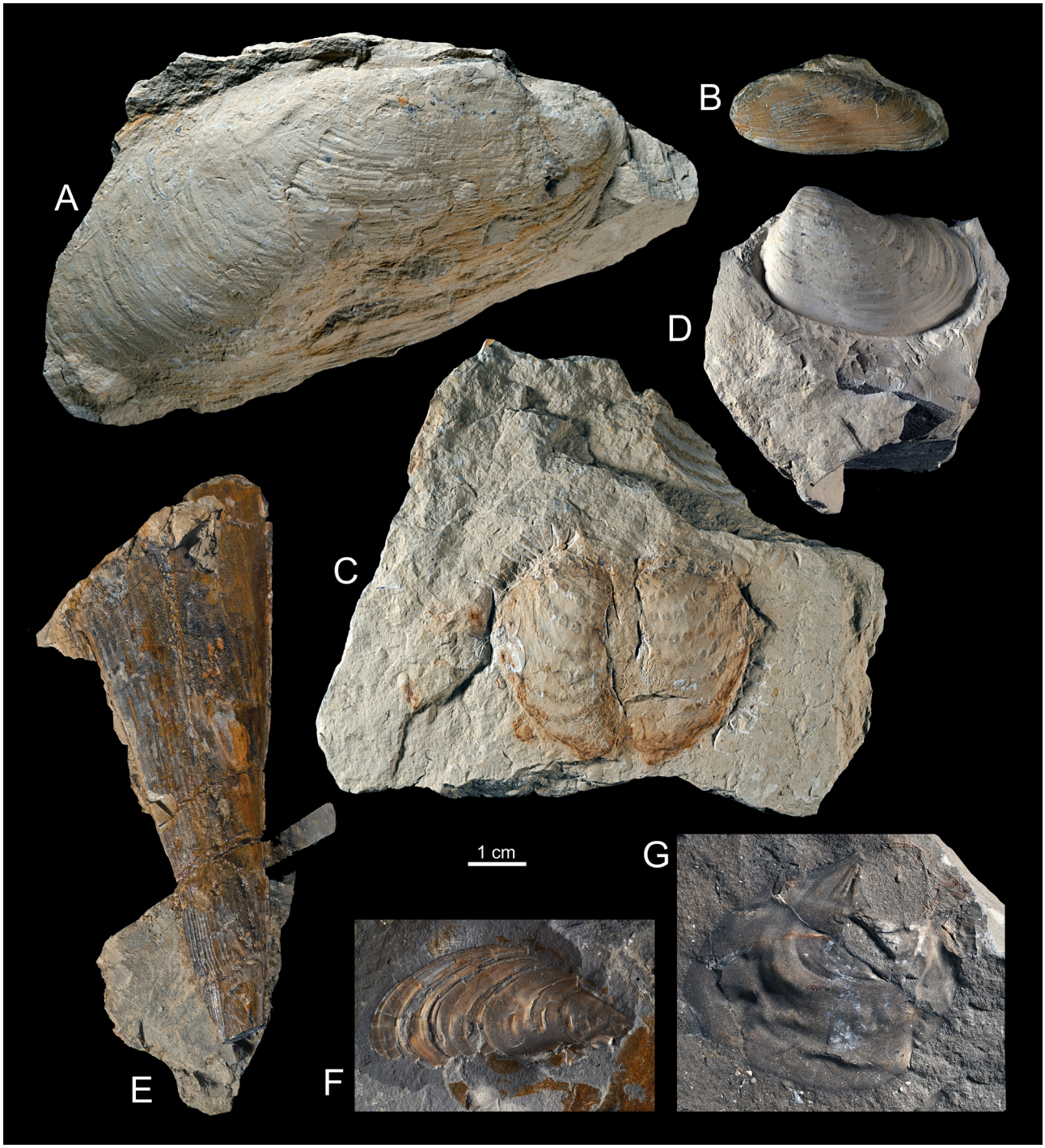

Fig. 3. Bivalve fossils from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (A–D) and Pałuki Fm (E–G)

A. *Myoconcha* sp.; **B.** mytiloid; **C.** trigoniid; **D.** *Pleuromya* sp.; **E.** *Pinna* sp.; **F.** bakevellid?; **G.** oyster

Fig. 4. Terebratulid brachiopod fossils from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (Unit I)

Unit II (*ca.* 2.2 m thick) is represented by micritic limestone beds, which are intercalated by very thin (2–4 cm) marly interbeds. Bivalves, decapod crustaceans (glypheoid lobsters), polychaete tubes and rare crinoids are found in these deposits. Unit II has also yielded an exceptional three-dimensionally preserved skeleton of an atoposaurid crocodyliform (Fig. 9). Atoposaurids are small-sized Mesozoic crocodyliforms of mainly European distribution, which are considered to be phylogenetically close to the origin of Eusuchia.

Unit III (*ca.* 12.8 m thick) consists of well-bedded "*Corbulomima*" micritic limestones. The lowermost part (1 m thick) comprises thick-bedded, hard, yellow limestones. The overlying beds (0.6 m thick) are paler in colour and very fossiliferous (Fig. 1).

Numerous specimens of horseshoe crabs (Xiphosurida, Arthropoda; Fig. 10) have been found in Unit III in association with mass-accumulations of small (up to 2 cm long) elongated bivalves (identified previously as "*Corbulomima*"), the remains of various fish and marine reptiles, rare ammonites and insects (Kin *et al.*, 2013; Błażejowski *et al.*, 2014, 2016). The extraordinary collection of horseshoe crabs described from this unit has a great significance for extending current knowledge of the group (Kin, Błażejowski, 2014; Błażejowski, 2015). The Late Jurassic horseshoe crabs preserved in sediments of Unit III lived in a restricted lagoon repeatedly subjected to dysoxia/anoxia, which promoted their excellent state of preservation (Błażejowski *et al.*, 2019, 2020). The discovery of new, more or less three-dimensionally preserved Late Jurassic xiphosuran arthropods adds significantly to our understanding of this group which has a very long geological range, including most of the Phanerozoic. The middle and the upper part of Unit III consists mainly of thin-bedded micritic limestones with thinner marly limestone intercalations and has not yet yielded well-preserved fossils. The beds of Unit III were most probably formed in shallow, stagnant waters of varying salinity with episodes of anoxia (Wierzbowski *et al.*, 2016, 2019).

The overlying deposits of **Unit IV** of *ca.* 2–3 m thickness are the youngest rocks of Owadów–Brzezinki quarry (Fig. 1). They contain rare ammonites, oysters, and small bryozoan-serpulid bioherms. The deposits of this unit most probably belong to the lower part of the so-called "serpulite beds". An erosional surface with conglomerate consisting of limestone pebbles with a subordinate amount of mudstones and quartz grains possibly of the Miocene age is developed locally on their top. The Jurassic strata are covered by Quaternary sands with gravels.

Fig. 5. Ammonite *Virgatopavlovia* from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (Unit I)

According to the stratigraphical studies by Kutek (1994) and Matyja and Wierzbowski (2016) based on the ammonite fauna, the lower part of section exposed at Owadów–Brzezinki quarry is dated to the *regularis* horizon (the uppermost part of the Brzostówka Marl Mb of the Pałuki Fm) and *zarajskensis* horizon (unit I of the Sławno Limestone Mb of the lowermost part of the Kcynia Fm). These horizons belong to the Zarajskensis Subzone of the Scythicus (Panderi) Zone of the "Middle Volgian", and to the Fittoni Zone of the "Bolonian" zonation of England. The upper part of the section (units III and IV belonging to the "*Corbulomima* limestones" and "serpulite beds", respectively) has, in turn, been assigned to both the Gerassimovi Subzone of the Virgatus Zone of the "Middle Volgian" and the Albani Zone of the "Portlandian" zonation of England.

AN OVERVIEW OF THE MOST IMPORTANT PALAEONTOLOGICAL FINDS

The Owadów–Brzezinki Lagerstätte serves as a unique "taphonomic window" into the Late Jurassic (Early to Late Tithonian boundary interval), providing valuable insights into the evolution of life on Earth within the stratigraphic, palaeogeographical and palaeoenvironmental contexts. Most notably, the site is the only existing non-Carpathian outcrop of the Tithonian in Poland, providing unique insight into the geological and palaeontological setting of this age in the regional perspective.

Of particular interest is the continuous discovery of new species endemic to this site. Notable examples include the lobster-like decapod crustaceans (Feldmann *et al.*, 2015;

Fig. 6. A highly articulated skeleton of ichthyosaur (Ichthyosauria: Ophthalmosauridae) from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (Unit I)

Błażejowski *et al.*, 2016; Fig. 11) and xiphosuran arthropods (Kin, Błażejowski 2012, 2014; Błażejowski, 2015; Błażejowski *et al.*, 2019, 2020; Bicknell *et al.*, 2021), constituting one of the largest accumulations of Jurassic horseshoe crabs ever found.

Bivalves are some of the most abundant and diverse invertebrates in the the Owadów–Brzezinki Lagerstätte. The bivalves of the Pałuki and Kcynia formations comprise more than 20 species altogether, chiefly pteriomorphs and hetero-

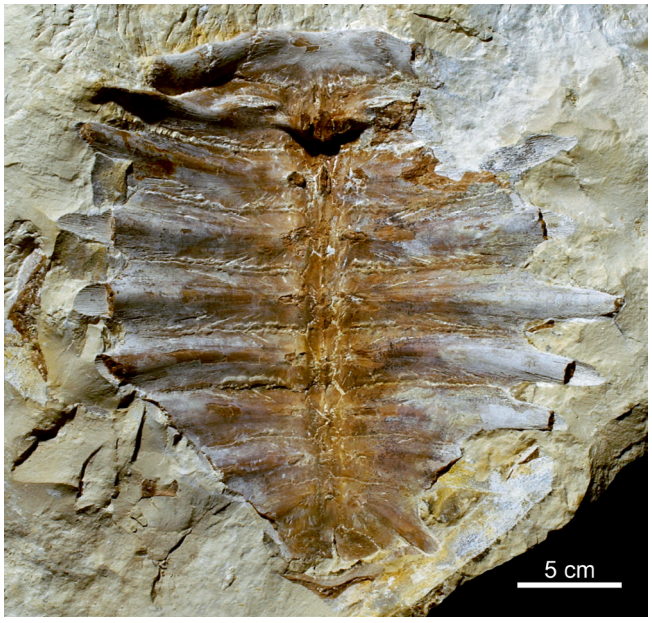

Fig. 7. The carapace of a Late Jurassic marine turtle (Thalassochelydia indet.). Late Jurassic (Tithonian), Kcynia Fm (Unit II)

Fig. 8. Plesiosaur tooth (ZPAL R.11/OB/T4). Late Jurassic (Tithonian), Pałuki Fm

Fig. 9. Three-dimensionally preserved atoposaurid crocodyliform from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (Unit II). Overview photograph of the original specimens in a piece of limestone

A. Dorsolateral view of skull; **B.** Articulated dorsal vertebra and associated osteoderms

donts (Fig. 3) as well as less abundant and diverse protobranchs. Preliminary observations indicate that the most abundant bivalve species within the Kcynia Fm, belong to the semi-infaunal (*Myoconcha* sp.; Fig. 3A; mytiloid, Fig. 3B), as well as shallow (trigoniids; Fig. 3C), and deep infaunal species (*Pleuromya* sp.; Fig. 3D). Within the Pałuki Fm, the contribution of semi-infaunal and epifaunal species is somewhat larger than in the Kcynia Fm (Fig. 3 E–G). Overall, the bivalves of the Owadów–Brzezinki Lagerstätte represent an assemblage of shallow-marine character and are comparable with Jurassic shallow marine bivalve faunas from carbonate settings in southern Germany (Wellnhofer, 1964) and Great Britain (Arkell, 1929–1937), but to some extent also with some faunas from the latest Jurassic–earliest Cretaceous siliciclastic deposits of Great Britain (Kelly, 1984, 1992; Clausen, Wignall, 1990).

Another group that will be the focus of future research are insects, which have been systematically collected over

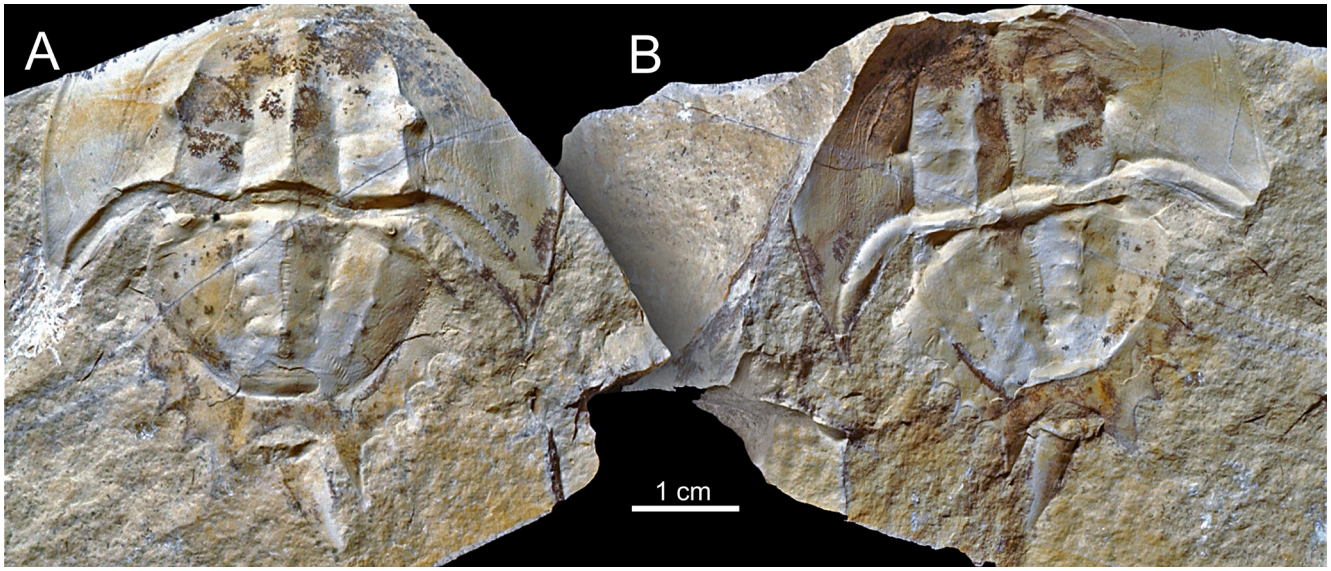

Fig. 10. Three-dimensionally preserved horseshoe crabs from Owadów–Brzezinki Lagerstätte (Tithonian, Late Jurassic), Kcynia Fm (Unit III). *Crenatolimulus darwini* (ZPAL X.1/O-B/14.1)

A. Negative; **B.** Positive (rock slab with imprint)

Fig. 11. Lobster-like decapod crustaceans '*Mecochirus*' sp. Late Jurassic (Tithonian), Pałuki Fm

the last decade (Fig. 12). All fossil insects from this site were found in the lowermost part of unit III ("*Corbulomima* limestones") of the Kcynia Formation. The specimens from this collection include members of Coleoptera, Orthoptera and Odonata, but several specimens are still indeterminated and may belong to other orders. Coleoptera are primarily represented by single elytra, but there are also instances of double (non-isolated) elytra and parts of abdomens. The sculpture of the elytra is present, being usually well-preserved and clearly visible. The other two orders, Orthoptera

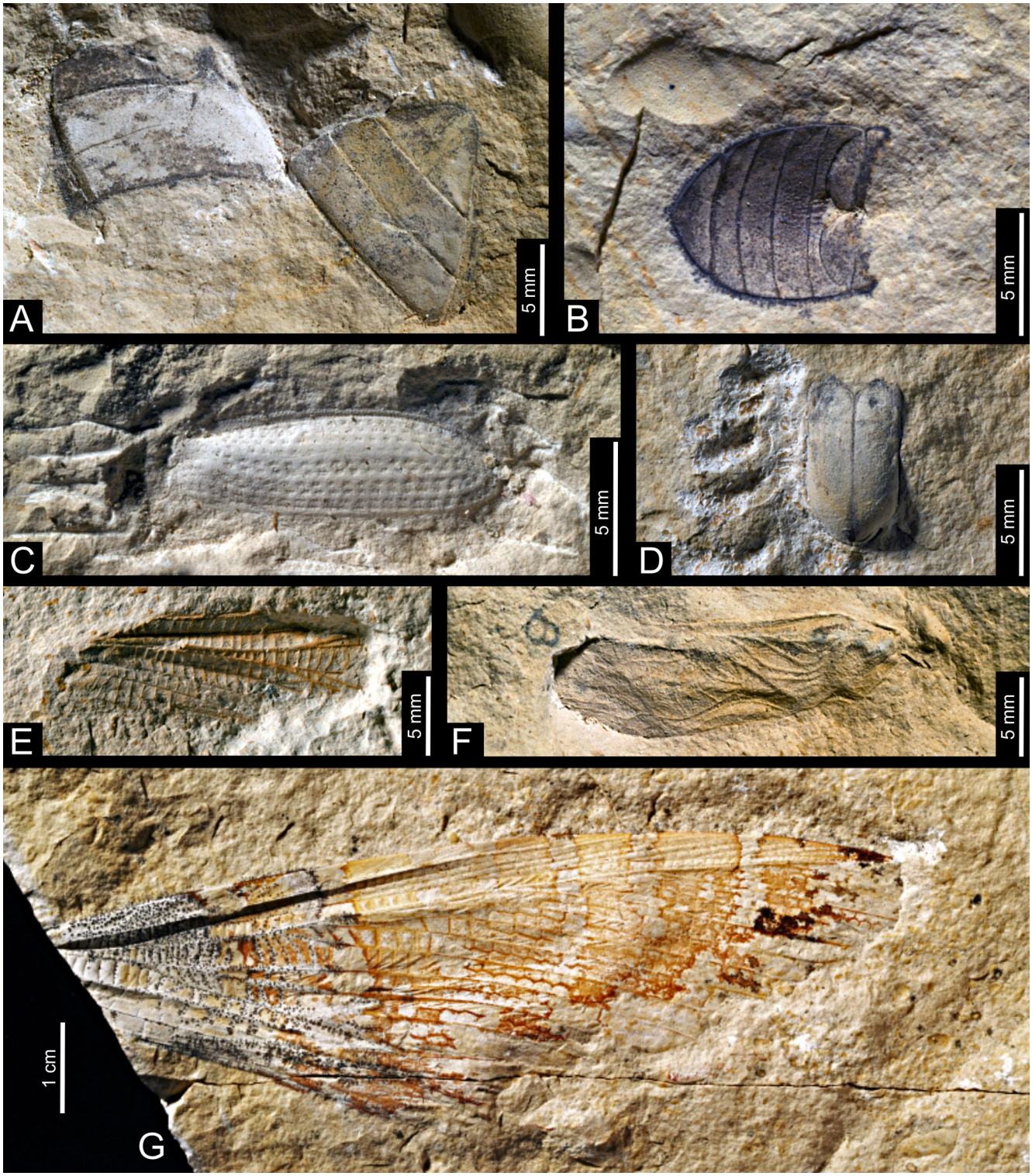

Fig. 12. Insects remains from Owadów–Brzezinki Lagerstätte (Late Jurassic, Tithonian)

A, B. Abdomens; **C, D.** Elytra; **E–G.** Wings. Late Jurassic (Tithonian), Kcynia Fm (Unit III)

and Odonata, are represented only by wings. The collected specimens contain full wings with venation clearly visible, as well as frequent irregular wing fragments, which, in some cases, even retain traces of their original colouration. The collection currently comprises nearly 50 specimens, with the majority being Coleoptera. Notably, a new species named *Eumorbaeschna adriankini* was described based on a dragonfly wing (Bechly, Kin, 2013).

So far, the collection has not yielded information about the habitat preferences of the insects within. Nevertheless, it is evident that some of these specimens are allochthonous, probably derived from ecosystems surrounding the lagoon. It is important to note that the number of specimens and species alone does not provide a sufficient basis for inferring the diversity of entomofauna (more critical in understanding the preservation of such delicate, tiny organisms in the field of taphonomy). Hence, the prevalence of Coleoptera in the collection may be a result of their robustness and ability for easy transport, rather than indicative of their environmental dominance. Moreover, the relatively low number of specimens could potentially suggest flat terrain around the lagoon, as mountainous areas often (not always) facilitate insect transport. Insect assemblages preserved in carbonate rocks are often dominated by species that rely on water for various reasons, such as feeding, habitation, or egg-laying. Palaeogeographically, this might indicate the presence of dry land in the area. Given the preservation state of the insects in the Owadów–Brzezinki Lagerstätte, it can be assumed they experienced considerable transport. Some of the disarticulation and fragmentation may have occurred prior to their deposition, perhaps near the lagoon's shores or on the water surface due to mechanical disintegration, possibly caused by atmospheric conditions. It is possible that insects were attracted to the lagoon's shores because of vegetation or the presence of deceased organisms. From this area, they could have been carried into the basin by the wind or other means, and trapped due to surface tension. Periods of environmental degradation related to dysoxia/anoxia were observed in the biotic and geochemical records; they may be partly linked to episodes of salinity increase of an isolated lagoon due to evaporation (Wierzbowski *et al.*, 2016, 2019). Salinity increase may have made it less likely that insects would settle to the bottom, resulting in their being exposed to additional external destructive factors in the water column. Subsequently, after penetrating the surface tension, they might have been carried further offshore by currents or consumed by fishes and other predators (Błażejowski *et al.*, 2015, 2016; Weryński *et al.*, 2023), which selectively consumed the nutritionally valuable parts of the insects, leaving behind wings and elytra (Coram, 2003; Martínez-Delclòs *et al.*, 2004; Żyła, Węgierek, 2011). An isolation barrier in the form of dysoxic/anoxic conditions near the bottom and fine grain sediment (Błażejowski *et al.*, 2019) is likely to have facilitated the preservation of delicate insect remains and anatomical details.

Some of the most spectacular discoveries from the Owadów–Brzezinki Lagerstätte are related to the vertebrates. The most prominent taxa of marine reptiles discovered so far are represented by the ichthyosaur *Cryopterygius kielanae* (Tyborowski, 2016), the pancryptodiran turtle *Owadowia borsukbialynickae* (Szczygielski *et al.*, 2018) and isolated plesiosaurian teeth (Weryński, Błażejowski, 2023). Other vertebrate taxa are represented by actinopterygians and elasmobranchs (Kin *et al.*, 2013; Błażejowski *et al.*, 2015) and marine crocodylomorphs (Błażejowski *et al.*, 2016), with an additional shore fauna represented by terrestrial crocodylomorphs, and possibly pterosaurs (Kin *et al.*, 2013).

Actinopterygii: The material comprises fossils of large predatory actinopterygians, primarily teeth, scales, and occasionally well-preserved jaw bones (Błażejowski *et al.*, 2015; Tyborowski, 2017). They represent caturoid and pachycormid macropredators, as well as durophagous pycnodontiforms. In the latest study of these large predators conducted by Weryński *et al.* (2023), an exploration into the microstructural and morphological attributes of caturoid and pachyformid teeth-form was undertaken. Its findings indicate the potential existence of environmental niche partitioning among these comparably sized predatory fish.

However, it is anticipated that in a prospering ecosystem a significant portion of the bony fish would tend to be of a smaller size, as this structure of the vertebrate fauna accommodates the nutritional needs of higher trophic levels. In fact, during field excavation, a small-sized, fully preserved Teleost specimen of questionable taxonomic status was discovered. This finding represents a pioneering sample of bony fish of exquisite preservation, akin in quality to the small actinopterygian specimens from the Solnhofen Plattenkalk.

Ichthyosauria: The specimen of *Cryopterygius kielanae* (or *Undorosaurus* sp. according to Zverkov, Jacobs, 2021) from Owadów–Brzezinki was found in Unit I of the Kcynia Fm (Tyborowski *et al.*, 2016). The material represents a medium-sized ophtalmosaurid ichthyosaur, with preserved elements of the jaw, axial skeleton, and shoulder girdle with forelimb (Fig. 6). It was previously suggested that the diagnostic characteristics of this specimen can be referred to those of boreal ichthyosaurs from Svalbard (Tyborowski, 2016). However, recent works have argued that the boreal *Cryopterygius* from Svalbard is a junior synonym for *Undorosaurus* (Zverkov, Jacobs, 2021), which occurs in Central Europe, in the European parts of Russia and across Svalbard, and thus has broad geographical distribution. Since this discovery, more ichthyosaur material referred to these

animals is being regularly uncovered. It is worth noting that an isotope study of ichthyosaur tooth enamel has shown an ontogenic, oxygen isotope shift of *ca.* 2‰ VSMOW, which may result from long-distance migrations (Wierzbowski *et al.*, 2019).

Plesiosauria: During recent field excavations, large conical teeth of Plesiosauria were discovered (Weryński, Błażejowski, 2023). The identification was based on the conspicuous pattern of enamel apicobasal ridges, overall morphology and the results of morphometric Principal Coordinates Analysis. The material consists of four large isolated teeth from the upper part of the Pałuki Fm and the lower part of the Unit I of the Kcynia Fm. These teeth have largely preserved crowns, in one case also showing a partially preserved root (Fig. 8). Given the stratigraphic context and overall morphology, it is highly probable that the described teeth belong to cryptoclidid plesiosaurs.

Crocodylomorpha: Atoposauridae is a family of small, short-snouted crocodyliforms ranging from the Middle Jurassic to the Late Cretaceous. It is inferred that these rather diminutive creatures spent most of their lives on land, due to their relatively long, strongly developed limbs, which suggest a terrestrial lifestyle. Atoposaurid material, representing cranial and postcranial remains, obtained from Unit II is currently under description, with a proposed new species referred to *Theriosuchus* (Fig. 9). Cranial material was previously presented by Błażejowski *et al.* (2016), and initially assigned to the Metriorhynchidae family, but since that time it has been re-evaluated as belonging to the Atoposauridae. Other crocodylomorph material includes remains which could possibly be ascribed to Thalattosuchia.

Testudinata: Szczygielski *et al.* (2018) introduced a new pancryptodiran turtle species from the Unit I: *Owadowia borsukbialynickae*. The fossil finding represents a large turtle, with a carapace length of approximately 50 cm. Comparisons with other Jurassic turtles can be drawn, and while the majority of common taxa exhibit unspecialized mandibles with short symphyseal areas, the substantial symphysis featuring a large surface area of *O. borsukbialynickae* is interpreted as an adaptation for durophagy. Additional turtle material is represented by the recently uncovered carapace (Fig. 7)

THE OWADÓW–BRZEZINKI GEOEDUCATION AREA

The discussed area is important not only for popularization of palaeontology but also for the development of the

Fig. 13. The entrance gate to the Owadów–Brzezinki Geosite (geopark) in Sławno Commune

region and its inhabitants. Over the past few years, workshops and lectures have been organized in the Sławno Commune with the aim of promoting geological knowledge, especially palaeontology, amongst the local population. These initiatives seek to foster an atmosphere of understanding and respect for the natural environment. New activities primarily target school children and youth, as well as individuals interested in the research and preservation of our country's geological heritage. The palaeontological pavilion located in the thematic geoeducation area, known as "Owadów–Brzezinki Geopark" (Fig. 13), and supervised by the Sławno Commune, plays a vital role in these endeavours (Błażejowski *et al.*, 2020; Błażejowski, Wierzbowski, 2021). It showcases fossils of Jurassic animals discovered at the site, along with their interpretations. Activities that are regularly undertaken in the Sławno Commune are a good example of cooperation between local government, industry, and the scientific community.

FUTURE PERSPECTIVES

The impressive biodiversity of the Owadów–Brzezinki region (Fig. 14) will continue to provide material for years of future research. The discovery of plesiosaur teeth provides us with an incentive for further exploration in search of more complete cranial and postcranial material. The discovery of insects opens up a whole new area of research at the site. In addition, the recently found largely complete cranium of an atoposaurid is a unique opportunity to study the mechanical properties of the skull and explore sensory capabilities, with the possibility of comparison with cognate taxa and contemporary relatives.

Every year, additional facets of research are integrated into the study of the site. Minding the quality and unique state of the preservation of specimens from this location, their reevaluation focusing on microstructure is planned us-

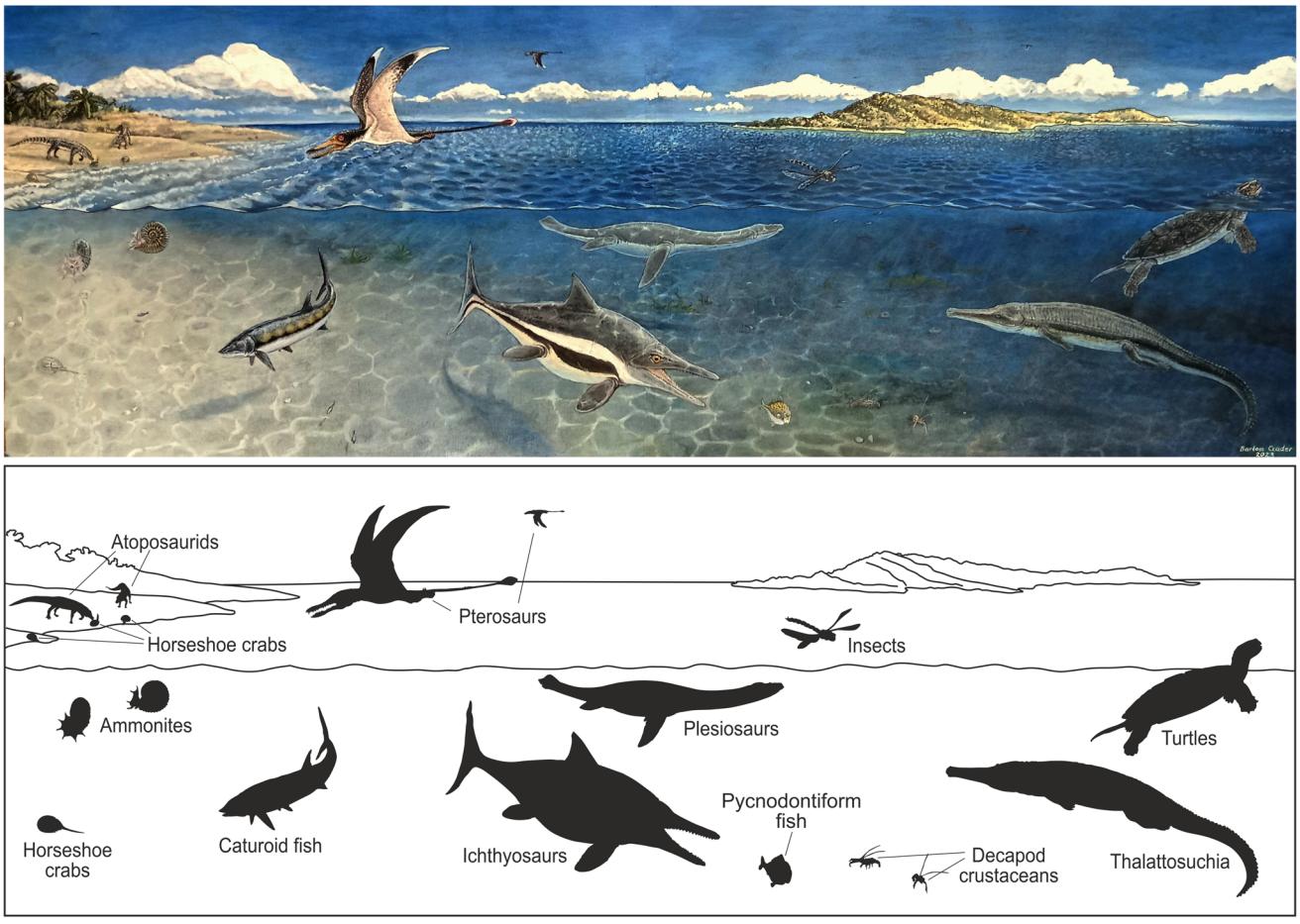

Fig. 14. Interpretative palaeoart drawn by Bartosz Czader depicting the biodiversity of Owadów–Brzezinki site, focusing on reconstruction of the environment and habits of the local fauna

ing state-of-the-art imaging and structural methods. For example, preliminary imaging tests of non-sputtered samples using the Scanning Electron Microscope (SEM) performed in environmental and/or low vacuum mode revealed details of microsculpture in samples of insects' elytra not visible before. Other samples, among which the eyes of horseshoe crabs or lobster-like decapod crustacean remains should be mentioned, as these are the most promising for such microstructure investigations. Moreover, specimens which retain traces of their original coloration hopefully will bring a better understanding of how the chemistry and taphonomy processes in Owadów–Brzezinki led to the creation of such a unique Lagerstätte.

The whole section of the quarry requires detailed ichnological studies. The preliminary studies (Kugler *et al*., 2023) show that the Pałuki Formation is partly bioturbated and contains abundant *Thalassinoides* isp., rare *Phycosiphon incertum*, *Planolites* isp., *Teichichnus* isp., *Chondrites* isp. and *Balanoglossites* isp. The abundant presence of the decapod crustacean '*Mecochirus*' sp. in the Pałuki Formation suggests that this crustacean may have been the tracemaker of *Thalassinoides* isp. A comparison of the minimum width of *Thalassinoides* isp. and the maximum width of the carapace of '*Mecochirus*' sp. confirms this possibility. However, the minimum width of a part of *Thalassinoides* isp. is larger than the maximum width of the carapace of '*Mecochirus*' sp. This suggests that *Thalassinoides* isp. was also produced by some other tracemakers or that '*Mecochirus*' sp. reached a larger size than that of the available material. In the Kcynia Formation, *Arenicolites* isp., *Trichichnus* isp., *Arachnostega* isp. (in bioclasts) and *Thalassinoides* isp. are present. The degree of bioturbation decreases towards the top of the section. Generally, the trace fossil assemblage from both formations belongs to the impoverished *Cruziana* ichnofacies. The reason for the impoverishment (abnormal chemistry of the environment?) requires a further explanation.

It is anticipated that through further exploration and ongoing research at Owadów–Brzezinki quarry, the scientific community will attain a comprehensive understanding of this invaluable palaeontological site. The understanding will encompass palaeobiological interpretations, firmly situated within a precise temporal framework (biostratigraphy), an assessment of the environmental context (sedimentology) and a broader perspective on palaeobiogeography and palaeogeography. The complementary approaches contribute to a more complete reconstruction of this ancient ecosystem, making it one of the most remarkable discoveries in the history of Polish palaeontology.

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