Excursion guide

REMARKABLY WELL-PRESERVED UPPER JURASSIC FOSSILS OF MARINE AND TERRESTRIAL BIOTA FROM THE OWADÓW-BRZEZINKI QUARRY, CENTRAL POLAND

Błażej BŁAŻEJOWSKI[1] and Daniel TYBOROWSKI[2]

[1]*Institute of Paleobiology, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland;* [2]*Museum and Institute of Zoology, Polish Academy of Sciences, ul. Wilcza 64, 00-679 Warszawa, Poland.*

Corresponding author: bblazej@twarda.pan.pl

The paleontological site located in the Owadów-Brzezinki Quarry is one of the most important discoveries recently unearthed in Poland (Kin et al. 2013). The study area is located about 20 km southeast of Tomaszów Mazowiecki (Fig. 1). Here, uppermost Lower Tithonian (= Middle Volgian) carbonate sediments are exposed in a small working quarry belonging to the Nordkalk Company (Sławno). At the moment, the Owadów-Brzezinki Quarry (Fig. 2) is the only place in extra-Carpathian Poland where the Tithonian strata are available for study (the classic locality Brzostówka is

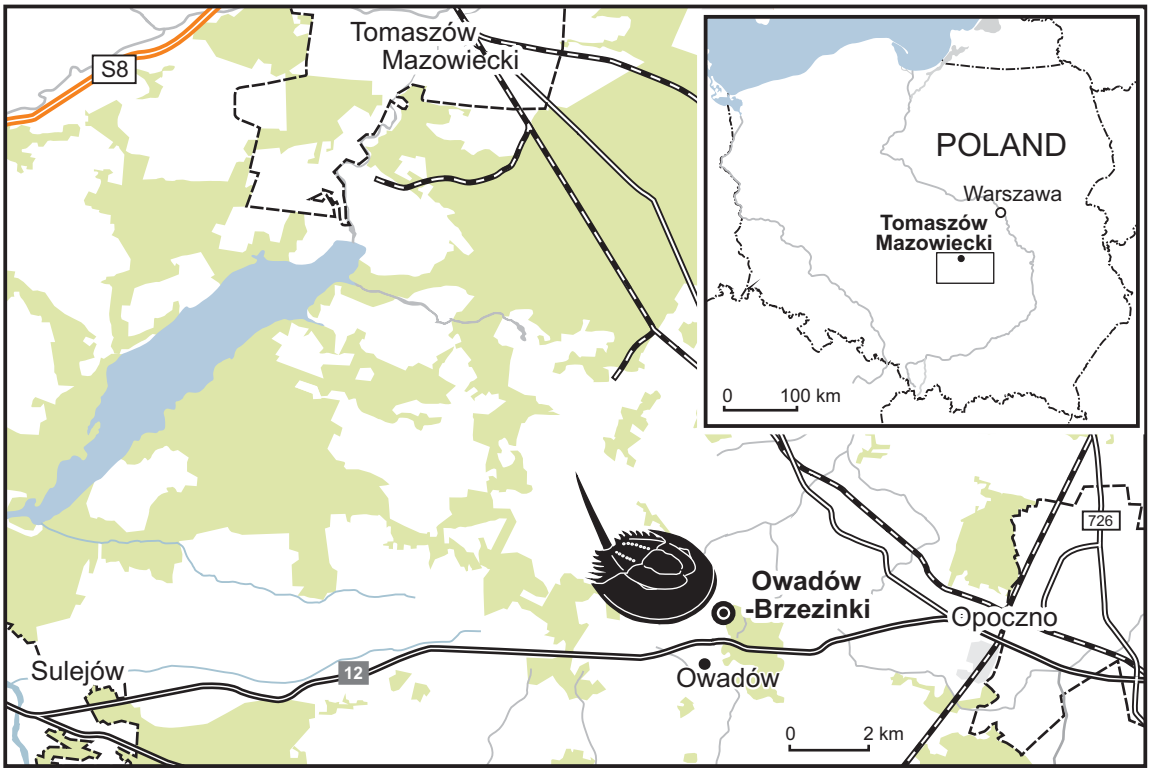

Fig. 1. Road map with the location of Owadów-Brzezinki Quarry and its proximity to Tomaszów Mazowiecki in Central Poland.

Fig. 2. Panoramic view of the highest level of exploitation in Owadów-Brzezinki Quarry, Poland.

now within the Tomaszów Mazowiecki town limits; quarries in Pomerania are flooded). Unusually well-preserved fossils of marine and terrestrial organisms provide an unprecedented opportunity to examine a part of the Late Jurassic world. Many aspects of biology, ecology, and geology are available to study, especially the taphonomy of the ecosystem, the evolutionary relationships of the taxa, and the record of paleoenvironmental changes. Similarities to the well-known Late Jurassic sites of *Fossil-lagerstätte* at Solnhofen, Eichtätt, Kelheim and Nussplingen in Bavaria, Southern Germany are highly interesting. These sites, only slightly older than Owadów-Brzezinki, seem to have a lot in common with the Polish locality, e.g. many aspects of the overall setting of a coastal-lagoonal ecosystem, great abundance of fossils and their excellent state of preservation. Paleontological discoveries associated with the famous Bavarian sites accumulated over more than 150 years of history provide a lot of exceptional and well documented material for comparative studies.

Previous assumptions regarding possible connections between biogeographical provinces suggest that the sediments in the Owadów-Brzezinki region should be a keystone link between Boreal and Tethyan faunas (Kutek and Zeiss 1988; Dzik 1994). Resulting correlations—so important for understanding Late Jurassic World—are being confirmed in the course of recent investigations (Matyja et al. 2016). The migration events recorded in the Owadów-Brzezinki Quarry may serve to correlate the Polish succession, representing the Subboreal Province of the Boreal Realm, not only with the Tethyan Realm sections, but even with the Boreal British and Arctic uppermost Jurassic. This statement is true not only in respect to the ammonite fauna, but also to many other groups of animals, and it is possible to trace animal migration routes between the latest Jurassic biogeographic regions, and thus to explain the faunal similarities and differences between Poland and elsewhere.

In describing the ammonite fauna from the nearby Brzostówka section, Kutek (1994) assigned the deposits of Owadów-Brzezinki to the Regularis Horizon being the uppermost part of the Pałuki Formation, and the Zarajskites Horizon forming an exposed part of the Kcynia Formation within the Zarajskites Subzone of the Scythicus Zone of the Middle Volgian (i.e. the uppermost Lower Tithonian).

The black, blue-grey and yellow-blue marls (c. 1.6 m thick) with the intercalation of thin oyster-bearing and marly limestone beds (Błażejowski et al. 2014) exposed in the lowermost part of the Owadów-Brzezinki Quarry belong to the uppermost part of the Brzostówka marls of the Pałuki Formation (Fig. 3). These marls have yielded abundant ammonites, bivalves, crustaceans and large actinopterygian fish bones. Of special interest are the relatively common and exquisitely preserved lobster-like decapod crustaceans (Glypheoidea; Mecochiridae), belonging to the genus

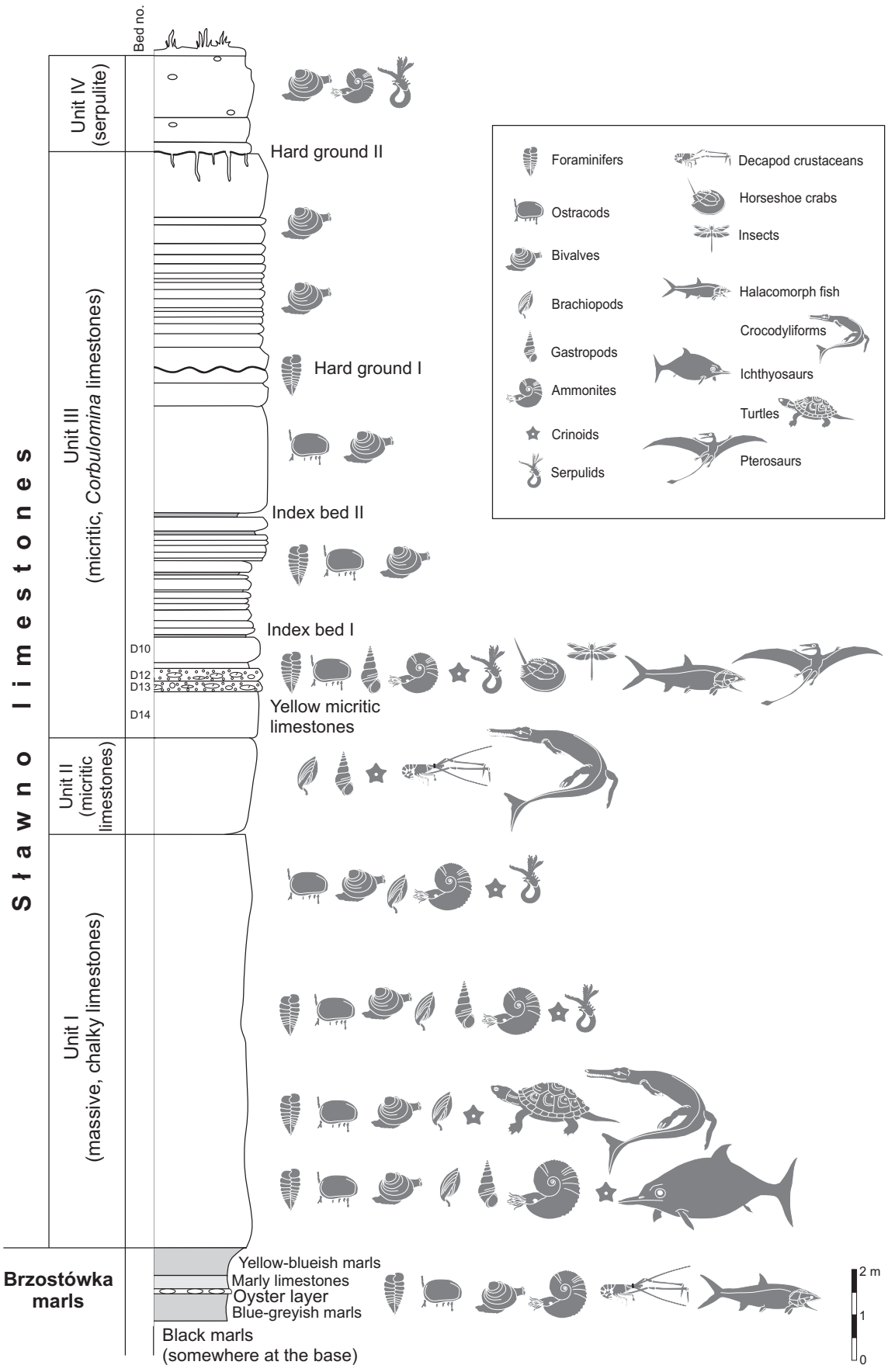

Fig. 3. Lithological succession of the Owadów-Brzezinki Quarry.

Fig. 4. Lobster-like decapod crustaceans *Mecochirus* sp. nov. (**A**) negative (external mold) and (**B**) positive (rock slab with imprint) (ZPAL Cr.11/O-B/15/1).

Mecochirus (Fig. 4) and their trace fossils—*Thalassinoides* burrow systems. The specimens found in the marly limestones of the Pałuki Formation appear to have been quickly buried alive, suggesting episodes of rapid sedimentation.

The overlying Sławno Limestone Member belongs to the Kcynia Formation. With c. 30 m, it is the thickest and most important part of the profile (Fig. 3) and has been subdivided into four distinct lithological units (Błażejowski et al. 2014 and references therein).

Unit I (c. 9.1 m thick) consists of massive, chalky limestone characterized by a general absence of sedimentary structure. Deep-burrowing bivalves *Pleuromya* accompanied by oysters *Deltoideum* and an unidentified trigoniid bivalves, rhynchonellid and terebratulid brachiopods, small gastropods and ammonites are common, especially in the lower part of this unit. Recenty, quite numerous bones of marine reptiles have been also recovered from Owadów-Brzezinki Quarry. These are represented by ichthyosaurs, turtles and crocodylomorphs (isolated teeth and long bones) with a remarkably good quality of preservation. Based on osteological analysis, the ichthyosaur remains from the Owadów-Brzezinki Quarry (Fig. 5) clearly belong to a member of the Ophthalmosauridae family and appear to be very similar to the genus *Cryopterygius*, previously known only from Spitsbergen (Roberts et al. 2014). The unarticulated skeleton of a cryptodiran turtle, consisting of several bones: coracoid, femur and parts of the lower jaw and pelvic girdle, was also discovered (Tyborowski et al. in press).

Unit II (c. 2.2 m thick) is represented by thin-bedded micritic limestones, which are underlain and overlain by very thin (2–4 cm) marly beds. Bivalves, ammonites, decapod crustaceans (glypheoid lobsters), polychaete tubes and rare crinoids are found in these deposits (cf. Kin et al. 2013). Unit II has also yielded a recent find of an exceptional three-dimensionally preserved skeleton of the crocodylomorph (metriorhynchiid), which is the only archosaurian group that can be defined as completely adapted to a pelagic marine life. The specimen, consisting of braincase (Fig. 6), teeth, osteoderms and caudal vertebrae was investigated using X-ray microcomputer tomography (XMT), a non-invasive tool, which permits examination of its internal structure, and, after computer processing, renders a 3-D model and precise images for histology studies (Fig. 6).

Unit III consists of well-bedded micritic limestones (c. 12.8 m thick). The lowermost part (bed

Fig. 5. A nearly complete skeleton of ichthyosaur (Ichthyosauria: Ophthalmosauridae) from Owadów-Brzezinki Quarry.

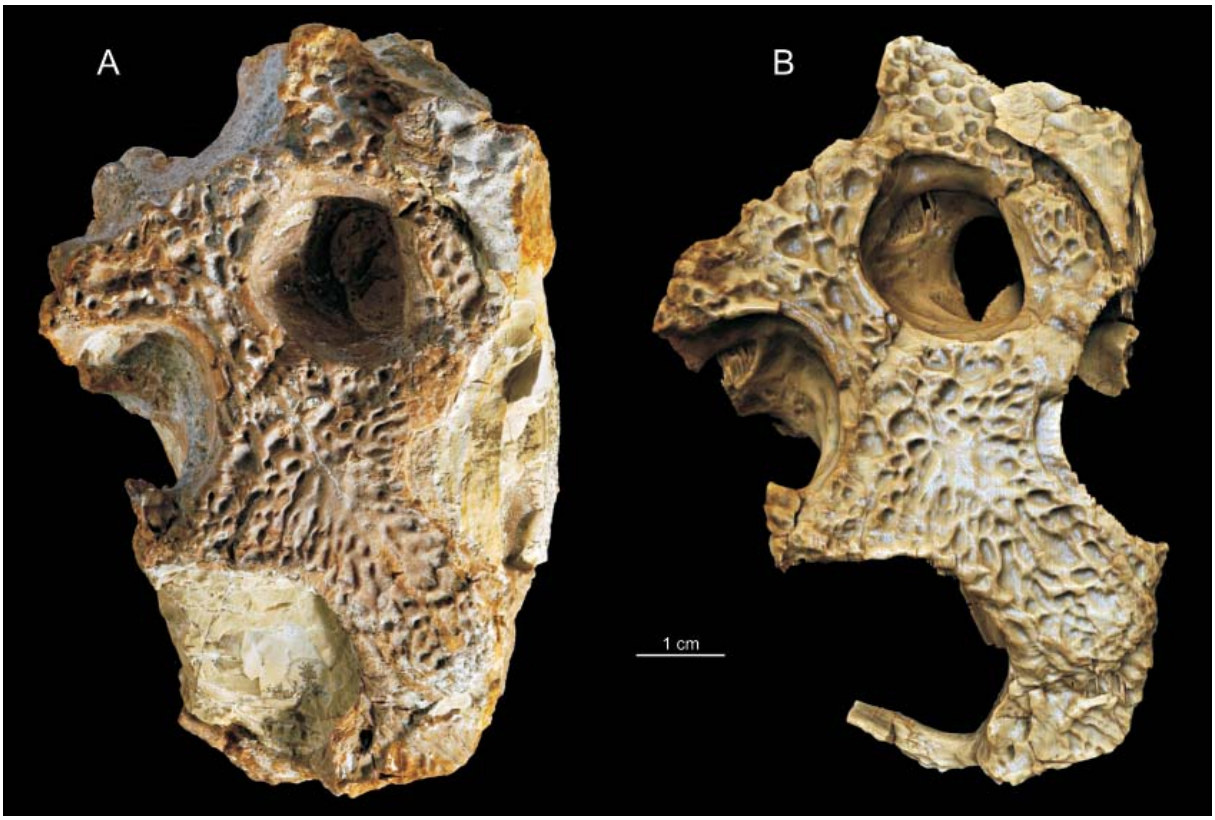

Fig. 6. Skull of marine crocodylomorph (metriorhynchidae) from Owadów-Brzezinki Quarry in dorsal view. **A**. Specimen in piece of limestone (photography). **B**. 3-D model of "virtual fossils"—view of the specimen after digital processing and analysis of tomographic data.

D14, 1 m thick) comprises thick-bedded yellow limestones (Fig. 2). The overlying D13 and D12 beds (1.2 m thick) are paler in colour and very fossiliferous (Fig. 3). Numerous specimens of horseshoe crabs (Fig. 7) have been found in Unit III in association with an enormously rich assemblage (mass-accumulations) of soft-shelled bivalves (either protobranchs or corbuloids), the remains of various fish and marine reptiles, rare ammonites, decapod crustaceans, land insects (dragonflies, beetles, grasshoppers) and isolated pterosaur teeth (Kin and Błażejowski 2012; Kin et al. 2012, 2013; Błażejowski et al. 2014, 2015; Błażejowski 2015).

Fig. 7. Late Jurassic horseshoe crabs from Owadów-Brzezinki, Poland; different stages of disarticulation (ZPAL X.1/O-B/XAC 8.3).

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. U-shaped burrows with polygonal patches at the top surfaces of the beds are sometimes observed in the limestones from this interval (cf. Kin et al. 2013). Mass-accumulations of small, unidentified bivalves occur in the younger deposits, but they are less common than in fossiliferous beds D12 and D13; the same applies to the ammonite fauna. Only a few small oyster shells were derived from Unit III and these rocks are devoid of crinoids (cf. Kin et al. 2013). The fossil remains of the large, predatory actinopterygians are the most common fossils of vertebrates in this unit. Błażejowski et al. (2015) described a large part of the upper jaw (maxilla) of a *Caturus*, also known to be one of the biggest predators in the Solnhofen Archipelago ecosystem. Smaller predators, such as the members of the Furidae, are also known from the Owadów-Brzezinki Quarry.

The uppermost part of the Owadów-Brzezinki profile is represented by Unit IV (c. 2.2 m thick), which is developed as organodetritical limestones rich in small oyster-like bivalves, bryozoans and serpulids (forming small bioherms). The rocks of Unit IV are highly weathered and karstified, especially at the contact with Quaternary sand cover.

The sedimentation pattern observed in the Owadów-Brzezinki section indicates shallowing of the depositional environment, from an offshore to nearshore, perhaps lagoonal or coastal environment (Błażejowski et al. 2014). The specimens from the most fossiliferous beds of Unit III are interpreted as having been rapidly buried (Kin et al. 2013). These beds were most probably formed in shallow, stagnant waters, under specific environmental conditions. Recent investigations indicate possible episodes of anoxia (Wierzbowski et al. in press). Such changes in the chemistry of the environment resulted in great transformations in the overall composition of the biota, including the appearance of specific bacteria and fungi; in turn, this might have had significant influence on

the fossilization processes, which resulted in such an excellent state of preservation, e.g. of the especially fragile parts of horseshoe crabs.

Fieldwork conducted in recent years at the Owadów-Brzezinki Quarry has provided many interesting paleontological discoveries. The collection of well preserved lobster-like decapod crustaceans (Glypheoidea; Mecochiridae) from the lowermost levels has provided a wealth of new information on the biology of the group, its geographical and stratigraphical distribution, and on many aspects of paleoenvironmental ecology. This genus is well known and commonly found also in the Solnhofen-Eichstätt Plattenkalk (Garassino and Schweigert 2006), and thus indicates a close connection with the Submediterranean Province of the Tethyan Realm, as—in terms of biogeographical distribution—the region of the so-called Solnhofen Archipelago is considered to be part of this province, whereas Middle and Northern Poland were thought to be part of the Subboreal Province (Kutek and Zeiss 1997), connected with the Arctic Basin to the north (Boreal Realm). Certainly, the most recent finds from Owadów-Brzezinki significantly expand our knowledge of the paleogeographic relations within the European Late Jurassic basin system.

Fossils of Tithonian marine reptiles were known to date from two regions: Southern Germany—Bavaria (so called Solnhofen Archipelago) and High Arctic (Spitsbergen). The first—commonly related to Solnhofen because of its fame—is located within the Submediterranean Province and is characterized by frequent finds of turtles, crocodylomorphs and ichthyosaurs (Bardet and Fernandez 2000). The second region, located at Spitsbergen, belongs to the Boreal Realm, and is also represented by ichthyosaurs (Roberts et al. 2014), but of completely different genera, whereas turtles and crocodylomorphs are not known there. The finds from Owadów-Brzezinki include cryptodiran turtles and metriorhynchiid crocodylomorphs characteristic of the Solnhofen-type ecosystem, and *Cryopterygius* ichthyosaurs specific only to the Boreal Realm (Tyborowski et al. in press). Fossil representatives of different faunal zones found in a close proximity within single outcrops aree evidence for a connection between the two mentioned provinces, a link for which the evidence has not previously been documented.

The latest examinations of the classic Tithonian sites in Bavaria, such as Solnhofen-Eichtätt-Kelheim, and a comparison with new excavation sites, such as that of Brunn, show that many of these sites are of different stratigraphic age and the faunas are also different (Ebert 2016). The Owadów-Brzezinki Quarry appears to be a new "taphonomic window" into the world of the latest Jurassic and clearly represents a very important closely-aged palaeontological "supplement" to the Tithonian Solnhofen Archipelago sites, thereby significantly expanding our paleogeographical and paleobiological knowledge beyond the regions explored so far. The continuous change of the environment, which is visible in the shallowing profile of Owadów-Brzezinki, provides a great opportunity for studying transitions within faunistic assemblages and helps us to understand paleobiological spatial relations. Furthermore, many similarities are supposedly to be found in Late Jurassic marine reptiles from Gondwana. Comparative studies with other paleontological material create a welcome opportunity for studying evolution and rates of speciation.

References

Bardet, N. and Fernandez, M.S. 2000. A new ichthyosaur from the Upper Jurassic lithographic limestones of Bavaria. *Journal of Paleontology* 74: 503–11.

Błażejowski, B. 2015. The oldest species of the genus *Limulus* from the Late Jurassic of Poland. *In*: R.H. Carmichael, M.l. Botton, PKS. Shin, and S.G. Cheung (eds.), *Changing Global Perspectives on Biology, Conservation, and Management of Horseshoe Crabs*, 3–14. Springer, New York.

Błażejowski, B., Matyja, B.A., Wierzbowski, A., and Wierzbowski, H. 2014. A new exceptionally preserved Late Jurassic ecosystem (Owadów-Brzezinki, Central Poland) and its geological background. *In*: A. Feldman-Olszewska and A. Wierzbowski (eds.), *Jurajskie utwory synkliny tomaszowskiej. Jurassica XI. Przewodnik wycieczek terenowych, abstrakty i artykuły. Spała, 9–11.10.2014 r.*, 21–26. Państwowy Instytut Geologiczny – PIB, Warszawa.

Błażejowski, B., Gieszcz, P., Brett, C.E., and Binkowski, M. 2015. A moment from before 365 Ma frozen in time and space. *Scientific Reports* 5: 14191; doi: 10.1038/srep14191.

Błażejowski, B., Lambers, P., Gieszcz, P., Tyborowski, D., and Binkowski M. 2015. Late Jurassic jaw bones of halecomorph fish (Actinopterygii: Halecomorphi) studied with X-ray microcomputed tomography. *Palaeontologia Electronica* 18.3.53A: 1–10.

Dzik, J. 1994. Sexual dimorphism in the virgatitid ammonites. *Proceedings of the 3rd Pergola International Symposium. Palaeopelagos. Special Publication* 1: 129–141.

Ebert, M. 2016. The Pycnodontidae (Actinopterygii) in the late Jurassic: 2) *Turboscinetes* gen. nov. in the Solnhofen Archipelago (Germany) and Cerin (France). *Achaeopteryx* 33: 12–53.

Garassino, A. and Schweigert, G. 2006. The upper Jurassic Solnhofen decapod crustacaen fauna: review of the types from old descriptions (infraorder Astacidae, Talassinidea and Palinura). *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia naturale in Milano* 34: 1–64.

Kin, A. and Błażejowski, B. 2012. „Polskie Solnhofen". *Przegląd Geologiczny* 60: 375–379.

Kin, A., Błażejowski, B., and Binkowski, M. 2012. "Polish Solnhofen": a long-awaited alternative?! *Geology Today*, 28: 92–95.

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

Kutek, J. 1994. The Scythicus Zone (Middle Volgian) in Poland: its ammonites and biostratigraphic subdivision. *Acta Geologica Polonica* 44: 1–33.

Kutek, J. and Zeiss, A. 1997. The highest Kimmeridgian and Lower Volgian in Central Poland: their ammonites and biostratigraphy. *Acta Geologica Polonica* 47: 107–198.

Matyja, B.A., Pszczółkowski, A., and Wierzbowski, A. 2016. Tothonian *Chitinoidella* Horizon and "Volgian" and "Portlandian" ammonites in the Owadów-Brzezinki section (central Poland)—a clue for Upper Jurassic interregional correlations. *In*: J. Michalik and K. Fekete (eds.), XIIth Jurassic Conference. Smolenice, Slovakia, April 19–23, 2016. *Field Trip Guide and Abstracts Book*, 65–67.

Roberts, A.J., Druckenmiller, P.S., Sætre, G-P., and Hurum, J.H. 2014. A New Upper Jurassic Ophthalmosaurid Ichthyosaur from the Slottsmøya Member, Agardhfjellet Formation of Central Spitsbergen. *PLoS ONE* 9 (8), e103152. doi:10.1371/journal.pone.0103152.

Tyborowski, D., Błażejowski, B., and Krystek, M. (in press). Reptile remains from the Upper Jurassic limestones of Owadów-Brzezinki Quarry (Central Poland). *Przegląd Geologiczny*.

Wierzbowski, H., Dubicka, Z., Rychliński, T., Durska, E., Olempska-Roniewicz, E., and Błażejowski, B. (in press). Depositional environment of Sławno limestones (uppermost Jurassic, central Poland): evidence from microfacies analysis, microfossils and geochemical proxies. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*.