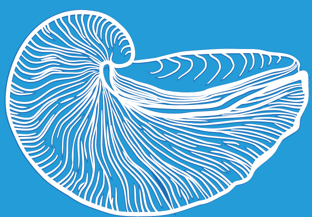
JURASSICA XV



19–22 September 2023
Iłża • Poland

Field Trip Guide and Abstracts

POLISH GEOLOGICAL SOCIETY
POLISH GEOLOGICAL INSTITUTE – NATIONAL RESEARCH INSTITUTE
Kraków–Warszawa 2023

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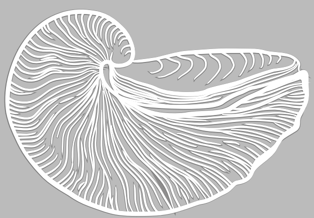

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INSTITUTE OF PALEOBIOLOGY
POLISH ACADEMY OF SCIENCES

STATE GEOLOGICAL INSTITUTE
OF DIONÝZ ŠTÚR

POLISH GEOLOGICAL SOCIETY
POLISH GEOLOGICAL INSTITUTE – NATIONAL RESEARCH INSTITUTE

Kraków–Warszawa 2023

ORGANIZING COMMITTEE

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Polish Geological Institute – NRI, Warsaw

Ewelina KRZYŻAK
Polish Geological Institute – NRI, Warsaw

Hubert WIERZBOWSKI
Polish Geological Institute – NRI, Warsaw

EDITORS:

Hubert WIERZBOWSKI, Andrzej WIERZBOWSKI, Błażej BŁAŻEJOWSKI

CONTACT PERSONS

Jolanta IWAŃCZUK
jolanta.iwanczuk@pgi.gov.pl

Hubert WIERZBOWSKI
hubert.wierzbowski@pgi.gov.pl

SCIENTIFIC COMMITTEE

Błażej BŁAŻEJOWSKI
Institute of Paleobiology, Polish Academy of Sciences

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Polish Geological Institute – NRI, Warsaw

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Polish Geological Society & Polish Geological Institute – National Research Institute

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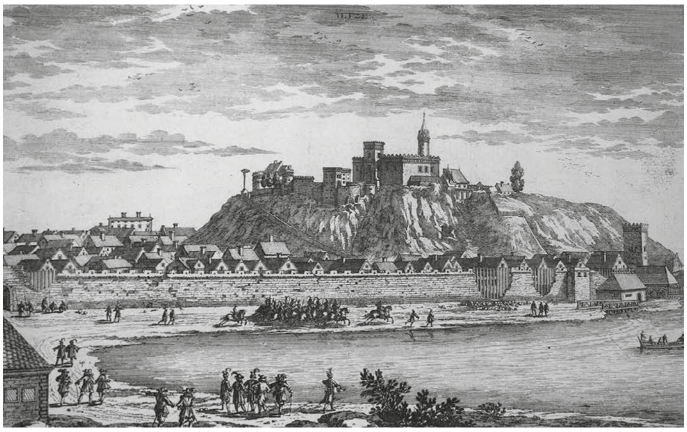
Table of contents

Iłża – history of the city

Iłża is one of the oldest cities in Poland. Its history begins in the Middle Ages, around the 10th or 11th century, with the first settlements established on the Iłżanka river. This place has its roots far back in the past, to prehistoric times – the time of the oldest Stone Age, through the Bronze Age, up to the Iron Age. Iłża from the 12th century until 1789 was the property of the Kraków bishops.



City and the bishops castle. Engraving by Eryk Dahlbergh, 1656

Most likely, even before the 11th century – at today's Staromiejska Street – an early-urban settlement of a production character was established. Around the 12th century, a small castle with a wooden watchtower was built near this settlement. In the early Middle Ages, the first wooden church dedicated to the Blessed Virgin Mary (Najświętsza Maria Panna) was built in the place where nowadays is located a church of the Our Lady of Snow (Matka Boska Śnieżna) along with a cemetery. Initially, Iłża developed primarily as a handicraft and market settlement, and its convenient location – on the trade route towards Solec and Kraków – favoured the development of an early-urban settlement. Unfortunately, in the 1241 and 1260 it was destroyed during the Tatar invasions. After these tragic events, in the 13th century, the bishops of Kraków moved the settlement 1.5 kilometers southward and founded a new city based on Magdeburg law. At the end of the 13th century began the construction of the castle on a limestone hill. It was completed during the thirties of the 14th century by Bishop Jan Grotowic. The bishops of Kraków applied for royal privileges for the city, which contributed to its development. Thanks to the efforts of Bishop Florian of Mokrsko, Iłża was surrounded by city walls, which were brought in the years 1367–1380. The course of the walls is still visible in the layout of the plots and the buildings on them, as well as in the naming of the streets. The city developed mainly through handicrafts and trade, initially having mainly wooden buildings. During the Middle Ages, apart from houses, economic and defensive buildings, the town hall was built – initially probably wooden, then a brick one. At that time there were three churches in Iłża – the brick one, built in 1325 under the name of the Blessed Virgin Mary (Najświętsza Maria Panna), the other one outside the city walls, located in the area of the old town, which was a wooden church of the Blessed Virgin Mary (Najświętsza Maria Panna), replaced in the 15th century by a brick temple and the third, also outside the city walls at today's Błazińska Street, founded in the middle of the 15th century, which was a church and hospital under the name of the Holy Spirit (Duch Święty).

Iłża had their heydays in the 16th century and the first half of the 17th century. During that time the castle, after successive reconstructions, becomes a bishop's residence and reaches its most

Iłża castle (phot. Gmina Iłża)

Iłża castle (*phot. Gmina Iłża*)

beautiful appearance. This period should also be associated with the splendour and development of Iłża pottery, which, among other things, was visualized in the city landscape by numerous pottery furnaces. Unfortunately, in the middle of the 17th century, during the Swedish Invasion (so called "Swedish Deluge"), the castle and the city were severely destroyed and never returned to their former glory. Although successive Kraków bishops rebuilt the castle and renovated it many times, it was no longer the same delightful fortified residence as before. At the end of the 18th century, as a result of the reforms of the Four-Year Parliament (Sejm Czteroletni), Iłża was taken over by the State Treasury and became a government town. After the Third Partition of Poland, Iłża came under Austrian rule, which lasted until the year 1809. After the Congress of Vienna, the city was incorporated into the Russian Empire and belonged to its part called the Kingdom of Poland, which existed in years 1815–1831. The plans of Stanisław Staszic, who incorporated it into the Old Polish Industrial District, were to extract Iłża from the economic stagnation. As a part of the District, on the initiative of Stanisław Staszic, a faience factory was established over Iłżanka river, which was started by Lewi Zelig Sunderland, an English Jew who sold porcelain. The operation of mills, sawmill, beer brewery and distillery in Iłża is associated with this industrial period.

Unfortunately, the development of Iłża was interrupted by the November Uprising (Powstanie Listopadowe). In August 1831 a battle between Polish and Russian armies took place here. As a result of the battle, a fire broke out, which almost completely destroyed the city. Soon after a cholera epidemic began, which completed the measure of destruction. Epidemics plagued Iłża several times during the 19th century. At the beginning of 1863, during the January Uprising (Powstanie Styczniowe), another battle took place in the city between the Polish and Russian armies, which was successful for the Polish side. At that time, the inhabitants of Iłża faced numerous repressions. In 1869, Iłża lost city rights and became a settlement. Despite difficult times, the Iłża inhabitants tried to develop their city. In the 19th century, a synagogue was built in the area of today's car park between Mostowa Street and Przy Murach Street, on the right side of Iłżanka river. At the beginning of the 20th century, a fire brigade, a cooperative bank and various civic associations were established. To the buildings of Iłża – in its past – were included also such objects as water mills or wooden windmills, which were located mainly outside the city walls.

The outbreak of the First World War interrupted the development of the city, and military actions in its the early years completely destroyed the city's buildings. The Russians troops which were withdrawing from this area, in the year 1915, first displaced city inhabitants, and then burned the city to the ground. The city was rebuilt rather slowly. In the mid-twenties it regained city rights, but the seat of the district became nearby Wierzbnik, where it was moved during the Second World War. During the interwar years, numerous investments were made in the city. Trade was growing, and cultural associations were also active. However, during the Second World War the achievements of Iłża people were again destroyed. At the very beginning of the war, on the 8th and 9th September 1939, the city and its surroundings were the site of a battle fought by the Polish army, retreating behind the Vistula River, with the advancing Germans. In the following year, the intellectual elite of Iłża people were murdered as a result of the A-B campaign. The years of Nazi occupation also brought the extermination of the Jewish community of Iłża, which perished in the German Nazi camp in Treblinka. During the war numerous units of resistance movement, which belong to the Home Army (Armia Krajowa) and Peasant Battalions (Bataliony Chłopskie) operated in this area. After the liberation begun reconstruction of the country. At the beginning of the fifties the Cepelia cooperative "Chałupnik" was established in Iłża, which offered local handicraft products. In the sixties industrial plants were opened in Zębiec in the vicinity of Iłża. In the next decade, the Car Parts Factory, which was a branch of Star Company from Starachowice, was established in Iłża itself.

Grzegorz Pieńkowski
(1953–2023)

Grzegorz Pieńkowski passed away suddenly on 19th April, 2023, at the peak of his scientific career and at a time when he had much to bring to the geological community. The Jurassica Meeting in Iłża, in north-eastern margin of the Holy Cross Mountains—which was one of the main areas of his research—is devoted to the memory of Grzegorz, Gregory, or Greg, our colleague and friend, as well as an eminent Polish geologist and a student of the Jurassic System.

Grzegorz took the first steps of his geological career during his studies at the Faculty of Geology at the University of Warsaw, where he achieved a degree in geology in 1976. At that time, as a member of the "Circle of Young Geologists", he participated in detailed elaboration of the geology of the Jurassic and Cretaceous rock formations exposed along the newly-constructed road from Krośnica to Kąty in the Pieniny Klippen Belt in southern Poland. The resulting paper, published in 1981 in *Studia Geologica Polonica*, remains an important contribution to the geology of the Pieniny Klippen Belt, and one of the most noteworthy student achievements in the faculty's history. It was also a time when alongside his love for geology, another feature of Grzegorz's character emerged: his sensitivity to political and social problems—and this continued throughout his life.

Grzegorz defended his doctoral thesis on the development of the Lower Jurassic (Hettangian and Synemurian) in north-eastern margin of the Holy Cross Mountains, at the Faculty of Geology of the University of Warsaw in 1982. He obtained his Habilitation degree in 2005 at the Jagellonian University in Kraków, presenting a stratigraphical-facies synthesis on the epicontinental Lower Jurassic of Poland. From 1980 until the end of his life, he was employed at the Polish Geological Institute – National Research Institute in Warsaw, and was appointed Professor of the Institute in 2005. On 8th November, 2013, Grzegorz was distinguished with the title of Professor of Earth Sciences by the president of Poland. Grzegorz acted as the head of the Geological Museum of the Polish Geological Institute (2000–2001), as a vice-director of the institute (2008–2012), and (2013–2015), and as its scientific secretary (2012–2013). He was a member of the editorial boards of well-known geological journals, including *Przegląd Geologiczny* and *Geological Quarterly*, as well as the deputy-editor of *Volumina Jurassica*.

Grzegorz's wide-ranging scientific interests included stratigraphy – cyclo- and sequence stratigraphy (later also climatostratigraphy), many aspects of sedimentology, and palaeoecology—including climate change and sea-level change. Although he studied deposits that range in age from the Permian and Triassic to the Palaeogene, the main field of his research was the epicontinental Lower Jurassic. The study of these deposits in Poland alone, in relation to Lower Jurassic successions in other European areas—in sedimentological, sequence stratigraphical, palaeoecological and chemostratigraphical aspects—brought him the international renown. He also presented the correlation chart of the Lower Jurassic between Poland and Sweden, prepared during his stays at Lund and Stockholm universities as a visiting professor.

He participated in several international projects, such as the IGCP project titled "Marine and non-marine global correlation and major geological events" (2005–2010). The main field of his research in later years remained, however, international cooperation within the Mochras project—a study of the Lower Jurassic succession in deep-borehole in the United Kingdom. The study of the deep-water deposits from the core yielded important information on sedimentology, chronostratigraphy (specifically, orbital cycles), and palaeogeography during the formation of the Laurasian Seaway joining during the Early Jurassic, Boreal, and peri-Tethyan domains. Grzegorz also became very active in international scientific organizations: in 2016, he became the vice-chairman of the Subcommission on Jurassic Stratigraphy of the International Union of Geological Sciences.

Grzegorz published nearly 200 research papers, including his last but unfinished study on the newly-discovered trace fossils of dinosaurs in Borkowice in central Poland. Grzegorz presented the preliminary results of that study, conducted together with Grzegorz Niedźwiedzki, during the 11th International Congress on Jurassic Stratigraphy in September 2022 in Budapest, under the title: "A world-class Hettangian tracksite from Poland – a new light on the early evolution of dinosaurs". Due to his interest in dinosaurs – the presentation served as a sort of farewell, and as an invitation for other scientists to continue his research.

Grzegorz was the leader of the Polish Jurassic Group (2001–2003), affiliated at the Polish Geological Society, and the organizer of the Second Jurassica Meeting in 2001 in Starachowice in north-eastern margin of the Holy Cross Mountains. He was also a prominent popularizer of geology and geotourism. He was a consultant of the department at Starachowice museum, and the leader of a project of the Kamienna Valley Geopark, as well as the co-author of a book on geology for school education.

Grzegorz was a man of wide interest—not only a scientist, but also a social and political activist. He participated in the "Solidarity" movement from its very beginning. He was a leader of the strike organized on 14th December, 1981 at the Polish Geological Institute in protest against the imposition of martial law by the Communist government. He was also a member of the underground structures of "Solidarity," in the "microregions" of "Wola" and "Mokotów". Directly after the fall of communism, he took the position of General Consul of Poland in Sydney, Australia (1991–1996). He was awarded the Golden Cross of Merit, and the Cross of Freedom and Solidarity by the president of Poland, as well as several departmental ones, including the medal, "Rewarded for Polish Geology" by the minister of the environment.

Andrzej Wierzbowski
Jarosław Zacharski

The latest dinosaur finds from the Early Jurassic of Poland – Grzegorz Pieńkowski's contribution to discovering the mysteries of "terrible lizards"

Grzegorz NIEDŹWIEDZKI[1, 2]

Much of what we know about the Świętokrzyskie Mountains dinosaurs comes directly or indirectly from the work of prof. Grzegorz Pieńkowski (1953–2023). His greatest achievement was a modern compilation of lithostratigraphic, sedimentologic and biostratigraphic data for the Lower Jurassic of Poland. Prof. Pieńkowski discovered the first dinosaur nests and eggs in the Polish Jurassic and laid the foundations for further studies of Triassic and Jurassic terrestrial ecosystems in Poland, Sweden and Greenland. His research allowed for a better understanding of the environmental changes and evolution of dinosaur assemblages in the Świętokrzyskie Mountains region. The sudden and unexpected death of Grzegorz took place at a time when we were collaborating on important research projects. I would like to briefly present here the preliminary results from two of those projects.

In 2021 during summer fieldwork in the Świętokrzyskie Mountains we (Grzegorz and me) made an accidental discovery. A year later it turned out to be a paleontological sensation that the media all over the world were talking about Borkowice claypit. Very rich site with dinosaur fossils, first of this kind in Poland, Borkowice turned out to be a genuine mine of different early dinosaurs' fossils. So far, the site has provided several thousand dinosaur footprints, numerous dinosaur bones and coprolites. It is a research material that has just come to light and is already the center of interesting studies. A large part of the footprint specimens shows (especially visible in 3D scans) three-dimensional natural casts of dinosaur feet, on which anatomical features and impressions of the scaly skin are preserved in unusual details. These are the best-preserved traces of dinosaurs so far discovered in Poland and the quality of their preservation is equal to the best-known discoveries worldwide. The collection also includes records of ethology (behaviour) left by dinosaurs running, swimming, resting and sitting on a muddy sediment, as well as many enigmatic biogenic structures, probably related

[1] Department of Organismal Biology, Uppsala University, Norbyvägen 18A, SE-752 36 Uppsala, Sweden; grzegorz.niedzwiedzki@ebc.uu.se
[2] Polish Geological Institute–National Research Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; gnie@pgi.gov.pl

to various life activities of dinosaurs living there. So far, dinosaur tracks representing at least seven different taxonomic groups have been collected and secured in Borkowice, as well as casts of bone remains of ornithischian dinosaurs. The prospects for new finds are even more promising.

For many years we discussed with Grzegorz the preservation and taphonomy of his finds of dinosaur eggs from Sołtyków in the Świętokrzyskie Mountains. Grzegorz's observations from the late 90s were intriguing. Technology keeps developing and the achievements of physics allows paleontologists to look inside fossils. Three years ago I was passionately convincing Grzegorz we need to look at his finds with new eyes. We decided to use synchrotron microtomography on the BM05 beamline of the ESRF-EBS (France) and analyzed the contents of four eggs from Sołtyków. The scans revealed that all four eggs, which were collected from the same nest structure, contain embryonic remains. The analysis of dinosaur embryos using propagation phase-contrast microtomography enables the extraction of valuable data even on poorly preserved, highly disarticulated and incomplete embryonic material. Grzegorz discovery enables us to study the oldest probable theropod embryos to date.

Grzegorz spurred everyone to do their best. He was a peerless role model. Apart from his intellectual prowess, he will be remembered most for his indomitable spirit. His fieldwork style was unapologetically exacting, he pushed me and other colleagues to reach for better science. At the beginning of April this year, we planned further trips together, studies and field research in Borkowice.

I will miss him. We will all miss him.

Development and chronology of the Late Jurassic shallow-water carbonate deposits of the north-eastern margin of the Holy Cross Mountains, central Poland

Andrzej WIERZBOWSKI[1]

Introduction

Publication of complete results of the study on the development and chronology of the shallow-water deposits of the whole Holy Cross Mts. is planned in forthcoming issue of *Volumina Jurassica*. This is a part of this study prepared on the occasion of the Jurassica XV Conference and devoted to north-eastern margin of the Holy Cross Mountains.

The detailed stratigraphical and sedimentological investigations on the Late Jurassic shallow-water carbonate deposits in the north-eastern margin of the Holy Cross Mts. have been developed during the last decades, their results being summarized in several important publications by Pożaryski (1948), Dąbrowska (1968, 1983a), Roniewicz and Roniewicz (1971), Liszkowski (1972, 1976), Kutek (1983, 1994) and Gutowski (1992, 1998, 2006ab). Additionally, some new observations gathered during last time by the author together with other geologists (see Wierzbowski *et al.*, 2023a, this volume), so far mostly not published, are also considered. The aim of the present publication is to summarize the current state of knowledge on the development of deposits, especially those representing shallow-water carbonate platform facies, and to give the basis for the chronostratigraphical subdivision of the summarized lithological column associated with climatically and tectonically controlled phenomena, dated also by the collected ammonites.

The Upper Jurassic carbonate deposits occurring around the Palaeozoic core of the Holy Cross Mts., and constituting its north-eastern, north-western and south-western margins (Fig. 1), represent remnants of the primary cover of the mountain area partly eroded due to subsequent tectonic movements: the Neo-Cimmerian (latest Jurassic/earliest Cretaceous to pre-Albian) and the Laramian (at the end of the Maastrichtian and during the Paleocene) ones. The Neo-Cimmerian movements especially active in south-western areas of Poland were responsible for erosion of the youngest Jurassic deposits (mostly Tithonian and uppermost Kimmeridgian) as recognized especially in north-eastern and south-western margins of the Holy Cross Mts. (see e.g., Pożaryski, 1948; Kutek, 1962), whereas Laramian movements resulted in total erosion of the Upper Jurassic deposits from the elevated central part of the mountains including their Palaeozoic core and adjoining areas (e.g., Kutek, Głazek, 1972). The character of the preserved Late Jurassic deposits of the Holy Cross Mts. margins allows for neglecting (see Kutek, 1962) older ideas on the elevation of the central part of the area during their sedimentation.

The stratigraphical subdivision of the Upper Jurassic deposits of the Holy Cross Mts have been markedly modified during the last decades. The first attempts to classify the Upper Jurassic deposits of the area into local stratigraphical "stages" like "Argovian", "Rauracian", "Astartian" and "Kimmeridgian", bearing in fact the lithostratigraphical character, enabled the detailed local correlations only (e.g., Pożaryski, 1948; Świdziński, 1962; see also Malinowska, 1970; Liszkowski, 1976, and older papers cited therein). The common usage of the Oxfordian, the Kimmeridgian, and the Tithonian stages as based on well-established ammonite chronozones, was preceded by stratigraphical discussion on the application of the Volgian Stage instead of the older "Bononian" (replaced later by Tithonian, see Kutek, 1962; Kutek, Zeiss, 1974, 1997; Matyja, Wierzbowski, 2016), and the marked modification of the position of the Oxfordian/Kimmeridgian boundary solved by the recent acceptance of GSSP of the base of the Kimmeridgian Stage. The latter resulted in the inclusion in the newly re-defined Kimmeridgian Stage a strati-

[1] Institute of Geology, Faculty of Geology, University of Warsaw, 02-89 Warszawa, Żwirki i Wigury 93, Poland; andrzej.wierzbowski@uw.edu.pl

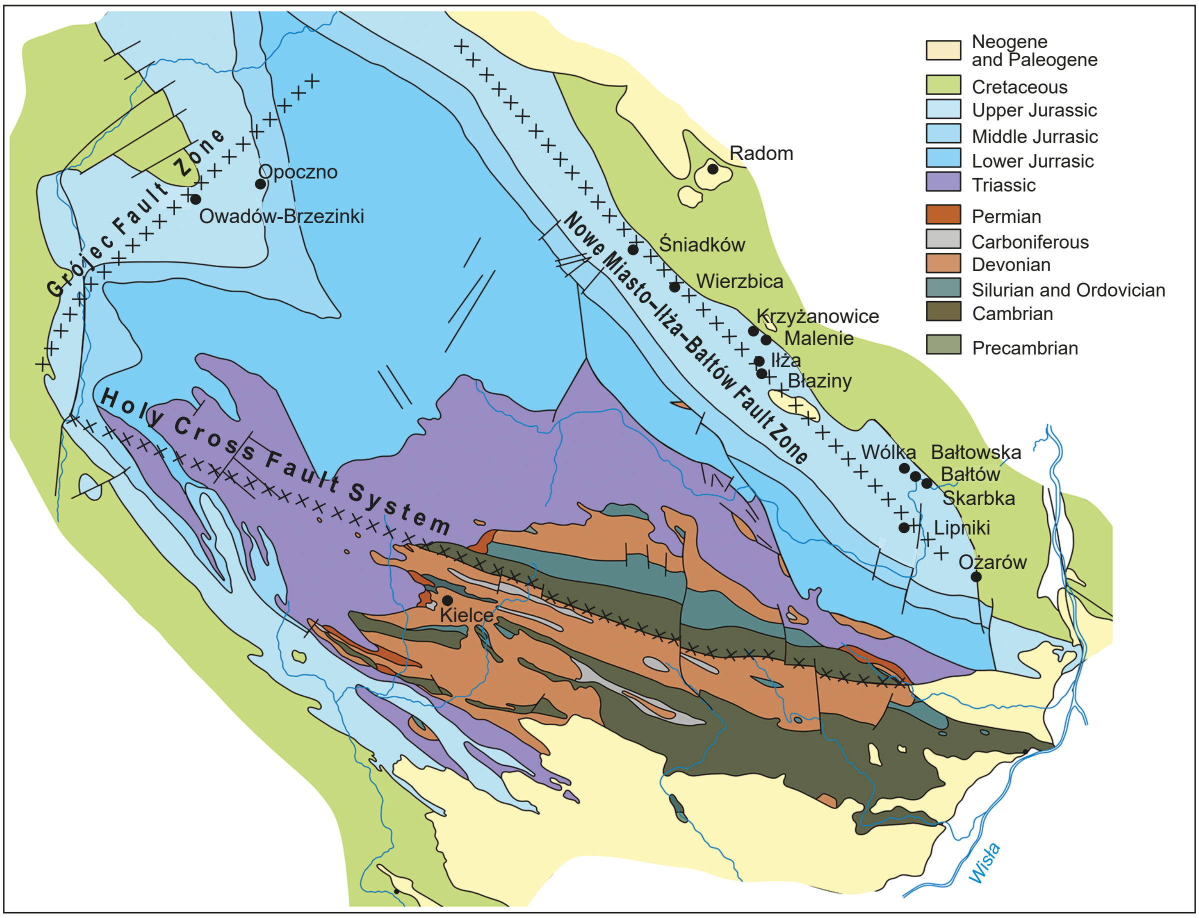


Fig. 1. Geological sketch-map of the Holy Cross Mts. (after Samsonowicz *in*: Książkiewicz and Samsonowicz, 1953, somewhat modified) showing the main tectonic fold units and the tectonic zones active during the Late Jurassic (crossed)

graphical interval corresponding to the Bimammatum and Planula ammonite zones previously correlated here (but also in other areas of the Submedierranean Province in Europe) with the uppermost Oxfordian (see e.g. Wierzbowski, 2020; see also Wierzbowski *et al.*, 2023b).

Shallow-water carbonate facies: general setting

The transition from the open shelf deep-neritic sponge megafacies to the shallow-water carbonate platform deposits was preceded in the whole area by the random development of the coral-buildups founded on the tops of the older cyanobacteria-sponge biohermal complexes (Gutowski, 1992; *cf.* Matyja, Wierzbowski, 1996). The coral reefs/bioherms composed initially of the foliaceous hermatypic corals were distinctive of a relatively deeper and quite-water environment (Roniewicz, Roniewicz, 1971). The areas of coral buildups became successively the places of sedimentation of various bioclastic and oncolitc limestones which commonly spread around, as a result of a sudden progradation of the shallow-water deposits under a sea-level fall.

Several major facies assemblages are conveniently to be recognized in the shallow-water successions as based on the detailed sedimentological and stratigraphical regional studies in the various areas of the Holy Cross Mts. (e.g., Kutek, 1969; Gutowski, 1992, 2006b; Matyja, 2011; Wierzbowski, 2020). They include four main facies types of the shallow-water carbonate platform, treated as the area of carbonate deposition occurring above, or close to the wave base: the chalky limestone assemblage, the oolitic limestone assemblage, the micritic lithographic, locally banded limestone assemblage, and the various grained to micritic limestone assemblage. All of them are representatives of the particular sectors of the general morphology of the shallow-water carbonate platform from the external or open platform environment through the oolitic barriers to the more restricted platform environment. The detailed characteristics of these facies assemblages is as follows:

– chalky limestone assemblage including the dominating well-bedded soft and porous ("chalky") limestones composed of various carbonate grains (including especially common oncoids) with abundant and diversified benthic fossils including hermatypic branching and massive corals as well as solenoporoids – especially common in bedded limestones following or replacing an older coral buildups – below, and bivalves (mostly diceratids and various oysters) and nerineid gastropods – above;
– oolite limestone assemblage including limestones with predominant occurrences of oolites – both cross-bedded and non-cross-bedded;
– banded and/or lithographic type micritic limestone assemblage, showing locally bands of micritic and very fine-grained organodetrital-oolite limestones, with a very poor macrofauna, sometimes with cherts – the deposits are commonly strictly related to the oolite limestone assemblage;
– micritic to various grained limestone and marl assemblage consisting of micritic and marly limestones usually with some amount of fine organodetrital material with admixture of carbonate grains (ooids, oncoids, pelloids) with commonly encountered impoverished fauna mostly of burrowing myid bivalves, such as *Pholadomya* and *Pleuromya*.

Some other lithological assemblages as that of the oncolitic limestones, and of the oyster lumachelles, yielding sometimes ammonites, can be additionally distinguished. They have been formed in a more open marine environment during episodes of partial drowning of the carbonate platform, and have a wide distribution (e.g., Matyja *et al*., 2006, see also Kutek, 1994). This also applies to widely distributed marly deposits representing the siliciclastic sedimentation in both open-marine and a non-fully marine environment, developed especially during the regressive episodes. The deeper-water deposits within the discussed succession of the Holy Cross Mts. developed when the carbonate platform or its parts have been fully drowned are also briefly considered.

Description of stratigraphical succession

The Upper Jurassic deposits of north-eastern Mesozoic margin of the Holy Cross Mountains are stretching along the north-eastern limb of the Gielniów Anticline and its south-eastern prolongation, between Dobrut and Śniadków in north-west and Zawichost in south-east. Three main groups of outcrops are placed in the following areas: (1) between Dobrut and Wierzbica, (2) in the environs of Iłża, (3) at the Kamienna river valley between Bałtów and Skarbka, as well as Przepaść and Podgrodzie to Ożarów. Five main lithological intervals including some smaller scale units characterized by different lithology, and controlled biostratigraphically, can be distinguished (Fig. 2). They can be easily correlated with lithostratigraphical units recognized here (Dąbrowska, 1983a; Kutek, 1983; Gutowski, 1992, 1998).

The transgressive-regressive units recognized formerly in south-eastern and central regions of epicratonic Poland by Kutek (1994) included three tectono-stratigraphic (non-eustatic dependant) sequences: the COK (Callovian-Oxfordian-Kimmeridgian) Sequence, the LUK (Lower Kimmeridgian-Upper Kimmeridgian) Sequence, and the KVB (Kimmeridgian-Volgian-Berriasian) Sequence. Their formation has been interpreted as caused by rapid stress-induced vertical motions of the blocks of lithosphere as a consequence of episodic changes in tectonic regime. On the other hand, somewhat different classification of the Upper Jurassic deposits in south-eastern margin of the Holy Cross Mts. (but also with correlation to adjoining areas) was proposed by Gutowski (e.g., 1992, 2006ab). According to this classification, given in terms of sequence stratigraphy, seven sequences bounded by the regional sedimentary unconformities controlled by changes of sea level were recognized. The sequences by Kutek (1994) were additionally accepted as three megasequences I-II-III (Gutowski, 2006b). Although driven by tectonic interplate stress changes, their sedimentary content was treated as "fairly isochronous" in the distant sedimentary basins placed close to the

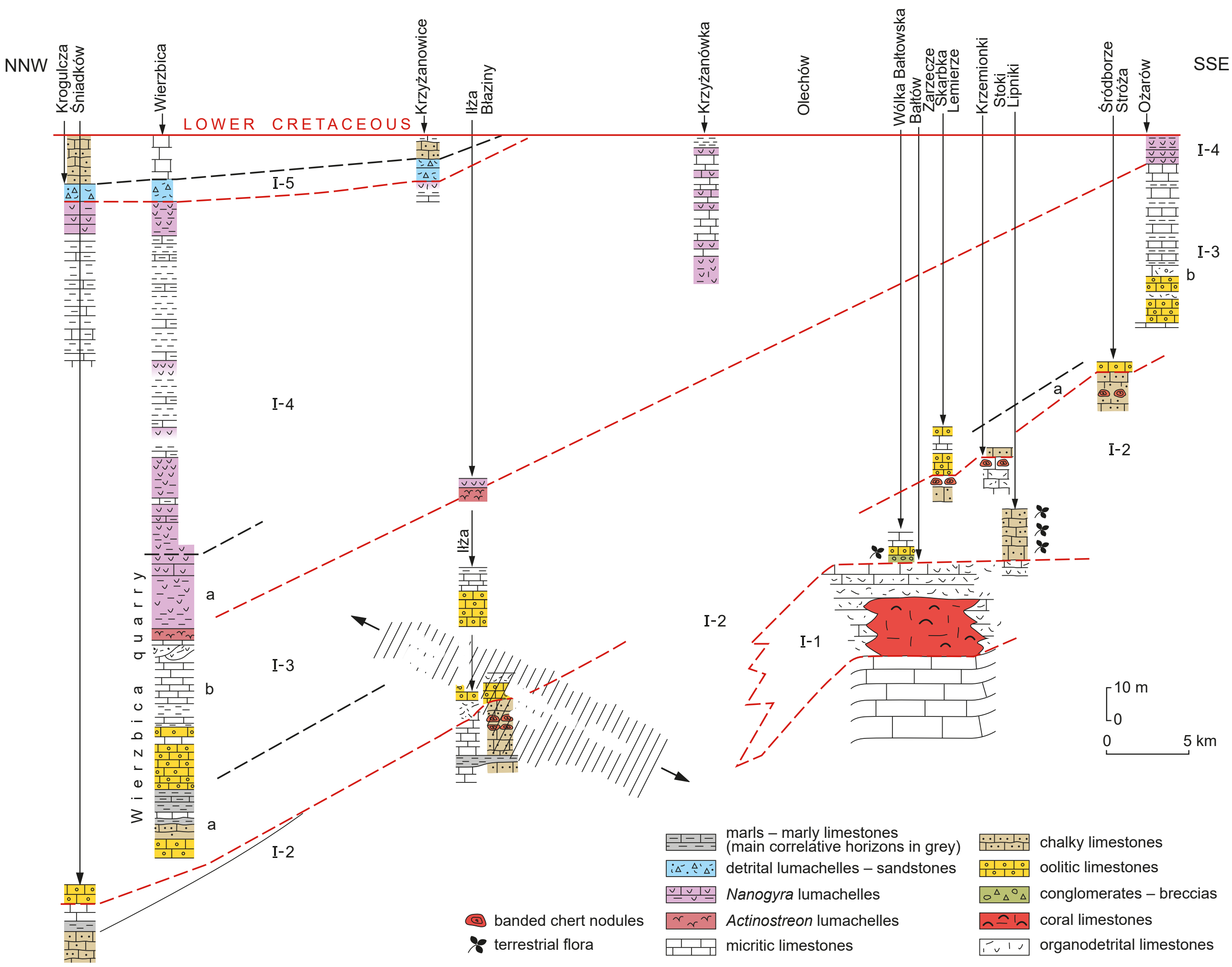


Fig. 2. Sketch of distribution of distinguished lithological intervals corresponding to main transgressive-regressive sequences in the north-eastern margin of the Holy Cross Mountains

Tethyan shelf of epicontinental Europe (Gutowski *et al.*, 2005).

The lithostratigraphical intervals recognized herein in the Upper Jurassic succession (I: 1–5) are interpreted as major-scale transgressive-regressive sequences. These correspond generally to the sequences COK, LUK and KVB as follows: the sequence I: 1-2-3 correspond to the upper shallowing upward carbonates of the shallow-water carbonate megafacies which developed after the sponge megafacies of the COK Sequence - these span, from the Upper Oxfordian to the Lower Kimmeridgian (Bifurcatus Zone to the upper part of the Hypselocyclum Zone); the sequence I-4 corresponds to the LUK Sequence, spanning from the upper part of the Lower Kimmeridgian to the lowermost part of the Upper Kimmeridgian (uppermost part of the Hypselocyclum Zone to the Acanthicum Zone); sequence I-5 corresponds to the lowermost part of KVB Sequence, which is located in the middle part of the Upper Kimmeridgian (mostly Eudoxus Zone).

The recognized sequences by Gutowski (1992, 2006ab) correspond in number to the stratigraphical sequences as recognized herein (including subdivision of the main “oolitic” and “lumachelle” sequences into two smaller scale units). Their boundaries have been placed at different position, however, allegedly corresponding to an extremely shallow-water environment according to sequence stratigraphy requirements. This is in opposition to the recognized sequences herein which are mostly placed at transgressive levels and similar in character to parasequence boundaries.

The rate and extent of transgressions and regressions very strongly influenced the spatial and temporal distribution of shallow-water carbonate facies, regardless of whether changes in sea-level were controlled by orbitally-climatic or tectonic phenomena. The transgressive or regressive tendencies shown in the character of deposits described can be related to changes in sea-level as they are related to orbitally-controlled eccentricity cycles (Boulila *et al*., 2008, 2010; see e.g., Wierzbowski 2020). On the other hand, the facies pattern could also be significantly modified by synsedimentary tectonic activity related to local basement tectonics. An important tectonic zone from the south-eastern margin of the Holy Cross Mountains was the Nowe Miasto–Iłża Fault (and its south-eastern prolongation towards Bałtów and Ożarów), treated as the south-west margin of the East European Craton, and a tectonic zone that bounds the Mid-Polish rift system from the east (Mid-Polish Trough – see e.g., Świdrowska *et al*., 2008). The activity of this fault during the Early and Middle Jurassic is well documented (e.g., Pieńkowski, 2006), but it became active also during the Late Jurassic as shown by differences in deposits thickness and in facies pattern (see e.g., Matyja, 2015).

Massive coral limestone-dominated interval (Middle to Upper Oxfordian: uppermost Transversarium to Hypselum zones) (sequence I-1ab).

The key-sections showing the beginning of the development of the shallow-water carbonate sedimentation occur at the Kamienna river valley near Bałtów (see Liszkowski, 1976, fig. 1). The exposed here massive coral limestones (Bałtów Coral Limestones) forming the flat coral-buildups of recognized thickness from a few to about 20 meters, contain numerous foliaceous and submassive coral colonies occurring in micritic or biomicritic matrix (Roniewicz, Roniewicz, 1971; Gutowski, 1992, 2004a, 2006a). The local depressions between the massive coral buildups are filled by bedded limestones showing a variable lithology – from mostly grained pelletal to more micritic in character (Roniewicz, Roniewicz, 1971, fig. 2). The discussed coral limestones and associated bedded limestones (denoted as 1a) rest here on micritic limestones with bivalves and ammonites (Bałtów Platy Limestones), which are indicative of the deep-water and open-marine environment (Gutowski, 1992, 1998; Fig. 2). The character of the coral assemblage suggests also a relatively deep and calm environment devoid stronger-water activity attaining some dozen meters in depth. It may be suggested that the foundation of coral buildups was limited initially to the topmost parts of older cyanobacteria-sponge bioherms of deep-neritic environment, such as those cropped out in the Podgrodzie-Przepaść area, about 20 km southward from Bałtów. Just in this area the appearance of the first foliaceous *Microsolena* corals was reported at Wyszmontów-Ożarów railway cut by Gutowski (1992). Successively the coral facies and associated bedded limestone facies prograded onto their close foreland areas originally being the place of the deep-water platy limestone sedimentation. Whereas the foundation of the coral-buildups took place during the latest Middle Oxfordian (at the end of the Transversarium Chron) as evidenced by occurrence of ammonites *Perisphinctes* (*Dichotomosphinctes*) ex gr. *wartae* Bukowski, *Taramelliceras anar* (Oppel) and others, a strong progradation of the coral-facies onto older micritic limestones occurred during the beginning of the Late Oxfordian, in the Bifurcatus Chron as evidenced by ammonite faunas of *Perisphinctes* (*Perisphinctes*, *Dichotomoceras*), *Subdiscosphinctes*, *Passendorferia* (Gutowski, 1992, 1998; see also Brochwicz-Lewiński, Liszkowski, 1976; Brochwicz-Lewiński, Różak, 1976).

The overlying limestones (denoted as 1b) in the discussed area are commonly well-bedded, mostly organodetrital and/or more micritic, in character. All these limestones (including the underlying coral ones) yielded the abundant and diversified faunas of corals (Roniewicz, 1966), calcareous sponges, bryozoans (Hara, Taylor, 1996), brachiopods (Barczyk, 1969, 1970), bivalves – including oysters (Pugaczewska, 1971) and rudistids (Karczewski, 1969), nerineid gastropods (Karczewski, 1960; Wieczorek, 1979), echinoids (Radwańska, 2004), crinoids, and others (see also Liszkowski, 1962).

A characteristic subunit occurring at Bałtów, but also at nearby Lemierze, is the oncolitic limestone, attaining up to about 3 meters in thickness. It often contains large oncolites, and foliaceous to massive coral colonies, the latter are commonly broken, abraded and covered by cyanobacteria crusts. This subunit is variously developed – in some areas like Stoki Duże the limestone is

Stop Bałtów-Zarzecze:
A. massive coral limestones; B. coral assemblage with foliaceous and submassive colonies: sequence I-1 (Upper Oxfordian, Bifurcatus Zone)

strongly organodetrital in character, and contain except fragments of coral colonies, also abundant echinoderm rests (Roniewicz, Roniewicz, 1971; Gutowski. 1992, 2004a, 2006a). The subunit is interpreted as representing "the most turbulent environment" of the whole coral-bearing succession (Roniewicz, Roniewicz, 1971, p. 404). It was also recognized as marking the top of the initial stage of shallow-water sedimentation characterized by the development of the massive coral facies – *i.e.* of the Bałtów Coral Limestones (Gutowski, 1992). This whole interval of development of the coralliferous deposits was commonly correlated in the past with the "Rauracian Stage" and a lower part of the "Astartian Stage" (*e.g.* Pożaryski, 1948; Liszkowski, 1962). The youngest deposits of this succession reveal commonly the presence of early diagenetic dolomitization, and silification, possibly related with local emersion (see *e.g.* Liszkowski, 1963; Roniewicz, Roniewicz, 1971; Gutowski, 2004a). The age of the youngest deposits documented by ammonites, corresponds to the Late Oxfordian – to the Bifurcatus Chron, but also to the Hypselum Chron, as proved by occurrence of *Taramelliceras externnodosum* (Dorn) and *Microbiplices* (see Gutowski, 1992, 1998) at Stoki Duże and Bałtów, respectively, near the upper boundary of the discussed deposits. The latter form (see Gutowski, 1998, pl.1: 2) can be actually referred to as *Microbiplices anglicus vieluniensis* Wierzbowski et Matyja which is a characteristic subspecies occurring at the topmost part of the Hypselum Zone, *i.e.* the topmost part of the Oxfordian (*cf.* Wierzbowski, Matyja, 2014).

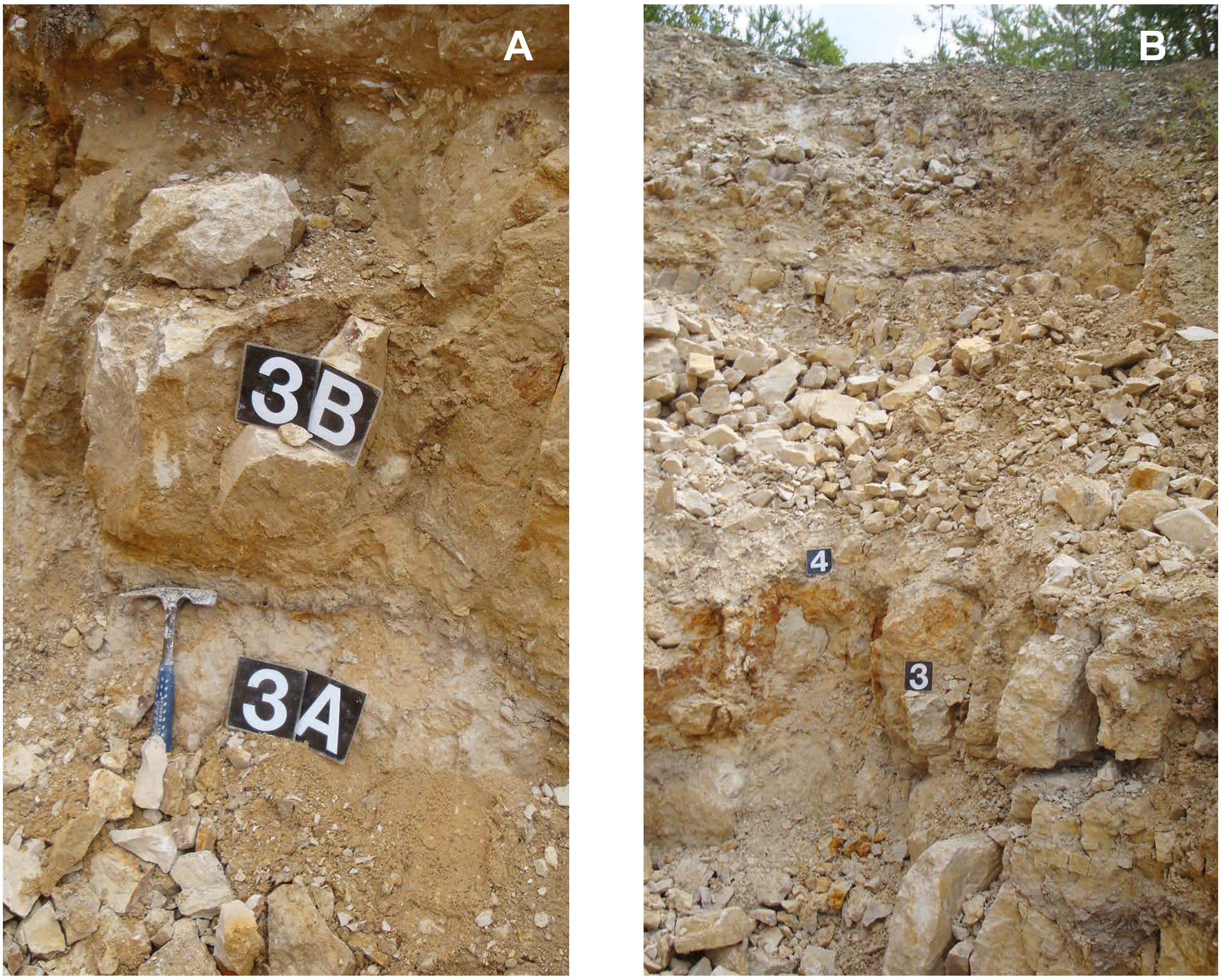
Somewhat different development of coeval deposits is recognized in the area between Lipniki, Jelenia Góra and Krzemionki Opatowskie. The old quarry of iron-works at Lipniki shows very reduced thickness of the massive coral limestones (Liszkowski, 1976, p. 116). The upper boundary of the coral limestone-dominated interval can be possibly placed here at about 4.5 m above the base of the section (see Gutowski, 1992, fig. 16, beds 1–2). At this level thick-bedded organodetrital limestones with solenoporoids, corals and crinoids are overlain by medium to thin-bedded organodetrital to micritic chalky limestones with oolites, and nerineid gastropods. The latter represent already a younger chalky limestone-dominated interval (see below). Remarkable is the occurrence here, in some beds, fairly numerous and well-preserved land-plant rests and limestone intraclasts (Liszkowski, 1972; Gutowski, 1992). Whereas the older, currently non-existing, quarries at Lipniki yielded some ammonites indicative of the Bifurcatus Zone of the Upper Oxfordian (see Gutowski, 1998, pl. 2: 5), the ammonites coming from the discussed above younger deposits at Lipniki (unfortunately found in the rubble) are poorly diagnostic, indicating a wider stratigraphical interval from the uppermost Oxfordian (Hypselum Zone) to the lowermost Kimmeridgian (Bimammatum to Planula zones) (see Gutowski, 1992).

Summarizing, the discussed major regressive **sequence I-1** includes a section of remarkable thickness, up to 20 meters, of coral buildups that pass locally into bedded limestones (denoted herein as smaller scale sequence **I-1a**), exposed between Olechów and Wyszmontów-Ożarów railway cut (*cf.* Gutowski, 1992). These deposits are underlain by bedded deep-water micritic limestones with ammonites of the late Middle Oxfordian (Transversarium Zone). The coral buildups possibly formed in a close relationship with an older cyanobacteria-sponge bioherm complex and its direct foreland. Their location was attributed to the tectonic uplift of the Nowe Miasto-Iłża-Bałtów Fault Zone. This elevation evidently took place at the end of the Middle and the beginning of the Late Oxfordian – at the end of the Transversarium Chron – the beginning of the Bifurcatus Chron. The discussed coral buildups cannot be traced far west because of erosional removal of the Upper Jurassic deposits. However, it may be suggested that these deposits passed laterally in that direction into the limestones of the sponge megafacies. A few isolated and poorly visible occurrences of bedded sponge limestones, including those at Jasieniec and Wola Lipieniecka in the middle and northern parts of the north-eastern margin of the Holy Cross Mts., yielded not fully recognized ammonite assemblages ("*Perisphinctes*") indicating the Middle to Late Oxfordian age of these deposits (see Różycki, 1950; Dembowska, 1953). This suggests the original occurrence of zone of deeper water west of the coral buildups center.

The growth of the coral buildups occurred in deeper and rather quite water environment as suggested by Roniewicz and Roniewicz (1971). During the successive shallowing detrital coralline deposits were formed leading to a change in the coral assemblages and the development of oncolitic limestones. The limestones clearly mark a prolonged phase of shallowing as evidenced by their lithological and faunal character, as well as their progradation over the whole visible areas of the north-eastern margin of the Holy Cross Mts. Moreover, they are affected by early dolomitization and silification at the top, indicating extremely shallow-water to subaerial conditions. Based on ammonite finds, the upper part of the coral limestone-dominated interval (denoted herein as smaller-scale sequence **I-1b**) can be correlated with a higher part of the Bifurcatus Zone and the whole Hypselum Zone of the Upper Oxfordian. It corresponds thus to the passage to regressive conditions, and correlates well with some similarly interpreted coeval deposits in other European sections (e.g., Gygi *et al.*, 1998).

Chalky limestone (locally with oolite and micritic limestones) – dominated interval (lowermost Kimmeridgian: Bimammatum to Planula/Platynota zones) (sequence I-2abc).

This stratigraphical interval is sharply marked at its base by specially developed deposits described from the quarry of Wólka Bałtowska near Bałtów. Its lithological succession begins with conglomerate composed of various limestone pebbles resting on the erosional surface of older biogenic limestones. It is overlain by oolite limestones, followed by micritic limestones. The latter contain abundant and diversified rests of land-plants (tree trunks, leaves, conifer cones), but also some other fossils, indicative of shallow-marine to lagoonal environments (Liszkowski, 1972; 1976; Gedl, Ziaja, 2004). These type of deposits correlates possibly with other flora-bearing limestones from this area (*e.g.* oolitic limestones with limestone intraclasts and abundant rests of flora at Lipniki: see above, also Gutowski, 1992; Fig. 2), which commonly occur in a narrow stratigraphical interval corresponding to the boundary-beds between the lower and middle parts of the "Astartian" (Liszkowski, 1972, fig. 1; see also Pożaryski, 1948). These deposits (denoted as 2a) represent the beginning of the new sedimentary cycle and may be interpreted as formed during transgression which resulted in flooding of the surrounding forested land areas (islands). This phenomenon possibly oc-



Stop Wólka Bałtowska: A. oolitic limestones (bed 3A) and micritic limestones with rests of land plants (bed 3B); B. micritic limestones (bed 3) overlain by micritic limestones and marls (bed 4): sequence I-2 (lowermost Kimmeridgian, Bimammatum Zone)

curred near the base of the Kimmeridgian as suggested by analysis of the dinoflagellate cyst assemblage (Gedl, Ziaja, 1992), and occurrence of several ammonites found by J. Liszkowski in close neighborhood of the discussed Wólka Bałtowska locality, and in similarly developed deposits, whose detailed interpretation is given herein for the first time. The first of them is amoeboceratid *Plasmatites lineatum* (Quenstedt) from micritic limestone, preserved with original label of Liszkowski: "*Amoeboceras* – upper Rauracian-lower Astartian, Eugeniów, 1964". It should be remembered that the genus *Plasmatites* including the species *P. lineatum* appears at the base of the Kimmeridgian, but it is especially common in central Poland in the lowermost part of the Hauffianum Subzone – in the upper part of the Bimammatum Zone (see Wierzbowski *et al*., 2023, and earlier papers cited therein, especially Matyja, Wierzbowski, 1997). Another ammonite described by Liszkowski as "*Discosphinctes virgulatus* – Wolanka river valley," showing fine oolite in its matrix, is *Vineta streichensis* (Oppel). This specimen is very close to that recently described from the Bimammatum Zone of the Cracow Upland (Wierzbowski, 2022, pl. 14: 4A-C). Two further specimens come from "series with land plants at Skarbka Dolna" including small-sized young specimen referred to as *Orthosphinctes* cf. *tiziani* (Oppel) and a juvenile *Vineta* sp.; both these forms are also indicative of the Bimammatum Zone (e.g., Schweigert, Callomon, 1997).

The discussed stratigraphical interval is related mostly to a thick sequence of deposits representing various types of chalky limestones with abundant fauna of rudistid bivalves (diceratids), nerineid gastropods (e.g., Karczewski, 1960, 1969, 1983; Wieczorek, 1979, 1983), small colonies of corals, and other faunas (brachiopods, bivalves, echinoids, crinoids), and of the micritic limestones, commonly occurring in vast areas of north-eastern margin of the Holy Cross Mts. from the Kamienna river valley in the south to Dobrut and Śniadków in the north. These deposits correspond precisely to unit 1 of Kutek (1983) from the area between Iłża and Śniadków. All these deposits reveal locally, especially in the lower part of the succession, numerous intercalations of oolitic limestones, reported from both southern and northern areas (Dembowska, 1953; Dąbrowska, 1968; Malinowska, 1970; Gutowski, 1992,; 2006a) and recognized sometimes as belonging to the separate oolitic units. The oolite subunits possess, however, possibly a local character, and represent a set of smaller scale oolitic bodies within the large chalky limestone complex. The upper boundary of the chalky limestone complex is placed higher in the succession close to the spectacular banded chert levels occurring in the Kamienna river valley in the south and environs of Iłża (Błaziny) in the north. Such approach better explains the occurrence of younger larger scale oolite units (see next stratigraphical interval), but it also results in a some change in the lithostratigraphical schemes e.g. in placing of the lower part of the Skarbka Oolite Limestones as recognized so far by Gutowski (1992, 1998, 2006b) in the chalky limestone-dominated interval (or in his Oncolite Chalky Limestones).

The banded chert nodules occur generally within a few closely-spaced chert levels of micritic limestones at the top of the discussed stratigraphical interval. They are interpreted as early diagenetic concretions developed along the crustacean burrows (Gutowski, Pieńkowski, 2004; Gutowski *et al*., 2006). They were formed in extremely shallow-water environment, near the tidal flat environments, proving the shallowing or even emersion of the area, and marking the top of the sedimentary sequence (Gutowski, 1992; 2006a). In some areas placed more westward the banded chert nodules are, however, missing, and the corresponding deposits are micritic limestones with poor bivalve fauna and marls, possibly developed in a more deeper environment. Such deposits have been recognized recently at Iłża-Zuchowiec and a newly opened quarry at Śniadków.

The ammonites are encountered very rarely in the middle- upper parts of chalky limestone interval. The fragmentary preserved specimen referred to as *Idoceras* (*Subnebrodites*) sp. by Gutowski from the Błaziny section (see Gutowski, 1992, pl. 3: 2 ; 1998, pl. 1: 1) differs, however, from representatives of *Subnebrodites* in its extremely evolute coiling, the presence of simple ribs, and much higher position of the secondary ribs on the whorl side. It seems closer to the Tethyan genus *Trenerites* (see Sarti, 1993, 2002) which occurs from the upper part of the Planula Zone through the Silenum Zone (corresponding generally to the Platynota Zone), being especially common in its middle and higher parts (Sarti, 2002; Enay, Howarth, 2019). Another specimen, coming from the uppermost part of the chalky limestone interval at old Marylin-Śniadków quarry and referred originally to as "*Rasenia* (*Eurasenia*) cf. *vernacula* (Schneid)" by Gutowski (1992, pl. 5: 4; 1998, pl. 1: 5; see also Kutek, 1983 who mentioned occurrence of *Eurasenia* at this level), belongs to the later established genus *Vielunia* (*cf.* Wierzbowski *et al*., 2010). It is especially similar to *Vielunia conspicua* (Schneid) known from the upper part of the Planula Zone to the lower/middle parts of the Platynota Zone of the Lower Kimmeridgian (see also Wierzbowski, 2017, 2022). It should be remembered that the celebrated specimens found at similar level by A. Łuniewski at old Marylin-Śniadków quarry, and referred to the genus *Ringsteadia* (e.g., Dembowska, 1953), which were unfortunately not illustrated and lost during the Second World War, most possibly belonged also to the genus *Vielunia.* They were considered for a long time as indicative of the Pseudocordata Zone (e.g., Malinowska, 1970, p. 156), and thus giving misleading correlation with the uppermost Oxfordian (*cf.* also Kutek, 1983).

In the middle levels of the discussed chalky limestone-dominated interval (denoted as 2b), in the marginal area of occurrence of chalky limestones at Błaziny quarry, interbeds of grey marls, attaining about 2–3 meters in thickness, are present. The same marly unit of about 7 meters in thickness has been recognized recently within the coeval micritic limestones, deposited in somewhat

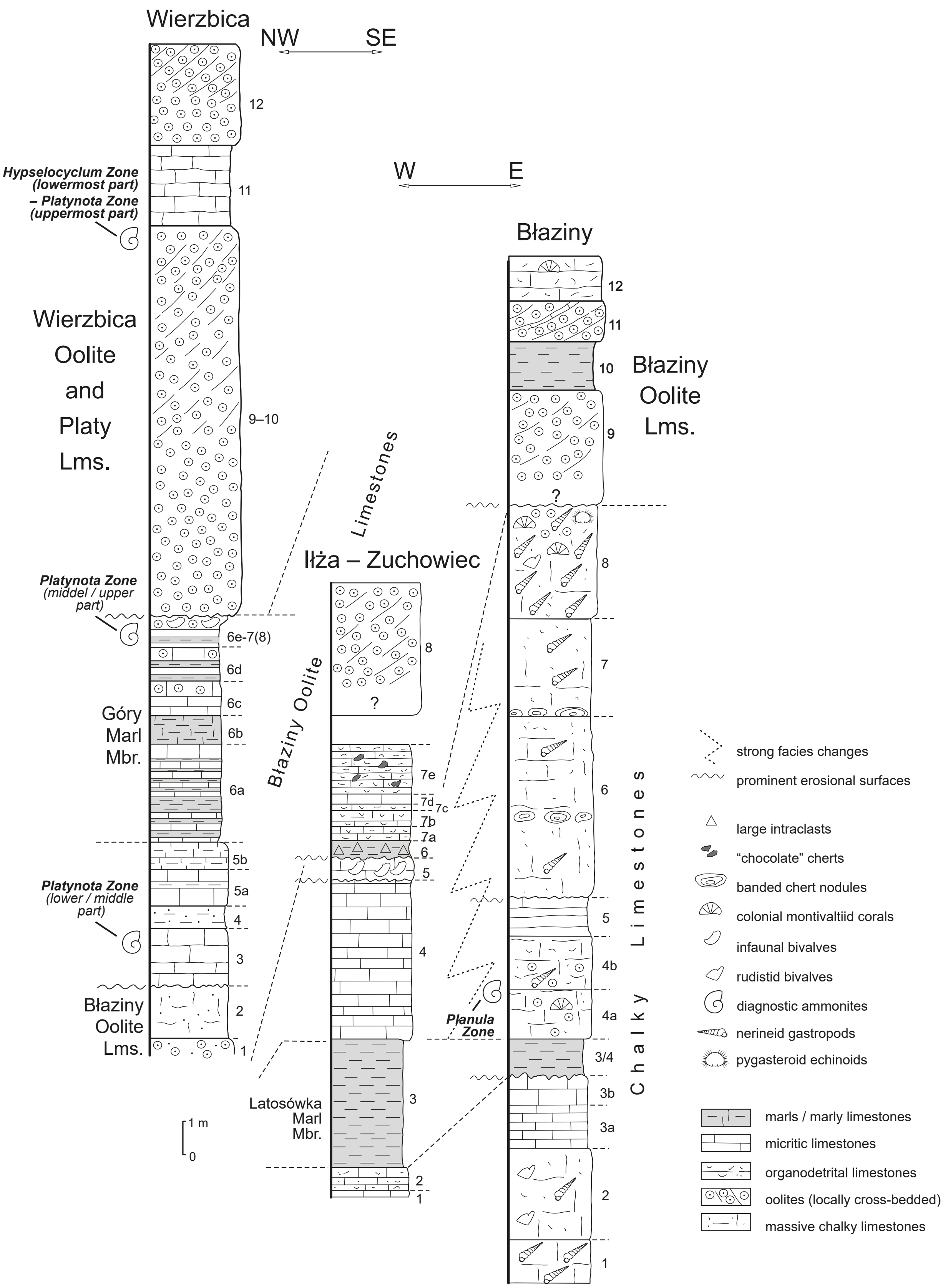


Fig. 3. Detailed correlation between the Błaziny quarry section, the Iłża-Zuchowiec ring-road section and the Wierzbica quarry section showing facies changes at the transition from sequence I-2 (chalky limestone dominated interval) to sequence I-3 (oolitic limestone dominated interval) in the north-eastern margin of the Holy Cross Mountains

deeper environment at Iłża-Zuchowiec, a few kilometers westwards, beyond the range of chalky limestones capped by the banded chert levels (Fig. 3). The discussed marly unit, because of its stratigraphical position corresponding possibly to the upper part of the Planula Zone, can be correlated with the Latosówka Marl Member distinguished in the Wieluń Upland, and the Częstochowa Upland within the deeper marine deposits, representing the foreland of the shallow-water carbonate platform. Another marly unit occurs locally at the top of the discussed chalky limestone-dominated interval (denoted as 2c): it includes some marly intercalations known at the base of the overlying oolites and organodetrital limestones of the younger stratigraphical interval at Iłża Zuchowiec, and possibly the marly interbeds, about 3.5 m in thickness occurring at the top of the chalky limestones succession at old Marylin-Śniadków quarry in the northern part of the north-eastern margin of the Holy Cross Mts. (Gutowski, 1992, Marylin-Śniadków, locality 10, bed 6). This younger marly unit can be possibly correlated with the Zapole Marly Bed recognized in the Wieluń Upland and some areas of the Holy Cross Mts. at the top of the lower part (Polygyratus Subzone) of the Platynota Zone (Wierzbowski, 2017, 2020).

Summarizing, the discussed major transgressive-regressive **sequence I-2** includes at its base the transgressive deposits (denoted herein as representing the smaller-scale sequence **I-2a**) overlaying a truncation surface developed on extremely shallow-water and terrestrial deposits, as seen spectacularly at Wólka Bałtowska, due to the transgression that flooded the forested island area (Liszkowski, 1972). This transgression occurred directly after the Hypselum Chron and during the Bimammatum Chron, very near the base of Kimmeridgian Stage, as indicated by the discussed ammonite occurrences. The boundary is closely related to the "2nd order transgressive" cycle opening recognized in other European regions including northern Switzerland (Gygi *et al.*, 1998). In coeval deeper marine deposits of central Poland such as those of the Wieluń Upland, and south-western margin of the Holy Cross Mts., the sea-level rise is marked by stratigraphical gaps and/or condensations (see Wierzbowski, 2020, 2022, and earlier papers cited therein). These new data indicate for the first time, the position of the base of the newly redefined Kimmeridgian Stage in the Upper Jurassic succession of north-eastern margin of the Holy Cross Mountains.

The bulk of the chalky limestones of the sequence which contains nerineid gastropods and rudistid bivalves was deposited in a shallow-water, open-marine sedimentary environment of low relief and of rather stable substrate, forming a large carbonate bank located far from the coast-line on the north-eastern margin of the Holy Cross Mts. (Wieczorek, 1979, 1983). The occurrence of small coral colonies and oolitic limestones as recognized at Śniadków (*cf.* Dembowska, 1953; Gutowski, 1992) suggest the increase in water turbulence towards the northwest.

The sedimentary facies at the top of the discussed sequence consist of micritic limestones which locally contain banded chert levels and are interpreted as formed in intertidal zone (Gutowski, Pieńkowski, 2004; Gutowski *et al.*, 2006). Their deposition occurred at the transition between Planula and Platynota chrons during the Early Kimmeridgian as evidenced by rarely found ammonites.

The prevalence of the deposits of a very high calcium carbonate content in the sequence I-2 is related to paucity of marly to silty deposits: the only exceptions being marly deposits of the Latosówka Marl Mbr. which close in its middle part a smaller-scale sequence (denoted as **I-1b**), and the Zapole Marl Bed forming at the top of another smaller-scale sequence (denoted as **I-1c**), both having a special stratigraphical correlation value, marking tectonically to climatically-controlled phenomena (e.g., Wierzbowski, 2017). These marly units represent possibly the regressive members of these sequences: the lower corresponding to a higher part of the Planula Zone (directly below the Galar Subzone), the upper placed at the top of the Polygyratus Subzone of the Platynota Zone, at the transition to the next major sequence I-3 (Wierzbowski, 2017, 2020). The topmost part of the discussed transgressive-regressive sequence I-2 appears to comprise more expanded marl formation in the western (offshore) areas, while the less complete part of the succession consisting of banded chert nodules in micritic limestones developed eastwards (shorewards) on a wide tidal flat.

Oolitic to micritic-marly limestone – dominated interval (Lower Kimmeridgian: Platynota to uppermost Hypselocyclum zones) (sequence I-3ab)

This stratigraphical interval can be subdivided into smaller scale members (Fig. 2): two of them distinguished herein as the subintervals 3a and 3b correspond approximately to sequences recognized by Gutowski (1992, 1998, 2004b, 2006b) as follows: (3a) including the Skarbka Oolite Limestones (as discussed above) and the Błaziny Oolite Limestones; and (3b) including the Ożarów Oolite and Platy Limestones and the Wierzbica Oolite and Platy Limestones. These two smaller scale members correspond also possibly to units 2 and 3 as recognized by Kutek (1983) between Iłża and Wierzbica.

Only two large bodies of lower and upper oolitic limestones and closely related micritic limestones are recognized within subintervals 3a and 3b between Zawichost-Ożarów in the south-east and Wierzbica-Śniadków in the north-west. Although parts of oolitic limestones were distinguished in the past under separate names, similar development, and their similar stratigraphical range as defined herein strongly suggest their lateral continuity over the whole north-eastern margin of the Holy Cross Mountains. The large oolitic units were in the past attributed to the "upper Astartian" and /or to the "Kimmeridgian" according to interpretation given (e.g., Pożaryski, 1948; Dembowska, 1953; Malinowska, 1970).

The lower oolite includes mostly cross-bedded oolites, almost without fauna occurring directly above the banded chert levels as recognized between Skarbka and Błaziny near Iłża. These oolites are a few meters in thickness (about 6 m at Skarbka quarry), and are overlain by micritic limestones and oolites – attaining also similar thicknesses. Locally, they are partly laterally replaced, and underlain by organodetrital limestones. These deposits, and especially their upper part, show concentrations of "chocolate cherts". They are overlain in north-western area between Błaziny and Wierzbica

Stop Skarbka quarry: micritic limestones with banded chert nodules (sequence I-2) overlain by cross-bedded oolite and organodetrital limestones followed by micritic limestones and dolomites (sequence I-3) (Lower Kimmeridgian, Planula to Platynota zones)

Stop Błaziny quarry: A. marly layer (bed 3/4) corresponding to the Latosówka Marl Mbr.; B. micritic limestones (bed 5) overlain by chalky limestones with banded chert nodules (bed 6 and higher): sequence I-2 (Lower Kimmeridgian: Planula to Platynota zones)

by strongly bioturbated limestone with commonly occurring myid bivalves, delimited from its base by the regional hard-ground surface; on the other hand, the deposits directly overlying the oolites in the south – at Skarbka quarry – are strongly dolomitized, but the regional hardground surface can also be recognized there (Liszkowski, 1976; Gutowski, 1992, 2004b, 2006b).

Some ammonites found directly below and directly above the discussed lower oolite were interpreted by Gutowski (1992, 1998) as belonging to the genus/subgenus *Eurasenia*, but their critical revision indicate that all of them are in fact late representatives of the later introduced genus *Vielunia*. This interpretation (see also comments given above at chalky limestone-dominated interval) refers also to the specimen "*Rasenia* (*Eurasenia*) sp." (see Gutowski, 1992, pl. 5:6) found directly above the lower oolite at Wierzbica. These determinations indicate that the lower oolite, corresponding to the Błaziny Oolite Limestones (and its lateral equivalent the Skarbka Oolite Limestones, as redefined here), cannot range stratigraphically higher than the middle part of the Platynota Zone of the Lower Kimmeridgian.

The lower oolite and micritic limestones with bivalves in the Wierzbica quarry are overlain by marly deposits about 7 meters thick (Fig. 3). These deposits according to the author's observation consist of marls, marly limestones and micritic limestones that contain in their upper part interbedded oolitic limestones and marls. Capping these deposits are bivalve coquinas, about half a meter thick, which consist of redeposited shells of semi-infaunal forms, mostly *Gervillia* and *Inoperna* occurring in micritic matrix with loosely spaced small ooids. A single ammonite found here is *Eurasenia frischlini* (Oppel) which suggests the presence of the middle to upper part of the Platynota Zone (*cf.* Geyer, 1961; Wierzbowski, 2022). The discussed marly unit because of its stratigraphical position can be correlated with the over-regional marly level called the Góry Marl Member (Wierzbowski, 2017), corresponding *int.al.* to the "lowermost marly horizon" of Kutek (1968) from southwestern margin of the Holy Cross Mountains.

The upper oolite includes the lower parts of the of the Ożarów Oolite and Platy Limestones and of the Wierzbica Oolite and Platy Limestones (*cf.* Gutowski, 1992, 1998, 2004b, 2006b) consisting mostly of oolites – commonly cross-bedded, and banded and/or lithographic type micritic limestone being their lateral equivalents. Its upper boundary runs in the middle of the unit D as recognized by Gutowski (2004b, 2006a) in the Wierzbica quarry section. These deposits attaining about 15–17 meters in thickness are recognized in the Wierzbica and Ożarów quarries. Similarly developed oolitic and micritic limestones also crop out at Iłża (see Dąbrowska, 1953).

The upper oolite yielded fairly abundant ammonite fauna described both from Wierzbica and Ożarów quarries. It includes: *Rasenia* (*Rasenia*) *inconstans* Spath (see Wierzbowski, 2022, pl. 2: 6), *Rasenia* (*Pachypictonia*) *perornatula* (Schneid) (see Wierzbowski, 2022, pl. 6: 1), *Rasenia* (*Pachypictonia*) sp. (Gutowski, 1992, pl. 5: 5; Gutowski, 1998, pl. 2: 2), *Eurasenia trimera* (Oppel) (see Wierzbowski, 2022, pl. 12), *Eurasenia pendula* (Schneid) (see Gutowski, 1992, pl. 5: 1; also pl. 5: 2 referred to as "*Rasenia* (*Eurasenia*) sp." which can be attributed with reservation to the same species). Additionally two ammonites described from coeval deposits at Iłża include: *Eurasenia gothica* (Schneid) and *E. rolandi* (Oppel) (Dąbrowska, 1983 b; see also Wierzbowski, 2022, p. 77). This ammonite fauna is very close to that described from similarly developed deposits in SW margin of the Holy Cross Mts. and can be correlated with the upper Platynota Zone –lowermost Hypselocyclum Zone (Wierzbowski, 2020; see also Kutek, 1968). It is worth noting that both in the area of study as well as in the SW margin of the Holy Cross Mts., a directly overlying marly unit can be considered as having a wider lithostratigraphical importance. This is correlated with the Kiełczygłów Marl Member known from the foreland of the shallow-water carbonate platform at the Wieluń Upland (see Wierzbowski, 2017, 2020).

The overlying deposits are represented by set of beds of micritic and marly limestones and marls with rare fauna. They are well seen at the Ożarów and Wierzbica quarries where attain about 25 to 30 meters in thickness (see Gutowski, 1992). This interval includes the deposits from the upper – marly part of unit D to unit F of the "oolite sedimentary cycle" of Gutowski (2004b, fig.2; 2006a, fig. B2.16) in the Wierzbica quarry section. It corresponds also to unit 4 of Kutek (1983). These deposits contain subordinate intercalations of organodetrital-oolitic limestones, sometimes with *Nanogyra* shells. The skeletal remains are, however, not very diversified, and together with rarely encountered levels with trace-fossils, mostly *Thalassinoides* burrows, represent a rather monotonous faunal assemblage composed mostly of oysters and crustaceans, without cephalopods.

The uppermost part of the interval consists of deposits showing markedly different lithological development. In the Ożarów quarry, in the south, it is mostly represented by marly deposits, about 5 meters in thickness, with erosional surface inside covered with quartz grains, and topped by the hard-ground surface. The corresponding deposits at the Wierzbica quarry, in the north, show a more diversified facies pattern representing the subtidal channel-fill sequence composed of oolite-organodetrital grainstones with abundant lithoclasts, overlain by silty marly mudstones with abundant quartz grains, glauconite grains and mostly oyster shell debris with low-angle cross-lamination. Locally accumulation of flat limestone pebbles, floral detritus, including even tree-trunks (Gutowski, 1992, 2004b, 2006a; Woźniak, 2007), and occurrence of pterosaur tracks (Pieńkowski, Niedźwiedzki, 2005) have been recorded, confirming the intertidal conditions of formation of these deposits. All the diversified deposits vary markedly in their thickness from a few centimeters to about 10 meters. The overlying discontinuous micritic limestone bed is highly bioturbated – commonly with *Thalassinoides* burrows, and is topped by the hard-ground surface encrusted by oysters and heavily bored by lithophags (Gutowski, 1992, 2004b, 2006a).

A few ammonites including *Eurasenia vernacula* (Schneid) (see Wierzbowski, 2022, pl. 11: 1) and *Prorasenia* sp. were found at the top of the discussed stratigrahical interval in the Wierzbica quarry section. They are indicative of the upper part of the Lower Kimmeridgian (especially of the Hypselocyclum Zone). More precise dating based on ammonites coming from directly younger deposits, however, indicate that the discussed stratigraphical interval corresponds to the Hypselocyclum Zone without its uppermost part.

Summarizing, sedimentation of the transgressive-regressive **sequence I-3** started with a distinctive transgressive surface followed by high-energy deposits (oolites, biogenic detrital limestones) which are exposed at Błaziny and Skarbka quarries. The deposits of the lower part of this interval can be divided into two laterally interfingering environments: (1) high-energy open marine oolite shoals, (2) low-energy lagoons sheltered by ooid shoals. Large bodies of oolite limestones commonly show large scale-cross-bedding but a more detailed study of the transport direction was only conducted at Wierzbica quarry on a fragment of the oolite limestone succession (Gutowski, 1992; Wojciechowska, 2007). It has indicated generally unidirectional transport of ooid grains toward east. It seems to correspond well to the suggested NNW–SSE longitudinal orientation of oolite barriers, which may have formed over "swell" areas situated over structurally controlled elevations of the sea-floor as controlled by the Nowe Miasto-Iłża-Bałtów Fault Zone.

The sequences **I-3a** and **I-3b** shows a smaller scale sequence pattern with two oolite limestone (and associated micritic limestone) bodies, yielding some ammonites, and separated by regressive marly deposits with poor fauna. These marly deposits are distinctive at Wierzbica and possibly correspond to the Góry Marl Member – which is recognized also outside the studied area of north-eastern margin of the Holy Cross Mts. It marks time of increased supply of siliciclastic-marly deposits during a lower sea-level period (Wierzbowski, 2020). The regressive facies pattern of the upper part of the sequence differs markedly from its lower part: it is dominated by micritic and marly limestones to marls with monotonous impoverished faunal assemblages of the inner parts of the shallow-water carbonate platform. Subtle changes in the open-marine environment are difficult to recognize in this area, and the occurrence of smaller-scale sequences can be easily overlooked without detailed studies.

The uppermost part of the discussed sequence displays deposits of tidal flats that are dissected by a network of tidal channels, which can be observed at the Wierzbica quarry. A decrease in grain size towards the top suggests some progradation of the tidal flat, which was abruptly stopped by the development of an eminent erosional transgressive surface marking the onset of the next major transgressive-regressive sequence. This interval corresponds to the boundary between the megasequences COK and LUK of Kutek (1994), and also signifies the end of major sequences 1–3 which represent the successive stages in the development of the Late Oxfordian to Early Kimmeridgian shallow-water carbonate platform in the south-eastern margin of the Holy Cross Mts.

Oyster lumachelle and micritic limestone to marl – dominated interval (Lower Kimmeridgian: uppermost Hypselocyclum – Divisum zones – to Upper Kimmeridgian: especially Acanthicum Zone) (sequence I-4ab)

These deposits are exposed mostly in the Ożarów quarry, in the south, and the Wierzbica quarry, in the north (Fig. 2). Some differences in the development of these deposits resulted in recognition of the two lithostratigraphical units (Gutowski, 1992, 1998, 2006a): the Ożarów Oyster Lumachelle and the Wierzbica Oyster Lumachelle, in the lower part of the discussed interval (distinguished herein as subinterval 4a). The Ożarów Oyster Lumachelle as described in detail by Gutowski (1992) attains about 20 meters in thickness but is truncated erosionally by the Albian deposits. It consists mostly of *Nanogyra* lumachelle beds, composed of non-crushed shells, their hash, and subordinately of marly beds.

The Wierzbica Oyster Lumachelle is fully cropped out at the Wierzbica quarry section, where it attains about 28 meters in thickness and consists of several subunits (Gutowski, 1992). The lowermost one, about 3 meters thick, consists of densely packed shells – mostly of oysters, especially *Actinostreon* ("*Lopha*", "*Alectryonia*"), associated with other bivalves *Trichites*, *Isognomon*, *Nanogyra*, *Liostrea*, *Mytilus*, *Trigonia*, *Pleuromya* and brachiopods – mostly *Epithyris* (Dzik, 1979; Machalski, 1993, 1998). It can be interpreted as a lag deposit formed from reworking of the original sediment during the high energy events (Seilacher *et al.*, 1985; Machalski, 1993). The overlying deposits of the Wierzbica Oyster Lumachelle consist of *Nanogyra* lumachelle beds (generally composed of non-crushed shells, and only subordinately of their

Stop Wierzbica quarry: A. marly deposits corresponding to the Góry Marl Mbr., B. cross-bedded oolites sandwiched by micritic limestones (Wierzbica Oolite and Platy Limestones): sequence I-3 (Lower Kimmeridgian, middle/upper Platynota to lowermost Hypselocyclum zones) detritus) interlayered with micritic limestone and marly beds. The bed surfaces covered with flat oyster shells of *Deltoideum delta* are commonly found in the uppermost part of the discussed interval (Machalski, 1989). The concentrations of ammonite shells of the genera *Crussoliceras* and *Garnierisphinctes* are also recognized close to these levels (see Gutowski, 1992). The whole sequence of these deposits attains about 25 meters in thickness and is composed in equal proportions of *Nanogyra* lumachelles and micritic limestones and marls.

Similar deposits composed of *Actinostreon* lumachelles, and the overlying *Nanogyra* lumachelles and micritic limestones and marls were recognized at Iłża (Dąbrowska, 1953) and at Marylin-Śniadków (Dembowska, 1953).

The discussed deposits yielded some ammonites found especially at the Wierzbica section. These include: *Ataxioceras hypselocyclum hypselocyclum* (Fontannes) (Gutowski, 1992, pl. 4: 5; 1998, pl. 1: 3, and *Ataxioceras* (*Parataxioceras*) *lothari huguenini* Atrops (originally referred to as *A. hypselocyclum hypselocyclum*, see Gutowski, 1992, pl. 4: 4; 1998, pl. 1: 4). All these ammonite specimens were found directly above the *Actinostreon* bed, in the lower part of the section. They are indicative of the uppermost part of the Hypselocyclum Zone: the Lothari Subzone and the *semistriatum* horizon (Atrops, 1982). Younger ammonites *Garnierisphinctes semigarnieri* (Geyer) (Gutowski, 1992, pl. 6:2; 1998, pl. 1:6) and *Crussoliceras atavum* (Schneid) (Gutowski, 1992, pl. 6: 1–2; 1998, pl. 2: 4) from the middle part of the section (see also Kutek, 1983) are indicative of the Divisum Zone.

The overlying deposits (distinguished herein as subinterval 4b; see also Gutowski, 1992, 1998, 2006a) are absent in southern part of the north-eastern margin of the Holy Cross Mountains because of the Neo-Cimmerian uplift and erosion. Their most complete sequence preserved is in the north, especially at the Wierzbica quarry, although because of the soft nature of the rocks it is generally poorly exposed here. The deposits attain here about 110 meters in thickness as seen in the core sections (Pożaryski *in*: Malinowska, 1970, p. 167–168). They consist of well-bedded marls and clays containing thin subordinate intercalations of lumachelles with *Nanogyra*; exceptionally a more thick subunit of lumachelle attaining 3 meters in thickness has been observed in the middle part of the discussed interval.

These deposits were distinguished by Dąbrowska (1983a) as the Kotlarka claystone and lumachelle member and by Gutowski (1992, 1998, 2006b) as the Guzów Clays and Lumachelles. They were recognized and described also in other places of the north-eastern margin of the Holy Cross Mts., mostly at Iłża (Pożaryski, 1948; Dąbrowska, 1953, 1983a) and Krogulcza (Malinowska, 1970). These deposits together with underlying oyster lumachelles were located by Kutek (1983) in his unit 5. It should be remembered that the characteristic detrital bioclastic oyster lumachelle, recognized as the Malenie level, and placed originally at the top of the Guzów Clays and Lumachelles by Gutowski (1992, 1998, 2006b) is actually excluded from the discussed stratigraphical interval and placed in the following one (see below).

The detailed biostratigraphical data coming from discussed deposits in the area are rather scarce. The ammonites coming from the directly underlying and the overlying deposits strongly suggest, however, that at least a large part of the discussed interval corresponds to the Acanthicum Zone of the Upper Kimmeridgian.

Summarizing, sedimentation of the **sequence I-4** started in the northern part of north-eastern margin of the Holy Cross Mts. with a remarkable lumachelle of crowded oysters (*Actinostreon*). It evidently reveals some episodes of reworking of the original deposit indicating the presence of high-energy events. Although similar deposits ("*Lopha*/*Alectryonia* shellbeds") are found in other areas of the Holy Cross Mts. (see e.g., Kutek, 1968; Matyja *et al.*, 2006), those described in the north-eastern margin are undoubtedly ones of the oldest, representing the upper part of the Hypselocyclum Zone as seen in the Wierzbica section. The overlying marls and lumachelles rich in *Nanogyra* shells contain Mediterranean-Submediterranean ammonites of closely related genera *Crussoliceras* and *Garnierisphinctes* (see Enay *et al.*, 2014), found in both Wierzbica and Ożarów quarries, which indicate the flooding of the older carbonate platform area. The concentration of their shells, as noted about 20–30 m above the indicated *Actionostreon* lumachelle, suggests stratigraphical condensation correlated with a high sea-level, presumably at the end of the Crussoliensis Subzone of the Divisum

Zone. This part of the smaller scale sequence is recognized herein as **I-4a**.

The younger deposits (**I-4b**) are generally thicker and of rather monotonous lithology. However, they are poorly exposed and have not been studied in detail. Presumably the upper part of the Divisum Zone which is correlated with the Uhlandi Subzone and is marked by common appearance of aspidoceratid ammonites (mostly *Pseudhimalayites*) in other areas of the Holy Cross Mts., may be present here.

The topmost regressive part of the major sequence I-4 is seen only in the boreholes at Wierzbica (Pożaryski *in*: Malinowska, 1970, p. 168) where its consists of dolomitic siltstones with small quartz grains, locally shell debris, and fragments of wood.

Oyster lumachelle – bioclastic-detrital limestone to nerineid limestone – dominated interval (Upper Kimmeridgian: middle Eudoxus Zone – to lowermost Autissiodorensis Zone) (sequence I-5)

These are the youngest Jurassic deposits exposed in north-eastern margin of the Holy Cross Mts. They have been studied – mostly in their northern sector of occurrence – at Malenie and Krzyżanowice near Iłża (Pożaryski, 1948; Dąbrowska, 1953, 1957, 1983a, and earlier papers cited therein) – the given below description with new observations refers mostly to that area, but similar deposits are also known at Wierzbica and Krogulcza (Fig. 2). Additionally, coeval deposits, differing somewhat in their development (see Pożaryski, 1948, 1976) were recognized already outside the north-eastern margin of the Holy Cross Mts., at the Annopol-Rachów Anticline – these are also briefly commented below.

The succession of deposits at Malenie and Krzyżanowice consists in its lower part (see Pożaryski, 1948; Dąbrowska, 1953, 1957) of lumachelles composed mostly of oyster and terbratulid shells (with some addition of other shells – mostly *Trigonia*) – about 4 m in thickness. Overlying deposits include a prominent sandstone bed composed of abundant shell hash with quartz and glauconite grains – a few tens of centimeters thick, and the occurring above the "upper detrital lumachelle" – composed mostly of shell detritus with a marked admixture of detrital quartz and chert grains – up to about 1 cm in diameter. This younger subunit attains from about 1–2 m to even 4 meters in thickness. All these deposits were distinguished by Dąbrowska (1983a) as the Malenie lumachelle and siltstone member; they correspond also to unit 6 of Kutek (1983). The detailed studies of the section, exposed recently at Krzyżanowice, revealed, however, a more complicated structure pattern. The section begins here with deposits representing possibly a middle part of the discussed above unit – from the prominent sandstone bed – 0.65 m in thickness (base still not exposed), and the directly overlying deposits of the "upper detrital lumachelle": 0.38 m – organodetrital limestone bed, at the top 0.05 m layer of sandstone; 0.60 m – organodetrital limestone at the top 0.05 m sandstone; 1.10 m organodetrital limestone, at the top sandstone. All these deposits are distinctly cross-bedded with well-distinguished cross-bedding sets, generally inclined (up to about 20°), mostly to the west. A spectacular finds of two ammonites has to be noted here – their stratigraphical position is commented below.

The overlying younger deposits at Malenie-Krzyżanowice include a fairly thick subunit of limestones with dominating nerineid gastropods, about 6 meters in thickness. It contains mostly nerineids (*Nerinea*, *Cryptoplocus*, *Nerinella* and others), but also other gastropods (*Harpagodes*, *Natica*), bivalves (ostreids, *Trigonia*), brachiopods (Karczewski, 1960, 1983; Wieczorek, 1983; see also Dąbrowska, 1957, 1983a), and locally the vertebrate bone accumulations, especially turtles (Borsuk-Białynicka, Młynarski, 1968) and pliosaurids (Tyborowski, Błażejowski, 2019). These deposits were distinguished by Dąbrowska (1983a) as the Krzyżanowice nerineid limestone bed and by Gutowski (1992, 1998, 2006b) as the Krzyżanowice Nerineid Limestone. The youngest marls without macrofaunal rests, but with ostracods, attain from several centimeters to about 2 meters in thickness, occurring below the Lower Cretaceous (Valanginian) deposits (Dąbrowska, 1957).

Similar deposits although poorly exposed, and generally not studied in detail, are known also from some other areas placed north-west from Malenie-Krzyżanowice, like Zalesice at Wierzbica, and Krogulcza (see Pożaryski, 1948; Malinowska, 1970). The more detailed succession of these deposits documented in boreholes near Wierzbica (Pożaryski *in*: Malinowska, 1970, p. 168) includes

Stop Krzyżanowice: detrital lumachelles interbedded with sandstones: sequence I-5 (Upper Kimmeridgian: Eudoxus Zone)

about 7 meters of siltstones with small bivalves, organodetrital limestones with quartz and chert grains with glauconite, and sandy dolomites with some bivalves, which are overlain by limestones containing numerous bivalves and gastropods, a few meters in thickness. Similar deposits were also penetrated by shafts and shallow boreholes at Ruda Wielka and Krogulcza where the "Krogulcza oyster lumachelle" is overlain by a few meter thick nerineid limestones topped locally by gray marls (Różycki, 1939).

The chronostratigraphical interpretation of all these deposits has been well established recently due to new finds of ammonites in the "detrital lumachelle" of the lowermost part of the discussed interval at Krzyżanowice (as indicated above). The occurrence of *Aulacostephanus eudoxus* (d'Orbigny) along with *Aspidoceras caletanum* (Oppel) here can be treated as indicative of the Caletanum Subzone of the middle part of the Eudoxus Zone of the Upper Kimmeridgian (*cf.* Hantzpergue, 1989). On the other hand, the occurrence of one reported previously ammonite from the directly overlying deposits, a small cardioceratid referred to as "*Amoeboceras* ex gr. *anglicum* (Salfeld)", which comes from the nerineid limestones (Dąbrowska, 1957, 1983a) – unfortunately not illustrated and lost – is consistent with such a stratigraphical interpretation. This ammonite referred to the small-sized genus *Nannocardioceras* suggests the uppermost part of the Eudoxus Zone – the lowermost part of the Autissiodorensis Zone of the Upper Kimmeridgian (*cf.* Wierzbowski, Wierzbowski, 2019). Still younger are marly deposits occurring in boreholes markedly toward north, near Radom, which are overlying there the nerineid limestones – they can be attributed to the uppermost Kimmeridgian (see Cieśliński, Pożaryski, 1970, p. 190). A marked development of these marly deposits (see also Pożaryski, 1948) indicates also the gradual disappearance of the discussed oyster lumachelle to nerineid limestone interval toward the north.

The corresponding deposits east of the Holy Cross Mts., are exposed in Annopol-Rachów Anticline where have been studied in detail by Pożaryski (1948, 1976). These deposits are lumachelles with terebratulids below, resting directly on marl to clay deposits with *Nanogyra*, and covered by dolomites with fragments of bivalve shells, which are in turn capped by oyster lumachelles with detrital quartz and chert grains. The latter attaining here about 5–6 meters in thickness show marked lithological similarity to the "upper detrital lumachelle" at Krzyżanowice in the north. These are overlain by a thin layer of sandstone, followed by marly dolomites, about 6 meters in thickness, showing some intercalations of hard limestones, which show also some similarity to the youngest limestones at Krzyżanowice. All these deposits can be thus correlated with the Upper Kimmeridgian (Pożaryski, 1976; Niemczycka, 1976, fig. 22).

Summarizing, the last major transgressive-regressive **sequence I-5** from north-eastern margin of the Holy Cross Mts., in its lower part represented by oyster-terebratulid lumachelles, sandstones and "detrital" lumachelles of the middle part of the Eudoxus Zone as proved by ammonites (see above), marks the beginning of the new transgressive impulse in Poland and everywhere (e.g., Wierzbowski, Wierzbowski, 2019).

The smaller-scale sequences observed at Krzyżanowice within the "detrital" nearshore lumachelles consist of coarse-grained lumachelles overlain by sandstones which exhibit a well-developed cross-bedding. The cross-lamination is generally inclined toward the west which is generally consistent with the projected, approximately longitudinal, elevation of the substrate related to the Nowe Miasto-Iłża-Bałtów Fault Zone. Moreover, it may be suggested that the specific development of deposits of the lower part of the sequence was partly influenced by tectonic activity within the fault zone.

The development of the lower part of the sequence I-5 can be inferred as resulting, from wider, possibly climatically controlled factors which were superimposed on the local tectonic activity. The regional character of the discussed sequence was neglected by Świdrowska *et al.* (2008, p. 51) who claimed "no evidence of a large regional role of the discontinuity surface proven in the Eudoxus Zone in NE margin of the Holy Cross Mts." Such opinion is, however, not accepted herein.

The following development of nerineid chalky limestones is generally considered to be a consequence of deepening of the depositional environment. It is also in agreement with the stratigraphical interval of occurrence of ammonite *Nannocardioceras* which was described by Dąbrowska (1957). It is worth noting that this group of ammonites marks the maximum of marine transgression at the boundary between the Eudoxus Chron and the Autissiodorensis Chron during the Late Kimmeridgian, not only in Poland but also in other areas of central and north-western Europe (e.g., Hantzpergue, 1995; Gygi *et al.*, 1998: Wierzbowski, Wierzbowski, 2019). Unfortunately, neither the precise location of the ammonite has been indicated, nor the detailed succession of deposits has been described. This lack precludes recognition of possible changes in the depositional environment of the chalky limestones. Nevertheless, it may be stated that the development of the chalky limestone itself, containing shallow-water fauna, indicates the temporary return of the shallow-water carbonate platform to the north-eastern margin of the Holy Cross Mountains.

The decline of the shallow-water sequence is marked possibly by the deposition of marls with poor assemblage of ostracods (Dąbrowska, 1957). The more-open marine marly deposits above, unfortunately preserved only in more northern areas, indicate possibly a part of the next sequence deposited in a deeper environment. This corresponds to some higher parts of the Autissiodorensis Zone of the uppermost Kimmeridgian, and the directly overlying lowermost Tithonian.

Final comments

The distinguished sequences from north-eastern margin of the Holy Cross Mts. (Fig. 2) can be interpreted partly in terms of the allostratigraphical (mostly tectono-stratigraphical) units, and partly of the chronostratigraphical units. The former were controlled mostly by the tectonic events – especially active within the area of study which constituted a part of the peri-Carpathian segment of the Polish Rift Basin and of the Metacarpathian Arch (Kutek, 1994). Strong downwarping or elevation resulted in the appearance of diversified lithological assemblages strongly correlated with development of the ammonite faunas (e.g., Wierzbowski, 2022).

The tectonic pattern of development of the Holy Cross Mts. area during the Late Jurassic was controlled by the four main synsedimentary active fault zones (Fig. 1): (1) the Nowe Miasto-Iłża-

Bałtów Fault Zone along the north-eastern margin of the Holy Cross Mts., (2) the Grójec Fault Zone in north-western part of the north-western margin of the Holy Cross Mts., (3) the Holy Cross Fault System in between the north-eastern and north-western margins against the south-western margin of the Holy Cross Mts., (4) the Zawiercie-Busko Fault Zone at the southern border of the south-western margin of the Holy Cross Mts. The area of study corresponding to the north-eastern margin, including the adjoining segment of the Holy Cross Mts. from the west devoid currently the Upper Jurassic deposits, was composed of two fault-bounded blocks showing different sedimentological characteristics during the Late Jurassic: (1) the north-eastern elevated block along the Nowe Miasto-Iłża-Bałtów Fault Zone, and (2) the adjoining from the south and south-west lowered block bounded by the Holy Cross Fault System from the south and linking north-western margin along the Grójec Fault Zone from north-west. Such a tectonic pattern can be assumed e.g. for development of the deep water coral buildups and related deposits of the sequence I-1, the development of the cross-bedded thicker oolite assemblages of the sequence I-3, and of the bioclastic-detrital lumachelles of the sequence I-5.

On the other hand, the climatically-controlled sedimentary cyclicity interpreted as a sea-level maximum flooding episodes (*cf.* Boulila *et al.*, 2008, 2010) can be also distinguished in the succession studied (*cf.* Wierzbowski, 2017, 2020). Such a relatively short-termed high sea-level stands corresponding to 405-kyr eccentricity induced orbital-climate cycle minima are recognized in the area of study (but also in other parts of the Holy Cross Mts.) mostly by concentration of ammonites in the shallow-water deposits, e.g. indicating the boundary between the lower (Polygyratus Subzone) and the middle (Desmoides Subzone) parts of the Platynota Zone of the Lower Kimmeridgian, as stated near the boundary between the sequences I-2 and I-3. The crucial for recognition of the climatically-controlled sedimentary cyclicity in the succession studied is the precise chronostratigraphical correlation with the well dated by ammonites the orbitally-calibrated Early Kimmeridgian succession of south-eastern France (Boulila *et al.*, 2008, 2010; see also Atrops, 1982).

Some of these high-sea level episodes, showing a high correlation value, have been strongly superimposed on the tectonic events, which resulted in a "mixed" character of several parts of the sequences. Such character reveals e.g. the sequence I-5 being strongly tectonically induced in its lower part – mostly due to uplift along the Nowe-Miasto-Iłża Fault Zone at the middle of the Eudoxus Chron of the Late Kimmeridgian. This was directly followed, however, by a high sea-level as interpreted from the special deep-water ammonite faunas, observed e.g. in neighboring north-western margin of the Holy Cross Mts., where the coeval deposits have been developed as monotonous marl to limestone dominated interval corresponding to the Pałuki Formation (*cf.* Wierzbowski, Wierzbowski, 2019).

Additionally there occurred also longer climatically-controlled cycles which resulted in development of some sequences. It refers especially to the youngest sequences, known from the most complete succession of the north-western margin of the Holy Cross Mts. (and denoted there as sequences II-1-7), having no counterparts preserved in the north-eastern margin because of the Early Cretaceous erosion. Such is marly to clayey a fairly deep-water sequence II-6 in the north-western margin which contains appreciable quantities of fine siliciclastic material, not known in older parts of the Late Jurassic succession. The siliciclastic material was possibly transported from southern directions (Matyja, Wierzbowski, 2014). These deposits show also the lowest content of carbonates, when compared with underlying ones of the Late Jurassic succession (Kutek, Zeiss, 1997, fig. 3B-C), as well as some specific features, as a marked abundance of the agglutinated foraminifers (e.g., Barwicz-Piskorz, Tarkowski, 1984). This stratigraphical interval of the Early Tithonian from the boundary with the Kimmeridgian to lower part of the Scythicus Zone, corresponding to the upper part of the Pałuki Fm., represents thus the specific palaeoenvironmental conditions generally indicative of dominance of humid climate. Similarly, the overlying interval of the Lower Tithonian, dominated by a shallow-water origin limestones of the Kcynia Formation cropped out at the famous locality Owadów-Brzezinki, corresponding to the sequence II-7, showing a sudden decrease in terrigenous input, generally indicates the environmental changes towards aridification, which finds its spectacular confirmation in detailed studies of coeval deposits in other areas in Poland and in Europe (Grabowski *et al.*, 2021, and earlier papers cited therein).

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Summary of a decade of research at the Owadów-Brzezinki palaeontological site

Błażej BŁAŻEJOWSKI [1] and Łukasz WERYŃSKI [2]

10 years of systematic excavation work at the Owadów-Brzezinki quarry have been recently concluded, yielding fruitful results with numerous spectacular discoveries made each year. Additionally, the establishment of the Owadów-Brzezinki Geoeducation Area has been a significant achievement. The Owadów-Brzezinki quarry is an active limestone mine, located in central Poland in the Łódzkie Voivodeship (Opoczno County) in the north-western margin of the Holy Cross Mountains (51°22'27" N, 20°8'11" E, Fig. 1). The research conducted at this palaeontological site has enhanced our understanding of the evolutionary lines of various animal groups, encompassing both vertebrates and invertebrates. Furthermore, it has provided valuable insights into palaeoenvironmental conditions and changes that occurred during the latest Jurassic in Poland (Błażejowski *et al*., 2023). The Owadów-Brzezinki site not only presents a previously unknown record of the evolution of living organisms in the Late Jurassic (placed near the Early/Late Tithonian boundary), but also sheds light on the palaeogeography of Europe during that time.

The excavation work, which has been carried out systematically since 2013 at the Institute of Paleobiology PAS in Warsaw as part of research projects supported by the Polish National Science Centre, has involved the participation of students, doctoral students and scientists from around the world. The remarkably well-preserved fossils of marine and terrestrial organisms of Late Jurassic age, many of which are new to science, offer an excellent opportunity to study various aspects such as the taphonomy of the ecosystem, palaeobiology of the newly discovered organisms, evolution and migration of taxa, and palaeoenvironmental changes (*cf.* Błażejowski *et al*., 2014, 2016, 2019, 2023; Wierzbowski *et al*., 2016).

The Owadów-Brzezinki section has recently attracted much attention not only because of the exquisite quality and quantity of preserved fossils, but also due to its palaeogeographic significance. This site is proposed to encompass an important region, situated at the border of the Boreal/Subboreal and Tethyan realms, where co-occurrence of temperate and tropical faunal biota occurred (Błażejowski *et al*., 2023). The Owadów-Brzezinki section provides important clues for stratigraphical correlation between the NW Europe, Russian and Tethyan domains in the Late Jurassic (Tithonian), linking calpionellid occurrences (a typical Tethyan stratigraphic proxy) with the well-established, ammonite, British ("Upper Kimmeridgian" and "Portlandian") and Russian ("Volgian") zonal schemes (Matyja, Wierzbowski, 2016; Błażejowski *et al*., 2023). The palaeontological discoveries from the Owadów-Brzezinki quarry establish that the Sławno region served as a palaeobiogeographic link between several regions during the Late Jurassic (Fig. 2).

Geological background

The rocks exposed in the quarry belong to the uppermost stage of the Upper Jurassic – the Tithonian, and are independently correlated with the local East European Substage – the "Middle Volgian".

The Owadów-Brzezinki section is located within both marly deposits of the Brzostówka Marl Mbr. of the topmost part of the Pałuki Formation (Fm.) and the overlying limestones of the Kcynia Fm. (Błażejowski *et al*., 2016; Fig. 1). The uppermost part of the Pałuki Fm and the overlying limestones of the Kcynia Fm, including the Sławno Limestone Member (units I–II), "*Corbulomima* limestones" (unit III), and a horizon of "serpulid" beds (unit IV), exposed in the section (Matyja, Wierzbowski, 2016; see also Kutek, 1994). The sedimentary pattern observed in the Owadów-Brzezinki section indicates generally a gradual marine regression, characterized by a transition from offshore to coastal and lagoonal settings,

[1] Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland.
[2] Doctoral School of Exact and Natural Sciences, Institute of Geological Sciences, Jagiellonian University, Gronostajowa 3a, 30-387 Kraków, Poland.

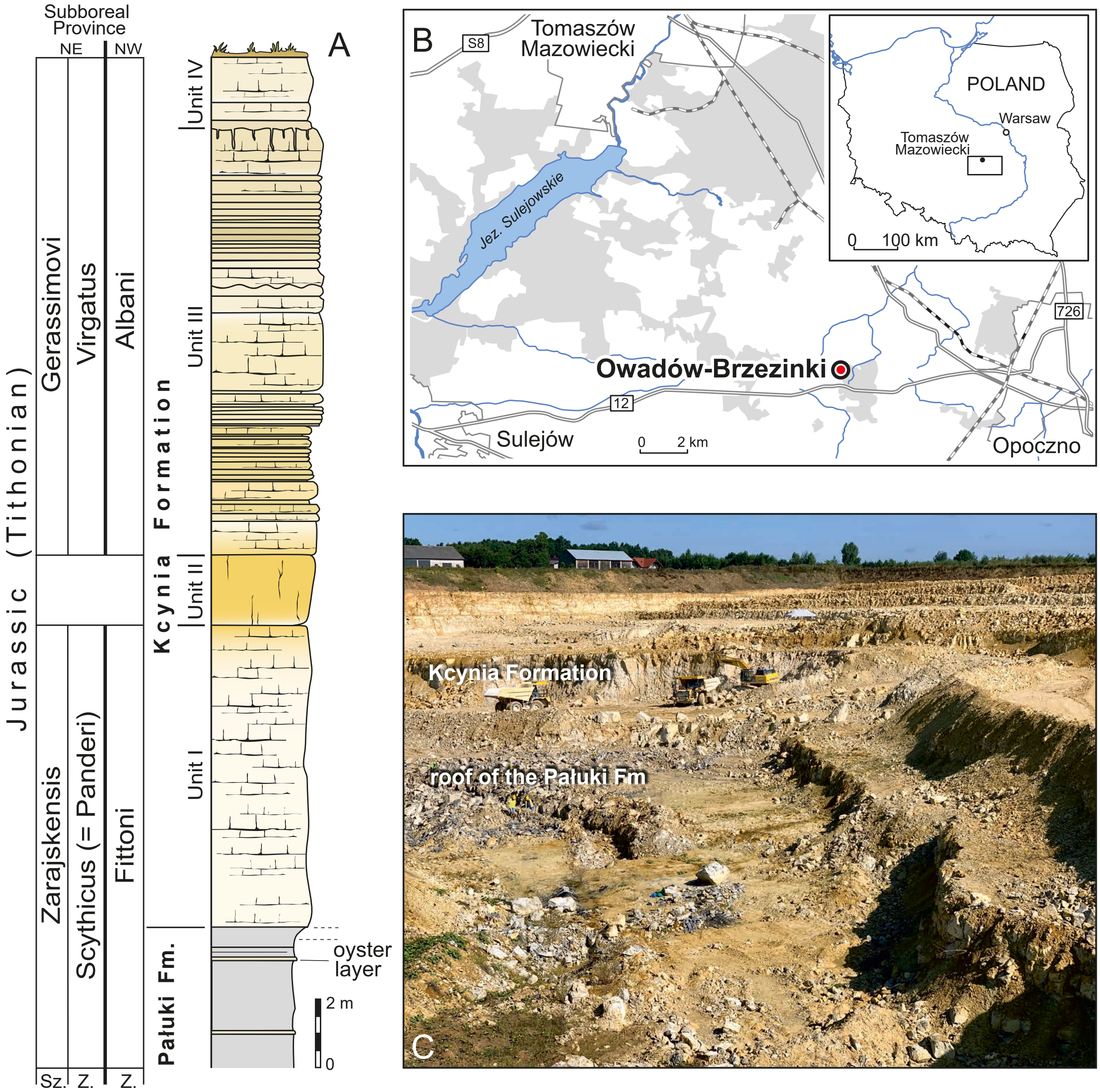

Figure 1. A. Lithological succession and biostratigraphy of the Owadów-Brzezinki quarry. The topmost part of the Pałuki Fm. and overlying limestones of the Kcynia Fm. (units I–IV). B. Road map with the location of Owadów-Brzezinki quarry in the proximity to Tomaszów Mazowiecki in central Poland. C. Panoramic view of the Owadów-Brzezinki section

but the uppermost part of the section was 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 Mbr. of the Pałuki Fm. from the Owadów-Brzezinki quarry (ca. 4 m thick) consists of black, blue-greyish and yellow-bluish marls with thin oyster-bearing and marly limestone interbeds (*cf.* Błażejowski *et al*., 2016; Wierzbowski *et al*., 2016). The marls yielded abundant marine microfossils, bivalves, ammonites, decapod crustaceans and fish (Błażejowski *et al*., 2016). The overlying limestones of the Kcynia Fm. have been subdivided into four lithological units (Fig. 1).

Unit I (ca. 9.1 m thick) consists of massive, fine-grained, chalky limestone characterized by a general absence of sedimentary structure. Deep-burrowing bivalves *Pleuromya* sp. accompanied by oysters *Deltoideum delta* (Smith) and unidentified trigoniid bivalves, terebratulide and rhynchonellid brachiopods, small gastropods, crinoids and ammonites (Matyja, Wierzbowski, 2016) are common, especially in the lower part of this unit. A rather monotonous ostracod assemblage has been reported from the unit I deposits (Wierzbowski *et al*., 2016). Recently quite numerous bones of marine reptiles have been also recovered. These are represented by ichthyosaurs (Fig. 3), turtles (Fig. 4), crocodyliforms and teeth of plesiosauroids (Fig. 5) with a remarkably good quality of preservation (Błażejowski *et al*., 2016; Tyborowski, 2016; Szczygielski *et al*., 2018; Weryński, Błażejowski 2023).

Unit II (ca. 2.2 m thick) is represented by thick-bedded micritic limestones, which are underlain and overlain by very thin (2–4 cm) marly beds. 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 atoposaurid crocodyliform (Fig. 6). Atoposaurids are small-sized Mesozoic crocodyliforms of mainly European distribution, which are considered to be phylogenetically close to the origin of Eusuchia.

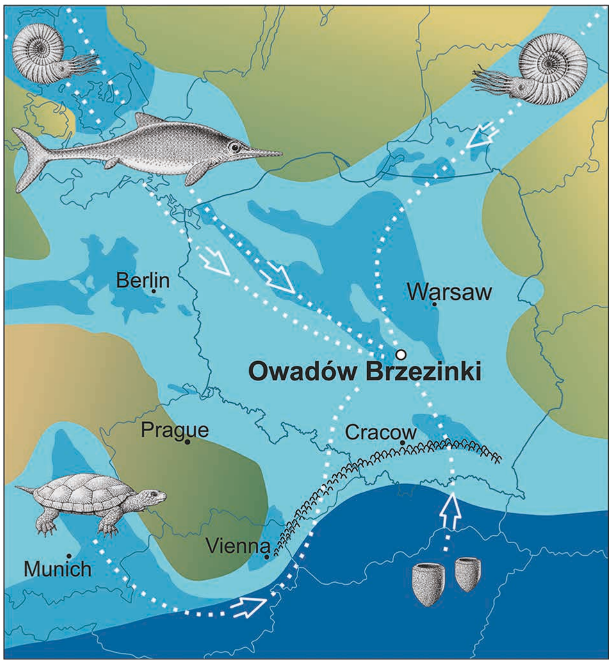

Figure 2. Palaeogeographical sketch-map of Europe at the end of Jurassic (acc. Błażejowski B., Hołda-Michalska A., Matyja B., Wierzbowski A.)

Unit III consists of well-bedded micritic limestones (ca. 12.8 m thick). The lowermost part (bed D14, 1 m thick) only comprises thick-bedded, hard, yellow limestones. The directly overlying D13 and D12 beds (0.6 m thick) are paler in colour and very fossiliferous (Fig. 1).

Figure 3. A nearly complete skeleton of ichthyosaur (Ichthyosauria: Ophthalmosauridae), Kcynia Formation (unit I), Upper Jurassic (Tithonian)

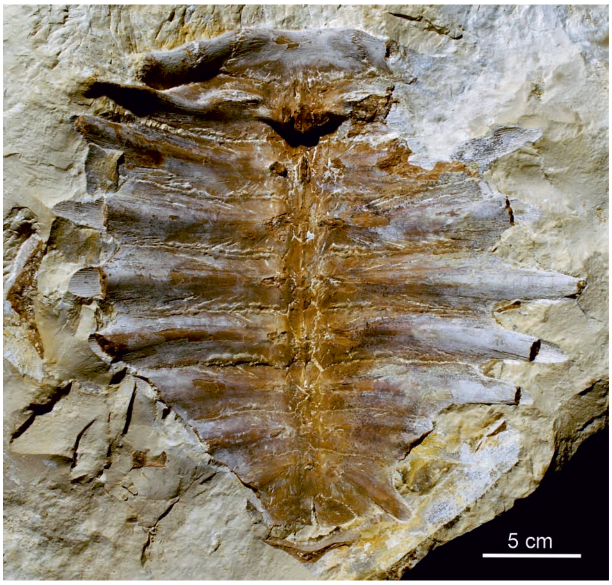

Figure 4. The carapace of marine turtle (*Thalassochelydia* indet.). Kcynia Formation (unit II), Upper Jurassic (Tithonian)

Figure 5. Plesiosaur tooth (ZPAL R.11/OB/T4). Pałuki Formation, Upper Jurassic (Tithonian)

Figure 6. Three-dimensionally preserved atoposaurid crocodyliform. Overview photograph of the original specimens in piece of limestone. A. Dorsolateral view of skull. B. Articulated thoracic vertebra and associated osteoderms. Kcynia Formation (unit II), Upper Jurassic (Tithonian)

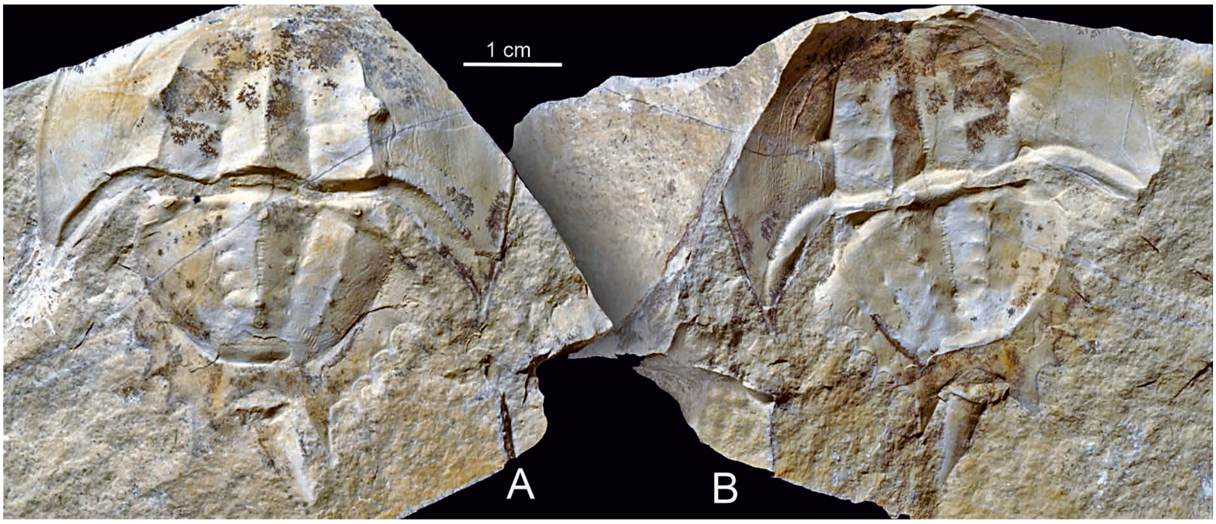

Figure 7. Three-dimensionally preserved horseshoe crabs. *Crenatolimulus darwini* (ZPAL X.1/O-B/14.1). (A) Negative and (B) positive (rock slab with imprint)

Numerous specimens of horseshoe crabs (Fig. 7) have been found in unit III in association with an enormously rich assemblage (mass-accumulations) of small elongated-shelled bivalves (either protobranchs or corbuloids), the remains of various fish and marine reptiles, rare ammonites and land insects (dragonflies, beetles, grasshoppers) (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). Late Jurassic horseshoe crabs preserved in sediments of the 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 Xiphosurida arthropods adds significantly to our understanding of a group which has a stratigraphic range throughout almost the entire Phanerozoic period. 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 with periodic episodes of anoxia (Wierzbowski *et al*., 2016, 2019).

The overlying deposits of **unit IV** are the youngest rocks of the Owadów-Brzezinki section (Fig. 1). They contain rare ammonites, bivalves, and small bryozoan-serpulid bioherms. The deposits of this unit most probably belong to the lower part of the so-called "serpulite beds". The Upper Jurassic deposits some tens of meters thick are actually covered by Quaternary deposits, although as seen in the neighbouring boreholes the occurrence of the Lower Cretaceous deposits can be also recognized locally.

According to the stratigraphical studies by Kutek (1994), Matyja and Wierzbowski (2016) based on the ammonite fauna, the lower part of the Owadów-Brzezinki deposits is dated to the *regularis* horizon (the uppermost part of the Brzostówka Marl Mbr. of the Pałuki Fm.) and *zarajskensis* horizon (unit I of the Sławno Limestone Mbr. 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 "Upper Kimmeridgian/Bolonian" zonation of England. The upper part of the Owadów-Brzezinki section (units III and IV belonging to the "*Corbulomima* limestones" and "serpulid" 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".

An overview of the most important palaeontological finds

The palaeontological sites of Owadów-Brzezinki serve as a unique "taphonomic window" into the Late Jurassic, providing valuable insights into the evolution of life on Earth within the palaeogeographical and palaeoenvironmental context. Most notably, the site in only non-Carpathian outcrop of Tithonian in Poland, providing unique insight into the geological and palaeontological setting of this age in the regions 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; Błażejowski *et al*., 2016; Fig. 8) and xiphosuran arthropods (Kin, Błażejowski, 2012, 2014; Błażejowski, 2015; Błażejowski *et al*., 2019, 2020; Bicknell *et al*., 2021), constituting one of the largest accumulation of Jurassic horseshoe crabs ever found.

Certainly, some of the most spectacular discoveries in this setting are related to the vertebrate fauna. Most prominent taxa of vertebrates discovered so far are represented by the ichthyosaur *Cryopterygius kielanae* (Tyborowski, 2016), the pancryptodiran turtle *Owadowia borsukbialynickae* (Szczygielski *et al*., 2018) and isolated plesiosaur teeth (Weryński, Błażejowski, 2023). Other vertebrate taxa are represented by Actinopterygii and Elasmobranchii (Kin *et al*., 2013; Błażejowski *et al*., 2015) and marine crocodylomorphs (Błażejowski *et al*., 2016), with additional shore fauna represented by insects, terrestrial crocodylomorphs, and possibly pterosaurs (Kin *et al*., 2013).

Ichthyosauria. The *Cryopterygius kielanae* (or *Undorosaurus* sp. according to Zverkov, Jacobs, 2021) specimen from Owadów-Brzezinki was found in unit I of 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. 2). Tyborowski (2016) has pointed out diagnostic characteristics suggesting an affiliation of this ichthyosaur with Boreal ichthyosaurs from Svalbard. However, recently Zverkov and Jacobs have argued that Boreal *Cryopterygius* from Svalbard is a junior synonym for *Undorosaurus*, thereby indicating more cosmopolitan distribution of this genus. It has been found from the European part of Russia, across Svalbard, up to Central Europe, i.e. from eastern part of the Subboreal province to the Boreal province.

Plesiosauria. During recent field excavations, large conical teeth of Plesiosauria were discoverd. The identification was based on the conspicuous pattern of enamel apicobasal ridges, overall morphology and the results of morphometric Principal

Figure 8. Lobster-like decapod crustaceans '*Mecochirus*' sp. Pałuki Formation, Upper Jurassic (Tithonian)

Coordinates Analysis (PCoA). The material consists of four large isolated teeth from the upper part of the Pałuki Fm. and the lower part of Unit I of the Kcynia Fm. These teeth have largely preserved crowns, with one case also showing a partially preserved root (Fig. 5). Given the stratigraphic context and overall morphology, it is highly probable that the described teeth belong to animals from the Cryptoclididae family (open nomenclature).

Crocodylomorpha. Atoposauridae is a family of small, short-snouted crocodylomorphs with a temporal range spanning 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 that suggest a terrestrial lifestyle. The Atoposauridae material obtained from unit II is currently being described, with a proposed new taxon referred to as *Theriosuchus* sp. nov. (Fig. 6). Cranial material was previously presented by Błażejowski *et al*. (2016), and was initially assigned to the Metriorhynchidae family, but has since been reevaluated.

Testudinata. In 2017 Szczygielski *et al*. (2018) introduced a new pancryptodiran turtle from Owadów-Brzezinki unit I: *Owadowia borsukbialynickae*. The fossils findings present a large Jurassic 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 *Owadowia* is interpreted as an adaptations for durophagy.

Actinopterygii. Currently, the site is predominantly known from the presence of large predatory Actinopterygii, primarily identified through teeth, scales, and occasionally well-preserved jaw bones (Błażejowski *et al*., 2015; Tyborowski, 2017). Among these substantial actinopterygians, there exist macropredators belonging to Caturoidea and Pachycormidae, as well as durophagous Pyncnodontiformes. In the latest study of these large predators conducted by Weryński *et al*. (2023), an exploration into the microstructural and morphological attributes of Caturoidea and Pachycormidae teeth from the Owadów-Brzezinki site was undertaken. The findings indicate the potential existence of niche partitioning among these comparably sized predatory fish.

However, in a biodiverse environment, it is anticipated that a significant portion of bony fish would tend to be a smaller size, as this accommodates the higher trophic levels. During student field excavations, a small-sized, fully preserved Actinopterygii specimen was discovered, possibly belonging to an order. This finding represents a pioneering sample of bony fish of such exquisite preservation, akin in quality to the small Actinopterygii specimens from Solnhofen.

The Owadów-Brzezinki Geoeduction Area

The discussed area is of importance not only for palaeontology as a science and popularization of this field in Poland, but also for the development of the region and its people. Over the past few years, workshops and lectures have been organized in the Sławno Commune with the aim of promoting geological knowledge, especially palaeontology, among the local population. These initiatives seek to foster an atmosphere of understanding and respect for the natural environment. The activities primarily target school children and youth, as well as individuals interested in research and preservation of our country's geological heritage. The palaeontological pavilion located in the thematic geoeduction area, known as "Owadów-Brzezinki Geopark" (Fig. 9), and supervised by the Sławno Commune, plays a vital role in these endeavors (Błażejowski *et al*., 2020; Błażejowski, Wierzbowski, 2021). It showcases fossils of Jurassic animals discovered at the site, along with their reconstructions.

Future perspectives

The impressive biodiversity of the Owadów-Brzezinki region 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 skeletal material. Additionally, the discovery of insects opens up a whole new area of research at the site. 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 related taxa and

Figure 9. The entrance gate to the Owadów-Brzezinki Geosite (geopark) in Sławno community

contemporary closest related animals. Every year, additional facets of research are integrated into the study of the site. 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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ABSTRACTS

Basin dynamics and stratigraphy in a half graben system during latest Jurassic – earliest Cretaceous rift climax – the Wollaston Foreland Basin in North-East Greenland

Peter ALSEN[1]

The latest Jurassic – earliest Cretaceous half graben system recorded by Vischer (1943) and described in detail by Surlyk (1978) is mainly exposed in the westernmost part of the Wollaston Foreland Basin (NE Greenland), where a several kilometre-thick coarse clastic dominated succession was deposited along the main fault against the Caledonian crystalline basement. Deposition was characterized by breccias nearest to the fault, grading into conglomerates and sandstone fans away from the fault towards the basin axis. Towards the east the rift climax interval is buried beneath progressively younger Cretaceous deposits.

Recent core drilling and outcrop studies have provided new data on the Upper Jurassic – Lower Cretaceous in eastern Wollaston Foreland and revise the understanding of the depositional system and its stratigraphy.

Two shallow cores provide a combined section covering the upper Kimmeridgian (Upper Jurassic) – Barremian (Lower Cretaceous) (Alsen *et al.*, in press). The black mudstone-dominated intervals are dated primarily by dinoflagellates and ammonites, whereas the calcareous mudstones – sandwiched between the black mudstones – are dated by calcareous nannofossils. The stratigraphy demonstrates an almost complete succession in a core that represents a deep position in the half graben. This contrasts to previous models which predicted a latest Jurassic rift climax hiatus for the eastern Wollaston Forland Basin. The other core represents a position closer to a block crest where unconformities developed. In combination the cores provide a key biostratigraphic reference section for the Jurassic–Cretaceous boundary interval in the Arctic.

A markedly different depositional type is a record of a basinally-isolated breccia–pebbly sandstone couplet that occurs in the axial part of the latest Jurassic rift-climax halfgraben (Alsen, Surlyk, 2023). Synrift breccias are otherwise restricted to a narrow zone along the scarp of the basin-margin fault. Towards the north the fault sidesteps *en echelon* towards the east. The breccia part of the couplet was transported by a noncohesive debris flow and the pebbly sandstone by a high-density turbidity. The couplet is located about 15 km east of the fault scarp and flowed southwards along the halfgraben axis. It is interpreted to have been derived from the fault side-step and had a run-out distance of at least 25 km. The angularity of the clasts reflects derivation directly from the fault scarp during a single catastrophic event. The occurrence of breccias thus cannot be taken as evidence of short transport and deposition at the foot of a scarp or steep slope.

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[1] The Geological Survey of Denmark Greenland, GEUS, Øster Voldgade 10, DK-1350 Copenhagen, Denmark.

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Posidonia Shale Formation / Grimmen Formation / Ciechocinek Formation – Lower Toarcian facies in the eastern part of the Central European Basin

Jörg ANSORGE [1], Matthias FRANZ [2] and Karsten OBST [3]

The marine Toarcian Posidonia Shale (Posidonienschiefer) is an organic rich laminated sediment with a carbonate content of 30–50 %. Its sedimentation lasted in Southern and Western Germany from the Tenuicostatum to the Bifrons zone. Intercalated carbonate concretions or banks can be correlated throughout the basin as marker beds in the otherwise uniform sedimentary succession.

In the eastern part of the North German Basin, Posidonia Shale like sediments with higher sand content and high total organic carbon (TOC) abundances occur in the upper Semicelatum Subzone following above a sand dominated unit with rich benthic life. The sedimentation of organic rich dark brown clay with low carbonate content lasted until the end of the Elegantulum Subzone during the sea level high stand.

At the beginning of the Falciferum Zone (Exaratum Subzone), sedimentation changed from laminated clay to grey-green clay with low content of organic carbon. These sediments with a restricted marine fauna, earlier known as Green Series (Grüne Serie) are now named Grimmen Formation. The lower part with dense laminated clay is represented by the Reinberg Member. At its top a concretionary limestone bank occurs, called lower elegans bed (Elegans Subzone). Upwards, the lamination of the clay reduces considerably with decreasing marine faunal elements and increasing sand content.

The marine to brackish-marine Grimmen Formation of the eastern part of the North German Basin represents the transitional facies to the marine Posidonia Shale Formation in the West and the freshwater-brackish Ciechocinek Formation of the Polish Basin in the East. The salinity of the Grimmen Formation is mainly controlled by high freshwater input from the Scandinavian mainland and a restricted water exchange due to emerging islands on the Ringkøbing–Fyn–Møn–Arkona High in the North and the Calvörde–Flechtingen Block with the Altmark Swell in the West (Figure 1).

The facies development of the eastern part of the North German and adjacent Polish Basin in the Toarcian is comparable to the recent Baltic Sea with its reducing salinity from the West to the East and its limited and temporary water exchange with the North Sea.

[1] Institute of Geography and Geology, University of Greifswald, Friedrich-Ludwig-Jahn-Str. 17A, D-17489 Greifswald, Germany, ansorge@uni-greifswald.de, ORCID 0000-0002-1284-6893.

[2] Geowissenschaftliches Zentrum der Universität Göttingen, Abteilung Angewandte Geologie, Goldschmidtstr. 3, D-37077 Göttingen, Germany, mfranz1@gwdg.de; ORCID 0000-0002-7054-9862.

[3] Geological Survey of Mecklenburg-Western Pomerania, LUNG M-V, Goldberger Str. 12, D-18273 Güstrow, Germany, karsten.obst@lung.mv-regierung.de, obst@uni-greifswald.de; ORCID 0000-0003-4416-0885.

Figure 1: Palaeogeographical map of central and northern Europe during the Lower Toarcian Falciferum Zone

<u>Main localities:</u> 1 – Grimmen, 2 – Dobbertin, 3 – Vicinity of Braunschweig (Schandelah, Hondelage), 4 – Upper Franconia (Mistelgau), 5 – Altdorf, 6 – Kerkhofen, 7 – Irlbach, 8 – Holzmaden, 9 – Dotternhausen/Dormettingen (1–9 – Germany), 10 – Hemmikon (Switzerland), 11 – Bascharage (Luxembourg), 12 – Sancerre borehole (France), 13 – Ilminster (Somerset, UK), 14 – Dumleton (Gloucestershire, UK), 15 – Mochras borehole (Wales, UK), 16 – Whitby (Yorkshire, UK), 17 – Mechowo borehole (West Pomerania, PL), 18 – Kozlowice (Upper Silesia, PL). Blue arrows indicate freshwater inflow. AS – Altmark Swell, CF – Calvörde–Flechtingen Block, KF – Karoo-Ferrar Large Igneous Province, NGB – North German Basin, SGB – South German Basin

Lower Jurassic Cephalopod Fauna from the Czech Republic (Lukoveček; Outer Western Carpathians)

Jan GEIST[1], Ján SCHLÖGL[2] and Robert WEIS[3]

The Lower Jurassic olistolith exposed in Lukoveček (*Klein-Lukow*) near Fryšták (*Freistadtl*) provides extraordinary insight into the sedimentological history of the Outer Western Carpathians. Geological and palaeontological investigations of these uniquely preserved deposits are, however, very few (it represents a single record within the Magura unit of the Carpathian flysh in Czech Republic). The relatively little scientific interest in this locality was probably also due to the poor preservation of fossils, which often does not allow a closer taxonomic determination. Several species of bivalves, ammonites, echinoids, brachiopods, forams and, last but not least, belemnites were reported (Rzehak, 1904).

Lithologically, the deposits consist of shallow-water crinoid limestones. Organic-rich intercalations contain pyrite and show, in some cases, pseudooolithic structures (Andrusov, 1959; Rakús *et al.*, 1990). Based on the recorded fauna, Oppenheimer (1913) previously assigned the grey heavy-bedded limestones to the Oxfordian-Kimmeridgian (Rakús, 1987).

It is possible that the Lower Jurassic rocks of the Magura Flysh of Western Slovakia have had a much more extensive area of occurrence (Andrusov, 1959). Apart from the rare occurrence of the Lower Jurassic rocks within the Flysch Belt, similar deposits can often be found within the Klippen Belt and other Carpathian units (Rakús *et al.*, 1990). The presence of the previously reported Oxfordian-Kimmeridgian fossils from Lukoveček is still not reliably tectonosedimentarily explained. Perhaps, they belong to another sort of deposits, which are not exposed nowadays and may have a similar origin as younger Jurassic exotica described from the territory of the surrounding states (e.g., Książkiewicz, 1956; Olszewska, Wieczorek, 2001; Wierzbowski *et al.*, 2006).

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[1] Institute of Geology and Paleontology, Faculty of Science, Charles University, Albertov 6, 128 43 Prague 2, Czech Republic.

[2] Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava, Slovakia.

[3] Musée national d'histoire naturelle de Luxembourg, 25 rue Münster, 2160 Luxembourg, Grand-Duchy of Luxembourg.

Dinosaur-bird link in the light of ichnological data

Gerard GIERLIŃSKI [1]

The feather and avian origin remained one of the most intriguing dilemmas for decades. Ichnological material may contribute importantly to our perspective on that subject. A sitting dinosaur track with imprint of an feathered belly, indicates a very early occurrence of plumage, in an Early Jurassic nonavian dinosaur. A long known, clearly bird-like shaped tracks of *Plesiornis* may suggest avian emergence comparably early, near the Triassic-Jurassic boundary.

The feathered belly imprint was found in the nineteenth century specimen of a squatting dinosaur track from the Lower Jurassic of Massachusetts (Gierliński, 1996a, 1997). The specimen is stored in the Amherst College, in Massachusetts, with the catalogue number of AC 1/7. It has been traditionally regarded as an early ornithischian track. However, some authors, including myself (Gierliński, 1994, 1996a), argued after its nonavian theropod origin. The resting trace of a middle sized trackmaker, consists of a pair of plantigrade footprints, a ischiadic imprint and a belly imprint. The belly imprint is covered by numerous feather impressions similar to those of semiplume (Gierliński, 1997), which are especially well visible along the left belly margin.

Such an early feather appearance in a nonavian dinosaur, is especially interesting with regard to the comparably early record of bird-like tracks. In spite of the pre-*Archaeopteryx* osteological and some ichnological evidence, which became questioned, it is hard to dismiss the avian traits of the *Plesiornis* tracks. Those distinctive and relatively rare footprints are reported from the Upper Triassic of Virginia, Lower Jurassic of Massachusetts and Poland. Characteristically small (35–53 mm long) tracks of *Plesiornis* share two pedal features of the avian morphological pattern, clearly differentiating them from nonavian dinosaur tracks (Gierliński, 1996b). The *Plesiornis* tracks, like the bird ones, exhibit swelled proximal pad of the inner (third) toe, while the lateral toes' proximal pads are not imprinted (Gierliński, 1996b). The next avian characteristic concerns the reversed hallux of *Plesiornis*, which is located exactly in the avian fashion, just below the third digit and very close to its base (Gierlinski, 1996b). The *Plesiornis* and *Archaeopteryx* hallux length equals only one-third of the third digit length, whereas later avians, such as *Sinornis*, have a hallux of nearly half of the third digit length, and some modern flying birds have a hallux the same size as their third digit. Consequently, if the hallux enlargement indeed reflects an adaptational trend of bird foot evolution, two alternative hypothesis may be put forward. Assuming a cursorial hypothesis for the origin of birds, the *Plesiornis* trackmaker might be even a pretty advanced flying creature. The hallux enlargement may have evolved in the parallel with wings' development, as compensation for the deterioration of the forelimbs' grasping functions, as perhaps a substitute for the beak, before it became adapted to such functions. Conversely, in the light of arboreal hypotheses, the *Plesiornis* trackmaker might be even a nonavian, diminutive arboreal animal, possibly a good candidate to evolve into a volant creature. Then, the reversed hallux, and swelled proximal pad of digit III, which extends the main catching surface axially from third digit to hallux, may have been developed specifically for climbing trees.

Whichever interpretation is correct, the above mentioned data would imply that we should search avian feathered ancestors among the earlier forms than higher tetanuran theropods – *Maniraptora*. Thus, the avian traits of maniraptorans may have been inherited from their common ancestor with birds.

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[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland.

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Upper Jurassic of Central Dobrudja (E Romania) – outline of issue

Ewa GŁOWNIAK[1] and Eugen GRĂDINARU[2]

Dobrudja (E Romania) is one of the classic areas of Jurassic carbonate marine facies in Europe (Simionescu, 1907). The purpose of the research carried out in course of the three research stays of E. Głowniak at the University of Bucharest (2018–2021) was to learn about the facial development of the Upper Jurassic in Central Dobrudja, their ammonite faunas and stratigraphic correlation with sections in Poland. The Jurassic marine formations lie transgressively on the Precambrian substrate in Central Dobrudja and stratigraphically range from the (?) Bathonian up to the Lower Kimmeridgian (Planula Zone, Galar Subzone, see Bărbulescu, 1974; Dragastan *et al*., 1998; Neagu *et al*., 2014). The Oxfordian – Early Kimmeridgian carbonates of the Casimcea Formation (Drăgănescu, 1976), have a total thickness of several hundred meters, a small regional dip, and are characterized by good accessibility of rock sections. Several sections located between the Hârşova town and Topalu were measured. This made it possible to identify the following bottom – up lithological succession: carbonate-siliceous formations (of Callovian age), a nodular layer (transition of Middle / Upper Jurassic), sponge-bearing limestones and marls passing upward into chalky and coralline limestones Oxfordian–Early Kimmeridgian in age, overlaid by bedded algal limestones and calcareous sandstones of uncertain age (probably Late Kimmeridgian or Tithonian). Ammonites collected in situ from layers showed the presence of the Oxfordian Cordatum and Transversarium, and Early Kimmeridgian Bimammatum and Planula zones, in the sections that so far have not had accurate biostratigraphic documentation. The information obtained from the field and the revision of the rich ammonite collection of Aurelia Bărbulescu (1974) and the unpublished collection of Prof. Eugen Grădinaru (University of Bucharest) enabled (i) the taxonomic and age reinterpretation of some classic ammonite taxa by J. Simionescu (1907) in their type area of occurrence, (ii) provided new dataset on the taksonomy, paleobiogeography and stratigraphy of the ammonite taxa, and (iii) enabled preliminary litho- and biostratigraphic correlations to be made with the Upper Jurassic formations in Poland.

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[1] Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, 02-089 Warszawa, Poland.
[2] Faculty of Geology and Geophysics, University of Bucharest, 1, N. Bălcescu Avenue, 010041, Bucharest, Romania.

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To be or not to be – occurrence vs. preservation of calcareous nannoplankton during the Toarcian Oceanic Anoxic Event

Annette E. GÖTZ [1, 2] and Mike REICH [3, 4, 5 *]

The Toarcian Oceanic Anoxic Event (T-OAE) has been classified as the most extreme episode of widespread ocean oxygen deficiency in the Phanerozoic, coinciding with rapid atmospheric pCO_2 increase and significant loss of biodiversity in marine faunas (*cf.* Little, Benton, 1995). Furthermore, a "marine phytoplankton black out" (e.g., Bucefalo Palliani *et al*., 2002; Van de Schootbrugge *et al*., 2005; Mattioli *et al*., 2009; Correia *et al*., 2017; Galasso *et al*., 2022) has been interpreted to document the severity of the environmental impact on the early Jurassic ocean system.

Here, we present new data of a Lower Toarcian nearshore setting of NE Germany (Grimmen section, Western Pomerania), revealing the preservation of nannofossils and their ghost imprints on amorphous organic matter (AOM) as documented by detailed SEM analysis. Ghost imprints were only recently reported from Lower Toarcian sections in Southern Germany, the UK and Japan (Slater *et al*., 2022) and interpreted as indicative of plankton resilience to high CO_2 and warming in the context of climate change.

The new findings from the Grimmen section of NE Germany raise a common question in palaeontological research, the question of occurrence vs. preservation as the AOM-rich deposits of the lower Toarcian also show well-preserved organic-walled phytoplankton (dinoflagellates, acritarchs), besides diverse calcareous nannofossils and striking prasinophyte blooms. The findings may point to a much more complex multi-phase event of multicausal nature, reflecting short-term changes of salinity and sea level rather than long-term variations in oxygen conditions. Here, the nearshore record with fluctuating salinity in response to transgressive–regressive events and freshwater influx will add new insights into an ongoing discussion on the causes and effects of the T-OAE. The careful study of marine plankton associations and their preservation in different settings applying different analytical methods might fill the gap of the so far postulated "black outs" indicating less environmental stress and/or less global but regional and local signals.

[1] State Authority for Mining, Energy and Geology, 30655 Hannover, Germany.

[2] Department of Structural Geology and Geodynamics, Georg-August-University Göttingen, Goldschmidtstr. 3, 37077 Göttingen, Germany.

[3] Landesmuseen Braunschweig | Staatliches Naturhistorisches Museum, Gaußstr. 22, 38106 Braunschweig, Germany.

[4] Ludwig-Maximilians-Universität München, Department für Geo- und Umweltwissenschaften, Paläontologie und Geobiologie, Richard-Wagner-Str. 10, 80333 München, Germany.

[5] GeoBio-CenterLMU, Richard-Wagner-Str. 10, 80333 München, Germany.

[*] Presenting author.

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Jurassic/Cretaceous boundary in the late Tithonian – is that a good idea?

Jacek GRABOWSKI [1]

Formal definition of the Jurassic/Cretaceous (J/K) or Tithonian/Berriasian (T/B) boundary is still a matter of debate (e.g., Wimbledon *et al*., 2020; Enay, 2020). Placement of the system boundary at the Berriasian/Valanginian (B/V) boundary (e.g., Granier, 2019), is an interesting and provocative solution, however it does not solve problem of the Tithonian/Berriasian boundary. It was agreed between International Subcommissions on the Jurassic and Cretaceous Stratigraphy, that it would be proper to define both stage boundaries first (i.e. T/B and B/V), with default J/K boundary at the T/B transition, and then to compare the global correlation potential of both T/B and B/V boundaries, choosing the most pragmatic solution in defining the system boundary.

The Berriasian Working Group (BWG) approach is to put the T/B boundary in the interval which might be most easily identified beyond the Western Tethys, where complete chronostratigraphic record is available between the Late Tithonian and lowermost Valanginian, due to integration of calpionellid, calcareous nannofossil and magnetic stratigraphy (e.g., Casellato, Erba, 2021). The crucial areas for global correlation remain: Sub-Boreal and Boreal basins of NW Europe and Arctic, Southern America, as well as Russian and Siberian domains.

It was recently discussed at BWG meetings, that the middle part of the Late Tithonian, roughly between magneto(sub)chrons M20n1r and M19r might deserve more attention as a possible J/K boundary interval. The interval is easily recognizable in Western Tethys, through numerous bioevents (e.g., base of Crassicollaria Zone or Cr. intermedia Subzone, and NJT17 calcareous nannofossil zone), as well as important palaeoecological trends: nannofossil calcification event (e.g., Bornemann *et al*., 2003), demise of Saccocoma microfacies (e.g., Grabowski *et al*., 2019) and change of calpionellid lorica structure (Reháková, Michalik, 1993). Correlation with Neuquen Basin (Argentina) seems

[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975, Warszawa, Poland.

easier in the Upper Tithonian than in the Lower Berriasian, due to robust magnetostratigraphic data and good consensus concerning ammonite stratigraphy (e.g., Aguiree-Urreta *et al*., 2019; Kietzmann *et al*., 2021). When comparing Siberian and Russian proxies (e.g., Bragin *et al*., 2013; Schnabl *et al*., 2015; Rogov *et al*., 2015) the interval might correspond either to the Middle/Upper Volgian boundary or to the Okensis/Tajmyrensis (Subditus/Nodiger) ammonite zonal boundary in the Upper Volgian. The weak point here is an uncertain stratigraphic position of the Okensis/Tajmyrensis boundary against magnetostratigraphic scale in Nordvik section (between M19r and middle M19n magnetozone).

The real challenge remains a position of the Portlandian/Purbeckian (P/P) boundary in the southern England, traditionally set at the top of Anguiformis ammonite Zone. It is tempting to correlate Late Tithonian palaeoenvironmental trends in the Tethys realm with aridification and regression trends in the P/P interval (e.g., Grabowski *et al*., 2021; Błażejowski *et al*., 2023). Taking into account different concepts of correlation between English and Russian-Siberian ammonites (Rogov, *in*: Wierzbowski *et al*., 2017; Cope, 2020; Wimbledon *et al*., 2020), the P/P boundary might be situated between the uppermost part of M20n2n and lowermost M19n2n magnetosubchron, which creates an uncertainty interval of ca. 1 My. However, bering in mind that position of the Okensis/Tajmyrensis ammonite zonal boundary is not well resolved (e.g., Schnabl *et al*., 2015), base Purbeckian might be as high as in mid-M19n magnetozone, coinciding rather with the base of Alpina Subzone, thus present-day position of the T/B boundary.

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Updated calpionellid stratigraphy and palaeoenvironmental proxies (gamma ray spectrometry and magnetic susceptibility) in the Clue de Taulanne section (Vocontian basin, SE France)

Jacek GRABOWSKI [1], Justyna KOWAL-KASPRZYK [2], Damian LODOWSKI [1,3], Jean-Francois DECONINCK [4], Mathieu MARTINEZ [5] and Izabela PLOCH [1]

Sedimentary successions of the Tithonian–Berriasian age from the Vocontian Basin (SE France) represent important palaeoenvironmental archive which contain reference data for reconstruction of climate dynamics around the Jurassic/Cretaceous transition (e.g., Deconinck, 1993; Morales *et al.*, 2013).

The Clue de Taulanne section is located ca. 3.5 km to the NW from Castellane. The biostratigraphically studied part of the section included interval of ca. 100 m, of the early late Tithonian to earliest Valanginian age. Samples represent carbonate hemipelagic facies of a deep basinal slope with numerous resedimentation features (Beaudoin, 1977; Rameil, 2005). The section has been previously dated by Remane (1970) and Beaudoin (1977), using standard calpionellid zonation of A, B, C and D zones. Here we apply an updated calpionellid stratigraphy using a Reháková and Michalík (1997) scheme developed in the Western Carpathians area. Magnetic susceptibility (MS) and gamma ray spectrometric measurements were performed in the field using hand-held devices.

Calpionellid zones and subzones were documented, from Chitinoidella boneti Subzone in the lower part of the Upper Tithonian, through Tintinnopsella remanei, Crassicollaria intermedia and Cr. colomi subzones in the Upper Tithonian. Calpionella alpina, Remaniella ferasini and C. elliptica subzones were proved in the Lower Berriasian, while Calpionellopsis oblonga and Praecalpionellites murgeanui subzones in the Upper Berriasian. The topmost 2.5 m belongs to the lower Valanginian Calpionellites darderi Subzone. Lack of Cps. simplex Subzone might indicate erosion and stratigraphical gap in the lower part of the Upper Berriasian.

[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland.
[2] AGH University of Science and Technology, al. Mickiewicza 30, Kraków, Poland.
[3] Geological Faculty, Warsaw University, al. Żwirki i Wigury 93, 02-089 Warszawa, Poland.
[4] Université de Bourgogne, Dijon UMR 6303, CNRS-Université de Bourgogne Franche-Comte, BP 47870, F-21078 Dijon Cedex, France.
[5] Université Rennes 1, Geoscience Rennes, France.

MS correlates well with gamma ray spectrometric measurements, accounting for detrital origin of MS carriers (mostly paramagnetic clay minerals). Detrital input decreases throughout the uppermost Tithonian (Cr. intermedia and Cr. colomi Subzones), and stabilizes in the C. alpina Subzone of lowermost Berriasian. Slight increase of clay mineral content is observed in the R. ferasini Subzone, however further decrease takes place towards the middle part of C. elliptica Subzone. Within the upper part of the Elliptica Subzone a long-term increase in clayey content starts, while its magnitude increases abruptly in the Cps. oblonga Subzone (Upper Berriasian). Unpublished clay mineral data (Schnyder, 2003) indicate increase of kaolinite content in the upper part of Elliptica Subzone, which accounts for transition from semi-arid climate in the Tithonian – early Berriasian to semi-humid conditions in the latest Early and Late Berriasian. Variations of clastic input in the Upper Tithonian – Lower Berriasian interval correlate well with data from Tre Maroua section situated in the central-northern part of the Vocontian basin (Grabowski *et al*., 2022).

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Astrochronology for the Early Jurassic – initial results from the JET Project

Stephen P. HESSELBO[1] and the Jet Project Science Team

Drilling for the Early Jurassic Earth System and Timescale ICDP project (JET) was undertaken between November 2020 and January 2021. This Prees 2 drill site is situated in a small-scale latest Triassic to Jurassic sag basin formed above a major Permian–Triassic half graben system in the Cheshire Basin, England, UK. The borehole was located to recover an expanded and complete succession from the mid Pliensbachian down to the Norian to complement legacy core from the Llanbedr (Mochras) Farm borehole drilled through 1967–69 on the edge of the Cardigan Bay Basin, N. Wales;

[1] Camborne School of Mines, Department of Earth and Environmental Sciences, University of Exeter, United Kingdom.

the overall aim is to construct an astronomically calibrated integrated timescale for the Early Jurassic and to provide insights into the operation of the Early Jurassic Earth System. Downhole and core data from both boreholes are now compared with additional new high-resolution geochemical datasets from offset wells (Wilkesley, Burton Row) and from GSSP (East Quantoxhead, Robin Hood's Bay) and other outcrop sections to revise the estimated lengths of all the Early Jurassic stages. Initial estimates are provided for the lower Jurassic stages and their component ammonite chronozones, constrained with a small number of U-Pb dates from distant locations and a Re-Os date from Prees.

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New collection of Boreal ammonites from Jurassic transgressive deposits on Bohemian Massif (Czechia)

Petr HYKŠ[1]

In Middle–Late Jurassic, most continental Europe was flooded by shallow epeiric seas inhabited by diverse marine fauna, including ammonites – the most valuable Jurassic index fossils. Ammonites usually display strong bioprovincialism. However, Middle-Late Jurassic transition records one of the most remarkable ammonite migration events – the maximum southward expansion of Boreal ammonites from the Boreal Province (the „Boreal Spread" *sensu* Arkell, 1956). Causes of this migration event remain poorly understood. A new collection of Boreal ammonites supports the hypothesis that this migration was most probably a result of a global sea-level rise (Matyja, Wierzbowski, 1995; Norris, Hallam, 1995; Wierzbowski *et al.*, 2009).

Studied localities Brno-Hády and Olomučany are valuable study-sections of Middle-Late Jurassic transgression onto Bohemian Massif. These erosional relics formed on the northern margin of the Tethys Ocean, and they correspond to the eastern part of the Submediterranean Province, as indicated by the common occurrence of Submediterranean ammonites (Perisphinctidae, Oppeliidae, Peltoceratidae, Euaspidoceratidae), and less common Mediterranean ammonites (Phylloceratidae, Pachyceratidae), Subboreal ammonites (Kosmoceratidae), and Boreal ammonites (Cardioceratidae). New sampling of ammonites was focused on Boreal Cardioceratidae. After almost 170 years, the occurrence of Late Callovian *Quenstedtoceras* in Olomučany (Reuss 1854) was finally confirmed, and it was also found in Brno-Hády for the first time. Boreal ammonites are most abundant in Lower Oxfordian ammonite-rich "cordatum beds" which correspond to the Cordatum Zone (Uhlig 1881), but also to the Mariae Zone, which was documented for the first time in this area. At Brno-Hády, the Mariae Zone is strongly condensed, but all three subzones of the Cordatum Zone were recognized by the index species: *C. bukowskii*, *C. costicardia* and *C. cordatum*.

The marine connection of the studied area with Boreal Province was established just at the time of the sudden „2nd migration wave" of Boreal ammonites (Callomon, 1985). The peak abundance of Boreal ammonites corresponds to the latest Callovian – Lower Oxfordian maximum of the „Boreal Spread" (Arkell, 1956). This southward migration of Boreal ammonites was previously regarded as a result of cooling climate (Dromart *et al.*, 2003), but the concurrent northward expansion of Tethyan ammonites, belemnites, and planktonic foraminifers shows that it was rather a result of paleoceanographic or paleogeographic changes (Matyja, Wierzbowski, 1995). The occurence of Boreal ammonites in Middle-Late Jurassic transgressive deposits at Olomučany and Brno-Hády supports

[1] Department of Geological Sciences, Faculty of Science, Masaryk University Brno, Kotlářská 267/2, 611 37 Brno, Czechia; hyks.petr@mail.muni.cz.

the hypothesis that this migration event was most probably a result of a global sea-level rise (*cf.* Matyja, Wierzbowski, 1995; Norris, Hallam, 1995; Wierzbowski *et al*., 2009).

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Ammonite biostratigraphy of Callovian-Oxfordian transition of the Moravian autochthonous Jurassic (Czechia)

Petr HYKŠ [1] and Tomáš KUMPAN [1]

The Jurassic sedimentary cover of Bohemian Massif is preserved mainly in the South Moravian Region (Moravian autochthonous Jurassic). Basinal facies do not crop out on surface, but carbonate platform facies are exposed in several erosional relics in the vicinity of Brno (Eliáš, 1981). Stratigraphy of these outcrops is based on historical interpretations of ammonites and lithostratigraphic correlation with localities in Western Europe (Uhlig 1881; Oppenheimer, 1907, 1926, 1932). Recently, new ammonites were collected at Brno-Hády and Olomučany sections and the Middle-Late Jurassic (Callovian-Oxfordian) transition, associated with the formation of stromatolites, was precisely identified in the studied area for the first time. The conference talk provides updated lithostratigraphic and ammonite biostratigraphic framework of these localities.

The oldest ammonite assemblage with *Hecticoceras pseudopunctatum* indicating Late Callovian age (Athleta-Lamberti ammonite zones) was found in sandy biodetrital limestone at Olomučany. At Brno-Hády, the Late Callovian age (Lamberti Zone and Subzone) of sandy biodetrital limestone

[1] Department of Geological Sciences, Faculty of Science, Masaryk University Brno, Kotlářská 267/2, 611 37 Brno, Czechia; hyks.petr@mail.muni.cz.

was documented for the first time by ammonite *Quenstedtoceras praelamberti*. At both localities, the sandy biodetrital limestone is capped by stromatolitic-glauconitic horizon which contains the first Oxfordian ammonites (e.g.„ *Cardioceras* sp., *Peltoceratoides* sp., and *Perisphinctes* sp.). This horizon is overlain by limestone with pebbles which contains Lower Oxfordian ammonites *Cardioceras* sp. and *Peltoceratoides* sp, but also reworked latest Callovian *Quenstedtoceras praelamberti* and *Kosmoceras* sp. At both localities, limestone with pebbles passes upwards into a spongolitic limestone. At Olomučany, the base of the spongolitic limestone yielded *Cardioceras scarburgense* indicating Lower Oxfordian Scarburgense Subzone of the Mariae Zone, but ammonites are more abundant in the upper part of the spongolitic limestone (cordatum beds *sensu* Uhlig 1881), where the common occurrence of *Peltoceratoides* and *Cardioceras* from the Cordatum Zone indicates Bukowskii-Costicardia subzones. The following Cordatum Subzone was documented only at Brno-Hády by the index species *Cardioceras cordatum* which occurs in spongolitic limestone with chert nodules and calcified sponges. In the studied area, limestones with sponges were previously regarded as equivalents of the Middle Oxfordian sponge-bearing limestones from Western Europe, such as Birmenstorf Member from Switzerland (Transversarium Zone; Uhlig, 1881; Oppenheimer, 1932), but they are rather equivalents of Lower-Middle Oxfordian Częstochowa Sponge Limestone Formation from Poland.

Studied sections are very similar to those exposed in Zalas and Ogrodzieniec quarries in the Polish Jura (see Wierzbowski *et al*., 2009; Głowniak, 2012). The close resemblance in lithology and ammonite biostratigraphy indicates the existence of a marine seaway connecting both areas during the latest Callovian – Early Oxfordian. Formation of strongly condensed Callovian-Oxfordian stromatolitic-glauconitic deposits can be explained by a marine transgression followed by basin starvation (Giżejewska, Wieczorek, 1976). As previously suggested, a global sea-level rise (Norris, Hallam, 1995) would also explain the massive southward migration of Boreal ammonites (Wierzbowski *et al*., 2009). A Callovian-Oxfordian sea-level rise associated with the immigration of Boreal ammonites was also documented from Jurassic transgressive deposits on Bohemian Massif (see also Hykš, 2023 – this volume).

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Elaboration of deep borehole sections from Poland. Why should we use published results of this book series?

Jolanta IWAŃCZUK [1]

The book series "Profiles of Deep Boreholes of the Polish Geological Institute" has been published since 1972 and is known to many geologists simply as "the brown books". Up to 2007, 115 books of this series were published, with a modest graphic design following an early method of presentation of research results that was developed in the initial period of their publication. A new editorial board of the book series, appointed in 2006, decided to modernize it, extending the spectrum of published research results, providing better illustrations, introducing elements translated into English (summary of the most important results, captions and explanations of figures and tables), changing the layout (new cover, new format) and the use of better print and paper quality. The changes aimed to improve the quality of the published books and adapting them to modern publishing standards. Another step in this direction was the introduction of external reviewers, for the first time for issues published in 2012. Currently, new borehole sections are in the development. As of 2023, a total of 162 monographs have been published.

The objective of the creation of this book series was to gather together all data, sometimes scattered, that had been obtained in different years, during and after drilling. Primary data were often unverified, inconsistent and difficult to use. The main goal of the publication, therefore, is to comprehensively develop, update and make available the study results from selected major wells drilled in Poland. It is worth noting, however, that basic lithological and stratigraphic data of old wells are independently available in the CBDG resources in the borehole database.

Currently, each monograph contains a full description of the given borehole, with a detailed stratigraphic and lithological profile. All tests and analyzes (sedimentological, stratigraphical, petrographic, geophysical, hydrological, geochemical) for each of the drilled systems are separately presented. If possible, analyzes of the content and maturity of organic matter as well as burial history and the sedimentation rate of deposits are also carried out.

The Kioto Carbonate Platform as a part of Jurassic deepening-upward sequence of the ThakKhola region (northern central Nepal)

Michał KROBICKI [1], Krzysztof STARZEC [2], Bishal Nath UPRETI [3], Kabi Raj PAUDYAL [3],
Jolanta IWAŃCZUK [1], Lalu Prasad PAUDEL [3] and Ananta Prasad GAJUREL [3]

In the ThakKhola region (upper part of the Kali Gandaki valley of northern central Nepal there are classic Jurassic and Cretaceous Eastern Tethys sections of sedimentary sequence of the northernmost, highest tectonic unit of the Himalayas – the so-called "Sedimentary series (zone) of the Himalayan (Tibetan) Tethys (= "Tibetan sediment zone")" or Tethyan Sedimentary Series or Tethyan Himalayan Sequence or Tethyan Sedimentary Sequence (TSS). This unit has limited extent in Nepal with the best sections being found in the Annapurna-Dhaulagiri, Dolpo and Manang regions. Alongside Kali Gandaki valley, between Jomosom, Kagbeni and Muktinath villages, the continous, deepening upward sedimentary sequence of the uppermost Triassic–Upper Jurassic units of the TSS constitute:

[1] Polish Geological Institute – Polish Research Institute, Rakowiecka 4, 00-975 Warsaw, Poland.
[2] AGH University of Kraków, Mickiewicza 30, 30-059 Kraków, Poland.
[3] Tribhuvan University, Kathmandu, Nepal.

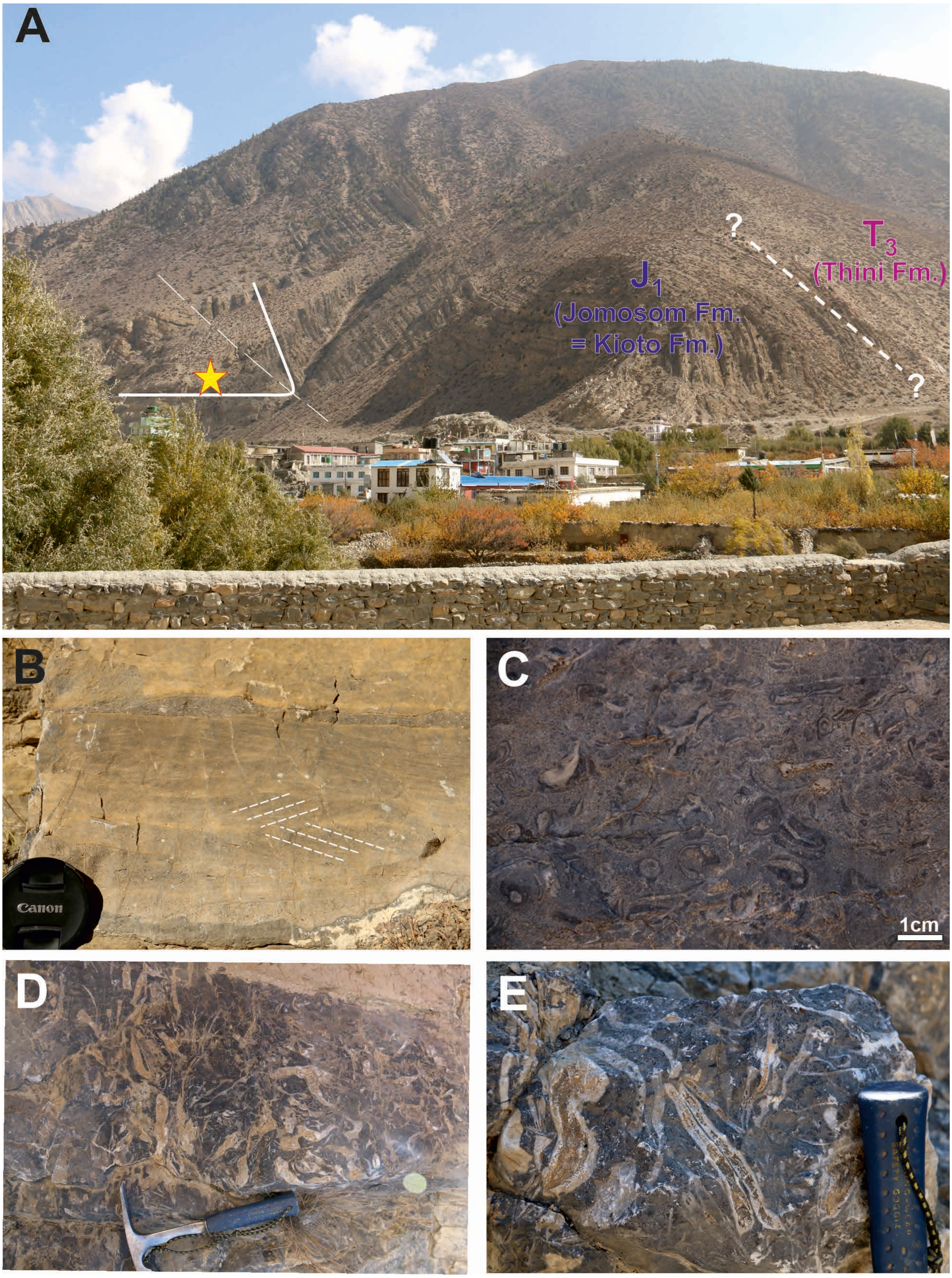


Figure 1: The latest Triassic and Early Jurassic Tethyan Sedimentary Sequence northward from Jomosom showing: A – a recumbent fold and location of Lithiotis-type bivalves biostrome (yellow star – A); B, C – carbonate deposits: oolitic cross-bedding limestones (B) and oncolitic limestones (C) and Lithiotis-type bivalves-bearing beds (D, E)

- calcareous shales, sandstones and thin concretion-rich limestones of fluvial-paralic, estuarine/tidal inlet environments of the Late Triassic (**Thini** Formation = **Quartzite** Formation) (250 m) overlying by white quartzose siliciclastics (quartzite and calcareous sandstones with cross-bedding structures) which are charactersitic lithological marker for the uppermost Triassic all along the Tethys Himalaya passive margin;
- fossiliferous, bioclastic and oolitic/oncolitic massive limestones (**Jomosom** Formation; 200–400 m) of subtropical carbonate platform and oolitic shoal of the Early Jurassic age (Pliensbachian–Early Toarcian; palaeogeographicaly as part of so-called **Kioto Carbonate Platform**);
- thin- and medium-bedded bioclastic and/or micritic limestones (**Bagung** Formation; 100–120 m; correlative of **Laptal** Formation) of terrigenous shelf muds, shell beds of tempestites and sands of the Middle Jurassic (?Aalenian--Bathonian/earliest Callovian) carbonates with condensed deposits with **Ferruginous Oolite** on the top (Late Bathonian-Middle Callovian) (5–20 m);
- grey marls and limestones yielding very rare ammonites of the **Dangar** Formation (late Callovian) (< 10 m);
- black organic shales with concretions with abundant ammonites of poorly oxygenated deep shelf/upper slope environments of the Late Jurassic (Middle Oxfordian-Late Tithonian) deposits of the **Nupra** Formation (= Spiti Shales – which have been known since the 19th century for the richness of the Late Jurassic ammonites, called Saligrams in Nepalese nomenclature – as representing the god Vishnu) (150–250, max. even 500 m) (after stratigraphical gap of **pan-regional hiatus** – Middle Callovian–Middle Oxfordian and origin of hard grounds).

The Early Jurassic (Pliensbachian–Early Toarcian) **Jomosom** Formation is represented by extremely shallow-marine/lagoon palaeoenvironments of oolitic limestones with cross-bedding structures and oncolitic limestones, including biostromes of *Lithiotis*-type bivalves (Fig. 1). This **Kioto Carbonate Platform** unit (Kioto Limestone/ Group), well known from the whole of the Tethys Himalaya, corresponds well with the Jomosom Formation of central northern Nepal but on the other hand correlation with the Pupuga Formation and/or Niehnieh Hsiongla Formation of Chinese authors is still unclear. The term Jomosom Limestone has been used the first time in 1964 and is a consistently used name until today but others preferred the older name Kioto Limestone, widely known from the beginning of the 20th century.

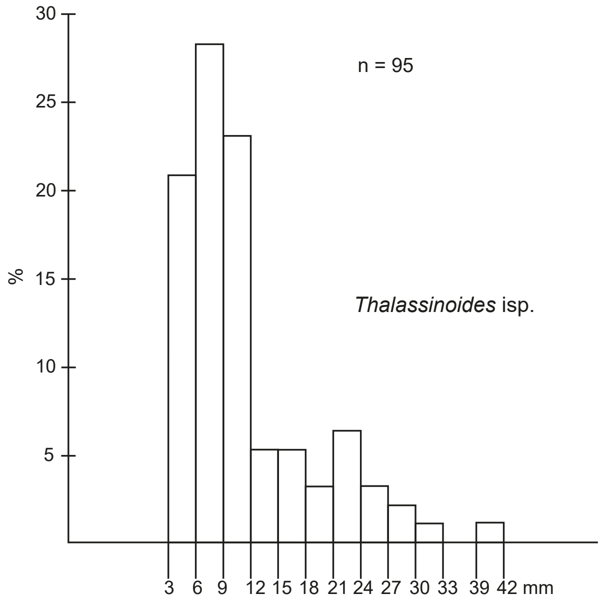
The Jomosom Formation consists also unique *Lithiotis*-type bivalves biostromes, which have been discovered recently in three sections along Kali Gandaki valley, but have been mentioned in another part of northern central Nepal, adjacent regions to Kali Gandaki valley (both in Dolpo and in Manang regions). They indicate probably either lagoonal-type palaeoenvironments or marginal part of such lagoons between nearshore areas and open marine conditions and palaeobiogeographically represent eastern Tethys *Lithiotis*-facies bivalves belt which occur along peri-Gondwanan margin during Pliensbachian–Early Toarcian times.

Ichnological analysis of the Tithonian deposits in the Owadów-Brzezinki section, Central Poland

Stanisław KUGLER[1], Alfred UCHMAN[1] and Błażej BŁAŻEJOWSKI[2]

The Owadów-Brzezinki quarry stands out as one of the most unique sites on the map of Polish Mesozoic. The location exposes the only Tithonian formations in the extra-Carpathian Poland, which is renowned for accumulation of *Fossillagerstätte*-type fossils (Matyja, Wierzbowski, 2014; Błażejowski *et al.*, 2016, 2019). However, so far, no studies have been conducted on trace fossils at this site.

In the quarry, the uppermost part of the Pałuki Formation and the overlying Kcynia Formation are exposed. Bioturbation structures are present in both formations, including trace fossils. In the Pałuki Formation, *Thalassinoides* isp., *Phycosiphon incertum*, *Planolites* isp., *Teichichnus* isp., *Chondrites* isp. and *Balanoglossites* isp. are identified. This formation shows a high degree of bioturbation, although primary lamination is evident in some layers. The ichnofossil assemblage suggests the presence of an impoverished distal *Cruziana* ichnofacies, which is usually characteristic of the lower offshore. In the Kcynia Formation, the fossil assemblage contains *Arenicolites* isp., *Trichichnus* isp., *Arachnostega* isp. (in bioclasts) and *Thalassinoides* isp. The lower part of the Kcynia Formation shows a very high degree of bioturbation, but trace fossils are poorly preserved or poorly visible. The higher part of the Kcynia Formation is less bioturbated. Sedimentary structures such as ripple, hummocky-cross or parallel lamination are present.



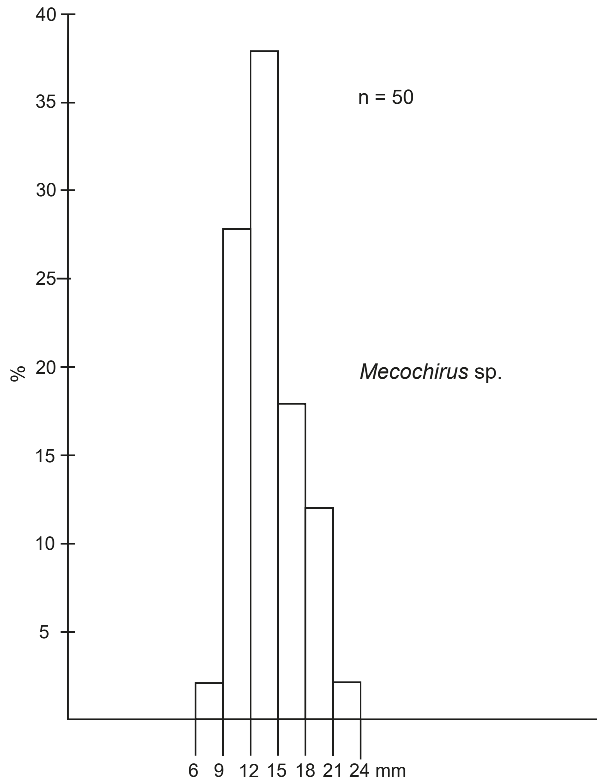


Figure 1: A comparison of the minimum width of *Thalassinoides* isp. and the maximum width of the carapace of *Mecochirus* sp. shown in the diagrams

[1] Jagiellonian University, Faculty of Geography and Geology, Institute of Geological Sciences, Gronostajowa 3a, 30-387 Kraków, Poland.
[2] Institute of Paleobiology, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland.

Trace fossils are more evident in the uppermost layers of this formation exposed in the quarry. *Thalassinoides* isp. is abundant here in tempestites. The assemblage of trace fossils from the Kcynia Formation indicates a transition from an impoverished distal to an impoverished archetypal *Cruziana* ichnofacies, which is typical of the upper offshore with a transition to the shoreface.

The succession of ichnofacies in the Pałuki and the Kcynia formations in the Owadów-Brzezinki quarry area suggests a transition from the lower offshore to the upper offshore. The impoverishment of the ichnofacies can be linked to the changing chemistry of the lagoonal environment, the poor lithological contrast of the sediments and the diagenetic obliteration of primary structures. The lagoonal environment is generally postulated for both formations (Wierzbowski *et al*., 2016).

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. (Fig. 1) confirms this possibility (Carvalho *et al*., 2007). 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.

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Late Jurassic insects from the Owadów-Brzezinki Lägerstatte, Central Poland

Monika MICHALSKA[1]

The Owadów-Brzezinki palaeontological site located near Sławno in the NW margin of the Holy Cross Mts is one of the most important palaeontological discoveries described from Poland (Kin and Błażejowski, 2012; Kin *et al*., 2013; Błażejowski *et al*., 2016). Unusually well preserved fossils of marine and terrestrial organisms of Late Jurassic (Tithonian) age, many of them new to science, provide a very good opportunity for studying the taphonomy of the ecosystem and evolutionary dependencies of taxa. The sedimentary pattern observed in the Owadów-Brzezinki section indicates

[1] University of Warsaw, Faculty of Geology, Żwirki i Wigury 93, 02-089 Warszawa, Poland.

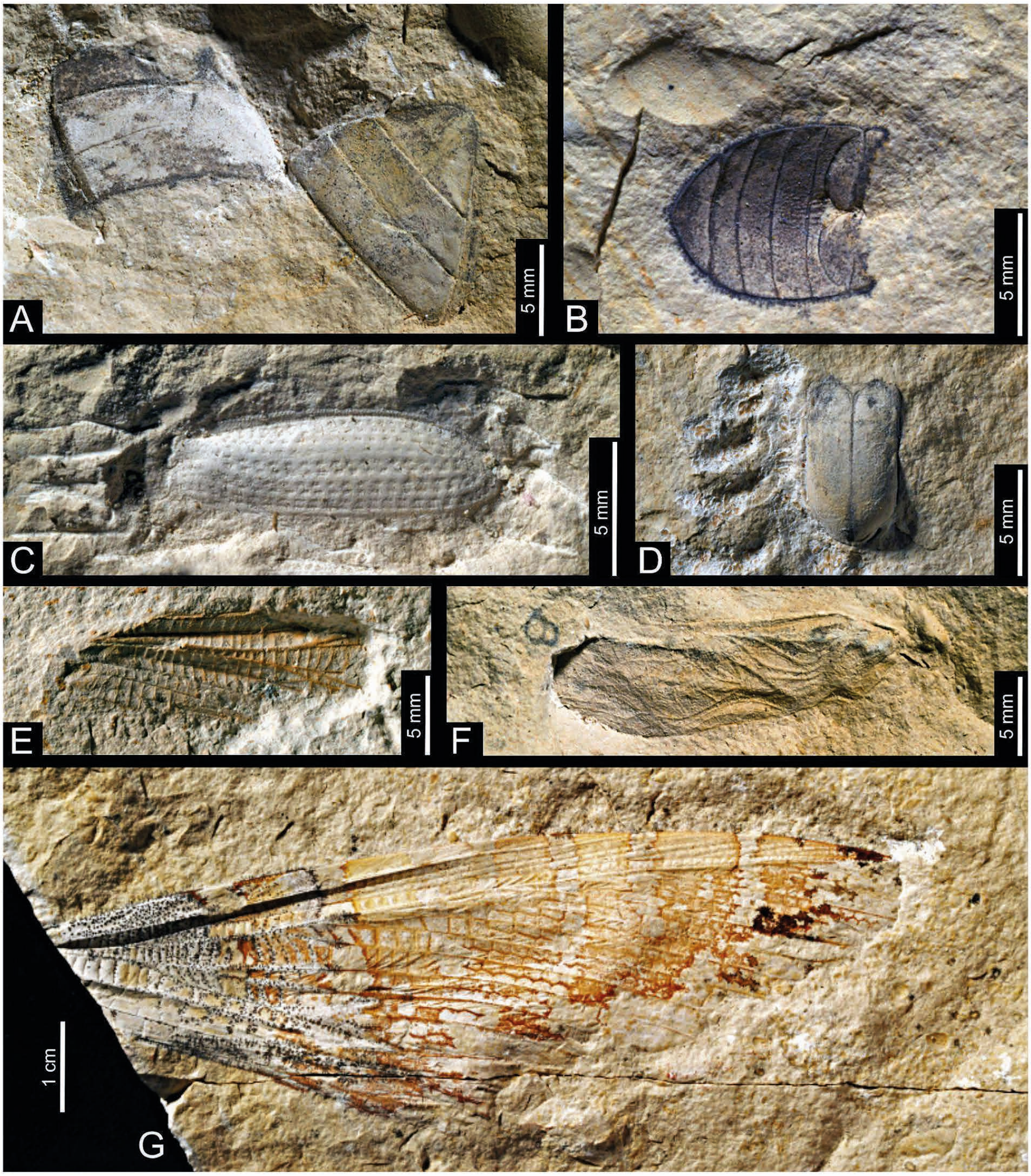

Figure 1: A, B – abdomens; C, D – elytra; E, F, G – wings

shallowing of the depositional environment and its transition from offshore to nearshore, even lagoonal (Matyja and Wierzbowski, 2016; Wierzbowski *et al*., 2016). This allows for comparative studies with other paleontological sites deposited under similar settings (Błażejowski *et al*., 2023).

The exposed carbonate sequence of the Sławno limestones belongs to the Kcynia Formation (Kutek, 1994), and is divided into four successive units. In general, first three units (I, II and III) appear to represent a continuous transition from an offshore to nearshore, perhaps lagoonal settings, whereas unit IV shows evidence of a return to more open marine conditions. The Kcynia Formation is underlain by yellowish marls and marly clays of the Pałuki Formation. The lowermost part of the unit III is highly fossiliferous (Kin *et al*., 2013; Błażejowski *et al*., 2016, 2019). Numerous specimens of land insects – wings of dragonflies and grasshoppers, as well as elytra and abdomens of beetles (Fig. 1) were found in this interval in association with an enormously rich assemblage of the softshelled bivalves *Corbulomima obscura*, the remains of various fishes, rare ammonites and horseshoe crabs. The collection consists of almost 50 samples to date. The sculpture of elytra, abdomens and insect wing veins, even with colour are present. The discovery of new, well-preserved Late Jurassic insects adds significantly to our understanding of a group.

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Geochemical composition of radiolarites from the Meliata Ocean – comparison of handheld XRF to whole rock analysis (Meliata Superunit, Western Carpathians)

Marína MOLČAN MATEJOVÁ [1] and Tomáš POTOČNÝ [1,2]

X-ray fluorescence spectroscopy is a well-established technique for determining the chemical composition of rock samples. Miniaturized portable handheld-XRF (hXRF) instruments allow measuring of samples out of laboratory settings, they are easy to use and can provide rapid, less financially burdening, on spot and reliable (when correctly used) measurements comparable to XRF laboratory results. We measured major oxides and elements in non-mineralized siliceous rocks of the Meliata Superunit using hXRF Niton XL3T GOLDD Plus device. To increase precision for the data measured with hXRF, multiple measurements (duration of 60s) of different points on each sample were executed. Raw data were recalculated from elements to oxides and compared with traditionally used whole rock geochemical analysis performed on the same samples at Bureau Veritas Mineral Laboratory in Vancouver, Canada and at ALS in Alba, Romania. Due to lower beam energies in hXFR it is more challenging to detect and measure lighter elements and impossible to measure trace elements and some of REE, therefore these groups of elements could not be compared. Attention was targeted on major oxides which bare important information about the origin of the sediment and the paleoenvironment.

In the Western Carpathian orogen, the Meliata Superunit incorporates the blueschists-facies Bôrka Nappe and the low-grade polygenous mélange – Meliata Unit s.s., both occurring as scattered tectonic slices in complicated accretionary wedge overlying the thick-skinned Gemer Superunit. Results from the geochemical analysis of the hXRF and the whole rock analysis of the radiolarites from Meliata Superunit are compared in Figure 1.

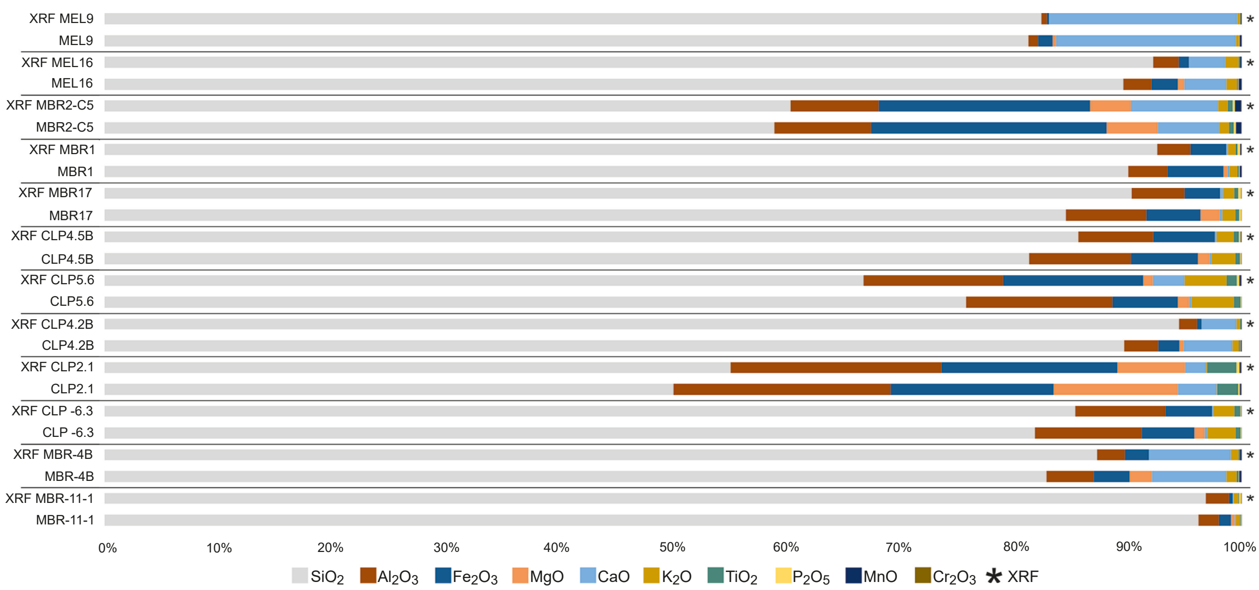

Figure 1: Comparison of geochemical analyses (major oxides) performed by handheld-XRF (hXRF) and by whole rock analysis, measured in selected radiolarite samples from the Meliata Superunit.

[1] Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovakia; marina.matejova@uniba.sk.

[2] Faculty of Geology, Geophysics and Environmental Protection, AGH – University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland.

Data or every sample are conformable in both methods and are sufficient and suitable for interpretations. These analyses are an important addition to stratigraphical data that have been already acquired from the radiolarites. The results and interpretations from geochemical data will be processed and released continuously. From the preliminary data, the sediment samples from the Meliata Unit s.s. and Bôrka Nappe gave significant results about the environment, source area and position in the basin.

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Calpionellid size in the fossil record as a determinant of their genus (*Crassicollaria* and *Calpionella*) affiliation – new evidence

Diana ÖLVECZKÁ [1,2] and Adam TOMAŠOVÝCH [1]

Body size is one of the most important characteristics of marine organisms that affects their physiology, ecology and evolution. Calpionellids and cysts of calcareous dinoflagellates have high preservation potential and their evolutionary changes in the size and shape can be assessed in the stratigraphic record. During the Jurassic-Cretaceous boundary, the decrease in the abundance of crassicollarians and the notable increase in the dominance of *Calpionella alpina* (just at the Tithonian/Berriasian boundary) are associated with a reduction in size and an increase in the sphericity of *Calpionella alpina*. Additionally, there was a morphological transition and an increase in the abundance of *Calpionella alpina*, coinciding with the extinction of certain *Crassicollaria* species. Kowal-Kasprzyk and Reháková (2019) found that the uppermost Tithonian assemblages of *Calpionella alpina* exhibited left-skewed size distributions, whereas the lowermost Berriasian assemblages showed right-skewed size distributions. This pattern was observed across the Tethys Ocean, indicating its geographical generality. However, they did not assess stratigraphic changes in lorica sizes at a high resolution, such as on a bed-by-bed basis, and it remains uncertain whether other species maintained a constant size during this period.

Species of the genus *Calpionella* are morphologically diverse (with spherical, large and elliptical forms) in the Intermedia and Brevis Subzones in the Middle of the Upper Tithonian. A decline in morphological variability of loricae occurs in the Colomi Subzone (in the top of the Upper Tithonian). At the Jurassic-Cretaceous boundary, as mentioned above, the size of of loricae of calpionellids tends to shrink. Throughout the middle Late Tithonian, the genus *Calpionella* exhibited a diverse range of morphologies. Variations included small, spherical forms (*Calpionella alpina*), large forms (*Calpionella grandalpina*), and elliptical forms (*Calpionella elliptalpina*).

Our aim is to investigate whether size and shape distributions differ among species or genera and whether changes in size and shape of calpionellids at high (cm-scale) stratigraphic resolution are exhibited by more than one species or genus. The samples were obtained from the Tithonian and Berriasian deposits in the Czorsztyn and Pieniny formations at the Brodno section (Pieniny Klippen Belt). The succession covers the transition between the Czorsztyn Formation, representing the Kimmeridgian-Lower Tithonian stage, and the Pieniny Formation, representing the Upper Tithonian-Berriasian stage. We focused our sampling on the

[1] Earth Science Institute of the Slovak Academy of Sciences, Dúbravská Cesta 9, P.O.Box 106, 840 05 Bratislava, Slovakia; diana.olveczka@savba.sk; adam.tomasovych@savba.sk.

[2] Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovakia; olveczka3@uniba.sk.

uppermost portion of the Czorsztyn Formation and its transition into the lowermost part of the Pieniny Formation. Using an Axio ZEISS Scope A1 optical microscope equipped with and Axiocam 208 Color ZEISS camera, all individuals present in the thin-sections were measured with the ImageJ program. We measured the length of the lorica without the collar and the width of the lorica. To investigate the differences in size and shape among genera and among species, the ANOVA test supplemented with post hoc tests is used.

In total, we measured 1277 specimens of calpionellids, with 763 specimens belonging to the genus *Calpionella*, 464 specimens of the genus *Crassicollaria* and 50 specimens of the genus *Tintinnopsella*. The most common species are represented by *Calpionella alpina* (695), *Calpionella grandalpina* (68), *Tintinnopsella carpathica* (50), *Crassicollaria intermedia* (36), *Crassicollaria massutiniana* (179) and *Crassicollaria parvula* (249). The width-to-length ratio indicates that the genus *Calpionella* has a ratio (on average) peaking around 1, while the genera *Crassicollaria* and *Tintinnopsella* are longer than wide. We detected significant differences in the length and width among the three genera.

Species-level ANOVA show a significant differences in width and/or length between *Calpionella alpina* and *Calpionella grandalpina*, indicating that the size can be used to separate these two species. *Calpionella grandalpina* is larger both in terms of width (on average about 8 um) and length (on average about 12.5 um). We did not detect any significant differences in the size of three species belonging to the genus *Crassicolaria*.

The observed morphological changes in Jurassic-Cretaceous calpionellids hold significant implications for understanding their evolutionary development. By examining morphological variations and stratigraphic ranges, it can be possible to identify either an anagenetic evolutionary progression of taxa or a series of distinct species with overlapping stratigraphic ranges. In future research, we will also examine the ratio of length to width, investigate other species, and investigate environmental factors affecting the size of calpionellids.

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Middle Jurassic clitellate cocoons (Annelida) from Grojec clays near Kraków

Grzegorz PACYNA[1], Jadwiga ZIAJA[2] and Maria BARBACKA[2,3]

The Clitellata (including Branchiobdellida, Hirudinea and Oligochaeta) are a class of annelid worms, characterized by having a clitellum. The clitellum is a thickened glandular and non-segmented section of the body wall near the head in these invertebrates, that secretes a viscid sac – cocoon, in which eggs are stored (Coleman, Shain, 2009). Clitellates have a poor and disputed body fossil record owing to their simple body form and lack of a robust skeleton (Wills, 1993). However, their cocoons consisting of very resistant substances are sometimes present in post-Palaeozoic continental strata (Manum, 1996). They have long been reported by palynologists and palaeobotanists in

[1] Jagiellonian University, Faculty of Biology, Institute of Botany, Department of Taxonomy, Phytogeography and Palaeobotany, Gronostajowa 3, 30-387 Kraków, Poland; grzegorz.pacyna@uj.edu.pl, ORCID: 0000-0003-4365-3549.

[2] W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland; j.ziaja@botany.pl, ORCID: 0000-0002-3562-4812.

[3] Hungarian Natural History Museum, Botany Department, H-1431 Budapest, Pf. 137, Hungary; maria.barbacka@gmail.com, ORCID: 0000-0002-1685-7741.

residues of sedimentary samples processed by acid bulk-maceration but misidentified as plant seeds, megaspores, animal, fungal or algal remains (e.g., Krassilov, 1972). Only Manum *et al*. (1991, 1992) in detailed analysis corroborated their identity as clitellate annelid cocoons. Unfortunately, there have been still few detailed studies of fossil clitellate cocoons. Their presence is indicative of terrestrial and freshwater environments. They also provide information on the response of litter decomposing soil invertebrates to environmental changes in the Mesozoic, e.g. degradation of environment during extinction episodes (Steinthorsdottir *et al*., 2015).

The first clitellate cocoons from Poland were reported by Marcinkiewicz (1971, 1980) during study of Jurassic megaspores. Two specimens (one from Hettangian of borehole Kamień Pomorski and the other from the Middle Jurassic of Grojec clays) have been most probably correctly assigned to the genus *Dictyothylakos* but misidentified as megaspore fragments. Recently Halamski *et al*. (2018, 2020) noted the presence of the *Burejospermum* and *Dictyothylakos* in mesofossil assemblage from the Upper Cretaceous of Lower Silesia but without description or illustration.

While working on cataloging late M. Reymanówna's collection one of us (J.Z.) found two slides with fragments of clitellate cocoons. The specimens are from Middle Jurassic Grojec clays and were obtained during the maceration of samples in search of plant remains (Reymanówna, 1963, 1973). Clitellate cocoons accompany a very rich macroflora and microflora (Ichas, 1986; Jarzynka, Pacyna, 2015; Jarzynka, 2016; Barbacka *et al*., 2021), first described at the end of the 19th century by famous Polish palaeobotanist M. Raciborski (Raciborski, 1894). The first slide contains three cocoon fragments from a spoil heap near Stella mine in Grojec belonging to the genus *Burejospermum*. The second slide contains two fragments from borehole Zabierzów D-2 depth 238.20–240.30 m belonging most probably to the genus *Pegmatothylakos*.

Genus *Burejospermum* is recorded second time in Poland, genus *Pegmatothylakos* is recorded first time in Poland. This is also the oldest record of the genus *Pegmatothylakos* known so far only from the Eocene of Seymour Island in Antarctica (McLoughlin *et al*., 2016). Determination of environmental factors affecting the presence of invertebrates that are the subject of present research will be the subject of further work on plants associated with cocoons in the same bed: pteridosperms, including caytonialeans, bennettitaleans, ginkgoaleans and conifers.

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Sea cucumbers (Echinodermata) from Late Jurassic Plattenkalk deposits of southern Germany

Mike REICH[1, 2, 3], Günter SCHWEIGERT[4], Martin RÖPER[5] and Monika ROTHGAENGER[5]

The Kimmeridgian and Tithonian Plattenkalk deposits of Bavaria and Württemberg were celebrated for their diverse and exceptionally preserved fauna and flora. The fauna also includes echinoderms (Grawe-Baumeister *et al*., 2000; Dietl, Schweigert, 2011; Hess, 2015; Reich, 2015; Röper, 2015), such as crinoids, which are very common at some sites. Articulated preserved representatives of the Echinodermata (crinoids and echinoids, but also asteroids and ophiuroids) are i.e. documented from Painten, Schamhaupten, Zandt, Hienheim, Pfalzpaint, Mörnsheim, Daiting, but also from Solnhofen and Eichstätt (Röper, Reich, 2018). More recent, systematically focussed studies on echinoderm ossicles recoverable by micropalaeontological methods are still missing so far. Our study has reviewed all Late Jurassic Plattenkalk sea cucumbers from southern Germany, which have so far only been documented with a few single specimens. Deducting various taxa/specimens erroneously assigned to the Holothuroidea (*Protholothuria annulata*, *P. armata*, *Pseudocaudina brachyura*), only three holothurian body fossils currently remain that can undoubtedly be assigned to the Holothuroidea. While one finding (from Solnhofen) does not allow any higher-level group

[1] 3Landesmuseen Braunschweig | Staatliches Naturhistorisches Museum, Gaußstr. 22, 38106 Braunschweig, Germany.

[2] Ludwig-Maximilians-Universität München, Department für Geo- und Umweltwissenschaften, Paläontologie und Geobiologie, Richard-Wagner-Str. 10, 80333 München, Germany.

[3] GeoBio-CenterLMU, Richard-Wagner-Str. 10, 80333 München, Germany.

[4] Staatliches Museum für Naturkunde, Rosenstein 1, 70191 Stuttgart, Germany.

[5] Museum Solnhofen, Bahnhofstr. 8, 91807 Solnhofen, Germany.

assignment, the other two finds (Eichstätt and Nusplingen) belong to the Synallactida and Holothuriida, based on the body outline and the preserved calcareous ring. These are medium-sized epibenthic forms that mostly feed on detritus. Corresponding microscopic body-wall ossicles have already been described from other Plattenkalk localities. However, the majority of the micropalaeontologically detectable sea cucumber ossicles belong to apodid sea cucumbers, especially The Kimmeridgian and Tithonian Plattenkalk deposits of Bavaria and Württemberg were celebrated for their diverse and exceptionally preserved fauna and flora. The fauna also includes echinoderms (Grawe-Baumeister *et al*., 2000; Dietl, Schweigert, 2011; Hess, 2015; Reich, 2015; Röper, 2015), such as crinoids, which are very common at some sites. Articulated preserved representatives of the Echinodermata (crinoids and echinoids, but also asteroids and ophiuroids) are i.e. documented from Painten, Schamhaupten, Zandt, Hienheim, Pfalzpaint, Mörnsheim, Daiting, but also from Solnhofen and Eichstätt (Röper, Reich, 2018). More recent, systematically focussed studies on echinoderm ossicles recoverable by micropalaeontological methods are still missing so far. Our study has reviewed all Late Jurassic Plattenkalk sea cucumbers from southern Germany, which have so far only been documented with a few single specimens. Deducting various taxa/specimens erroneously assigned to the Holothuroidea (*Protholothuria annulata*, *P. armata*, *Pseudocaudina brachyura*), only three holothurian body fossils currently remain that can undoubtedly be assigned to the Holothuroidea. While one finding (from Solnhofen) does not allow any higher-level group assignment, the other two finds (Eichstätt and Nusplingen) belong to the Synallactida and Holothuriida, based on the body outline and the preserved calcareous ring. These are medium-sized epibenthic forms that mostly feed on detritus. Corresponding microscopic body-wall ossicles have already been described from other Plattenkalk localities. However, the majority of the micropalaeontologically detectable sea cucumber ossicles belong to apodid sea cucumbers, especially representatives of the Chiridotidae and Myriotrochidae. Representatives of both groups are small, mostly infaunal, detritus-feeding holothurians. The new find from Nusplingen closes a gap in the fossil record of the Holothuriida/Synallactida (formerly Aspidochirotida) and substantially expands the known diversity and diversification of this group, as well as our knowledge on the origin of shallow-water sea cucumbers.

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Middle Jurassic of a motorway transect between Radom and Szydłowiec (central Poland)

Tomasz SEGIT[1]

The roadcut of the newly constructed motorway S7 north-east of Szydłowiec provided a unique insight into the Bajocian through ?Callovian strata, which are barely exposed elsewhere in the surrounding area. The transect crosses the Mesozoic margin of the Holy Cross Mountains, characterized by strata gently inclined to the north. The lower part of the sequence studied predominantly consists of heteroliths with an interval of black clays and several interbeds of limonitic coquinas and limonitic sandstones. Following the next unexposed interval, crinoidal and organo-detrital sandy limestones occur, overlain by marls and monotonous reddish sandstones on the top. Coquinas yielded rare ammonites indicative of the Upper Bajocian. Palynofacies containing dinoflagellate cysts were recovered from the intervals of black clays and marls.

The transect cuts across an old abandoned mining area at Chustki (see Różycki, 1939, 1955), where the Middle Jurassic ironstones were exploited up until the first half of the 20th century. During the motorway construction some shallow shafts and galleries were excavated.

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[1] Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, 02-089 Warszawa, Poland.

Deposition, ichnology and cyclostratigraphy of the Toarcian from the Mochras drill core, Cardigan Bay Basin, UK

Alfred UCHMAN[1], Grzegorz PIEŃKOWSKI[2], Krzysztof NINARD[1] and Stephen P. HESSELBO[3]

The continuous uppermost Sinemurian – Toarcian section of the Llanbedr (Mochras Farm) Borehole in the Cardigan Bay Basin, UK, comprises hemipelagic calcareous mudstones, wackestones/siltstones and subordinate packstones/sandstones. As in the Pliensbachian of the section (see Pieńkowski *et al*., 2021), several beds in the Toarcian show bigradational grain-size trends, and their sedimentary structures are typical of contourites. Most of them show a transition from massive, organic-rich calcareous mudstone to siltstone or very fine-grained sandstone/calcarenite with shallow-water bioclasts, and back to the massive mudstone. Many layers of siltstone/very fine-grained sandstone/calcarenite show pinstripe lamination and small current ripples, which are usually partly disturbed by bioturbation. The contourites were hypothesised to have been deposited by thermohaline-driven geostrophic contour currents flowing between the Boreal ocean and Peri-Tethys through the NE–SW trending, narrow and relatively deep Cardigan Bay Strait.

The contourites are heavily bioturbated. The siltstone/very fine-grained sandstone/calcarenite beds contain the most diverse and best visible trace fossils. Trace fossils are strongly dominated by *Phycosiphon incertum* (represented by four morphotypes (Ph1–Ph4)), which was produced by

[1] Jagiellonian University, Faculty of Geography and Geology, Gronostajowa 3a, 30-087 Kraków, Poland.
[2] Polish Geological Institute–National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland.
[3] Department of Earth and Environmental Sciences, University of Exeter, Penryn, Cornwall TR10 9FE, UK.

opportunistic colonizers. The dwelling and deposit-feeding structures, such as *Thalassinoides*, *Schaubcylindrichnus,* and *Teichichnus* are relatively common. They are accompanied by *Trichichnus*, which is a deep-tier trace fossil (chemichnion) produced by filamentous sulfide-oxidizing bacteria with a high tolerance for dysoxia, less common *Zoophycos* (fodinichnia), *Planolites* (pascichnia), *Palaeophycus* (pascichnia), *Lockeia* (cubichnia), and rare dwelling structures, such as cf. *Polykladichnus*, *Siphonichnus*, *Monocraterion*, *Arenicolites*, and *Skolithos*. Contrary to existing views that *Phycosiphon* is generally uncommon in contourites, the contourite deposits in Mochras are strongly dominated by *Phycosiphon incertum*. The trace fossil assemblage resembles the Zoophycos ichnofacies, but the eponymous ichnotaxon is uncommon. The intensive bioturbation is conditioned by a relatively stable supply of organic-rich sediment and oxygen.

The contourites in the Toarcian succession are more frequently base- or top cut than in the Pliensbachian, which suggests less stable conditions in the depositional system. The system was distinctly disturbed at the Pliensbachian-Toarcian transition and at the beginning of the negative carbon-isotope excursion (To-CIE) marking the Toarcian Oceanic Anoxic Event (T-OAE), where the bioturbation was less intensive, *Phycosiphon* is less abundant, and *Trichichnus* is more common. However, the anoxia marked by unbioturbated laminated mudstones is marginally developed, and the peak and recovery phase of the negative excursion of the anoxic event is characterised loss of *Trichichnus* and better oxygenated sea-floor conditions. The Pliensbachian-Toarcian boundary event appears to be a significant palaeoceanographic turning point, starting a $CaCO_3$ decline with the most severe oxygen depletion, stronger than during the T-OAE (but dysoxic, not anoxic). This can have been caused by the extreme climate warming during the To-CIE, which may have enhanced and caused a reversal in the direction of deep marine circulation, improving oxygenation of the sea floor. A minor dysoxic event also occurred in the latest *thouarsense* and *dispansum* zones.

Ichnological and lithological signals suggest repetitive fluctuations in benthic conditions attributed to a hierarchy of orbital cycles (precession and obliquity [4th order], short eccentricity [3rd order], long eccentricity [2nd order], and Earth–Mars secular resonance [1st order]). Spectral analysis of binary data for ichnotaxa appearances gives high confidence in orbital signals in accord with previous work based on geochemical time series (Storm *et al*., 2020). This allows refined estimation of ammonite zone lengths. The estimations are as follows: *aalensis* – >0.1 Myr, *pseudoradiosa* – 1.8 Myr, *dispansum* – 0.3 Myr, *thouarsense* – 0.9 Myr, *variabilis* – 2.3 Myr, *bifrons* – 1.7 Myr, *serpentinum* – 1.7 Myr, and *tenuicostatum* – 0.9 Myr. The duration of the Toarcian is estimated to be at least ~9.7 Myr.

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Late Jurassic teeth of plesiosaurian origin from the Owadów-Brzezinki Lägerstatte, Central Poland

Łukasz WERYŃSKI [1], Błażej BŁAŻEJOWSKI [2] and Stanisław KUGLER [3]

Owadów-Brzezinki is currently one of the most promising Upper Jurassic sites (Kin *et al*., 2012, 2013; Błażejowski *et al*., 2016) in Central Poland, with a wide array of both vertebrate and invertebrate fossil fauna present. It has recently attracted attention due to discoveries of large-bodied marine reptiles fossils representing ichthyosaurs, turtles, and marine crocodylomorphs, but until now plesiosaurs were one characteristic Mesozoic marine group yet to be found. In the short report (Weryński, Błażejowski, 2023) we would like to acknowledge the presence of the plesiosaur remains, represented by four isolated teeth with distinguishing apicobasal ridging pattern and elongated, conical shape characteristic for plesiosaurians. Based on Principal Coordinates Analysis (PCoA), of the largest and most complete specimen ZPAL R.11/OB/T4 it enabled us to confirm classification the examined teeth as belonging to the Plesiosauroidea. This discovery provides further evidence for the importance of the site, once again expanding the broad spectrum of fossil taxa present in this site and together with previous findings of plesiosaur material in a nearby region, providing evidence for presence of Plesiosauroidea at Owadów-Brzezinki Lägerstatte.

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Articulated fossil of *Stenopterygius* (Ichthyosauria) from the historical collection of the Jagiellonian University – an unusual story of preservation

Łukasz WERYŃSKI [1], Błażej BŁAŻEJOWSKI [2], Tomasz SZCZYGIELSKI [2] and Bartłomiej KAJDAS [4]

Holzmaden is one of the best-known examples of fossil Konservat-Lagerstätten in the world. This Jurassic site features a wealth of excellently preserved fossil fauna, including numerous marine reptiles. One of the most characteristic taxa from this site is the genus *Stenopterygius*, a medium-sized Stenopterygiidae ichthyosaur represented by numerous specimens (e.g., Urlichs *et al*., 1979; Dick, 2015; Maxwell *et al*., 2022) which are very often articulated, featuring specimens exhibiting life activities such as life-birth or feeding (van Loon, 2013).

[1] Doctoral School of Exact and Natural Sciences, Institute of Geological Sciences, Jagiellonian University, Gronostajowa 3a, 30-387 Kraków, Poland.
[2] Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland.
[3] Institute of Geological Sciences, Jagiellonian University, Gronostajowa 3a, 30-387 Kraków, Poland.
[4] Nature Education Centre, Jagiellonian University, Gronostajowa 5, 30-387 Kraków, Poland.

In this presentation, we reveal an extremely well-preserved *Stenopterygius quadriscissus*? (Fig. 1) from the Jagiellonian Nature Education Centre (Jagiellonian University, Cracow, Poland) and its incredible story, which ultimately leads this fossil to become the future main attraction of the NEC collection. The specimen of *S. quadriscissus*? (historically labelled *Ichthyosaurus communis*) has been bought in 1850/1851 and subsequently catalogued under the number 825, without the notice of from whom and at what cost the fossil was bought. Most peculiarly, during the long history of the housing of the specimen at the św. Anny 6 building of Jagiellonian University, it has been covered with dark paint. We interpret this as either an attempt to hide the valuable specimen from the invaders of the occupation forces during the World War II, which would gladly acquire such a treasure, or to make the specimen look more aesthetically pleasing with an uniform cover of dark paint. With time, the fact that the coat of paint hides an original paleontological specimen had been forgotten and the ichthyosaur skeleton was assumed to be a mere plaster cast or sculpture.

Lately, it was rediscovered that the painted sculpture of the ichthyosaur at the Institute of Geological Sciences of Jagiellonian University, which has long been considered a gypsum model, is indeed an articulated ichthyosaur fossil, so the paint has been removed and conservatory work of the specimen has been undertaken. After cleaning and conservation, the specimen has been moved to the Jagiellonian Nature Education Centre. The preservation state of the revealed specimen of *S. quadriscissus*?, based on a comparison with the study of Maxwell *et al.* (2022), suggests that post-mortem it has landed rostrum first on the sea floor, which caused fracturing of the snout and distortion of the spine. Subsequently, the gastrointestinal content consisting of belemnites (preserved as rostra) has probably been displaced around the individual due to the expanding volume of gas buildup.

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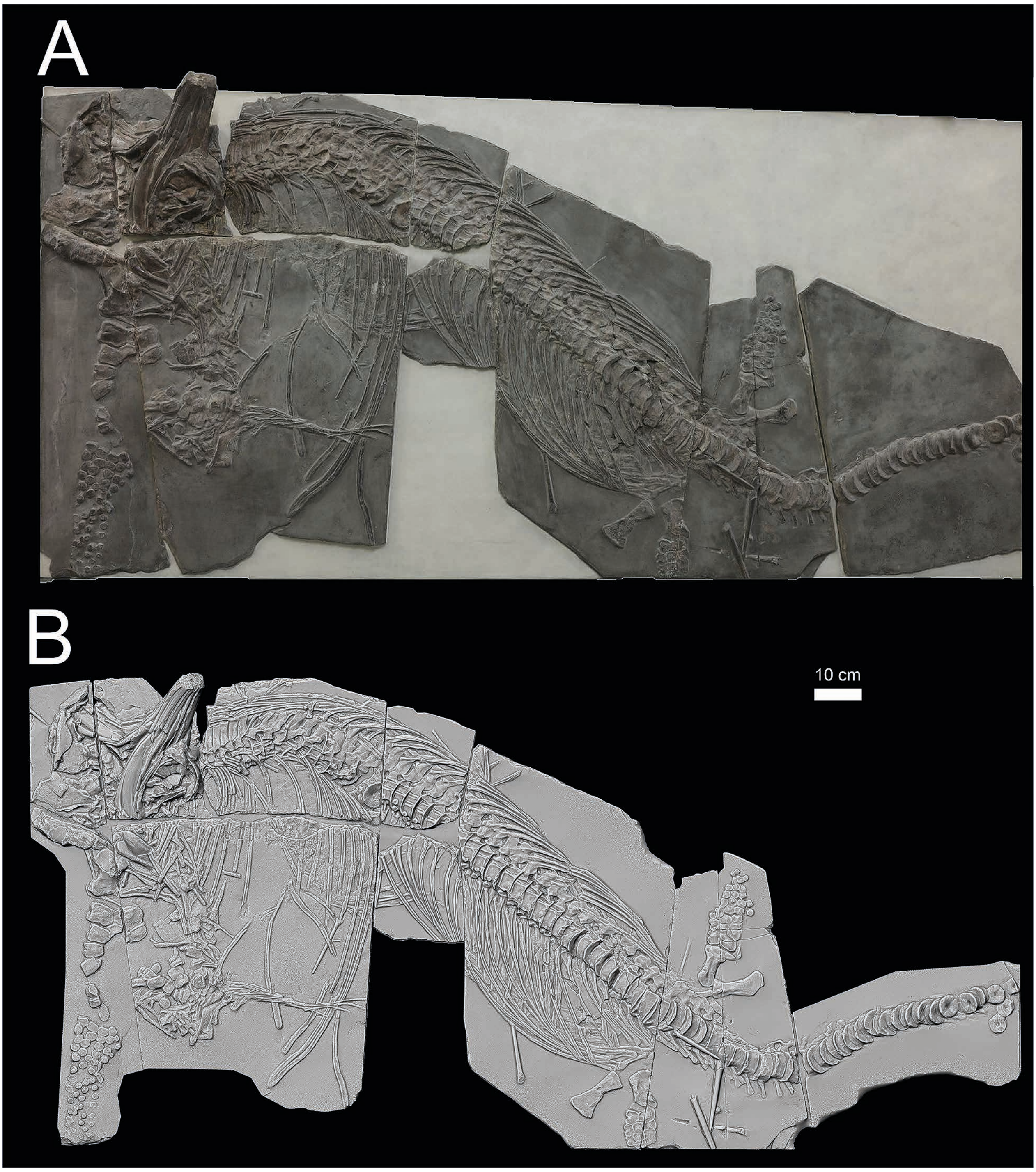

Figure 1: The overview of the described *S. quadriscissus?* individual. Articulated skeleton photo (A) and 3D scan image (B)

New data on biostratigraphy, microfacies and geochemistry of shallow-marine carbonate deposits from the vicinity of Iłża and Wierzbica (NE margin of the Holy Cross Mts, central Poland)

Andrzej WIERZBOWSKI [1], Ewelina KRZYŻAK [2], Michał FĄFARA [1], Hubert WIERZBOWSKI [2], Błażej BŁAŻEJOWSKI [3] and Jacek GRABOWSKI [1]

The Błaziny and Wierzbica quarry sections and a newly exposed section at the Iłża ring-road have yielded new information on the development of the Lower Kimmeridgian shallow-marine carbonate succession of the north-eastern margin of the Holy Cross Mts.

The studied rocks represent the final stage of a marine regression of the major COK (or I) sequence of the middle Callovian–Early Kimmeridgian age (*cf.* Kutek, 1994; Gutowski *et al*., 2005) and consists of the shallow water carbonate platform deposits accumulated during second-order transgressive-regressive cycles. The rocks are included into the (Oncolite) Chalky Limestones, the Błaziny Oolite Limestones and the Wierzbica Oolite and Platy Limestones (Gutowski, 1998; Wierzbowski, 2023) and comprise various types of chalky, micritic, organodetrital and oolite limestones and intervening marly layers. The marly layers were described previously from western margin of the Holy Cross Mts. and the Częstochowa-Wieluń Upland and are considered as having a large lithostratigraphical correlation value (*cf.* Wierzbowski, 2017, 2020). They may have been formed as a result of tectonically and/or climatically controlled sedimentary cycles and show, laterally, a bit different sedimentological development.

The (Oncolite) Chalky Limestones from the Błaziny quarry and the Iłża ring-road are characterized by different facies pattern (chalky limestones with abundant benthic fauna in the former *versus* almost faunistically barren micritic limestones in the latter), which is interpreted as a result of synsedimentary activity of the Nowe Miasto-Iłża Fault Zone. The lowest marly layer is recognized in the upper part of this unit. It corresponds to the Latosówka Marl Member assigned to the upper part of the Planula Zone (*cf.* Wierzbowski, 2017). The lowest marly layer from the Iłża ring-road section yielded foraminiferal assemblages diagnostic of the marginal-marine environment, which may point to a regressive character of these deposits. It is replaced by the normal marine foraminiferal assemblage in overlying limestones.

The Błaziny Oolite Limestones are characterized by strongly contrasted development as shown by occurrence of cross-bedded oolites in Błaziny, which are partly replaced, towards the NW, by fine organodetrital limestones with "chocolate" cherts. Another marly layer, recognized in the Błaziny and the Iłża ring-road sections occurs directly below this unit or within its lower part. The discussed marly deposits correspond possibly to the Zapole Marl Bed assigned to lower-middle parts of the Platynota Zone (*cf.* Wierzbowski, 2017). Re-deposited fragments of marly deposits with reworked fauna observed in the Iłża ring-road section confirm the existence of original bottom relief possibly related to activity synsedimentary faults. The foraminiferal assemblage indicates normal marine environment.

The Wierzbica Oolite and Platy Limestones are outcropped in the Wierzbica quarry. They consist of massive oolite limestones and intervening layers of micritic and organodetritic limestones. A marly layer, recognized in the Wierzbica quarry section, occurs directly between the Błaziny Oolite Limestones and the Wierzbica Oolite and Platy Limestones. It is fairly thick and contain some oolitic and bivalve coquina interbeds in its upper parts. This marly layer is assigned to middle-upper parts of the Platynota Zone, which strongly suggests its correlation with the Góry Marl Member (*cf.* Wierzbowski, 2017, 2020). It yielded abundant microfossils including foraminifers and ostracods.

[1] Faculty of Geology, University of Warsaw, al. Żwirki i Wigury 93, 02-089 Warszawa, Poland.
[2] Polish Geological Institute – National Research Institute, Rakowiecka, 4, 00-975 Warszawa, Poland.
[3] Institute of Paleobiology, Polish Academy of Sciences, Twarda 51, 00-818 Warszawa, Poland.

Thin section analysis has shown significant variability of microfacies starting from mudstones and wackestones to packstones and grainstones. Limestones from the Błaziny, Iłża ringt-road and Wierzbica sections show an increasing upward amount of peloids, ooids, oncoids, intraclasts and partly organic grains. It may be linked to increasing carbonate productivity in the high energy environments of the deposition of oolite and organodetrital limestones, which generally overlay micritic, marly and chalky beds. The presence of echinoid debris and fragments of brachiopod shells points to salinity close to normal marine. The uppermost, highly weathered part of limestones from the Iłża ring-road section (bed 8) shows partial dolomitization, which may be linked to late diagenetic phenomena.

Magnetic susceptibility (MS) of the rocks from Błaziny and Wierzbica sections is dependent on the presence of lithogenic material; high values of MS are measured from marly layers.

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Chemostratigraphy and organic matter of the Upper Kimmeridgian–Lower Tithonian (Upper Jurassic) Pałuki Formation of central Poland and its correlation to coeval organic matter rich deposits of Western Europe

Hubert WIERZBOWSKI[1], Jacek GRABOWSKI[1], Barbara MASSALSKA[1] and Anna FELDMAN-OLSZEWSKA[1]

Fine-grained and organic matter rich deposits (average TOC content of 2.9 wt.%) of the Pałuki Formation (also called Shale-Marly-Silstone Formation; Dembowska, 1979) occur in most parts of the Polish Lowlands but are generally deeply buried. This has caused, for a long time, problems with determination of their detailed biostratigraphy and geochemistry.

We present results of a new, detailed geochemical study of the Pałuki Formation from two borehole sections (Uniejów IGH 1 and Koło IG 4) in central Poland, whose ammonite biostratigraphy was determined previously (*cf.* Wierzbowski, Wierzbowski, 2019). Published and new organic matter analyses have shown the presence of numerous major (up to 10.7 wt.%) and minor (up to 5.2 wt.%) organic matter rich horizons within the upper Eudoxus–Pseudoscythica zone interval. Precise biostratigraphical correlations show strict simultaneity of occurrences of the organic matter rich horizons of the Pałuki Formation and their equivalents known from the Eudoxus–lower Pectinatus zone interval of NW Europe i.e. the Kimmeridge Clay Formation of Dorset in S England and the Cleve-

[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland.

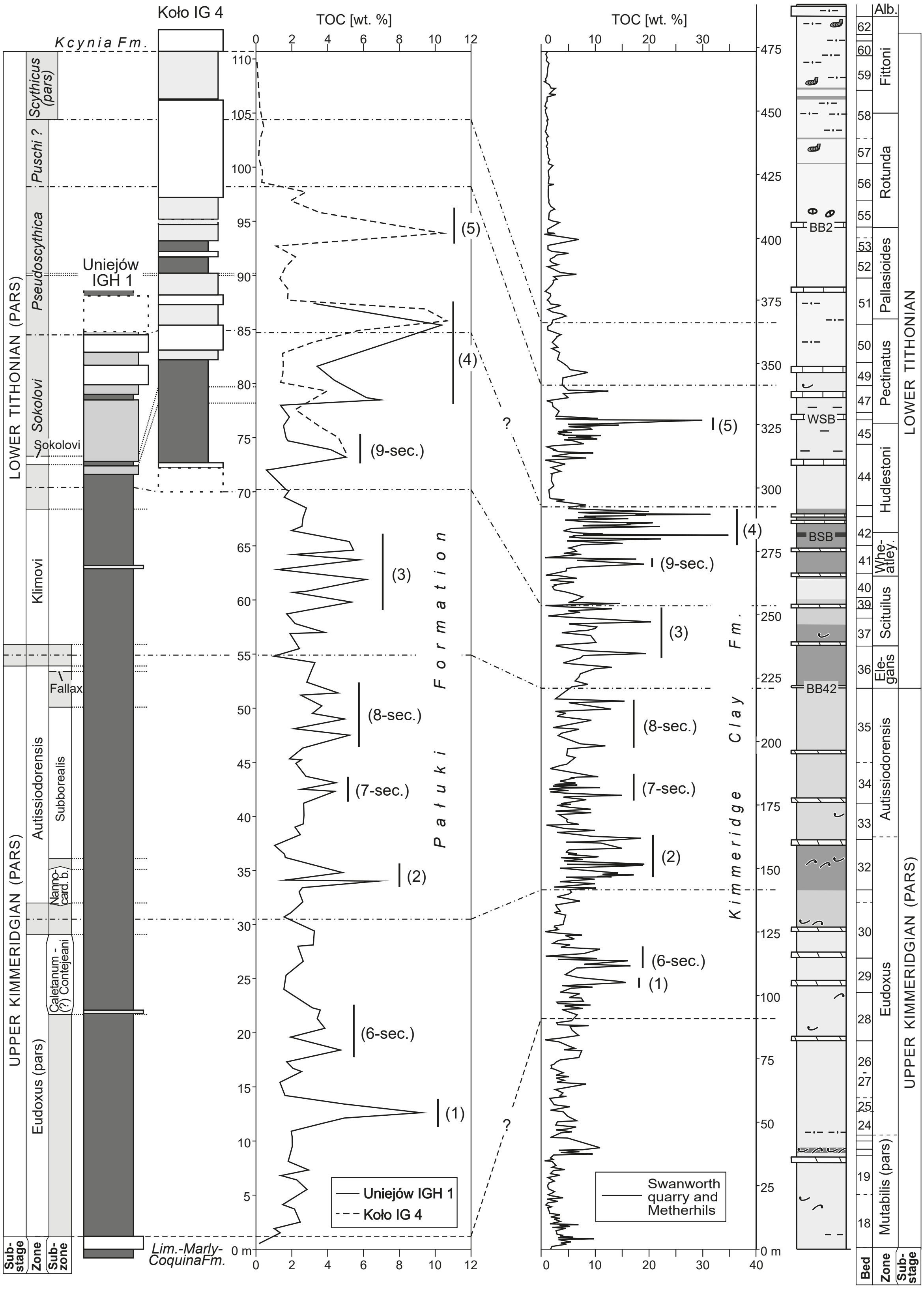

Figure 1: Biostratigraphy and TOC content of the Pałuki Formation from central Poland and their correlation with TOC content of the Kimmeridge Clay Formation of Dorset from southern England (after Morgans-Bell *et al*., 2001). The sections have been correlated according to the Tithonian biostratigraphical zonal scheme of Wierzbowski *et al*. (2017)

land Basin of NE England as well as the Argiles de Châtillon and the Argiles de la Crèche of the Boulonnais region of northern France (*cf.* Morgans-Bell *et al*., 2001; Deconinck *et al*., 1996; Tribovillard *et al*., 2001; Atar, 2019; Fig. 1). This is despite a specific sequence stratigraphic framework of the Pałuki Formation of central Poland, which is mostly different from well-studied transgressive–regressive sequences of the Boulonnais area (Proust *et al*., 1995).

The chemical redox and palaeoproductivity indices show the predominance of subooxic and more oligotrophic settings during the deposition of the organic-rich, lower part of the Pałuki Formation, dated to the Upper Kimmeridgian–lowermost Tithonian (Eudoxus–Klimovi zone interval), which is followed by a gradual change of the depositional environment to more anoxic and eutrophic one. The uppermost, carbonate-rich portion of the Pałuki Formation, dated to the uppermost Lower Tithonian (the Puschi–Scythicus zone) is, nevertheless, characterized by a diminished organic matter content. Its deposition coincided with gradual aridification of the latest Jurassic climate.

The strict correlation of the major and minor organic rich horizons between the NW Europe and central Poland shows the coincidence of high-amplitude environmental variations responsible for sedimentation of organic rich beds, which may be linked to orbital forcing. The obtained data also point to synchronicity of long-term climatic changes in Europe.

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Storage potential of Jurassic formations in Poland

Adam WÓJCICKI [1], Anna FELDMAN-OLSZEWSKA [1] and Jarosław ZACHARSKI [1]

Climate change and environmental protection (e.g., reductions in CO_2 and greenhouse gas emissions) have a great impact on the ongoing energy transformation and the use of natural resources, including fossil fuels. These circumstances have created demand for additional underground geological storage (UGS) facilities, which can be used for storing energy carriers or waste products. Under-

[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975, Warszawa, Poland;
e-mail: awojci@pgi.gov.pl.

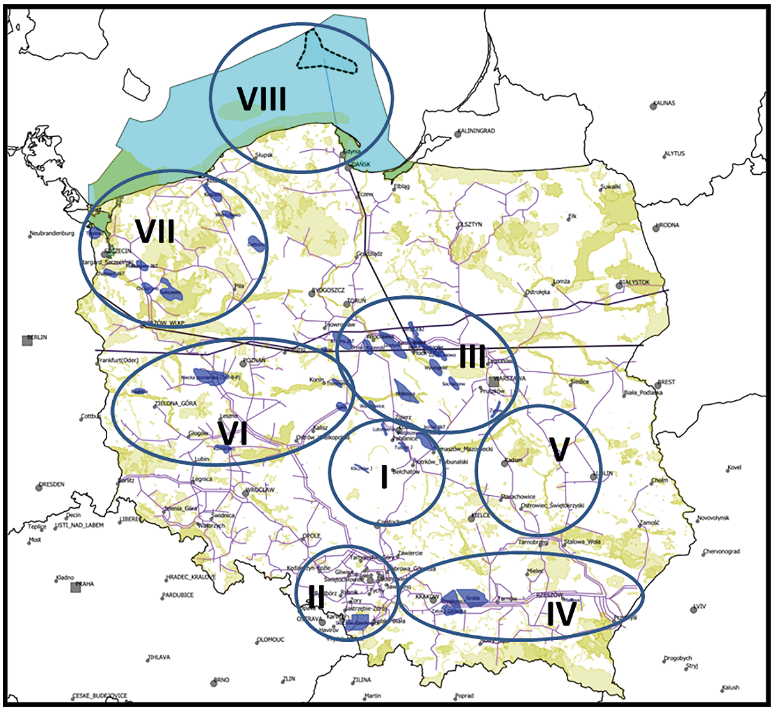

Fig. 1. Locations of selected saline aquifers that can be used for CO_2 storage in Poland (Wójcicki *et al*., 2013; Wójcicki *et al*., 2021)

ground storage spaces maybe natural or artificial. The natural storage spaces include depleted oil and gas fields, saline aquifers characterized by high quality reservoir parameters, and karst rocks. Underground salt formations (e.g., salt dome, salt beds) offer other options for storage. However, underground caverns leached in salt structures are most commonly artificially made.

Currently, there are ten underground storage facilities in Poland, one of which is only used to store crude oil and petroleum products. The rest are used to store natural gas. Seven storage facilities were built using depleted hydrocarbon reservoirs of various ages, and three UGS spaces were built in the Zechstein salt caverns. Although Jurassic formations have not yet been used for storage purposes in Poland, their potential is very high. This applies both to depleted hydrocarbon fields (mainly in southern Poland) and especially to saline aquifers. Lower and Middle Jurassic sandstone formations of the Polish Lowlands may be particularly useful for CO_2 storage.

In 2008–2013 and in 2021–2022, under the supervision of the Polish Geological Institute, various analyses were performed and many reports were published (*cf.* Nagy, Wójcicki, 2022). During those periods, forty-three objects in saline aquifers were identified in Poland, whose storage potential was estimated at approximately 12 Gt of CO_2. Approximately half of those objects were identified in Jurassic formations.

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Results of current geological mapping of the Jurassic deposits in the Wierzbica area (NE margin of the Holy Cross Mts)

Ryszard ZABIELSKI [1] and Mirosław LUDWINIAK [1]

As part of the project "Update of the Detailed Geological Map of Poland in the scale 1:50,000", geological mapping were carried out in the area of the Wierzbica Sheet (SMGP 743).

The fieldworks covered mainly the areal outcrops of the Upper Jurassic, and also the Middle and the Lower Jurassic. The GPS receiver and the Digital Terrain Model (DTM) allow for more precise location of the some geological boundaries. Also, all available description of borehole profiles, geological documentations and other archival studies (e.g., Dąbrowska, 1953, 1957, 1968; Dembowska, 1953) were analyzed. All data was collected and processed using the GIS applications.

Compared to the previous version of the geological map (Barcicki, 1983, 1986), the Kimmeridgian deposits were divided into some informal lithostratigraphic units. This division is based on field observations in outcrops, mainly in the "Wierzbica" quarry, as well as the lithofacial and biostratigraphic studies by Gutowski (1992, 1998). The latest stratigraphic divisions of the Upper Jurassic formations (Wierzbowski *et al*., 2016) were also taken into account, which allowed the revision of the Oxfordian/Kimmerdgian border in the study area.

The locations of the Middle Jurassic outcrops (Bajocian, Bathonian) were also verified, and the lithostratigraphic division of the Lower Jurassic formations in the borehole profiles based on sequential stratigraphy was studied in details (Pieńkowski, 2004).

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[1] The Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warsaw, Poland.

An interesting polliniferous cone with *in situ Araucariacites* pollen grains from Wólka Bałtowska, NE margin of Góry Świętokrzyskie Mts, Poland

Jadwiga ZIAJA [1], Maria BARBACKA [1, 2] and Grzegorz PACYNA [3]

An Upper Jurassic site with macroflora at Wólka Bałtowska was discovered by Liszkowski in 1967 and published by him in 1972. This is one of few known sites with Upper Jurassic plant remains in Poland (e.g., Premik, Zabłocki, 1925). Preliminary results of palynological studies of this locality were published by Gedl and Ziaja (2004). Based on collected fauna, especially an ammonite of the genus *Discosphinctes*, Liszkowski (1972) interpreted the age of the sediment in question as late Oxfordian. Age-assessment of limestone from Wólka Bałtowska based on dinoflagellate cysts implies late Oxfordian to early Kimmeridgian (Gedl, Ziaja, 2004).

On the ground of Reymanówna's unpublished data Liszkowski (1972) reported a list of determined plants including one genus of Sphenophyta (*Equisetites* sp.), three genera and two species of gymnosperms (*Ctenozamites* sp., *Pachypteris* sp., *Pseudotorellia* sp., *Pagiophyllum connivens* and *Brachyphyllium* aff. *crucis*) as well as undeterminable fragments of Bennettitales. Liszkowski (1972) mentioned also the occurence of *Classopollis* and *Araucariopollites* pollen grains, and dinoflagellate cysts.

A polliniferous cone with *in situ* pollen grains was found among specimens from Wólka Bałtowska stored in Herbarium KRAM of W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow, Poland in Palaeobotanical collection. Pollen grains were examined under LO, SEM and TEM microscopes. They are similar to dispersed *Araucariacites* pollen grains described and illustrated e.g. by Couper (1958) or Archangelsky (1994). Probably cone belonged to the same parent plant as *Araucariacites australis* pollen grains noted from palynological samples of Wólka Bałtowska (Gedl, Ziaja, 2004). According to preliminary research this cone derived from conifer of the family Araucariaceae.

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[1] W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland.

[2] Hungarian Natural History Museum, Botany Department, H-1431 Budapest, Pf. 137, Hungary.

[3] Jagiellonian University, Faculty of Biology, Institute of Botany, Department of Taxonomy, Phytogeography and Palaeobotany, Gronostajowa 3, 30-387 Kraków, Poland.

New results on the bio- and lithostratigraphy of the Untere Felsenkalke Formation (Late Jurassic, Kimmeridgian, Pseudomutabilis Zone) of S Germany

Armin SCHERZINGER[1] and Günter SCHWEIGERT[2]

The bio- and lithostratigraphy of the Upper Jurassic Untere Felsenkalke Formation in the area of the Swabian Alb was subject to numerous publications in the second half of the last century (e.g., Aldinger, 1945; Ziegler, 1955a, b, 1959; Seeger, 1958, 1961). The alternation of thick biodetritic limestone beds and intercalated thin marl layers confirmed a long-distance correlation of most individual beds over all studied Swabian sections as well as in the westernmost part of Franconia (Schmidt-Kaler, 1962). These studies also provided preliminary results on the distribution, abundance and ranges of certain ammonite species in sections.

New bed-by-bed collections of ammonites (>2,000 specimens) from the upper part of the Untere-Felsenkalke Formation (Weißjura δ3–δ4 *sensu* Aldinger 1945) of Swabia, SW Germany give insights into the assemblages of the Pseudomutabilis Zone. This zone can be divided into two subzones (Schilleri and Pseudomutabilis subzones) and eight new biohorizons (*prominens-hoelderi* α, *prominens-hoelderi* β, *eumela-levipictus*, *pseudomutabilis-eudoxus* α, *pseudomutabilis-eudoxus* β, *semicostatum* α, *semicostatum* β, and *semicostatum* γ). The ammonite assemblages are generally diverse, with a mixture of Mediterranean, Submediterranean and Subboreal elements.

The new research confirms a phylogenetic lineage of *Aulacostephanus pseudomutabilis*/*A. eudoxus* and closely related species from the base till the top of the Pseudomutabilis Zone. *Physodoceras acanthicum* s. str. is restricted to the Acanthicum Zone. At the base of the Pseudomutabilis Zone, only a late ancestor still coexists with *Physodoceras* cf. *haynaldi* and *Sutneria hoelderi*. The presence of *Orthaspidoceras schilleri* in the lowest of the three faunal horizons of the Pseudomutabilis Zone, Schilleri Subzone, allows a precise correlation between the Subboreal Province and the study area. The younger *Orthaspidoceras orthocera* is not recorded from S Germany. *Orthaspidoceras lallierianum* is restricted to the upper part of the Acanthicum Zone. *Sutneria eumela* s. str. appears for the first time in the eumela-levipictus Biohorizon at the top of the Schilleri Subzone. In the same level, *Streblites levipictus* has its last occurrence. At the base of the Pseudomutabilis Zone, *pseudomutabilis-eudoxus* Biohorizon α, oppeliids predominate the ammonite assemblage. In the succeeding *pseudomutabilis-eudoxus* Biohorizon β, *Aulacostephanus pseudomutabilis* and *Aulacostephanus eudoxus* are very frequent, especially in the so-called "Glaukonitbank", an easily recognizable lithostratigraphic marker-bed in the middle part of the sections (Aldinger, 1945; Ziegler, 1955a, b, 1959). At this level, besides *Sutneria eumela* the first *Sutneria eumela* morph *lorioli* occurs. In the *semicostatum* Biohorizon α, *Lingulaticeras semicostatum* coexists with true *Aulacostephanus pseudomutabilis*, *Aulacostephanus eudoxus*, a still unnamed *Physodoceras* species with small spines (frequent), and *Physodoceras* cf. *longispinum* (rare). The ammonite assemblage of the *semicostatum* Biohorizon β yields e.g., *Lingulaticeras semicostatum*, *Physodoceras longispinum* (very frequent), *Physodoceras* sp. with small spines (rare) and *Sutneria eumela morph lorioli*. At the top of the Pseudomutabilis Zone, *semicostatum* Biohorizon γ, *Mesosimoceras cavouri* allows a correlation with the Cavouri Zone of the Mediterranean Province (Scherzinger *et al*., 2016). In the same level occurs *Aulacostephanus* ex gr. *pseudomutabilis*, *Aulacostephanus* n. sp., and for the first time since the lower Pseudomutabilis Zone, Schilleri Subzone, perisphinctids become abundant again.

[1] Maurenstraße 26, 78194 Immendingen-Hattingen, Germany.
[2] Staatliches Museum für Naturkunde Stuttgart, Rosenstein 1, 70191 Stuttgart, Germany.

The new results are the key for a precise correlation between the Mediterranean, Submediterranean and Subboreal provinces during the early Late Kimmeridgian and the starting point for a fundamental systematic revision of the associated ammonite assemblages.

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