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Upper Callovian and Oxfordian molluscs and brachiopods from selected localities of the Kraków-Częstochowa Upland and the Świętokrzyskie Mountains, Poland

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abstract

The aim of the study was the taxonomic, morphological, ecological and stratigraphic characterization of marine invertebrate groups from the localities of Wiek and Wysoka (Krakow-Częstochowa Upland) and Gnieździska (Świętokrzyskie Mountains). All of these three localities were unused quarries where limestone was once mined. The material consisted of a total of 756 fossils collected by the author from the studied sites or constituting part of the collections of the Department of Vertebrate Ecology and Palaeontology at the University of Environmental and Life Sciences in Wrocław. When describing and marking the fossils, attention was paid to the state of preservation, morphology, size, shape and the presence of structures characteristic of a given taxon. Among the studied material were fossils of gastropods, bivalves, ammonites, belemnites, and brachiopods. These organisms were found in upper Callovian (Middle Jurassic) and Oxfordian (Upper Jurassic) sediments and are approximately 157.3–166.1 million years old. Different groups of invertebrates dominated in the material collections from individual sites. Among the fossils from the Wiek quarry, the most numerous were brachiopods, the material from the Wysoka locality was dominated by ammonites, and the most numerous group in the collection from the Gnieździska quarry were belemnites. In total, 18 genera belonging to 13 families were recorded. The most numerous group among the studied fossils were Ammonitida, mostly represented by the genus *Perisphinctes*. In the collection from the Wysoka quarry, a single ammonite shell belonging to the genus *Horioceras* was recorded, which has not been recorded at this site so far. Among the collected ammonites, the genera *Cardioceras, Lissoceratoides*, and *Trimarginites* were also distinguished. The most diverse group among the collected fossils were brachiopods, of which eight genera were recorded: *Lacunosella, Septaliphoria, Epithyris, Juralina, Loboidothyris, Sellithyris, Zeillerina*, and *Terebratulina*. The studied material also revealed the presence of one genus of gastropods — *Nerinea*, two genera of bivalves — *Lima* and *Posidonia*, and two general of belemnites — *Belemnopsis* and *Hibolites*. These organisms inhabited the shallow and warm shelf sea that covered a large area of present territory of Poland during the Jurassic period.

Молюски та брахіоподи Верхнього Келовею та Оксфорду з вибраних місць Краківсько-Ченстоховської височини та Свентокшиських гір Польщі

Себастян Вшелякі

Резюме. В роботі подані результати таксономічної, морфологічної, екологічної та стратиграфічної характеристики морських безхребетних з місцезнаходжень Вєк та Висока (Юра Краковсько-Ченстоховська) та Гнєздзіска (Свентокшиські гори) в Польщі. Зараз всі досліджені місцезнаходження є виробленими кар'єрами де колись добували вапняк. Рештки організмів були знайдені у відкладах Верхнього Келовею (Середня Юра) та Оксфорду (Верхня Юра) та мають вік в межах від 157,3 до 166,1 млн років. Матеріал налічував 756 скам'янілостей, зібраних автором з вивчених місцезнаходжень та з колекцій Відділу екології хребетних та палеонтології Природничого університету у Вроцлаві. Рештки організмів були відпрепаровані та по можливості визначені до рівня родів. При описі та маркуванні скам'янілостей звертали увагу на стан збереженості, розміри та морфологічну будову, а також наявність ознак, характерних для даного таксону. Подано кількісні та якісні характеристики представників таких таксонів як молюски (равлики, амоніти, белемніти) та брахіоподи. Всього було визначено 18 родів, які належали до 13 родин. Серед скам'янілостей з місцезнаходження Вєк брахіоподи були найчисленнішими, у матеріалі з Висока переважали амоніти, а белемніти були домінуючими в місцезнаходженні Гнєздзіська. За кількістю решток переважали амоніти, серед яких рід *Perisphinctes* був домінуючим. У колекції з кар'єру Висока вперше для цього місця було зафіксовано черепашку амоніта роду *Horioceras*. Також були знайдені види родів *Cardioceras, Lissoceratoides* і *Trimarginites*. Найрізноманітнішою групою серед зібраних скам'янілостей були брахіоподи, яких визначено 8 родів: *Lacunosella, Septaliphoria, Epithyris, Juralina, Loboidothyris, Sellithyris, Zeillerina* і *Terebratulina*. У дослідженому матеріалі також були виявлені: один рід черевоногих молюсків — *Nerinea*, два роди двостулкових молюсків *Lima* і *Posidonia* і два роди белемнітів *Belemnopsis* і *Hibolites* Охарактеризоване біоценотичне угрупування організмів існувало в мілководному і теплому морському шельфі, охоплюючи значну територію сучасної Польщі в юрський період.

Ключові слова: Брахіоподи, Келовей, Юра Краківсько-Ченстоховська, молюски, Оксфорд, гори Свентокшиські

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Introduction

Study of extinct taxa, including on the basis of their remains, enables the reconstruction of possible biocoenotic relations in biocoenoses, of which these taxa were an inseparable part. They also play a key role in stratigraphy, that is, in determining the geological age of the rocks and sediments from which they originate. Numerous studies have been conducted in Poland, thanks to which the stratigraphy of most of the sites from which the fossil material was obtained was determined. However, there are fewer works that would focus specifically on the taxonomic analysis of specimens from discovered palaeontological sites. Some of these sites have been well described in terms of their fossil fauna, but some are yet to be developed.

This work focuses on the description of the fossil material from three sites: the Wiek cement plant quarry in Ogrodzieniec (Śląskie Voivodeship), the quarry in the village of Wysoka (Śląskie Voivodeship) and the quarry in the village of Gnieździska (Świętokrzyskie Voivodeship). The first two sites represent the area of the Kraków-Częstochowa Upland, and the third site belongs to the Świętokrzyskie Mountains. Both the Kraków-Częstochowa Upland and the Świętokrzyskie Mountains are pieces of Jurassic sediments, representing the so-called non-Carpathian area (Mizerski & Orłowski 2017). During the Jurassic period, this area was largely covered by the Danish-Polish basin, which was part of the epicontinental basin, in which the conditions (shallow depth, sufficiently high

temperature) allowed the development of a biocenosis with fauna of ammonites, belemnites, brachiopods, bivalves, gastropods, and sponges (Mizerski & Orłowski 2017). All localities examined in the work represent the period of the turn of the Middle and Late Jurassic (upper Callovian and Oxfordian), which is 166.1–157.3 million years (ICS 2020).

Ammonites, brachiopods, and belemnites dominate among the collected invertebrate remains. They lived in a warm sea, which was part of the epicontinental basin, covering most of Poland during the Jurassic period (Mizerski & Orłowski 2017).

The Wysoka quarry has previously been investigated, on the basis of other material, in terms of the taxonomic and morphological characteristics of the specimens there (Kieryluk 2013). Wiek and Wysoka quarries have been thoroughly described in terms of their geomorphology and practical use in tourism and recreation (Majgier *et al.* 2010; Skreczko & Wolny 2014). The geological profile of the Wiek quarry was also created on the basis of the found ammonite remains (Matyja & Głowniak 2003). The exact structure of the Gnieździska quarry is also known (Konon & Mastella 2001). The stratigraphy of the sites and sediments on which the sites are located has already been defined, mainly as Oxfordian, which is the Late Jurassic (Malinowska 1968).

The aim of the study is a taxonomic, morpho-ecological, and stratigraphic characterization of groups of marine invertebrates from the Jurassic localities of Wiek and Wysoka (Kraków-Częstochowa Upland) and Gnieździska (Świętokrzyskie Mountains).

Geomorphology and Geology of the Research Area

The Wiek quarry in Ogrodzieniec

The Wiek quarry is located in Ogrodzieniec (Silesia Province, Zawiercie County) (Fig. 1). It belonged to the Wiek cement plant, which fell out of use in the 1990s (Skała & Hetnał 2007). Ogrodzieniec is part of the Kraków-Częstochowa Upland (Kraków-Wieluń Upland), belonging to the Silesian-

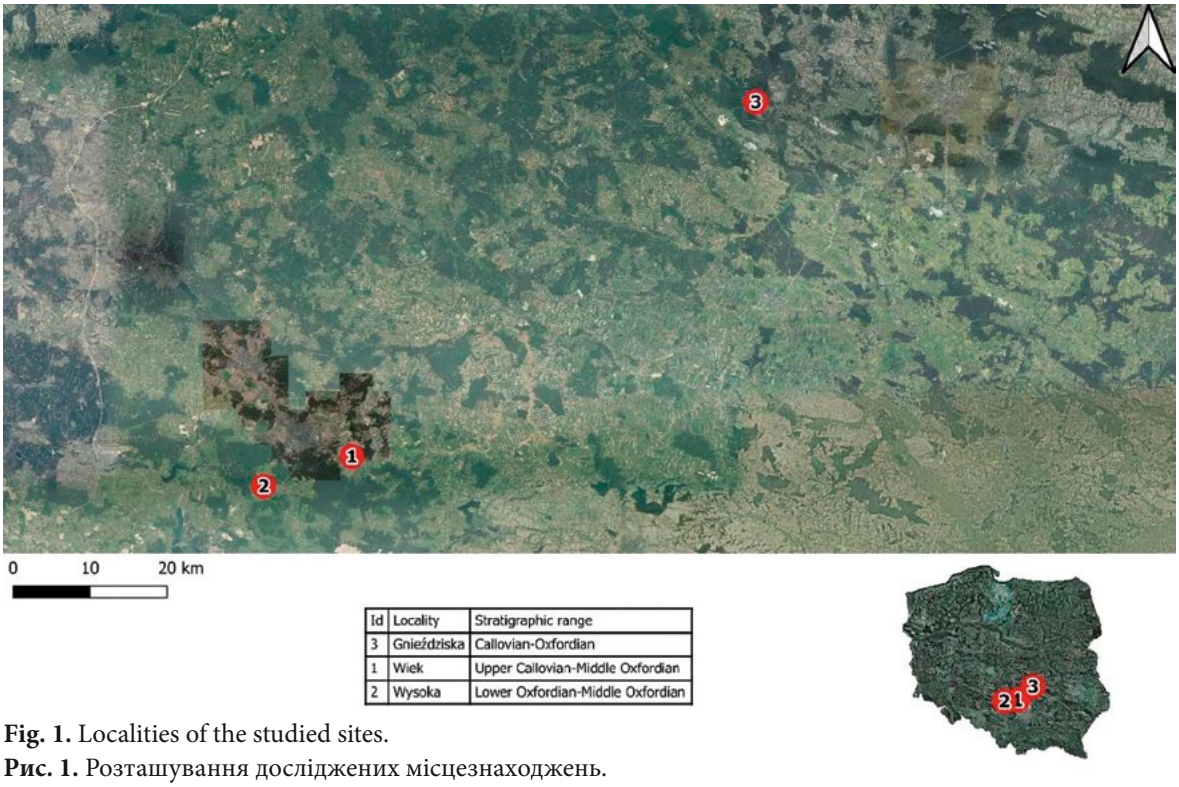

Fig. 1. Localities of the studied sites.
Рис. 1. Розташування досліджених місцезнаходжень.

Kraków monocline (Mizerski 2014). At the beginning of the Late Jurassic, the epicontinental basin reached its maximum extent, covering areas of the Kraków-Wieluń Upland (Mizerski & Orłowski 2017). At the end of the Jurassic, there were upward movements that contributed greatly to the retreat of the sea from these areas (Michalik 1974). The remains of dead marine organisms, whose shells were rich in calcium carbonate, formed numerous carbonate deposits in the late Jurassic period in the form of limestones and marls, in which the remains of these animals have been preserved (Mizerski & Orłowski 2017).

The Wiek quarry is located at an altitude of about 420–440 m above sea level (Fig. 2). It is a single-level and extensive single-section excavation with a wall height up to 20 m (Majgier *et al*. 2010). The quarry is located on glauconite sandy limestones, dated to the upper Callovian and lower and middle Oxfordian (Matyja & Głowniak 2003; Skreczko & Wolny 2014). Clay marls and thin-bedded marly limestones with a thickness of 3.30 m are the oldest sediments in the Wiek quarry and represent the lower Oxfordian (Matyja & Głowniak 2003). The middle Oxfordian consists of thick-fledged Zawodzia limestones and limestones from the Jasna Góra layer, whose common thickness is about 25 m (Matyja & Głowniak 2003). Ammonites, brachiopods, and silica sponges are common in these rocks. The quarry in Ogrodzieniec is the largest outcrop within the Lower Silesian Industrial District (Skreczko & Wolny 2014).

Wysoka quarry

The Wysoka quarry is located in the village of Wysoka (Silesia Province, Zawiercie County) (Fig. 2). Similarly to the Wiek quarry, it belongs to the area of Kraków-Częstochowa Upland. In the quarry profile, there are marly limestones, medium and thick-bed limestones, as well as massive limestones in which the remains of ammonites, brachiopods, bivalves, and sponges are preserved (Poulsen 1995; Skreczko & Wolny 2014). The sediments from Wysoka represent the lower and middle Oxfordian (Kieryluk 2013). Among the lower Oxfordian sediments, there are sponge limestones belonging to the Jasna Góra layers (Kieryluk 2013). The middle Oxfordian includes plate limestones with marly inserts, as well as bioherms and sponge biostromes (Kieryluk 2013). Contrary to the Wiek quarry in Ogrodzieniec, in the Wysoka quarry there are currently no sediments from the highest Callovian, although they were previously present in the quarry in the form of limestones with ferruginous ooids (Kieryluk 2013).

Gnieździska quarry

The Gnieździska quarry is located in the village of Gnieździska (Świętokrzyskie Province, Kielce County) (Fig. 2). Gnieździska belongs to the Mesozoic margin of the Świętokrzyskie Mountains, which belongs to the Szydłowiec segment (Mizerski 2014). During the Jurassic period, the area of the Świętokrzyskie Mountains, like the area of the Kraków-Częstochowa Upland, was covered with an epicontinental basin (Mizerski & Orłowski 2017). The Mesozoic edge of the Świętokrzyskie Mountains is divided into north-east and south-west, to which the Gnieździska quarry belongs. The sediments of the south-west wing of the Świętokrzyskie Mountains, from the Late Jurassic period, include, among others limestones, marls, claystones and sandstones (Mizerski 2014).

The Gnieździska quarry is currently out of use as a limestone extraction facility (Fig. 3). The quarry profile is formed by yellowish limestone, representing the Callovian, as well as thin-bedded white marly limestones, which then turn into plate gray limestones, representing Oxfordian (Konon & Mastella 2001). In some places, quarry sediments create fracture zones that occur in the end parts of brachysynclines (Stupnicka 1971). Sponges are very numerous in the sediments of the Gnieździska quarry. Belemnites are also common, while ammonites and brachiopods account for a smaller proportion of fossils in this area.

Fig. 2. Wiek Quarry in Ogrodzieniec (photo by Nikodem Mazur).
Рис. 2. Кар'єр «Вєк» в Огродзінцю (фото Нікодема Мазура).

Fig. 3. Gnieździska Quarry (photo by Nikodem Mazur).
Рис. 3. Кар'єр Гнєздзіська (фото Нікодема Мазура).

Material and Methods

The material in the study consisted of invertebrate remains obtained from the three previously described sites. The entire material consisted of complete fossils, their fragments and prints. Information on the material from the Wiek site was obtained from an earlier study (Wszelaki 2018) and re-used in this study. The fossil material from the Wysoka was obtained from the collections of the Department of Vertebrate Ecology and Palaeontology at the University of Environmental and Life Sciences in Wrocław. The material from the Gnieździska site was collected from the quarry by the author and accompanying persons on 26 October 2019.

The material from the Wiek site consists of 251 fossils. The material from the Wysoka comprises 395 fossils. A total of 104 fossils were obtained from the Gnieździska site. The remains obtained from all sites belong to one of two types: molluscs or brachiopods.

Invertebrate remains were isolated from sedimentary rocks (mainly limestones) using a hammer, chisel, and preparation needle. Some fossils could not be completely separated from the bedrock with the tools at hand without risking damage or destruction. In these cases, they were cleaned to the extent that they could be identified and classified. Some fragments did not have the characteristics to classify them, so they were left at family or order rank.

During the collection of the material, sponge fossils were also found, but they were not classified to a lower taxonomic rank and were not included in the study material.

Molluscs are represented in the material by four systematic groups: ammonites (Ammonitida), belemnites (Belemnitida), gastropods (Gastropoda), and bivalves (Bivalvia). Their designation to the genus was based on the type, shape, and ornamentation of the shells (e.g. the formation of ribs or the shape of the rostrum). Brachiopods are represented by two orders: Rhynchonellida and Terebratulida. Their designation to genus was mostly based on the shape of the shell and their ornamentation. Only taxa occurring in the Callovian and/or Oxfordian were taken into account in the taxonomic determination. Descriptions, figures, and photos from relevant studies were used for marking (Arkell *et al.* 1957; Bieda 1966; Lehmann & Hillmer 1987; Williams 2000; Czubla *et al.* 2014). The work uses the stratigraphic table of the International Commission of Stratigraphy from January 2020.

Results

A summary of the fossils from individual taxa that were collected from the three examined sites, along with their number, is presented in Table 1. Depending on the site, it was dominated by a different group of invertebrates (Fig. 4). Molluscs dominate in the studied fossil material, and they account for 63.2% of the collected fossils. Among the molluscs, Ammonitida were the dominant group which constitute about 82% of all molluscs collected. Later in the chapter, descriptions of individual taxa will be presented, along with a description of the fossils studied. The most abundant genus among all the studied material was *Perisphinctes*, which accounted for 43.5% of all fossils assigned to the type and 30.4% of all collected fossils (Fig. 5).

Table 1. **Taxonomic composition and number of fossils from the sites of Wiek, Wysoka, and Gnieździska**
Таблиця 1. **Таксономічний склад та кількість скам'янілостей з місцезнаходжень Вєк, Висока та Гнєздзіска**

Genus	Site		
	Wiek	Wysoka	Gnieździska
Nerinea	1	1	0
Posidonia	0	2	0
Lima	0	9	0
Lissoceratoides	16	37	3
Trimarginites	0	1	0
Horioceras	0	1	0
Cardioceras	0	11	13
Perisphinctes	78	184	9
Belemnopsis	0	3	3
Hibolites	0	2	3
Lacunosella	63	9	0
Septaliphoria	0	10	0
Epithyris	0	0	2
Juralina	23	0	0
Loboidothyris	0	26	7
Sellithyris	39	17	2
Zeillerina	0	8	8
Terebratulina	0	27	0
Total genera	6	16	9
Total fossils	238	395	110

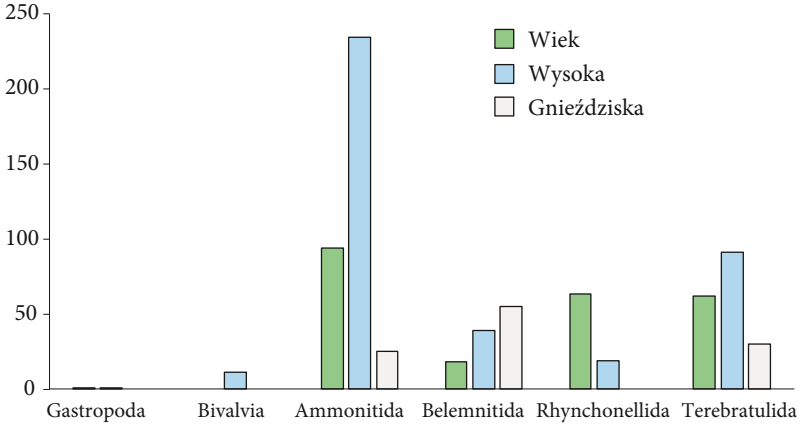

Fig. 4. Comparison of the number of fossils of individual taxa on the sites studied.

Рис. 4. Порівняння кількості скам'янілостей з окремих таксонів на досліджуваних ділянках.

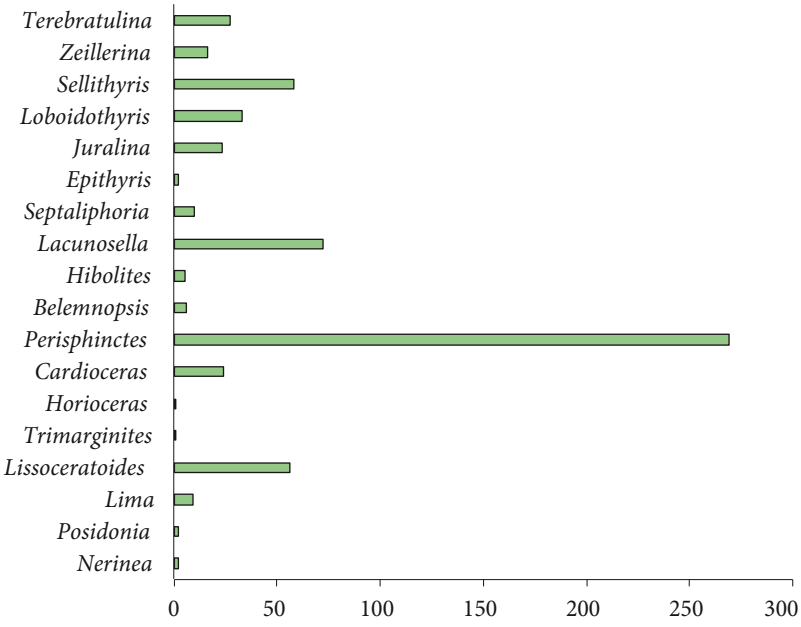

Fig. 5. The share of individual taxa in the studied material.

Рис. 5. Частка окремих таксонів у досліджуваному матеріалі.

Phylum Mollusca

Class Gastropoda Cuvier, 1779

Subclass Heterobranchia J.E. Gray, 1840

Superfamily Nerineoidea Zittel, 1873

Family Nerineidae Zittel, 1873

Genus *Nerinea* Deshayes, 1827

Stratigraphic range: Bajocian (Middle Jurassic)–Maastrichtian (Upper Cretaceous).

The shell is shaped like a slender turret with numerous whorls. Surface smooth or covered with two spiral rows of warts. A post with one fold present or completely smooth. Two folds present elsewhere in the inner wall of the coils. The shell can reach very large sizes.

Two *Nerinea* shells are present among the collected fossils (Fig. 6 *A*). One of them is from the Wiek site and the other from the Wysoka site. The shells from both sites differ in size to a large extent. The width of the shells from the Wiek site is 1 cm, and the width of the shells from the Wysoka is 2.5 cm. The whorls characteristic of this type are visible on both shells.

Phylum Bivalvia Linnaeus, 1758

Order Ostreida Fërussac, 1822

Family Posidoniidae Frech, 1909

Genus *Posidonia* Bronn, 1828

Stratigraphic range: Silurian–Jurassic.

A thin shell with an oblique oval shape. Both shells are the same, with concentric incremental bands. Hinge edge straight and short, without teeth. External ligament.

This genus, in the form of two impressions of shells, has been found only in the material from the Wysoka (Fig. 6 *B*). In the imprints of the shells, incremental bands are clearly visible.

Order Limida Moore, 1952

Family Limidae Rafinesque, 1815

Genus *Lima* Bruguière, 1789

Stratigraphic range: Carboniferous–present.

An almost equilateral shell, elongated anteriorly. Hinge lip almost without teeth. Small ears on the front and back of the shell. Shell slightly opened at the front. Imprint of the contracting muscle shifted towards the back of the shell. Variable ornamentation from smooth to strongly ribbed forms. Triangular internal ligament.

Nine fossils of the genus *Lima* have been found in the material from the Wysoka site (Fig. 6 *C*). They are fragments of shells of these clams preserved in the rock or their prints. All shells are finely ribbed. The diameter of the shells does not exceed 4 cm.

Class Cephalopoda Cuvier, 1797

Subclass Ammonoidea Zittel, 1884

Order Ammonitida Hyatt, 1889

Family Lissoceratidae Douville, 1885

Genus *Lissoceratoides* Spath, 1923

Stratigraphic range: upper Callovian (Middle Jurassic)–upper Oxfordian (Upper Jurassic).

Involute, smooth shell, possibly with marked lines of growth or delicate ventral-lateral ribs. Closely related to the genus *Lissoceras*.

Fossils of this type have been recorded at all three sites studied (Fig. 6 *G*). The shells are available in various sizes, and their diameter ranges from 1 to 4.7 cm. The shells are smooth and have no ribs.

Family Oppeliidae Bonarelli, 1894

Genus *Trimarginites* Rollier, 1909

Stratigraphic range: Oxfordian (Upper Jurassic).

A very involute and discoidal shell. Strongly triple ribbed. The internal whorls are smooth.

Among the studied material, there is only one shell of this type, coming from the Wysoka site (Fig. 6 *H*). Its height is 4.8 cm. There are faint traces of ribs on the edge of the shell.

Genus *Horioceras* Munier-Chalmas, 1892

Stratigraphic range: upper Callovian (Middle Jurassic)–lower Oxfordian (Upper Jurassic).

Shell without ribs and slats. Navel with a channel between large, pointed spines.

This genus is represented in the material by a single shell from the Wysoka site (Fig. 6 *D*). The diameter of the shell is 1.3 cm. Pointed spikes are visible on the shore.

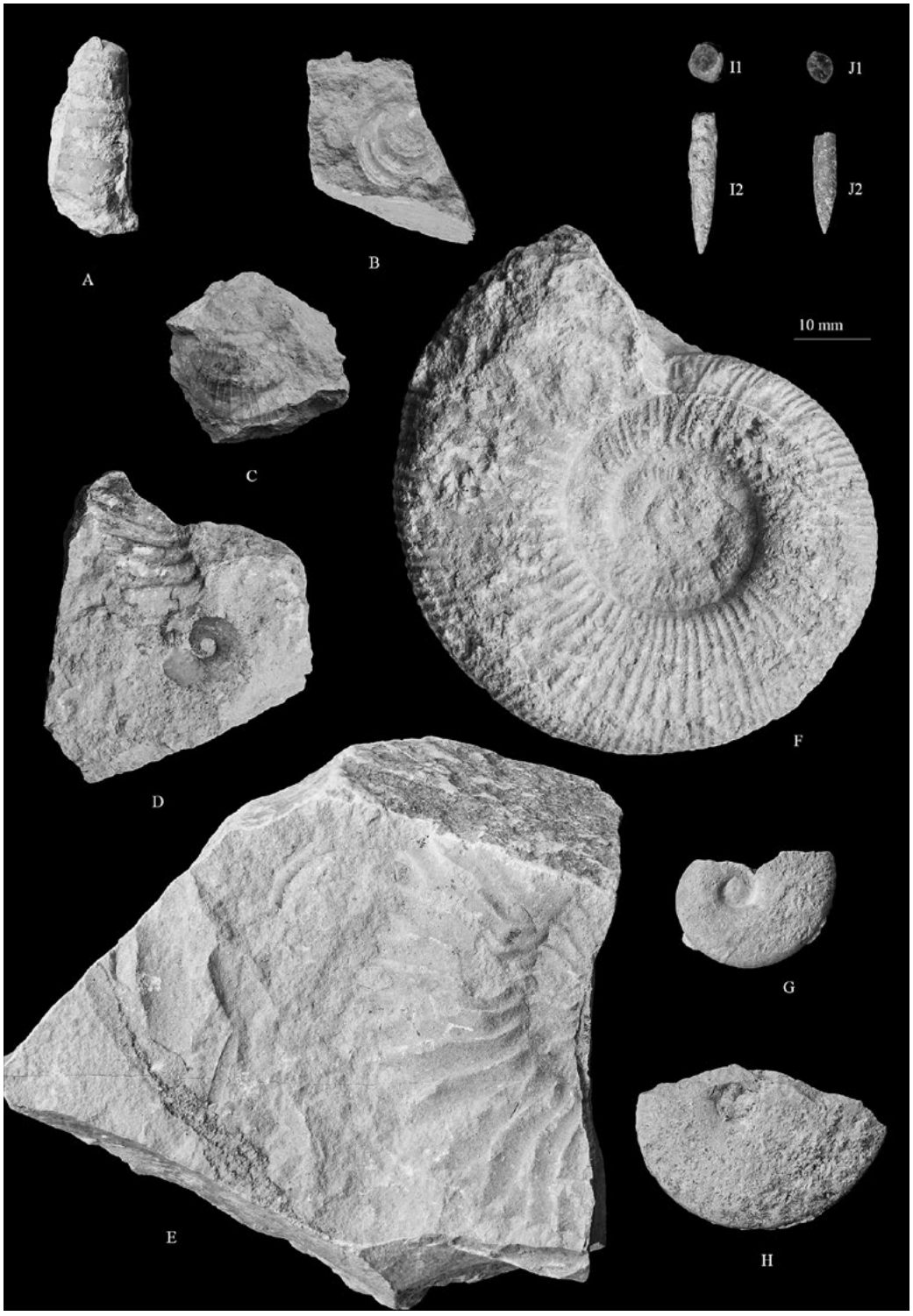

Fig. 6. Fossils of molluscs from the studied sites: *A—Nerinea, B—Posidonia, C—Lima, D—Horioceras, E—Cardioceras, F—Perisphinctes, G—Lissoceratoides, H—Trimarginites, I—Belemnopsis* (1—alveolar view, 2—rostral view), J—*Hibolites* (1—alveolar view, 2—rostral view).

Рис. 6. Скам'янілі рештки молюсків з досліджених місцезнаходжень: *A — Nerinea, B — Posidonia, C — Lima, D — Horioceras, E — Cardioceras, F — Perisphinctes, G — Lissoceratoides, H — Trimarginites, I — Belemnopsis* (1 — вигляд спереду, 2 — вигляд з ростральної частини), *J — Hibolites* (1 — вигляд спереду, 2 — вигляд з ростральної частини).

Family Cardioceratidae Siemiradzki, 1891

Genus *Cardioceras* Neumayr & Uhlig, 1881

Stratigraphic range: Oxfordian (Upper Jurassic).

Forms involute folded. Shell ornamentation in the form of bent, forking ribs. On the ventral side, the ribs reach the keel (sharp edge).

Among the studied material, the genus *Cardioceras* appeared at the sites of Wysoka and Gnieździska (Fig. 6 *E*). It is the most numerous type of Ammonitid among the material collected from the Gnieździska site. At the Wysoka site, the genus *Cardioceras* appears in the form of large but incomplete prints. At the site of Gnieździska, it occurs in the form of imprints and shell fragments, the most complete of which is 6.5 cm in diameter.

Family Perisphinctidae Steinmann, 1890

Genus *Perisphinctes* Waagen, 1869

Stratigraphic range: Oxfordian (Upper Jurassic).

Large or very large, evolute, discoidal shell. The ribs are numerous and split in the middle of the whorls or near the ventral edge. No nodules, but constrictions are common.

This genus is the most abundant ammonite in the studied material (Fig. 6 *F*). In total, it accounts for about 33% of all marked fossils. Fossils of this kind occur in the form of imprints, fragments as well as complete shells. The shells occur in different sizes. Clear and dense ribs are visible on all shells, splitting at the edge of the shell.

Subclass Coleoidea Bather, 1888

Order Belemnitida Zittel, 1895

Family Belemnopseidae Naef, 1922

Genus *Belemnopsis* Bayle, 1878

Stratigraphic range: Bathonian–Callovian (Middle Jurassic).

Cylindrical rostrum. The abdominal furrow runs from the alveoli to the end.

The genus *Belemnopsis* was recorded at the sites of Wysoka and Gnieździska (Fig. 6 *I1-I2*). Among the fossils from the Wiek site there are also belemnitid rostra, but their condition does not allow for an unambiguous determination of the genus. All rostra have a characteristic cylindrical shape.

Genus *Hibolites* Mayer-Eymar, 1883

Stratigraphic range: Middle Jurassic–Lower Cretaceous.

Club-shaped rostrum. Present abdominal furrow and well-developed side lines.

The genus *Hibolites* was recorded at the sites of Wysoka and Gnieździska (Fig. 6 *J1–J2*). As in the case of the genus *Belemnopsis*, its presence cannot be clearly confirmed at the site of Wiek due to the extensive damage to the rostra. The specimens from the Wysoka differ significantly in size and the specimens from the Gnieździska site are of similar size. In the found specimens, a characteristic widening at the top of the shell is visible, giving a club-like shape.

Phylum Brachiopoda Dumèril, 1806

Class Rhynchonellata Williams et al., 1996

Order Rhynchonelida Kuhn, 1949

Family Basiliolidae Cooper, 1959

Genus *Lacunosella* Wiśniewska, 1932

Stratigraphic range: Jurassic–Cretaceous.

Biconvex, sometimes asymmetric, triangular or pentagonal shells. Thick ribs. The commissure of the shells is zig-zag. Very small foramen. Often referred to generally as '*Rhynchonella*.'

The genus *Lacunosella* has been recorded at the Wiek and Wysoka sites (Fig. 7 *A1–A5*). In the Wiek site, it is the most numerous type among the brachiopods found. Both complete shells and their fragments were found. The shells show 3 ribs on the dorsal side, which go between 2 ribs on the ventral side. The size of the shells from both sites is similar and ranges from 1.2 to 2.2 cm.

Family Cyclothyrididae Makridin, 1964

Genus *Septaliphoria* Leidhold, 1920

Stratigraphic range: Middle Jurassic–Lower Cretaceous.

Biconvex shells with prominent ribs. A zig-zag commissure is present on the shells. The ventral shell is larger, with a well-developed umbo, and a deep furrow in the middle. A circular opening is present within the palintrop.

The genus *Septaliphoria* was recorded only at the Wysoka site (Fig. 7, *B1–B5*). Clear ribs are visible on all shells. The length of the shells does not exceed 2.8 cm.

Order Terebratulida Waagen, 1883

Family Terebratulidae Gray, 1840

Genus *Epithyris* Phillips, 1841

Stratigraphic range: Middle Jurassic–Upper Jurassic.

The shell is large, biconvex, smooth, and pentagonal. Triangular outer hinge plates. A wide transverse strip, strongly arched. Present collar. Small hinge process.

The genus *Epithyris* was recorded only at the site of Gnieździska (Fig. 7 *C1–C5*). There are only two shells of this kind in the material. Their length is 1.4 cm.

Genus *Juralina* Kyansep, 1961

Stratigraphic range: Upper Jurassic.

The shell is large, oval, smooth, and flat or biconvex. Large, exposed opening. Triangular loops present. Clearly marked hinges. Present collar.

The genus *Juralina* has only been recorded in the collection of fossils from the Wiek site (Fig. 7 *D1–D5*). The shells are ovoid in shape and flattened. Lines of growth are visible on the shells. Their length is in the range of 1.1–2.1 cm.

Genus *Loboidothyris* Buckman, 1918

Stratigraphic range: Middle Jurassic–Upper Jurassic.

Smooth, medium to very large shells. Round to oval. Outer hinge plates short, triangular. Present central furrow. Short collar. Low hinge process.

The genus *Loboidothyris* was recorded at the sites of Wysoka and Gnieździska (Fig. 7 *E1–E5).* All shells are oval in shape, with lines of growth visible on the shells. Their sizes are similar and are in the range of 1.3–2.2 cm.

Genus *Sellithyris* Middlemiss, 1959

Stratigraphic range: Jurassic.

Smooth, biconvex shells with a round opening. One saddle and two deep furrows are present in the middle part of the shell. A deep furrow and two saddles on both sides are visible on the dorsal shell.

The genus *Sellithyris* was recorded in all the sites studied, the most of its fossils from the Wiek site (Fig. 7 *F1–F5*). All found shells have a spherical shape and marked growth lines. Their sizes vary and range from 0.7 cm to 3 cm.

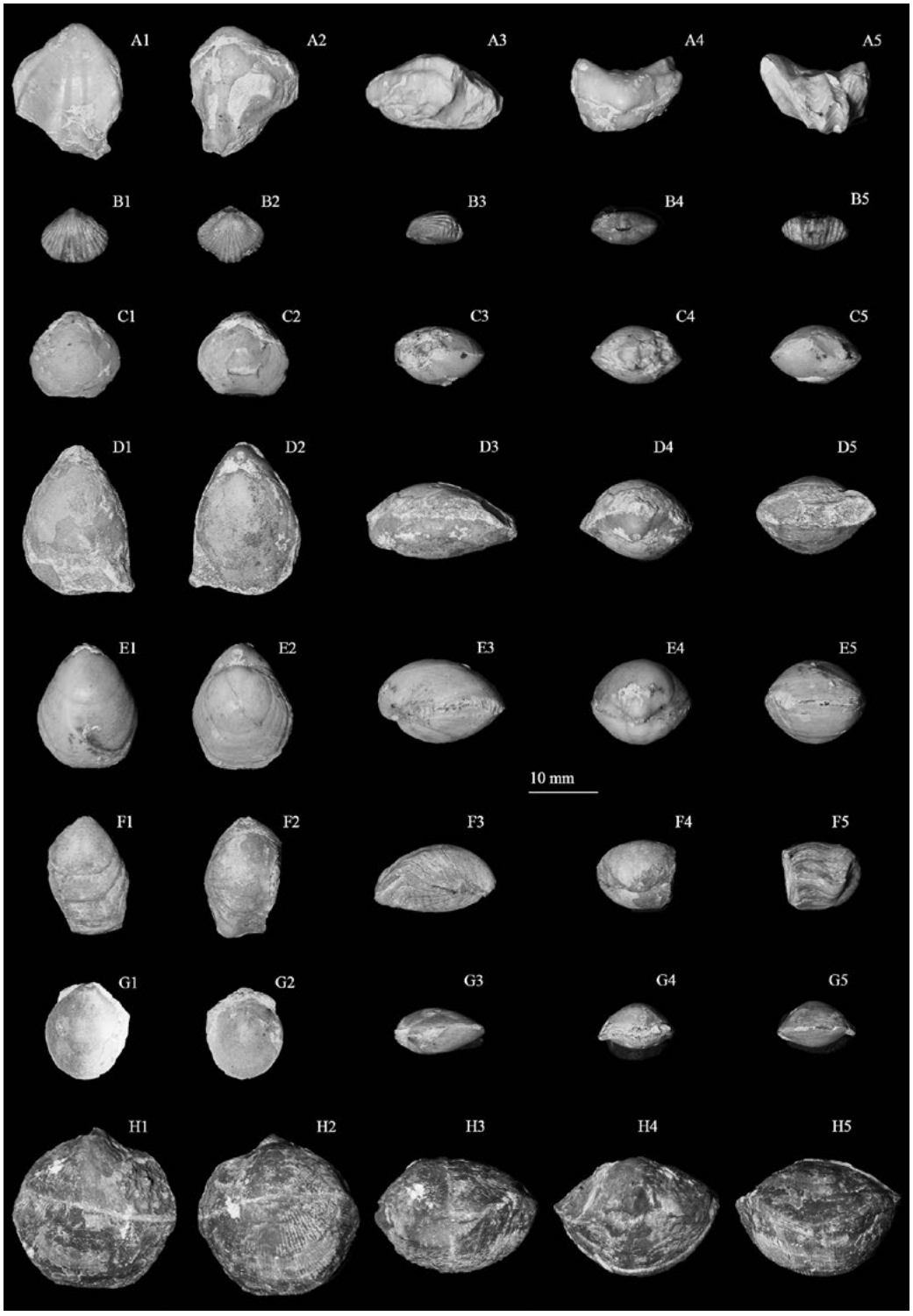

Fig. 7. Brachiopod fossils from the studied sites presented from ventral (1), dorsal (2), lateral (3), posterior (4) and anterior (5) views: *A—Lacunosella, B—Septaliphoria, C—Epithyris, D—Juralina, E—Loboidothyris, F—Sellithyris, G—Zeillerina, H—Terebratulina.*

Рис. 7. Скам'янілі рештки плечоногих з досліджених місцезнаходжень. Зображення з боків: вентрального (1), дорсального (2), латерального (3), заднього (4) переднього (5): *A — Lacunosella, B — Septaliphoria, C — Epithyris, D — Juralina, E — Loboidothyris, F — Sellithyris, G — Zeillerina, H — Terebratulina*.

Family Zeilleridae Allan, 1940

Genus *Zeillerina* Kyansep, 1959

Stratigraphic range: Upper Jurassic.

Smooth, biconvex, oblong-oval, pentagonal shell. Strongly developed hinge edge, straight to slightly curved. Present collar. Small hinge process, usually poorly developed.

The genus *Zeillerina* was recorded at the sites of Wysoka and Gnieździska (Fig. 7 *G1–G5*). All shells are round and flattened. The shells from the Gnieździska site are smaller than those from the Wysoka.

Family Cancellothyrididae Thomson, 1926

Genus *Terebratulina* D'Orbingy 1847

Stratigraphic range: Upper Jurassic–Holocene.

Small to large, oval to pentagonal, smooth or slightly ribbed, and biconvex shell.

The genus *Terebratulina* was recorded only at the site of Wysoka, where it was the most numerous type of brachiopods (Fig. 7 *H1–H5*). All shells are spherical in shape. The shells show delicate but dense ribbing. Their length is in the range of 0.7–2.6 cm.

Discussion

In this work, which includes a description of marine invertebrates from three selected sites from the Middle and Late Jurassic, a total of 756 fossils have been collected, which to a greater or lesser extent may contribute to a better understanding of the world of Jurassic organisms in the territory of modern Poland.

No gastropod remains were found at the site of Gnieździska, however, research conducted in the Mesozoic border of the Świętokrzyskie Mountains (from the middle Oxfordian to Kimmerdigian) showed the presence of *Nerinea* along with other representatives of the Nerineidae family at many sites (Wieczorek 1979). These studies, however, did not take into account the site of Gnieździska, and due to the lack of evidence in the form of fossils of these snails collected from this location, the presence of this group cannot be clearly confirmed at the site of Gnieździska, although it is very likely.

Bivalve fossils have been found only in the sediments of the Wysoka quarry. In studies on Jurassic bivalves in the Kraków-Częstochowa Upland and Łęczyca, focusing on the Middle Jurassic period (from Bajos to upper Callovian), the occurrence of *Lima* and, to a lesser extent, *Posidonia*, has been proved, as well as several other genera, including *Placunopsis*, *Melarginella*, and *Pleuromya* (Pugaczewska 1986). However, none of the localities discussed in this paper were taken into account in these studies. One of the sites—Mount Żar—was located near Ogrodzieniec, where the Wiek site is located, which may suggest that there are also bivalves of one of the described types. The current results confirm the presence of at least two genus and two families of bivalves in the Wysoka. No Jurassic bivalves have been found at the site of Gnieździska.

The most numerous of the types of ammonites found was *Perisphinctes,* which was found at all three sites studied, of which at the Wysoka site it was the dominant type among the excavated remains of Jurassic invertebrates. Perisphinctidae ammonites are very important in stratigraphy because they were found only in the Middle and Upper Jurassic, and the genus *Perisphinctes* is characteristic only for the Oxfordian (Głowniak 2002). Its numerous occurrences in the Wysoka quarry and the slightly less numerous, but also high attendance in the Wiek quarry indicate the origin of most of the sediments of these two quarries from the Oxfordian period. The presence of the genus *Perisphinctes* in the profiles of the Wiek and Wysoka quarry has also been confirmed in other studies (Głowniak 2002; Barski *et al.* 2004; Wasilewska 2008; Kieryluk 2013). Perisphinctid ammonites are found on almost all the outcrops from the Oxfordian, including in Zalas, Młynka, Podłęże, Rudniki, and Morawica (Głowniak 2002; Wasilewska 2008; Jurkowska & Kołodziej 2013). One of the largest outcrops of Perisphinctid remains in Europe is located in Zawodzie near Częstochowa (Malinowska 1972). The small

share of the genus *Perisphinctes* in the material from the Gnieździska quarry indicates that some of the sediments come from the Oxfordian, but probably the sediments from the upper Callovian predominate there. Research conducted on ammonites from the Perisphinctidae family showed that these animals developed best in the shelf zone, 150–200 m deep, with sufficient reservoir ventilation and normal salinity (Malinowska 1972). A similar number of individuals from the family Perisphinctidae found in the Wysoka and the Wiek sites may suggest that in the middle and late Jurassic period similar conditions prevailed in these areas.

Cardioceras is also a very numerous and commonly found genus of ammonite from Jurassic. In the studied material, it was found in the Wysoka and Gnieździska quarries, but the data from the literature confirm its presence also at the Wiek site (Głowniak 2002). The Cardioceratidae along with the Perisphinctidae, Aspidoceratidae, and Haplocerata are the main families of ammonites found in Callovian and Oxfordian sediments of the Polish Jurassic (Matyja & Giżejewska 1979). *Lissoceratoides* is also a genus of ammonites that occurred in all three examined sites. It was also found in large numbers in the Zalas quarry near Kraków (Garlicka & Tarkowski 1980; Matyja & Tarkowski 1981). Additionally, at the Wysoka site, one fossil belonging to the genus *Trimarginites* and one fossil belonging to genus *Horioceras* were found. While the genera *Trimarginites* were previously found at the site Wysoka (Kieryluk 2013), there is no information on finding the genus *Horioceras* at this site. This would be the finding of a new genus of ammonite in the Wysoka. The results of other studies additionally show the presence of such genera as *Kosmoceras, Peltoceras, Quenstedtoceras, Taramelliceras, Trimarginites, Phylloceras*, and *Creniceras* in the Wiek quarry profile (Matyja & Głowniak 2003; Barski *et al.* 2004). In the section of the Wysoka quarry, the presence of such genera as *Glochiceras, Popanites, Creniceras, Euaspidoceras, Taramelliceras, Ataxioceras*, and *Idoceras* was additionally found (Wasilewska 2008; Kieryluk 2013).

Belemnites were found in all three studied sites, the most numerous of which was found in the sediments of the Gnieździska quarry. Among the Belemnite remains collected, there were very few undamaged rostra that allowed individuals to be identified by genus. On the basis of these few rostra, two types were distinguished in the material from the Wysoka and Gnieździska quarries: *Belemnopsis* and *Hibolites*. These are the types commonly found in Poland, especially from the Callovian (Pugaczewska 1961). Other studies conducted on belemnites from the Wiek quarry confirm the presence of these two types also in the open-pit mines from this site (Pugaczewska 1961). The genus *Belemnopsis* and *Hibolites* were also found in the Mesozoic border of the Świętokrzyskie Mountains, to which the Gnieździska site belongs. Damaged rostra probably also belongs to one of the two types. Apart from these two genera, the following genera were also distinguished in the Callovian and Oxfordian in Poland: *Hastites, Gastrobelus, Dactyloteuthis, Dicoelites, Duvalia, Rhopaloteuthis,* and *Pseudobelus* (Pugaczewska 1961).

In studies on brachiopods of Rhynchonellida, which were carried out in Oxfordian sediments in the Kraków-Częstochowa Jura, the occurrence of three genera was noted: *Lacunosella, Septaliphoria,* and *Monticlarella*, of which the genus *Lacunosella* accounted for over 90% of all found brachiopods from this superfamily (Wierzbowski 1970). The results of these studies are in line with those obtained from the Wiek and Wysoka quarries, which belong to the Kraków-Częstochowa Upland. Although no representatives of the order Rhynchonellida were found at the site of Gnieździska, the genera *Lacunosella* and *Septaliphoria* were found in the Oxfordian sediments of the Świętokrzyskie Mountains (Wierzbowski 1970). The genus *Sellithyris*, recorded on all three surveyed sites, is often found in the Upper Jurassic sites of the Kraków-Częstochowa Upland and, apart from the studied quarries, was also abundant at the site of Julianka near Częstochowa (Heliasz & Racki 1980). Extensive research was carried out on Upper Jurassic brachiopods from the order Terebratulida (Barczyk 1969) at the sites included in the Mesozoic margin of the Świętokrzyskie Mountains. Among the brachiopods from the Oxfordian found on the sites, studied were the genera *Nucleata, Epithyris, Goniothyris, Juralina, Loboidothyris, Lobothyris, Wattonithyris, Sellithyris, Terebratina, Zeillerina, Cheirothyris,*

Dictyothyropsis, and *Ismenia* (Barczyk 1969). These studies were carried out on numerous sites within the Świętokrzyskie Mountains, but the Gnieździska quarry was not included. The current research on the Gnieździska quarry may constitute a supplement to that study. In addition, the results of the research presented in Barczyk's work prove that all types of brachiopods found within the Kraków-Częstochowa Upland at the places of Wiek and Wysoka are also found at the sites of the Świętokrzyskie Mountains in Oxfordian.

The difficulty in the correct classification of brachiopods is their morphological similarity and the fact that one genus can develop many different morphotypes. For this reason, the taxonomic affiliation of the found brachiopods may be questionable. At the site in Wierzbica near Radom, which belongs to the Świętokrzyskie Mountains and represents the area of the lower Kimmeridgian (Upper Jurassic), the found brachiopods, which originally belonged to the five previously described genera of the order Terebratulida, were recognized as differently developed morphotypes of one kind — *Epithyris* (Dzik 1979). Recently, several new species of brachiopods of the genera *Craniscus* and *Rioultina*, originating from the Oxfordian sediments of the well-known Zalas site near Krakow, have also been described (Radwańska 2017). This confirms the legitimacy of conducting research not only on new paleontological sites, but also on well-researched and described sites. Despite the low importance of brachiopods in the stratigraphy, where ammonites play an important role, some species may be useful in estimating the age of Polish sediments due to their narrow range of occurrence (Wierzbowski 1970).

On the basis of the collected material, it can be concluded that the greatest generic diversity was present at Wysoka. It should be noted, however, that this site also contained the largest number of fossils collected. Nevertheless, the samples collected from each quarry are a good reflection of the invertebrate fauna that existed in the area at the turn of the Middle and Upper Jurassic. Interestingly, at each of the studied sites, a different group of invertebrates dominated in the collected paleontological material, which reflects the state of the biocenosis. In the Wiek quarry, these were brachiopods, in Wysoka—ammonites, and in the Gnieździska quarry—belemnites. This may indicate a slightly different nature of the environmental conditions represented by the sediments occurring in each of these sites. According to the conventional division, snails, clams and brachiopods dominate in the sponge limestone fraction; ammonites from the Perisphinctidae dominate in the fraction of lamellar limestones, and ammonites from the Cardioceratidae dominate in the silt-clay-marly fraction (Malinowska 1972). This statement is confirmed by the obtained results, because limestones are mainly present in the profile of the Wiek, Wysoka, and Gnieździska quarries, of which, apart from numerous limestones, a large accumulation of sponge limestones has been noticed in the Age and Gnieździska quarries. On the basis of the collected fossils, it is also possible to confirm the stratigraphy of the studied areas. The Wiek and Wysoka quarries mainly represent Oxfordian sediments, as indicated by numerous fossils of the genus *Perisphinctes*, while the Gnieździska quarry is dominated by sediments from the upper Callovian, which is indicated by a small share of the genus *Perisphinctes* and a large share of *Belemnopsis* and *Hibolites*, which are most frequently found in sediments dated Callovian.

Conclusions

1. Among the studied material, 18 genera were distinguished belonging to 13 families within two phyla: molluscs and brachiopods.
2. The most abundant group of fossils in the entire material are ammonites, and the most abundant is the genus *Perisphinctes*.
3. On the basis of the studied invertebrate fauna, an attempt was made to reconstruct the environmental conditions and determine the state of the sea basin during the second half of the Jurassic. It was found that the fauna reflects the state of palaeobiocoenoses in the shelf zone with a shallow depth and warm water, which was inhabited by pelagic (ammonites, belemnites) and benthic (sponges, gastropods, bivalves, brachiopods) forms. The taxonomic diversity and quantitative characteristics

indicate that the palaeobiocoenoses, although slightly different from each other, existed under conditions of optimal functioning, maintaining normal food chains.

4. All recorded genera, with the exception of a single individual of the genus *Horioceras* found at the Wysoka site, were previously recorded from the Jurassic of Poland.
5. The collected material combined with data from the literature and new collections from palaeontological sites in Poland, provides information necessary for a more detailed understanding of the palaeobiology and palaeoecology of extinct organisms of the Jurassic period.

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