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Re-evaluating 'Silkworm' Cocoons in Early Medieval Poznań: A Critical Analysis

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In memory of Andrzej Sikorski (1953-2023)

Abstract. We provide a comprehensive re-examination of the early medieval cocoons unearthed during archaeological excavations in the Cathedral Square at Ostrów Tumski, Poznań, Poland, in the 1950s. We challenge previous identifications, in particular the misidentification of these cocoons as *Bombyx mori* (silk moth) which influenced the interpretation of sericulture practices in the region. Comprehensive comparative microstructural analyses, including digital microscopy and scanning electron microscopy, as well as the association of the cocoons with structures, validate our revised identification as Hymenoptera (possibly parasitic wasp) cocoons. While silkworm breeding and silk production did not occur in 11th-century Poznań, our meticulous review of the historical records highlights the appearance of silk fabric as early as the 9th and 10th centuries in Poland trough trade routes likely originating in China and Byzantium. We underline the significance of Hymenoptera cocoons, a rarity in archaeology. In addition to contributing to a more accurate understanding of the history of silk textiles in early medieval Poland, and enriching knowledge of global trade contacts and cultural connections, our study emphasizes the importance of challenging and updating scholarly findings as the research methods improve.

Keywords: silkworm cocoons, sericulture, early Middle Ages, silk, Poznań, Ostrów Tumski, Poland.

Introduction

Remarkable archaeological finds of materials originating from distant areas, sometimes thousands of kilometers away, constitute precious sources for a better under-

standing of the past. They serve as evidence of social contacts and trade, indicating wealth and prestige, but also the transfer of knowledge and traditions between communities that were separated by significant distances. Recent scientific advances and the development of suitable research methods allow verification of what were often macroscopic visual identifications of these sometimes rare, non-local materials. This was one of the reasons why the authors of the study undertook the analysis of remains of early medieval elite textiles, fragments of silk fabrics, and golden 'threads' discovered at the Ostrów Tumski archaeological site in Poznań, Poland, using modern microscopic methods. During these analyses, it was decided to closely examine finds of early medieval 'silkworm' cocoons discovered during research in the Cathedral Square sector of the site for comparative purposes.

In this article, we present results regarding the revised identification of cocoons, as their discovery significantly impacted the interpretation of early medieval silk textiles found in Poland. We will illustrate how these findings and the earlier incorrect identification influenced scholars' hypotheses and interpretations in the context of discoveries from the early medieval period.

History of Archaeological Research: Unearthing the Cocoons

Extensively conducted archaeological excavations following World War II, commonly referred to as *millennial studies*, contributed to the recognition of many central strongholds of the Piast dynasty's rule, including the Poznań stronghold on Ostrów Tumski. These studies facilitated the documentation of the structure of defensive fortifications, settlement layouts, and the identification of artifacts related to the daily lives of inhabitants, including those of medieval elites. In the years 1958-1959, archaeological research was carried out in the square to the west of the Cathedral on Ostrów Tumski by Maria Malinowska, under the direction of prof. Wojciech Kóčka, as part of the activities of the Poznań-Gród Station on behalf of the Institute of the History of Material Culture in Poznań (Malinowska 1974, p. 7).

The excavation covered an area of 1.5 acres (with an additional 1.5-meter-wide section) in the central part of Cathedral Square on its southern side (Fig. 1). Within the early medieval layers identified by numbers VI and VII, amid a substantial quantity of organic materials, predominantly wood, several cocoons were unearthed (Fig. 2). The lower of the layers, No. VII (53.10/52.10 – 52.00/51.40 m.a.s.l.), comprised dense dark brown soil containing a significant amount of fascine in the form of branches and wood chips, along with stones. The presence of fragments of freshwater mollusk shells and remnants of moss suggests its marshy character (Malinowska 1974, p. 11, tabl. I, VI, VIII, XII). Above, at a depth of 53.10/52.70 m.a.s.l., was Layer VI. This layer, identified through the presence of massive logs and oak planks, with a smaller proportion of pine, along with brown sand occasionally mixed with organic remains, was interpreted as a deposit originating from

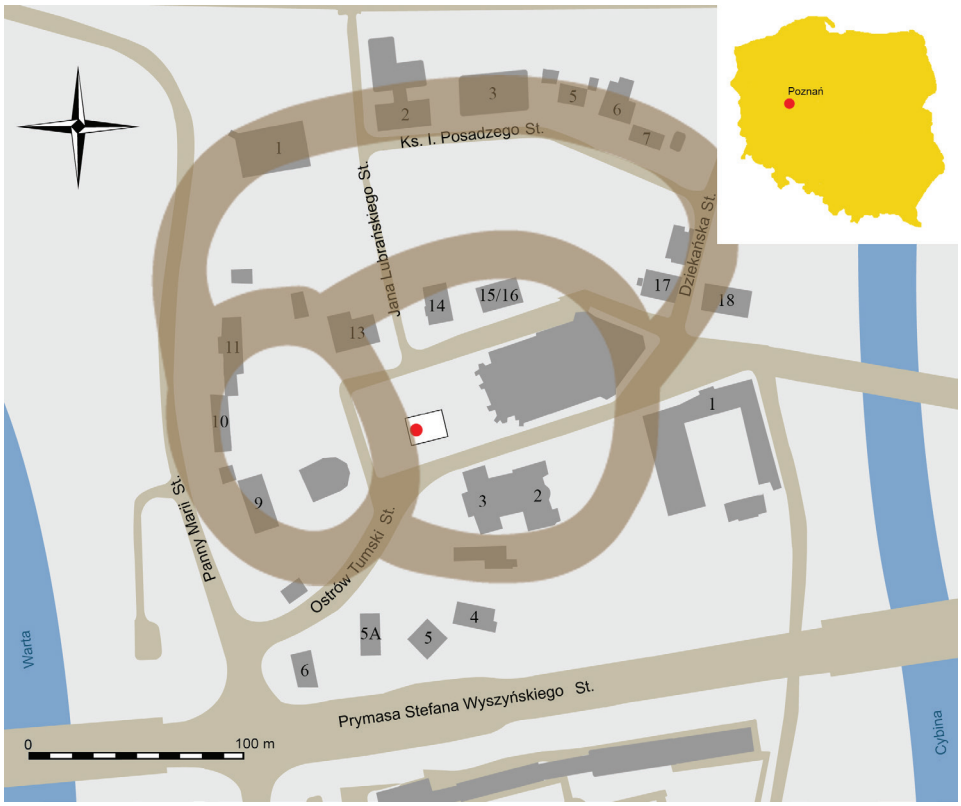

Fig. 1. The location of Ostrów Tumski in Poznań with the find location of the cocoons marked against the backdrop of the outline of the Poznań stronghold (Fig. O. Antowska-Gorączniak)

the nearby fortification wall of the stronghold. According to recent findings, this rampart served as a separation between the princely section and the cathedral section of the stronghold. M. Malinowska proposed that a portion of the organic debris, including wood and some of the cocoons, may have shifted from Layer VI to the bottom of Layer VII. As a result, the cocoons from both layers were collectively analyzed (Malinowska 1974, p. 14-15, Fig. 7, note 39).

Complete and fragmented cocoons, along with other botanical and animal remains including invertebrates and bird egg fragments, were submitted for further analysis to the Paleobotanical Laboratory of the then Institute of the History of Material Culture (currently the Institute of Archaeology and Ethnology, Polish Academy of Sciences). In 1960, two articles were published referring to ‘sensational’ findings regarding these cocoons (Moldenhawer 1960; Klichowska 1960). Melania Klichowska is credited with the taxonomic identification, which she describes in her published work as follows: “One find caught my attention due to its extraordinariness and the

Fig. 2. Cocoons from the studies conducted at Cathedral Square in 1958-1959 (Malinowska 1974). The re-analyzed cocoon is demarked with the red circle

first occurrence in Poland and probably in Central Europe, namely: 12 silkworm cocoons have been preserved" (Klichowska 1960, p. 121). Both Konstanty Moldenhawer and M. Klichowska refer to consultations conducted with Prof. Jan Sokołowski – an '*eminent expert on butterflies*' – to confirm their suspicions.

> Prof. J. Sokołowski, after a thorough examination of the cocoons, concluded that these are the cocoons of true silkworms and come from individuals bred for silk production. This is evidenced by the fact that they have a 'burned' hole from the moth and are not suitable for silk extraction, as the thread has been repeatedly broken in them. Therefore, it is understandable that they were thrown into the trash and, as a result, have survived to our times. (Moldenhawer 1960, p. 111).

It should be emphasized that these findings were based solely on macroscopic analysis, without detailed observations under a microscope.

Moldenhawer also conducted a comparative analysis, comparing a fully preserved cocoon with photographs of cocoons from various '*races of Bombyx mori'*.

According to applied entomology, prolonged breeding of *Bombyx mori*, which now exists only in a domesticated form, has led to the development of three morphologically distinct races: East Asian, West Asian, and European. Currently, in industrial sericulture, inter-racial hybrids are used (Soszka 2002). Based on his photographic comparison, Moldenhawer (1960, p. 115, Fig. 1) suggested that the shape of the silkworm cocoons most closely resemble those from the provinces of Hubei or Henan. Based on this information, both K. Moldenhawer and M. Klichowska hypothesized that not only silkworm breeding, but also silk weaving, could have taken place in early medieval Poznań (Moldenhawer 1960, p. 114-115; Klichowska 1960, pp. 122-123).

In a subsequent publication from 1974, Volume IV of '*Poznań in the Early Middle Ages*', M. Klichowska reiterates this species identification, though expressing a degree of uncertainty: 'Several cocoons, *likely* of the silkworm (Bombyx mori), have been preserved from butterflies (Lepidoptera)' (Klichowska 1974, p. 48, emphasis added by the authors). However, in Table 2 of the study, among the remains from trench II, the cocoons were identified as: 'butterflies (Lepidoptera): silkworm (*Bombyx mori*)'. This study provides more detail on the distribution and archaeological association of the cocoons, providing Layer VII the date of 10th/11th century (n = 2 cocoons) and Layer VI the date of 1st half of the 11th century (n = 10 cocoons) (Klichowska 1974, table 2).

Methods

For comparative analyses with silk textile fragments, a well-preserved cocoon discovered at the Cathedral Square site in Poznań, from the collections of the Paleobotanical Laboratory at the Institute of Archaeology and Ethnology, Polish Academy of Sciences, was provided. Currently on loan, it is exhibited in the permanent display at the archaeological reserve, Genius Loci, on Ostrów Tumski in Poznań. The remaining fragments of cocoons discovered during the research on Cathedral Square, were used for C^{14} dating as part of the NPRH project No. 11H13021682 titled 'Clarification and verification of the chronology and periodization of strongholds of the so-called central monarchies of the early Piasts (Gniezno, Poznań, Giecz) based on accelerator mass spectrometry radiocarbon dating', confirming their early medieval origin. For comparative purposes, the authors acquired contemporary silkworm cocoons of the *Bombyx mori* species from the Institute of Natural Fibers and Medicinal Plants – State Research Institute in Poznań.

In addition to entomological identification, we documented the cocoons with comprehensive photographs using the digital microscope Keyence VHX-7000 and the scanning electron microscope (SEM) Tescan Vega 4 in the ArchaeoMicroLab, at the Faculty of Archaeology, Adam Mickiewicz University.

Results

The early medieval cocoon from Cathedral Square in Poznań significantly differs in dimensions, structure, and microstructure from a modern cocoon of the silkworm species *Bombyx mori.* Larvae of *Bombyx mori* construct their cocoons entirely from a single silk thread, which is solidified with protein compounds. The cocoons discovered during excavations exhibit a completely different structure (Fig. 3). It is instead characteristic of Hymenoptera larvae, which build their cocoons on a framework of silk threads, resulting in thin structures reinforced with various protein compounds and stained with melanin (Szwanwicz 1956). Since the cocoons were found in archaeological layers containing remnants of walls constructed from wood and soil they may be cocoons of parasitic wasps, whose larvae develop within the larvae of large saproxylobiont beetles. Unfortunately, precise identification of the insect-based solely on the cocoon is not possible, as its taxonomic characteristics are unknown.

A Brief History of Silkworms and Silk in Eurasia

Insect larvae can produce silk threads in their silk gland (Szwanwicz 1956, pp. 420-431). Silk threads are used by moths caterpillars to make loose silk tents in which they feed in groups to protect themselves against parasites, including species from the genera: *Yponomeuta*, *Euproctis*, *Eriogaster*, and others. In the last phase of development, larvae of many insects of various orders use silk glands located next to the chewing mouthparts to produce silk threads from which cocoons are created to protect the pupa. Usually, these are small amounts of silk threads that create a cocoon skeleton filled with protein compounds and organic fragments, most often colored with melanin (Szwanwicz 1956, pp. 420-431). The highest quality commercially utilized silk is derived from species of Saturniidae and Bombycidae, particularly from the caterpillars of the silkworm moth (*Bombyx mori*) native to Asia and commonly known as the silkworm. Only a few cocoons produced by moth larvae from the Saturniidae family exhibit sufficient distinctiveness in appearance to allow for species identification based on their morphology.

The credit for the discovery of silk fiber, its utilization in textile production, and the domestication of the silkworm (from *B. mandarina* – the wild precursor of *B. mori*) is bestowed upon the Chinese. The oldest known artifact, a fragment of silk fabric, originates from Southern China (Qianshanyang) and is dated to 3300-2250 BCE (Good 1995, p. 962). Silk, a prized luxury item of the ancient world, served as a traded commodity over extensive distances between China and Europe.

The Chinese tightly guarded the entire process of silk production, and historical records suggest severe consequences for those involved in the export of silkworms, cocoons, larvae, caterpillars, mulberry seeds, and seedlings, or the divulgence of

Fig. 3. Archaeological cocoon (a, b, c, d) and a modern silkworm cocoon (*Bombyx morii*) (e, f, g). Microphotographs taken with a digital microscope (c – magnification 400× and f – magnification 100×); SEM microphotographs (d and g) – magnification 400×
(Fig. A. Kurzawska)

breeding and production technologies, with such acts being punishable by death (Good 1995).

While earlier claims of silk textiles in Europe from the Iron Age have been made (Good 1995), subsequent investigations, notably by Lise Bender Jørgensen (2013), have failed to substantiate these findings. Archaeological revelations now propose that before the domestication of the silkworm (*Bombyx mori*), fibers might have been sourced from various other caterpillar species, contingent upon their distribution in Asia (Lee et al. 2022, Fig. 1).

The first silk fabrics reached southern Europe during the Roman Empire. However, there is no conclusive evidence that this silk was obtained from *Bombyx mori*, and such fabrics are not recorded north of the Alps during that time (Rast-Eicher 2016, p. 278). The Chinese monopoly on the art of silk production through *Bombyx mori* breeding was broken by people of Arab origin and the Byzantines. According to the descriptions of Theophanes and Procopius of Caesarea, around the mid-6th century, two monks were said to have smuggled silkworm eggs into Byzantium in hollowed-out walking sticks (Rast-Eicher 2016, p. 281; Turnau 1987, p. 104). The codex of Emperor Justinian from the 6th century emphasizes that silk production became a state monopoly, with fabrics exclusively manufactured in state workshops (Rast-Eicher 2016, p. 282). During the medieval period, Byzantine silk dyed with purple was particularly valued, but Persians and Arabs were also significant traders of luxurious fabrics. With the Arab conquest of the Iberian Peninsula, silk found its way to Spain. The knowledge of silk fabric production, along with mulberry cultivation and silkworm breeding, was transferred to Sicily in the 12th century during the rule of Roger II, who brought Byzantine weavers to Palermo (Rast-Eicher 2016, p. 283). From there, the silk workshop knowledge spread to southern Italy, in centers such as Lucca, Florence, Bologna, Genoa, Venice, and Spain.

In the late 14th and early 15th centuries, Florence and Venice became important silk centers, where weavers developed a new type of fabric known as velvet. Around 1470, French cities such as Tours, followed by Nîmes, Avignon, and Lyon, began silk production, gaining fame as centers for silk manufacturing and trade. It was only after the Edict of Nantes (late 16th century) that Huguenots, who had to leave the country, transferred silk production skills to Germany and England (Rast-Eicher 2016, p. 283). The widespread cultivation of silkworms and silk production in Central Europe occurred relatively late, in the 17th and 18th centuries (Turnau 1987, pp. 141-145).

Discussion

It is worth tracing the impact of the 1960 findings and how the myth about silkworm breeding and its use in fabric production in the lands of the early Piasts has enduringly persisted in science. Presumably influenced by the conclusions of

Klichowska and the article by Moldenhawer, in 1960, in the popular scientific publication *Najdawniejsze stolice Polski* by Witold Hensel, there is a passage mentioning the inhabitants of the Poznań stronghold engaging in sericulture:

> Perhaps, through Byzantium or Rus, they became acquainted with silkworm breeding. Local weavers, taught by the craftsmen in those regions, locally produced silk threads, and lesser-grade silk fabrics (Hensel 1960, p. 190).

The erroneous identification of cocoons as 'silkworms', hesitantly acknowledged with the term 'likely' by the M. Klichowska, persisted in scientific knowledge for over six decades. Interestingly, in subsequent citations, the word 'likely' was omitted, thereby elevating the '*silkworm*' cocoons of the early medieval stronghold in Poznań to the status of a scientific fact. In the same Volume IV of *Poznań in the Early Middle Ages*, while discussing the stratigraphy of the excavation and the content of the layers, M. Malinowska already omits 'likely' in her description of '*moths of the silkworm species (2 cocoons)*' and the discovery of '*11 cocoons of the silkworm Bombyx mori*' as the most intriguing find (Fig. 2) (Malinowska 1974, p. 14, 16, Fig. 11).

In her interpretation, Malinowska repeats the 1960 theories of K. Moldenhawer and M. Klichowska, asserting that these were cocoons "*from intentional breeding of this moth*." Furthermore, like her predecessors, she justifies local silkworm breeding with a hypothesis about local silk production:

> All the cocoons had openings, indicating that moths emerged from them, and the cocoons themselves, considered useless in this case as the thread is broken, were discarded. These findings contribute significantly to the issue of silkworm breeding in Central Europe. It sheds new light on the discovery of silk fabrics in Opole, Gdańsk, and Wrocław, allowing for a cautious suggestion that some of these fabrics might have been locally produced from indigenous raw materials (Malinowska 1974, p. 16-17).

In subsequent years, archaeologists and researchers specializing in textiles and textile technology have referred to the silkworm cocoons discovered in Poznań. In some instances, there was agreement with the proposition that as early as the 11th century, 'sericulture was practiced in our lands' (Nahlik 1966, pp. 91-92; 1971, pp. 5-11). However, others cited the presence of cocoons in layers from the early medieval period, but approached hypotheses about the production of silk threads in Poznań with considerable caution. They believed that the cocoons merely indicated an unsuccessful attempt at silkworm cultivation and did not shed light on the matter of local sericulture (Maik 1988, pp. 102-103; 1991, p. 69; 1997, p. 173; Antosik, Maik, Rybarczyk, Słomska and Wtorkiewicz-Marosik 2018, p. 898; Pawlak, Pawlak and Sikorski 2019, p. 403). Cocoons of the 'silkworm' were also included in the catalog of all Poznań sites studied until 2006, titled *Archeologia miasta Poznania. Stan badań i materiały* (Kaczmarek 2008, p. 201), ensuring them

a lasting place in the field of scientific inquiry. The assumed importance of this find is further highlighted by the placement of the sole surviving cocoon in the permanent display case of the archaeological reserve *Genius Loci* in the Archaeological Museum on Ostrów Tumski in Poznań.

Silk textiles were undeniably a commodity that originally reached the territory of present-day Poland during the early medieval period through trade routes from the Middle East and Byzantium, facilitated by Scandinavian or Arab merchants via Kievan Rus. The exchange of goods in the Baltic Sea region by the Scandinavians could have also contributed to the supply of these products (Moldenhawer 1960, p. 114; Maik 1988, pp. 171-172; 1991, p. 69; Grupa 2009, p. 273). Other directions, such as Italy or Spain, cannot be excluded. The oldest examples include fragments of silk fabrics from Wolin, discovered in layers dating back to the 9th-10th centuries (Maik 1988, p. 171; 1997, p. 174). In sites dating from the 10th to 11th centuries, fragments of silk textiles and ribbons made in the samitum technique were noted, for example, in Opole (4th quarter of the 10th century – 4th quarter of the 12th century – Maik 1991, pp. 20-60), Gdańsk (10th-13th centuries – Kamińska, Nahlik 1958, pp. 106-111), Kałdus (Grupa 2007), Gruczno (Grupa 2009), and Poznań (late 10th – mid-11th century – Pawlak, Pawlak and Sikorski 2019, pp. 402-403). Between the 12th and 13th centuries, silks from Western and Southern Europe, including Spain, Sicily, and Italy, also made their way to the Piast lands (Maik 1997, p. 173).

In historical sources, the first mentions of silkworm breeding and silk fabric production (*Officina Brodensis bombycina*) emerge in Zyznowski's[1] panegiryc from 1659, specifically concerning the city of Brody in Podolia (Zyznowski 1659; Przezdziecki[2] 1891). By the 18th century, the first Polish book on silk production, authored by Jan Ferdynand Tym and titled *Practice of Making Silk*, was published in Kwidzyn. During this period, silk production was primarily centered in Polish manors, with cocoons being dispatched to Vienna or Lyon for further processing. Some manors even undertook the reworking of cocoons themselves. In a relatively short span, the opulent robes of the Radziwill brothers from Sluck, the weaving mill established in Grodno by Polish king Stanisław August Poniatowski, the weaving mills of Count Tyzenhan, and silk-adorned materials gained widespread recog-

[1] The surname "Zyznowski" was used based on the original version of the old print panegyric: *Cursus Gloriae, Fllustrissimi et Excellentissimi Domini D. Alexandri in Koniecpole Koniecpolski, Palatini Sendomiriensis, S.R. Imperii Principis, Pereasłauinenis, Koszuneń, Kaniouień, Dolineń. Praefecti. Ad posthumam memoriam, Panegyrico adumbratus et Inter lugubres Exequias, ad feralem urnam. VIII. Calend. Decembr. Anno Dńi, M. DC.LIX. In Ecclesia Brodensi, luci publicae exhibitus. Operâ M. Stanislai Zyznowski. Philozophiae Doctoris et Proffesoris, Almae Academiae Cracouiensis. Cracoviae, Apud Viduam et Haeredes Chrstophori Schedel, S.R. M. Typhografum. Anno Dńi, 1659.* In publications, the term "Żyznowski" is often encountered (e.g. Rychlewska 1966, p. 473).

[2] The surname "Przezdziecki" was used based on the publication from 1891; in other publications, the spelling "Przeździecki" is encountered (e.g. Kamińska and Turnau 1966, p. 623).

nition throughout Poland and beyond (Rychlewska 1966; Łochyńska 2010; Grześkowiak and Łochyńska 2021, p. 12, and references therein).

The breeding of silkworms in Poland is contradicted by the lack of a readily available source of their food, namely mulberry leaves. There are no documented findings of white mulberry trees during the reign of the early Piasts. The introduction of this species occurred much later in the 2nd half of the 17th century, eliminating the possibility of sericulture in the early medieval period making the hypothesis that sericulture was developed in Poznań highly improbable.

The discovery of 11th-century 'silkworm' cocoons would imply their cultivation (and the presence of mulberry) in areas decidedly peripheral to influences likely emanating from Byzantium. Furthermore, if this was the case, it is surprising that such crucial information and technologies were not recorded in written sources or iconography. The existence of several cocoons found in just one location at a single archaeological site in Poland appears implausible, even for cautiously envisioning the production of silk in the domain of the early Piasts.

In the 1960s, Polish archaeology witnessed significant scientific advancements, particularly in the extensive integration of natural sciences for examining organic remnants at archaeological sites. Concerning cocoon discoveries, a probable lack of entomological consultation and communication between archaeologists and naturalists is noted. This absence contributed to the suppositions regarding identification published by M. Klichowska and K. Moldenhower (unfortunately confirmed by Prof. Sokołowski) along with an overinterpretation concerning silkworm breeding and the alleged involvement of the settlement's inhabitants in sericulture. These assumptions became a scientific fact utilized for years in archaeological interpretations.

The information mentioned by M. Klichowska (1960) and K. Moldehawer (1960), reiterated by M. Malinowska (1974), regarding holes in the cocoons (Fig. 3) indicating the emergence of insects (imagines), considering their shape and location, is an overinterpretation. We believe that these are mechanical damages that occurred post-pupal stage. Insects whose larvae secure their pupae by constructing a cocoon, anticipate the necessity of its exit by the imago. Frequently, the larva weakens a portion of the cocoon during its construction, which is later removed by the emerging imago. Hymenoptera from the genus *Diprion* belong to this group. Most insect imagines use various enzymes secreted from the digestive tract to break through the cocoons in which they are located, causing the deterioration of silk threads and the dissolution of reinforcing proteins (Soszka 2002).

In entomological samples from archaeological sites, the most commonly found insects are representatives of beetles (Coleoptera) and flies (Diptera), along with traces of their life activities, such as larval feeding sites in wood (Jach et al. 2018, Kadej et al. 2021). Remains of other insects are very rare findings. Hence, the discovery of several Hymenoptera (likely parasitic wasp) cocoons and their fragments constitutes a somewhat unique discovery, albeit not isolated. Fragments of

very similar cocoons (also Hymenoptera) were unearthed in early medieval layers at sites 2 and 4 in Kruszwica (Bąkowski 2023).

Conclusions

The development and spread of silkworm breeding and silk production are crucial for understanding global trade contacts and cultural connections. Silk, being a luxurious and valuable fabric, was a desirable export commodity, and both China and Byzantium guarded the process of its production. Therefore, the emergence of silk fabrics in the Polish territories holds significance for research on trade relations with often distant areas, revealing the growing importance of the Piast elites and their economic capabilities. Our revised identification of the cocoons makes it evident that silk fabrics exclusively made their way to the present-day Polish territories as imports, starting as early as the 9th to 10th centuries. Notably, there was no silkworm cultivation, let alone silk production, in the 11th century within the Poznań stronghold. Nevertheless, the identification of a Hymenoptera cocoon stands out as a particularly noteworthy discovery, given the rarity of such findings. Its association with remnants of the rampart and the larval feeding environment adds significance. The re-examination of the cocoon allowed for the (in) validation of earlier conclusions using contemporary analytical methods. As a fundamental proposition, we underscore the critical importance of consistently challenging and updating our knowledge within the scientific domain.

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Authors' Contributions: The authors confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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