Abhandlung

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Raw material preferences within ornament production in the Late Neolithic amber workshops of Żuławy Wiślane in Northern Poland

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Zusammenfassung: Im 3. Jahrtausend v. Chr. verbreitete sich Bernsteinschmuck in ganz Mitteleuropa. Im Einzugsgebiet der Flüsse Weichsel und Oder sind derartige Artefakte aus fünf spätneolithischen archäologischen Kultureinheiten bekannt (Kugelamphorenkultur, Złota-Kultur, Rzucewo-Kultur, Schnurkeramikkultur und Glockenbecherkultur). Bernsteinobjekte wurden einerseits aus Gräbern der oben genannten archäologischen Kultureinheiten und in deutlich geringerem Umfang als kontextlose Zufallsfunde geborgen. In beiden Fällen handelt es sich um fertigen Schmuck. Andererseits wurden sie auch aus Bernsteinwerkstätten an der südöstlichen Ostseeküste, vor allem aus Żuławy Wiślane, als in verschiedenen Verarbeitungsstadien aufgegebene Gegenstände sowie als Abfall aus deren Herstellung geborgen. Der in Gräbern und als Zufallsfunde gefundene Bernsteinschmuck ist stark verwittert und daher nicht geeignet, die Eigenschaften des Rohmaterials zu bestimmen, aus dem er hergestellt wurde. Nur Artefakte aus Bernsteinwerkstätten in Żuławy Wiślane sind aufgrund der Umgebung, in der sie gefunden wurden, in einem so guten Zustand, dass eine vollständige Identifizierung des Rohmaterials und damit eine Untersuchung der Rohmaterialpräferenzen ihrer spätneolithischen Hersteller möglich ist. Dieser Artikel berichtet über die Ergebnisse der Rohmaterialanalyse, die an Proben aus Bernsteinwerkstätten durchgeführt wurde, die in der Nähe des Dorfes Niedźwiedziówka in Żuławy Wiślane entdeckt wurden. Untersuchungen haben ergeben, dass ein Rohstoff mit gleichmäßiger Struktur in den Farbtönen Gelb, Opak und gemischt mit einem kleinen Anteil Transparent bevorzugt wird.

Schlüsselworte: Bernsteinwerkstätten, Żuławy Wiślane, Spätneolithikum, Schmuck und Bernsteinrohstoff, Nordpolen, Mitteleuropa

Abstract: In the 3rd millennium BC, amber ornaments became widespread across Central Europe. In the basin of the Vistula and Oder rivers, such artefacts are known from five Late Neolithic archaeological cultural units (the Globular Amphora Culture, the Złota Culture, the Rzucewo Culture, the Corded Ware Culture and Bell Beaker Culture). Amber objects have been recovered, on the one hand, from both the graves of the aforementioned archaeological cultural units and, to a much lesser extent, as contextless chance finds. In both cases, they are found as finished ornaments. On the other hand, they also have been recovered from amber workshops on the south-eastern Baltic coast, mainly from Żuławy Wiślane, as items abandoned at various stages of processing as well as waste from their manufacture. The amber ornaments found in graves and as chance finds are heavily weathered, and thus not suitable for determining the characteristics of the raw material from which they were made. Only artefacts from amber-processing workshops in Żuławy Wiślane are in an excellent enough condition, due to the environment in which they were found, to allow full raw material identification, and thus enable an examination of the raw material preferences of their Late Neolithic makers. This paper reports the results of the raw material analysis conducted on samples from amber workshops discovered near the village of Niedźwiedziówka located in the region of Żuławy Wiślane. The research has revealed that an amber raw material with a uniform structure, in shades of yellow, opaque and mixed with a small proportion of transparent variety was preferred.

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Keywords: Amber workshops, Żuławy Wiślane, Late Neolithic, ornaments and raw amber material, northern Poland, Central Europe

Abstrakt: W 3 tys. BC w Europie Środkowej doszło do upowszechnienia ozdób bursztynowych. W dorzeczu Wisły i Odry takie artefakty znane są z pięciu późnoneolitycznych kultur (kultura amfor kulistych, kultura złocka, kultura rzucewska, kultura ceramiki sznurowej i kultura pucharów dzwonowatych). Wyroby bursztynowe tego rodzaju pochodzą z jednej strony z grobów wymienionych jednostek archeologicznych i w znacznie mniejszym stopniu z pozbawionych kontekstu znalezisk luźnych. W obu przypadkach są to gotowe ozdoby. Z drugiej strony pochodzą one z pracowni bursztyniarskich nad południowo-wschodnim pobrzeżem Bałtyku, głównie jednak z Żuław Wiślanych i są to przedmioty porzucone na różnych etapach obróbki oraz odpady z ich wytwarzania. Zarówno ozdoby bursztynowe znalezione w grobach, jak i te pozbawione kontekstu są silnie zwietrzałe i tym samym niezdatne do określenia odmian surowca z jakiego je wykonano. Jedynie przedmioty pochodzące z pracowni obróbki bursztynu na Żuławach Wiślanych są w doskonałym stanie ze względu na środowisko, w jakim przebywały i tym samym umożliwiają pełną identyfikację surowcową i określenie preferencji surowcowych, jakimi kierowali się ich późnoneolityczni wytwórcy. Prezentowany tekst przedstawia wyniki analizy surowcowej dokonanej na podstawie materiałów pochodzących z pracowni bursztyniarskich odkrytych w okolicy wsi Niedźwiedziówka na Żuławach Wiślanych. Badania ujawniły, że preferowano surowiec o jednolitej strukturze, w odcieniach barwy żółtej, nieprzezroczysty i mieszany z niewielkim udziałem przezroczystego.

Słowa kluczowe: Pracownie bursztyniarskie, Żuławy Wiślane, późny neolit, ozdoby i surowiec bursztynowy, północna Polska, Europa Środkowa

Introduction

Baltic amber, also known as succinite, is a fossil resin that is highly non-standardised as a material. It comes in different varieties, ranging in colour from red to various shades of yellow and orange, to white. Additionally, it exhibits considerable variation in transparency, the presence of air bubbles, and its structural composition. Both in historical times and today, these natural variations within Baltic amber, expressed through formal characteristics such as transparency[1], colour, and internal structure, has always been of paramount importance for determining the very value of the raw material and, consequently, of items made from it. Its classification in terms of quality is related to two basic factors: structure and current aesthetic preferences[2]. The first is timeless, as the degree of uniformity within the structure of the raw material has a direct impact on its processing, which encompasses the splitting of primary nodules, the shaping of forms, drilling, and finally the finishing of the surface. Thus, layered and cracked amber is usually perceived as unsuitable for ornament production, as it could laminate or disintegrate during manufacture. The second factor influencing the choice of raw material is aesthetic considerations, which formally include colour and degree of transparency. These considerations are, however, changeable, as they are related to the aesthetic preferences prevailing in the particular period.

For archaeological amber, identifying the factors influencing these raw material preferences is particularly challenging, as amber – being a delicate material – undergoes various weathering processes that may alter its appearance. Another issue is the nature of amber finds in the Baltic region, which only begin to appear in larger quantities from the 4th millennium BC and become more widespread in the 3rd millennium BC, especially as the so-called reproducible amber ornaments (which may have even been related to mass production processes). This is best demonstrated on the south-eastern shores of the Baltic Sea, where numerous artefacts of this type have been found, mainly associated with five archaeological cultural units (Fig. 1). These were the Globular Amphora Culture (GAC), Złota Culture (ZC), and Rzucewo Culture (RC), as well as, to a lesser extent, the Corded Ware Culture (CWC) and the communities associated with the Bell Beaker phenomenon (BB)[3]. However, the clearest evidence of the growing interest in amber ornaments is the amber workshops associated with the RC themselves, the remains of which are located in the deltaic zone of the Vistula River mouth (*Żuławy Wiślane*), as well as the cemeteries of the ZC population, which contain burials rich in amber artefacts, situated in the vicinity of Sandomierz in the upper reaches of the Vistula River.[4].

At this point, it should be also mentioned that the preserved finds of amber items from the 3rd millennium BC in the Vistula basin area, associated with the GAC, CWC, and BB, are characterised by a high degree of stylistic and technological similarity with the workshop materials from

1 In regard to the air bubbles contamination.

2 Leciejewicz 2005, 5–7; Kosmowska-Ceranowicz 2012, 70–81.

3 Wiślański 1979, 261–265; 288–290; Machnik 1979, 339–343; 366–368; 375; 379; 389–390; Mazurowski 1983; Budziszewski/Włodarczak 2010; Manasterski *et al.* 2020.

4 Machnik 1979, 366–392; Mazurowski 2014, 33–37.

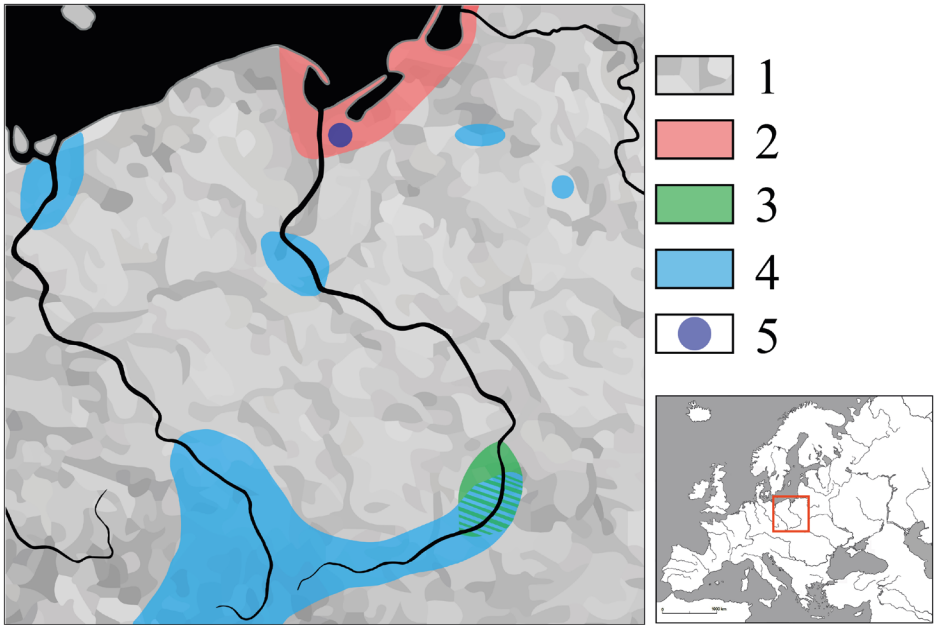

Fig. 1: Study area. Archaeological cultural units from the 3rd millennium BC: 1 – Globular Amphora Culture and Corded Ware Culture; 2 – Rzucewo Culture; 3 – Złota Culture; 4 – communities associated with the Bell Beaker phenomenon, and 5 – amber workshops near the village of Niedźwiedziówka in Żuławy Wiślane (acc. Kempisty 1989, Fig. 14; Kaczanowski/Kozłowski 1998, Figs. 51; 55; Manasterski *et al.* 2022a, Fig. 1; Manasterski *et al*. 2022b, Fig. 1).

Żuławy Wiślane[5]. The area thus outlined is dominated by tubular beads and buttons with a V-shaped perforation and, to a lesser extent, by pendants, cylindrical and double-ax-shaped beads, tetragonal and oval plates, disks, rings, and separators (Fig. 2)[6].

Interestingly, only the RC finds of amber artefacts came from settlement contexts, whereas within the other cultural units they were recovered almost exclusively from graves[7]. Also associated with the RC are settlement sites with reported amber workshops, concentrated in the vicinity of the village of Niedźwiedziówka. This is located in the extensive former Vistula delta in Żuławy Wiślane (also known as the Vistula Fens), where, under layers of arable soil, peat, and gyttja, there is a primary beach of the Vistula Lagoon, in the sand of which are lumps of Baltic amber (succinite) of various sizes[8]. The population to whom the remnants of these workshops relate were involved in the extraction of succinite, its processing, and the production of ornaments[9]. They most likely also distributed finished artefacts, their semi-finished products, and the raw material itself. This seems to be evidenced by the finds of amber nodules collected within the workshops, cut into standardized plates, as well as raw specimens with visible flake scars verifying the quality of the raw material[10]. All of the amber artefacts and ecofacts were mainly discovered in one sedimentary level, currently located 2 m below sea level, comprising the boundary between the bottom of the crumbled peat and the top of the moderately decomposed, often silted peat[11]. Given that the degradation of amber is influenced by multiple post-depositional factors, which include oxidation, temperature, and exposure to natural light or various acidity (pH) conditions that accelerate the destruction process[12], the context in which these artefacts have resided for over 4,000 years has contributed to their excellent preservation.

Both the post-depositional anaerobic environment and proper storage after the extraction of these artefacts[13] enable their technological and typological identification, related to the production process and determination of

5 Ibid.
6 Mazurowski 1983; 1985; 2014.
7 Mazurowski 1983; 2014.
8 Kondracki 2022, 64–66; Mazurowski 2014.
9 Machnik 1979, 374–375.
10 Mazurowski 2006.
11 Mazurowski 2014, 54.
12 Shashoua *et al.* 2006, 1225; Pastorelli *et al.* 2012, 269; Pastorelli *et al.* 2013, 2320.
13 Storage should be maintained in stable conditions, preferably in containers filled with saline water. If this is not possible, the humidity within the containers should be kept above 50 %, with a temperature of around 18 °C, and in complete darkness (it must not be exposed to daylight). Viewing or exhibition, on the other hand, should take place under so-called cold light, such as LED bulbs.

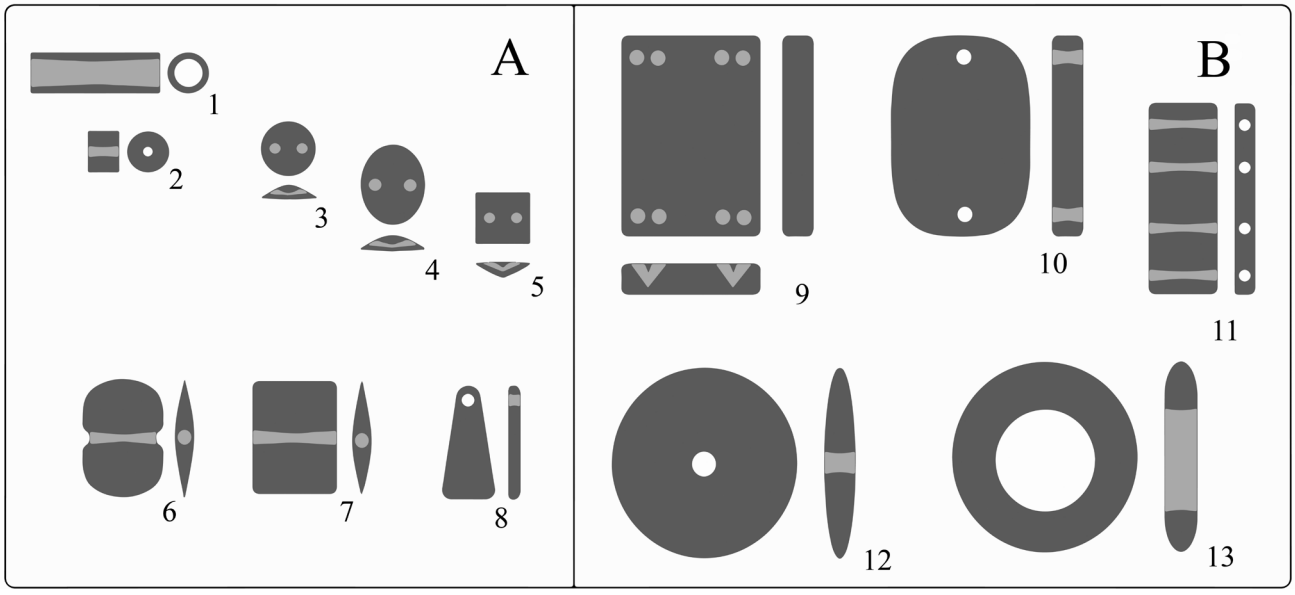

Fig. 2: Types of amber ornaments from the 3rd millennium BC from the area of the Vistula and Odra basins (according to R. F. Mazurowski 1983). A – ornaments unequivocally identified in the material from the workshops in Żuławy Wiślane: 1 – tubular beads, 2 – cylindrical beads, 3–5 – buttons with a V-shaped perforation, 6–7 – double-ax-shaped beads, 8 – pendants; B – ornaments not clearly identifiable in the materials from the workshops in the Żuławy Wiślane: 9–10 – tetragonal and oval plates with V-shaped and frontal perforations, 11 – separators, 12 – disks with central perforations, 13 – rings.

amber varieties. Artefacts preserved in this way constitute the basis for analyses aimed at determining quality preferences in the selection of amber raw material for their production. Therefore, the features of the amber raw material were analyzed, mainly related to its quality, which may have been important in the production of specific forms of jewellery. Finally, specific choices made by the Late Neolithic amber ornament makers in Żuławy Wiślane were identified, which may reflect a technological validation system crucial for selecting the proper raw material.

Materials and Methods

The amber artefacts selected for analysis from Late Neolithic workshops in Żuławy Wiślane have been provided for the study with courtesy of the Polish Academy of Sciences Museum of the Earth in Warsaw. The total of 1024 specimens include damaged ornaments at various stages of their manufacture and approximately 892g of small waste associated with their processing. Chemical investigation previously carried out on this artefact assemblage revealed that they were made from Baltic amber, also known as succinite[14]. From this collection, a group of 483 pieces was selected for subsequent study. These were exclusively items that had been rejected before the final processing stage of precise grinding and polishing, due to damage caused during the most difficult manufacturing phase, which was drilling the perforation (Fig. 3).

Otherwise, if no such damage had occurred, they would have been finished in the intended manner to achieve their planned appearance, after which they would have been taken out of the workshop and put into use. This selection criterion, based upon our current understanding of the production sequence for these amber objects, enabled the study of ornaments exhibiting the definite preferred appearance for this period, crafted according to a well-defined rationale (know-why) and standardised techniques (know-how). In particular, it allowed the examination of items where the choice of raw material characteristics could have been driven by the aim of producing high-quality desirable products, influenced by the specific preferences of the time.

For the remaining 541 specimens, it was not possible to be absolutely certain whether they reflected these preferences, as such specimens may have been rejected during initial processing, when the maker usually examines the raw material, verifying its properties and testing its endurance, to spot any 'flaws' that may cause adverse consequences during subsequent manufacture.

The selected artefacts were subjected to typological and technological analyses according to the systematics of

14 Manasterski *et al.* 2022b.

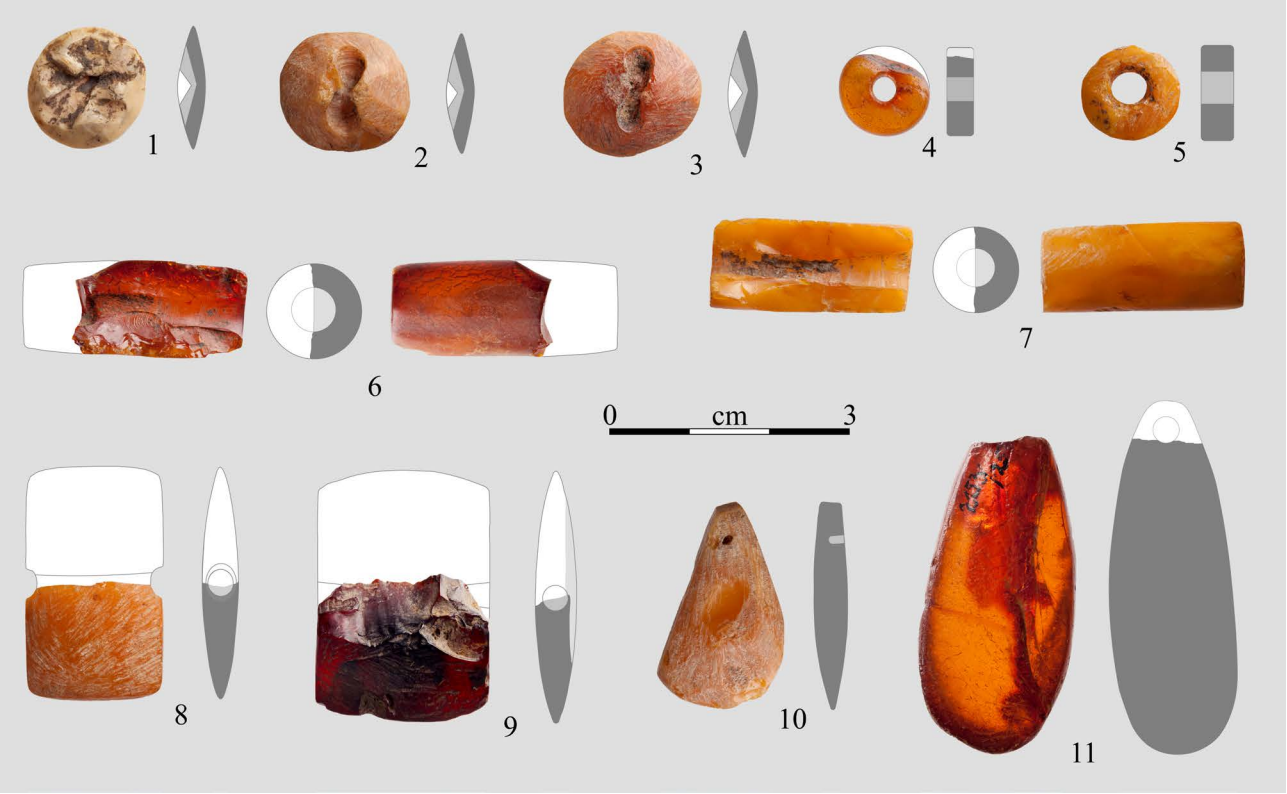

Fig. 3: Examples of damaged forms of amber ornaments from the workshops in Żuławy Wiślane from the collection of the Polish Academy of Sciences Museum of the Earth. 1–3 – nodular beads with a V-shaped perforation (1 – uniform mass of amber, opaque, shades of white; 2 – uniform mass of amber, opaque, shades of yellow; 3 – uniform mass of amber, mixed transparency, shades of yellow and red); 4–5 – cylindrical beads (4 – uniform mass of amber, transparent, shades of yellow; 5 – uniform mass of amber, opaque, shades of yellow); 6–7 – tubular beads (6 – uniform mass of amber, transparent, shades of red; 7 – uniform mass of amber, mixed transparency, shades of yellow); 8–9 – double-ax-shaped beads (8 – uniform mass of amber, opaque, shades of yellow; 9 – uniform mass of amber, mixed transparency, shades of red); 10–11 – pendants (10 – uniform mass of amber, opaque, shades of yellow; 11 – uniform mass of amber, transparent, shades of red) (photo: M. Bogacki).

Ryszard F. Mazurowski and Katarzyna Kwiatkowska[15], and subsequently examined in terms of their raw material characteristics based on the range of variation distinguishable within Baltic amber according to Krystyna Leciejewicz's[16] classification scheme (see Fig. 4). The following attributes were chosen for analysis from the range available, based on those that could have been taken into account by past manufacturers and thus plausibly guided the selection of raw material for ornament production: the degree of transparency, colour, and the uniformity of its mass[17]. However, it should be noted that certain difficulties prevent an unambiguous classification of amber items because amber is not a homogeneous material and, moreover, it is often subject to varying degrees of weathering, which is of particular relevance for archaeological finds[18]. Furthermore, the classification divisions proposed by Leciejewicz were too detailed for this study, as they were developed for contemporary jewellery purposes[19]. Accordingly, to analyze these archaeological artefacts, the categories were blurred into generalised ranges. Thus, the following classification scheme was adopted:

1. in terms of uniformity of the raw material mass:
   a) uniform – Fig. 4,1.5–9;
   b) layered – Fig. 4,2;
   c) cracked – Fig. 4,3;
   d) with inclusions – Fig. 4,4;
2. in terms of degree of transparency:
   a) transparent – Fig. 4,4.9;
   b) opaque – Fig. 4,2–3.5–7;
   c) mixed – Fig. 4,1.3.8;

15 Mazurowski 1983; 1985; Kwiatkowska 1996.
16 Leciejewicz 2005, 5–12.
17 Kosmowska-Ceranowicz 2012, 70–81.
18 Żurawlow 2010, 217; Kvyatkovskaya/Manasterskiy 2019.
19 Leciejewicz 2005.

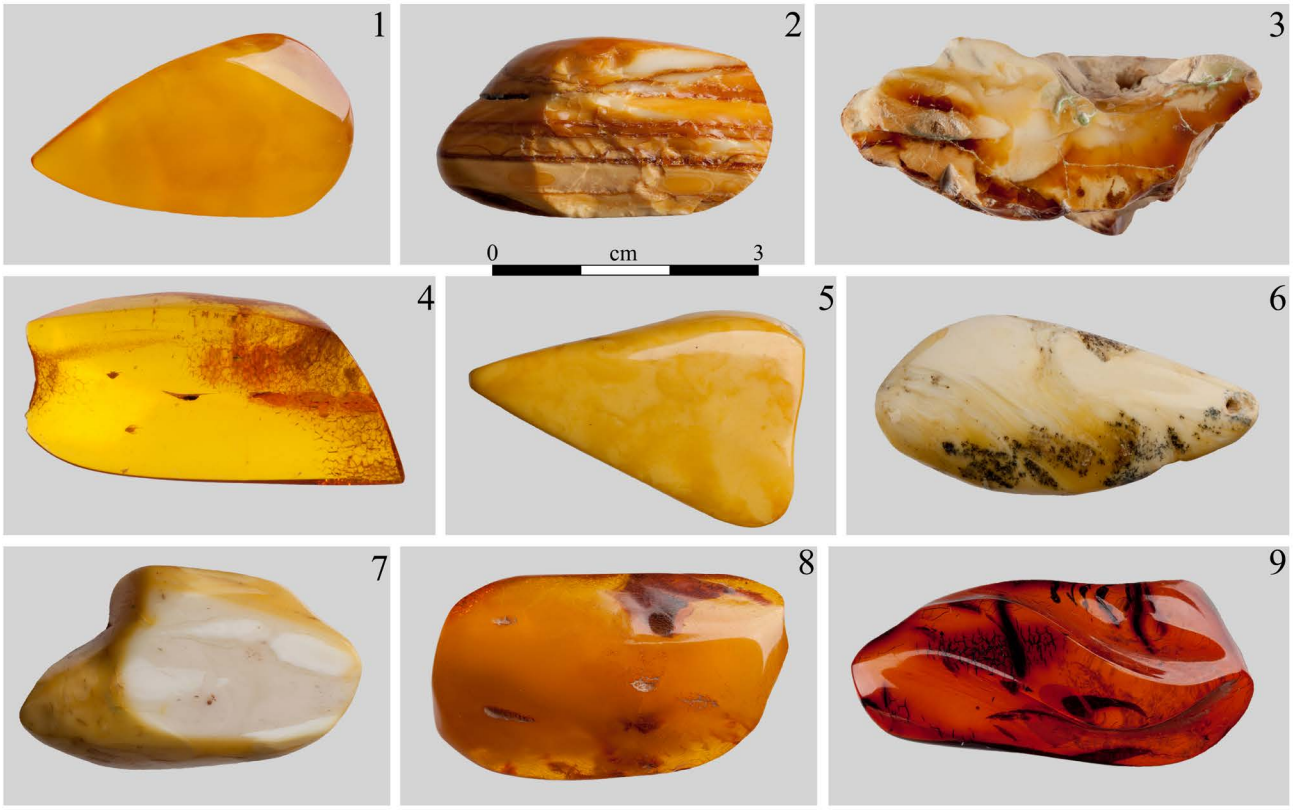

Fig. 4: Selected examples of Baltic amber from the collection of the Polish Academy of Sciences Museum of the Earth in Warsaw distinguished according to the systematics of K. Leciejewicz 2005. 1 – amber of uniform mass, mixed transparency, shades of yellow, 2 – layered amber, opaque, shades of white and yellow, 3 – cracked amber, opaque, mixed transparency, shades of white and yellow, 4 – amber with inclusions (Diptera), transparent, shades of yellow, 5 – amber of uniform mass, opaque, shades of yellow, 6 – amber of uniform mass, but superficial small inclusions of "earth", opaque, shades of white with a small addition of yellow, 7 – amber of uniform mass, opaque, shades of white, 8 – amber of uniform mass, mixed transparency, shades of yellow, 9 – amber of uniform mass, clarified, cherry-coloured, obtained by annealing in sand (semi-finished brooch from the 1950s made in the State Factory of Amber Products, Gdańsk, Poland); (photo: M. Bogacki).

3. in terms of colour:
   a) shades of white – Fig. 4,6–7;
   b) shades of yellow – Fig. 4,1.4–5.8;
   c) shades of red – Fig. 4,9.

Identification of the varieties of the raw amber used in regard of the uniformity of the raw material mass, the degree of transparency and in terms of colour was established on the basis of macroscopic analysis, while the uniformity of mass was analyzed through the illumination of individual artefacts with a blue light from a focused beam using an OPTA-TECH STX 12 microscope.

It was intended that the results would be compared with published data on GAC, CWC and ZC ornaments, collected from archaeological studies in Poland of mainly funerary contexts[20].

However, it was impossible to verify the original colour, transparency, and uniformity of the amber used to make them due to severe weathering, as well as the conservation methods used[21].

Results

As discussed above, the overall condition of the artefacts was good, in some cases even excellent, which enabled a thorough typological and technological analysis to be conducted on every specimen within the study group. On a few specimens slight darkening ("sooting") was noted (Fig. 3,6; Fig. 5).

The selected artefact collection consisted of 231 tubular beads, 187 nodular beads, 32 pendants, 20 cylindrical beads,

20 See Mazurowski 1983, 115–122.

21 See Żurawlow 2010.

Fig. 5: Two ornaments with traces of sooting (photo: M. Bogacki).

and 13 double-ax-shaped beads (Fig. 2A). The remaining forms, i.e. oval and rectangular plates, disks, rings, and separators, could not be clearly identified (Fig. 2B). This may be related to the fact that, in their final form, these ornaments were relatively large, as confirmed by the grave finds, and therefore could have been divided and reworked into smaller typologically different ornaments after being damaged during manufacture in the workshop. Consideration must also be given to the fact that the RC population may have 'exported' relatively large semi-finished products, from which purchasers/makers associated with other archaeological cultures may have produced at home some of the ornaments that have been discovered in graves or as chance finds. The manufacture of the objects under study all followed the *chaîne opératoire* described by R. F. Mazurowski in 2014 with later additions[22]. This included a pre-treatment stage, consisting of shaping using chipping and scraping techniques, as well as the so-called coarse, angular grinding. The items were abandoned at the perforation drilling stage due to accidental damage.

The macroscopic analyses (Tab. 1, Figs 6–8) showed that the vast majority of the amber ornaments analyzed were made of internally uniform raw material (474 specimens – 98.14 %), which was not layered and had no inclusions. However, a small proportion of specimens with visible fine cracks (9 specimens – 1.86 %) was noted. For the objects made of uniform raw material, it should be emphasised that, in terms of transparency, the collection was almost equally divided: roughly half of the specimens were opaque (227 specimens – 47.00 %) and mixed (210 specimens – 43.48 %) with a small share of transparency (46 specimens – 9.25 %). Shades of yellow amber predominates by far (452 specimens – 93.58 %), with a small proportion of shades of red amber (29 specimens – 6.00 %) and just a couple of examples in shades of white amber (2 specimens – 0.41 %). Interestingly, these proportions are generally applicable across all the individual artefact classes (Tab. 1). It should be observed that the two white amber products are both nodular beads.

Discussion

As already mentioned, amber is an inherently non-homogeneous material, displaying significant differences in colour, transparency and structure. Thus, the research into the

22 Mazurowski 2014, 231–250; Manasterski *et al.* 2022b.

Tab. 1: Characteristics of the raw material of the analyzed amber ornaments.

Characteristics of the amber raw material		Type of ornaments				
		Tubular beads	**Nodular beads with a V-shaped perforations**	**Double-ax-shaped beads**	**Cylindrical beads**	**Pendants**
Uniformity of the raw material mass	uniform	224 (96.97 %)	186 (99.47 %)	13 (100 %)	20 (100 %)	31 (96.88 %)
	layered	0	0	0	0	0
	cracked	7 (3.03 %)	1 (0.53 %)	0	0	1 (3.12 %)
	with inclusions	0	0	0	0	0
Degree of transparency	transparent	25 (10.82 %)	5 (2.68 %)	1 (7.69 %)	6 (30 %)	9 (28.13 %)
	opaque	109 (47.19 %)	91 (48.66 %)	7 (53.85 %)	6 (30 %)	14 (43.74 %)
	mixed	97 (41.99 %)	91 (48.66 %)	5 (38.46 %)	8 (40 %)	9 (28.13 %)
Colour	shades of white	0	2 (1.07 %)	0	0	0
	shades of yellow	214 (93.94 %)	178 (95.18 %)	11 (84.62 %)	18 (90.00 %)	31 (96.88 %)
	shades of red	17 (6.06 %)	7 (3.74 %)	2 (15.38 %)	2 (10 %)	1 (3.12 %)
Total number of items – 483:		**231** (100 %)	**187** (100 %)	**13** (100 %)	**20** (100 %)	**32** (100 %)

selection preferences for different varieties of amber often presents significant challenges. This is further complicated by the lack of wider statistical analyses on the prevalence of specific amber types. However, even based on observations alone, it is evident that along the south-eastern coast of the Baltic Sea uniform amber nodules with solid transparency and colour are exceptionally rare. Insights on this topic can be found in the works of Krystyna Leciejewicz and Barbara Kosmowska-Ceranowicz.[23]

Contemporary amber specialists[24] also note that Baltic amber from the Gulf of Gdańsk region is predominantly mixed, meaning a single nodule often contains both transparent and opaque material in various shades of yellow. Occasionally, different hues of white or reddish amber can be found within the same piece, along with so-called "earthy" amber, which contains numerous natural impurities. As a result, amber nodules typically exhibit internal variation rather than uniformity.

Given this natural diversity, archaeological artefacts made from seemingly homogeneous amber may suggest that, during various stages of processing – from the initial assessment of raw nodules through test strikes, division into smaller pieces, and the removal of unwanted fragments – certain varieties and colours of amber were intentionally discarded. This selection process was likely guided by predefined criteria or driven by material defects such as internal fractures, natural impurities, or structural inconsistencies, which could cause breakage during drilling, particularly at the boundaries between different amber layers.

Patterns of such processes have been identified in material from the Late Neolithic amber workshops in the Żuławy Wiślane region, particularly during the initial selection phase of this study. The largest group of artefacts consisted of discarded pieces, damaged forms, and unfinished objects. Additionally, "training materials" – remnants

23 Leciejewicz 2005, Kosmowska-Ceranowicz 2012

24 Outcomes of verbal communication with geologists, chemists, and amber craftsmen (jewellers specialising in amber processing).

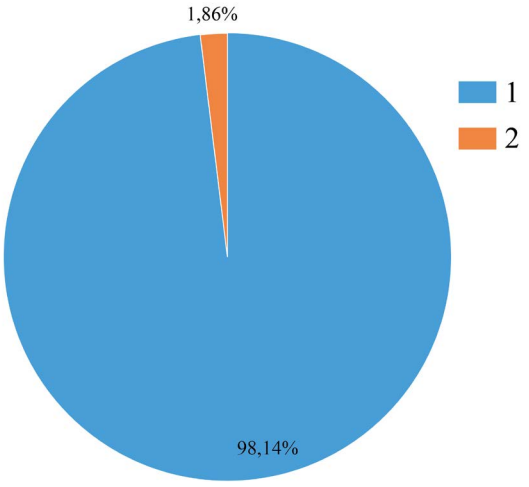

Fig. 6: Uniformity of the mass of the raw amber material among the analyzed ornaments: 1 – uniform, 2 – cracked.

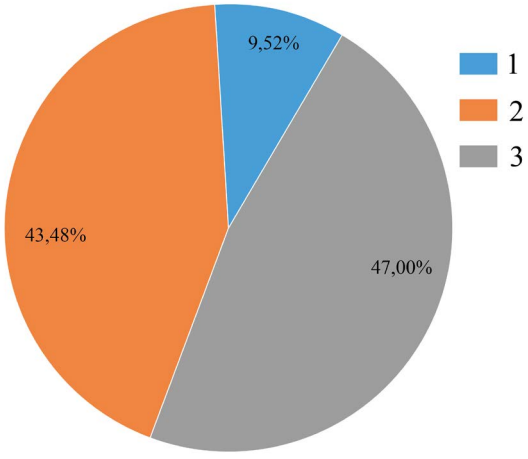

Fig. 7: Transparency of the raw amber material among the analyzed ornaments: 1 – transparent, 2 – opaque, 3 – mixed.

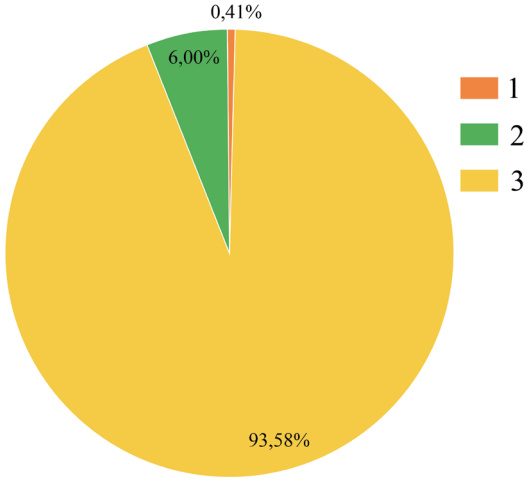

Fig. 8: Colour of the amber raw material among the analyzed ornaments: 1 – shades of white, 2 – shades of yellow, 3 – shades of red.

of skill-development exercises – also were recognised. However, the most reliable method for identifying actual raw material preferences – reflecting intentional choices made by amber artisans – is through the study of finished or semi-finished forms, the latter of which are discussed in detail below.

The technological and raw material analyses of a selection of amber ornaments have demonstrated the existence of patterns related to the choice of quality, colour and transparency of the raw material from which they were made. The vast majority of the amber ornaments analyzed were made of internally uniform raw material (98.14 %), in terms of transparency, the collection was almost equally divided to opaque (47.00 %) and mixed (43.48 %), and in colour the shades of yellow amber predominated (93.58 %). These indicate that communities living in the 3rd millennium BC, just like contemporary ones, were not indifferent to the aforementioned characteristics.

The makers, and presumably also the users, of these ornaments preferred particular degrees of transparency and colours for the raw amber, and rejected pieces without a uniform structure (due to layering, cracks, inclusions). These observations indicate that the makers did not only take into account the preferences of the ornament users, but more importantly the condition (quality) of the raw material available for processing. This concern is visible primarily among other aforementioned RC materials from Żuławy Wiślane, where plentiful evidence for the testing and verifying of raw amber properties has been detected, including pieces that were rejected even at the earliest manufacturing phases, during the initial division of primary nodules and pre-treatment stages. The complete absence of artefacts made from layered amber or amber with inclusions, and marginal share of amber with internal cracks is particularly significant. This indicates a thorough understanding and careful selection of raw material, guided by experience, to exclude pieces with undesirable qualities or appearance that were unsuitable for further processing.

Given that amber inclusions do not pose major problems in terms of production, it remains an open question as to why such specimens were not found. It is possible, due to the size of the assemblage under study, that this is coincidental, and has no bearing on the selection criteria employed in the Neolithic workshops. However, it cannot be ruled out that inclusions were considered an undesirable feature. If this were the case, it would most likely relate to aesthetic values, not technological considerations – perhaps the pristine nature of the amber. Aesthetic values probably also determined the choice of colour and degree of transparency. Neither of these characteristics affect the difficulty of

processing the amber into ornaments. Therefore, the definite predominance of products made of opaque raw amber or with mixed degree of transparency in shades of yellow may be related to preferences and, as a result, the selection of amber with such characteristics (Fig. 3). Both white and orange/red colouration can result from natural processes: white amber from intense foaming of the solidifying resin, orange/red amber, even cherry-hued, through progressive natural degradation[25].

Within this assemblage, only two nodular beads, from a total of 187 specimens of this type, were made from white amber (Figs 3,1; 8; Tab. 1). They therefore represent not only a small percentage of the total assemblage, but also of this specific category of ornament. Nodular amber beads with V-shaped perforations appear as early as the 4th millennium BC in the Narva culture of the eastern Baltic region, as one of the local products within the amber-bearing zone of Sambia. However, they become particularly widespread in the Late Neolithic and Early Bronze Age, at which point they can be found in various archaeological cultural units across almost all of Europe[26]. However, there is no information in the literature about the colours and varieties of the raw material from which they were made. Among the first users of amber objects in the Oder and Vistula basin, including nodular beads with V-shaped perforations, outside their production centres were the GAC and ZC communities. Subsequently, in the middle of the 3rd millennium BC, communities associated with the BB phenomenon spread this category of amber ornaments over vast areas of their ecumene (Jutland, British Isles, France to the Mediterranean coast, Austria, Bohemia)[27].

These nodular beads were part of the BB cultural package, and were produced not just in amber, but also stone, ivory, and metal (namely copper, bronze, and especially gold)[28], i.e. prestigious raw materials. Therefore, it would be interesting to consider that the use of white amber (also known as 'bone amber') may have been intended to imitate the BB ivory ornaments known from the Iberian Peninsula[29]. Especially, if we take into account the influence of the BB phenomenon in north-east Poland[30], even in the amber manufacture layer in Żuławy Wiślane workshops, occurring as the presence of nodular beads with a V-shaped hole drilled in the typical BB manner, i.e. from the flat side[31].

A similar raw material differentiation, but with a different meaning was used by GAC to produce the same category of ornaments. Discs with solar ornaments found in graves (human and animal) of this taxonomic unit and intended for ritual purposes were made of both amber and bone. However, the amber discs were intended for deceased members of the community, while the bone discs were placed in the graves of livestock (primarily cattle)[32]. Despite this, both ornaments were decorated with solar symbols.

The 29 amber artefacts in shades of red exhibit a colour that is unnatural for naturally weathered, freshly acquired raw material (Figs 3,6; 9; 11; 4,9; Tab. 1). Although they are most numerous among tubular beads (17 specimens), they were roughly equally present in each of the ornament categories present in the assemblage (see Tab. 1, Fig. 8). It must be emphasised that, in the case of worked material, especially specimens damaged before the final stage of processing, where orange to cherry-red amber co-occurs in the same context as yellow or white specimens, deliberate heating (clarification) to alter the colour of the amber cannot be ruled out[33]. Therefore, the consistent presence of amber in shades of red across different ornament types seems to indicate intentionality. This possibility is strengthened by the 'sooting' discovered on two of the damaged ornaments, resulting from contact with fire. The intentional slow heating of amber to clarify the raw material or change its colour has been practiced since antiquity and is still used in modern amber jewellery manufacture[34].

These traces may therefore indicate that this technique was already known and used in Late Neolithic amber workshops in the Żuławy Wiślane region. Similar to direct heating over an open flame, heating ("boiling") amber in fat, as described in historical sources, may ultimately achieve the same effect. While heating over an open flame leaves visible traces (charring and soot deposits), these are noticeable only in the earlier stages of processing (see Fig. 5) as they are effectively removed during surface polishing. It is also difficult to determine with certainty whether the boiling technique in fat was used, as it does not leave identifiable marks on the surface of the treated object. This method could, therefore, have been applied to fully finished ornaments. One thing is certain: in both cases, the amber would acquire a reddish hue, resembling cherry, while its interior would appear uniform.

25 Kosmowska-Ceranowicz 2006, 50–51; 2014, 70–81.
26 Kostyleva/Utkin 2010; Czebreszuk 2011, 31–43.
27 Czebreszuk 2011, 36–44.
28 Ibid. 43; Harrison 1977.
29 See Hajek 1957; Harrison 1977, 39–42; 1980; Vandkilde 1996, 295; Czebreszuk/Makarowicz 1993, 530; Czebreszuk 2001, 129; 2011, 41–44.
30 E.g. Manasterski *et al.* 2020 a,b; Manasterski *et al.* 2022a;b.
31 Kwiatkowska 1996, 80–81; Czebreszuk/Szmyt 2008, 25–27.
32 Szmyt 1996, Fig. 81; Butrimas 2018, 77–89.
33 See Dahms 1894; 1920; Kosmowska-Ceranowicz 2014, 80–83.
34 See Kolendo 1985, 22; Dahms 1894; 1920.

Conclusions

Similar to today, the transparency, colour, and internal structure of raw material were of paramount importance to the craft people working in the Late Neolithic amber workshops in the vicinity of Niedźwiedziówka in Żuławy Wiślane. These preferences relate to both technological and aesthetic concerns. The results indicate that RC ornaments makers preferred raw material with a uniform structure, colouration in shades of yellow, and opaque or of mixed transparency with a distinct, but small proportion, of transparent raw amber. Among the study collection, there was a slight occurrence of raw material with a cracked structure, with a total absence of layering and inclusions. The small proportion of cracked items may indicate that this defect was overlooked during earlier stages of processing, and only became apparent at the final stage of manufacture, namely the drilling of perforation stage. White amber and amber in shades of red were apparently of lesser significance within the 'mass' production of ornaments. In the case of the extremely few white amber products (two nodular beads with a V-shaped perforation), they may be considered imitations of ivory ornaments – one of the prestigious raw materials used for BB material culture, depending on the region. The possibility that the specimens in shades of red were obtained by deliberate heating over a fire is analogous to the known jeweller's technique of clarifying amber, and should be considered a method of improving its aesthetic value.

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