SPRAWOZDANIA ARCHEOLOGICZNE 76/1, 2024
PL ISSN 0081-3834
DOI: 10.23858/SA76.2024.1.3585

Aldona Kurzawska[1], Iwona Sobkowiak-Tabaka[2],
Małgorzata Mrozek-Wysocka[3], Tomasz Oberc[4]

TRACING THE PAST: MICROWEAR ANALYSIS OF STONE AND SHELL BEADS UNEARTHED IN EARLY NEOLITHIC BURIALS AT SAMBORZEC, POLAND

ABSTRACT

Kurzawska A., Sobkowiak-Tabaka I., Mrozek-Wysocka M. and Oberc T. 2024. Tracing the Past: Microwear Analysis of Stone and Shell Beads Unearthed in Early Neolithic Burials at Samborzec, Poland. *Sprawozdania Archeologiczne* 76/1, 309-334.

This paper presents a thorough analysis of ornaments discovered in two Neolithic burials at Samborzec Site 1, providing valuable insights into their origins and significance. The artefacts, retrieved over six decades ago in the burials of a woman and child, have undergone extensive examination, including raw material identification, microwear studies, and the analysis of red residues found on their surfaces. While most of the ornaments concerned were crafted from marble, two beads were identified as *Spondylus* shells. Chemical analysis of residues, primarily found on the marble ornaments, revealed the presence of cinnabar, a red pigment of foreign origin. The remarkable similarities in ornaments between the investigated burials strongly suggest the association of both with LBK communities. The presented studies offer valuable insights into their object biographies, from the acquisition of raw materials from distant regions through their manufacture, assembly, and prolonged use as personal items. In this context, our research emphasizes their belonging to a shared Neolithic tradition in Europe.

Keywords: Neolithic, *Spondylus*, marble beads, LBK burials, cinnabar, red pigment
Received: 09.10.2023; Revised: 18.11.2023; Accepted: 25.03.2024

1 Faculty of Archaeology Adam Mickiewicz University, Uniwersytetu Poznańskiego 7, 61-614 Poznań, Poland; aldona.kurzawska@amu.edu.pl; Institute of Archaeology and Ethnology, Polish Academy of Sciences; ORCID: 0000-0003-0215-046X
2 Faculty of Archaeology Adam Mickiewicz University, Uniwersytetu Poznańskiego 7, 61-614 Poznań, Poland, iwosob@amu.edu.pl; ORCID: 0000-0001-5913-1177
3 Institute of Geology Adam Mickiewicz University, Krygowskiego 12, 61-680 Poznań, Poland, mrozekm@amu.edu.pl; ORCID: 0000-0002-8194-4331
4 Institute of Archaeology and Ethnology, Polish Academy of Sciences, Sławkowska 17, 31-016 Kraków, Poland, t.oberc@iaepan.edu.pl; ORCID: 0000-0002-0186-261X

INTRODUCTION

It has long been recognized that ornaments, beyond mere decoration, carry significant meanings and can assume various functions, such as indicators of the identity, social status, and social roles of both individuals and groups (d'Errico and Stringer 2011; Rigaud *et al.* 2018; Micheli 2021). This significance is prominently evident in the Neolithic burial practices and differences in grave inventories between buried individuals from the same communities (Czerniak 2012; Kadrow 2008; Siklósi 2013) as only certain deceased individuals were buried with ornaments of specific types. The observed changes in the utilization of ornaments during the Neolithic primarily relate to variations in the use of different raw materials and types that were common throughout Europe during that time (Rigaud *et al.* 2015).

In the territory of modern-day Poland, the Early Neolithic period is primarily associated with the existence of the Linear Band Pottery culture (LBK), which thrived from around the 2nd half of the 6th – the beginning of the 5th millennium BC in Lesser Poland, Silesia, Kuyavia, the lower Oder region, and Chełmno Land, with smaller clusters of settlements in Greater Poland and Polish Pomerania (Czekaj-Zastawny and Oberc 2021; Oberc *et al.* 2022). An outstanding feature of the LBK in Central Europe is the remarkable consistency seen in its material culture, observable in both settlement structures and burial customs. In the inhumation burials discovered in Poland, common grave goods included vessels, animal bones, antlers, and flint tools. Red pigments, either covering the deceased or in the form of lumps or powder deposited in a vessel, are also characteristic (Jeunesse 1997; Kulczycka-Leciejewiczowa 2008; Czekaj-Zastawny *et al.* 2009; Czekaj-Zastawny 2016; Hedges *et al.* 2013). Although ornaments made from white stones (marble/limestone), animal bones, and *Spondylus* shells are frequently discovered in LBK burials across Central Europe, specifically in Germany, Slovakia, the Czech Republic, Hungary, and other regions (see for example, Bonnardin 2009; Nieszery 1995; Séfèriadès 2010), in Poland such items constitute special finds rarely encountered (Kurzawska and Sobkowiak-Tabaka 2020; Kurzawska and Sobkowiak-Tabaka 2024). Despite having been only occasionally studied in detail, such artefacts provide new data and valuable insights into Neolithic communities that once existed in the present-day territory of Poland.

In recent years, the authors have begun extensive studies on the biographies of shell ornaments from the Neolithic and Early Bronze Age context discovered in the area of present-day Poland in order to provide new data about their use and significance. Many of them, however, were artefacts that lacked proper identification or detailed analysis. Encouraged by previous results, we decided to republish some finds that were, in our opinion, unique and deserved detailed analysis and discussion. As such, *Spondylus* ornaments have long been recognized as important items acquired through exchange and trade, associated with the introduction of agriculture and the emergence of a new social order (Séfèriadès 2010). In Poland, such finds are exclusively associated with the early Neolithic period and a total of seven ornaments (discovered at five archaeological sites) have been encountered in burials associated with LBK, Stroke Band Pottery Culture (SBK), and Brześć Kujawski Culture (BKC) communities (Kurzawska and Sobkowiak-Tabaka 2020). In the published description of a female burial (Burial 208) from Samborzec, Site 1, we discovered information concerning beads that had been identified as being made from a bivalve shell (Czekaj-Zastawny *et al.* 2009). Consequently, we decided to conduct a more detailed analysis of these artefacts – ornaments that were discovered over 60 years ago in two burials, namely the above-mentioned Burial 208 and an additional one, No. V(28), in which ornaments were also found. Fortunately, modern microscopy analysis has made it possible to identify the raw materials from which they were made, trace their object biographies, and assist in associating one of the burials with the LBK culture.

SAMBORZEC SITE 1

Site 1 at Samborzec situated in southern Poland, southwest of Sandomierz, is well-known as a multi-phase settlement and cemetery. It spans various historical periods, including the Neolithic, Early Bronze Age, Bronze Age, Przeworsk culture, and Medieval period. The site was initially unearthed by a team led by J. Żurowski and first excavated in 1930 by Kazimierz Salewicz. Over time, it has been subject to exploration by several archaeological expeditions in the 1950s and 1960s, involving researchers such as Kamieńska (1964a, 1964b), Kamieńska and Kulczycka-Leciejewiczowa (1970), Włodarczak (1999), Kulczycka-Leciejewiczowa (2008), Budziszewski and Włodarczak (2009), Czekaj-Zastawny *et al.* (2009), and Burchard and Włodarczak (2012).

Situated on the southern slopes of a broad loess ridge, the site is located on the high bank of the Gorzyczanka river, which serves as a western tributary of the River Vistula.

The settlement horizons were distinguished based on an analysis of pottery decoration. The oldest corresponds to Phase I (Gniechowice style), the next to Phase II (The Music-Note style), and the youngest to Phase III (Želiezovce style). Confirmation of these distinctions came from two radiocarbon determinations. One was obtained from animal bone, and the other from charred plant remains found within a pot. The nature of the remaining three samples remains unknown (Kulczycka-Leciejewiczowa 2008, fig. 55, 104). Unfortunately, none of the dates are associated with burials.

This settlement comprised multiple households and was inhabited by several dozen individuals. Initially, only five graves were linked to the LBK culture, specifically denoted as Features 41, 42, 60, 71, and 208 (as cited by Kamieńska and Kulczycka-Leciejewiczowa in 1970; further discussed by Kulczycka-Leciejewiczowa in 2008). Among these, particular attention was drawn to the grave denoted as '208' due to the presence of grave goods, particularly personal ornaments. Besides this burial, an additional one containing ornament was found amidst burials associated with the Bell Beaker culture (BBC). Since these were the only burials in which ornaments were discovered, both were subjected to analysis.

Burial 208

The burial was discovered during the archaeological campaign in 1966 in the north-western part of the site. This deep oval pit grave, which extended over a depth of more than 1 m, was meticulously prepared. A 36-year-old female was positioned in a contracted posture, lying on her left side with her palms placed next to her face (Fig. 1). The skeleton was aligned in an east-west direction, with the head oriented towards the east and the face facing south. A layer of red residue covered the head:

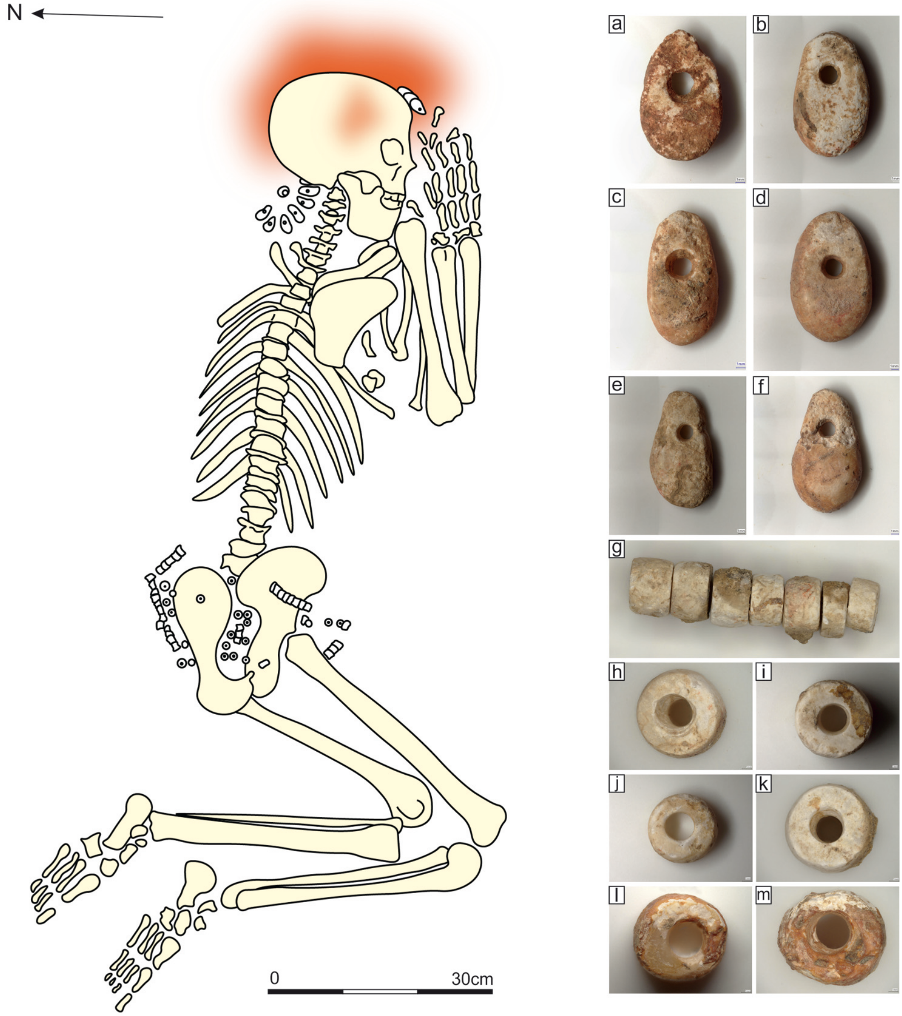


Fig. 1. Burial 208 with examples of discovered marble pendants (a-f), short beads made from marble (g-k), and short beads made from *Spondylus* shell (l-m)
(Burial drawing based on original documentation, prep. P. Rutkowska, photo A. Kurzawska)

Next to the skull were found 31 beads made of animal teeth, initially forming either a necklace or hair ornaments (Kulczycka-Leciejewiczowa 2008), and a necklace of 31 soft limestone beads with visible ochre traces on the surface (Czekaj-Zastawny *et al.* 2009). Additionally, 151 beads made of animal bones (Kulczycka-Leciejewiczowa 2008) and various bivalve shells (Czekaj-Zastawny *et al.* 2009) were discovered on the pelvis, probably associated with a belt or skirt.

Within the pit's infill, various fragments of kitchen pottery, two flint artefacts, and two animal bones were unearthed. Roughly 20 centimetres above the skeleton, fragments from a single pottery vessel were also found. Based on pottery analysis, the burial was associated with phase Ia (Gniechowice) of LBK development (Kulczycka-Leciejewiczowa 2008; Czekaj-Zastawny *et al.* 2009). Although at this point there are only two radiocarbon determinations associated with this phase, which do not allow for reliable dating, the whole phase I (Ia and Ib; pre-Music-Note phase) are can be dated to c. 5350/5300-5250/5200 BC (Czekaj-Zastawny and Oberc 2021; Oberc *et al.* 2022).

Burial V(28)

This burial was excavated in 1962, amidst a series of Bell Beaker burials (Fig. 2). Situated 0.6 meters beneath the contemporary surface, this oval pit grave cradled a child in a contracted posture, lying on their left side with their face turned towards the south. The child's palms were positioned adjacent to the face. The only items interred with the child were ornaments – namely, beads, distributed along the backbone, pelvis, and legs. A single long

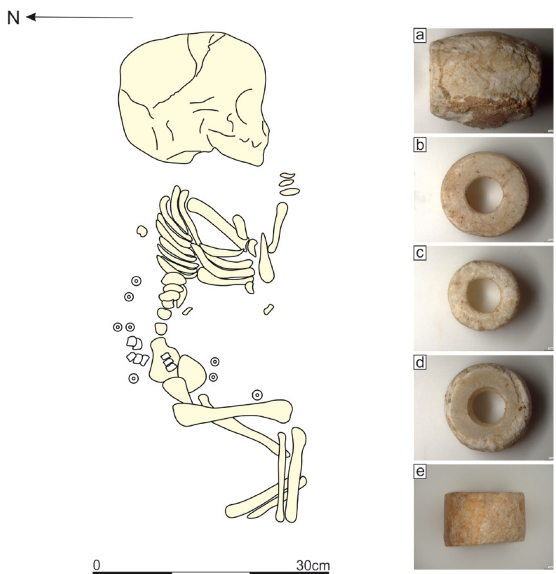


Fig. 2. Burial V(28) with examples of discovered beads (a – long barrel-shaped marble bead; b-e – marble short beads) (Burial drawing based on original documentation, prep. P. Rutkowska, photo A. Kurzawska)

barrel-shaped bead was unearthed at the bottom of the pit, suggesting that it was originally under the head of the deceased (Kamieńska 1963, 1964b).

This burial was initially classified with some caution as associated with the BBC. Probably due to a notable difference in the east-west alignment of the skeleton, unlike other north-south oriented BBC burials (Kamieńska 1964b), a comment about a possible connection to the LBK was added to the field book (by P. Sikora) and marked with a question mark (Kamieńska 1963). It was located c. 120 m, in a straight line from the LBK burial 208 (Kulczycka-Leciejewiczowa 2008).

MATERIALS AND METHODS

All ornaments found in these two burials underwent various analyses, including raw material identification, microwear studies, and the identification of the red residue discovered on their surfaces. The ornaments were classified based on the types they represented following Beck's 1928 and Kenoyer's 1991 definitions below:

A disc bead is a regular bead in which the length is less than one-third the diameter of the bead. A short bead is a regular bead in which the length is more than one-third the diameter of the bead and less than nine-tenths the diameter (Beck 1928, 4).

Pendants are a type of bead that is perforated at one or both ends rather than symmetrically through the middle (Kenoyer 1991, after Choyke and Bar-Yosef Mayer 2017).

Measurements were taken, including the length and width of the pendant, the length and diameter of beads, and whenever possible, the morphology of the perforation was specified (uniform/conical/biconical) along with the diameter of the perforation. Table 1 provides a summary of the measurements, including the mean and standard deviation, in order to enhance comprehension of the bead size trends in the studied assemblage.

We decided to clean, in the ultrasonic tank, only beads that were pre-selected for further microwear studies while using a stereoscopic microscope at low magnification (up to 40×). Beads with traces of red residue were left uncleaned.

The ornaments underwent analysis using a Nikon SMZ 445 optical microscope, a Keyence VHX-7000 digital microscope, and specifically, the identified shell ornaments using a Tescan Vega 4 scanning electron microscope (SEM) at the ArchaeoMicroLab of the Faculty of Archaeology at the Adam Mickiewicz University in Poznań, Poland. The SEM aimed to document the shell microstructure of shell beads for subsequent species identification (BSE-compo detector, low vacuum mode, condition: 25 Pa; 15.0 kV beam voltage). The descriptions of the shell microstructures are based on Sakalauskaite *et al.* 2020, and Gardelková-Vrtelová and Golej 2013.

In the study of ornament technology, we conducted a microscopic analysis of manufacturing use-wear marks and taphonomy using the Keyence VHX-7000 digital microscope. The description and observations were based on the information found in Bonnardin 2009;

Knaf *et al.* 2022; Van Gijn 2017; Groman-Yaroslavski and Bar-Yosef Mayer 2015; Baines 2012; Falci *et al.* 2018; Margarit 2017, and references therein).

To facilitate the analysis, the technique of creating silicone casts of ornament perforations was employed – a method used originally by Gorelick and Gwinnett (1978, 1990). This approach allowed observations to be conducted on the imprint of the entire hole while using the SEM. Among the ten ornaments subjected to silicone casting, six underwent further processing: they were sputtered with a 50 Å gold coating (while using a VAC COAT DSR1 desk sputter coater) before SEM imaging in order to achieve high-quality images. SEM microphotographs were subsequently captured in low vacuum mode using an SE detector (condition: 15 Pa; 20 kV beam voltage).

The petrographic and chemical analyses were conducted at the Laboratory for Scanning Electron Microscopy and Microanalysis, the Faculty of Geographical and Geological Sciences at the Adam Mickiewicz University in Poznań. The description of the raw material was based on petrographic features that could be perceived with the naked eye such as grain size, colour, and homogeneity, supported by SEM-EDS micro-area analyses. They were performed on the selected objects in low vacuum mode using a Hitachi S-3700N Scanning Electron Microscope coupled with a Noran SIX Energy Dispersive Spectrometer (VP-SEM condition: 25 Pa; 15.0 kV beam voltage; images obtained in backscattering electron mode 3D). Colour determination for both the stone ornaments and the reddish pigment was carried out using an objective colour standard, namely the Munsell® Soil Colour Charts, 2000. We chose to prioritize the preservation of the ornaments, being aware of the currently employed standard archaeometric procedures for identifying stone materials, especially archaeological marbles, as demonstrated, among others, by Antonelli and Lazzarini 2015, and Brilli *et al.* 2015, which involve destructive methods for determining petrographical and geochemical parameters (O and C isotopic signatures, CL and/or EPR analyses). Therefore, we decided to confine our research to nondestructive methods.

To acquire essential information regarding the archaeological context of the discovered artefacts, the studies were based on the original documentation of the excavated burials from 1962 and 1966. The documentation (field books, notes, plans, and drawings) was kindly provided by the Institute of Archaeology and Ethnology at the Polish Academy of Sciences in Kraków and was carefully studied.

RESULTS

Typology of ornaments and measurements

In the discussed burials a total of 211 ornaments were encountered. Among them, the following types were identified (after Beck's 1928 and Kenoyer's 1991 definitions):

Pendants:

– These are elongated/oval in shape, resembling known ornaments made from red deer

Table 1. Typology of beads and pendants with their range of measurements (mean – $\bar{x}$ and standard deviation – σ)

Burial No.	Context	Pendant/ Bead type	Length [mm]	width [mm]	perforation diameter [mm]
208	193/66	pendants	14.33-21.06	7.91-12.8	1.08-2.99
			$\bar{x}$ = 17.5; σ = 1.8	$\bar{x}$ = 10.24; σ = 1.19	$\bar{x}$ = 2.29; σ = 0.35
	194/66	disc bead	2.51	7.13	2.92
V/(28)	97/62	disc bead	2.08	8.78	4.3
			3.87	7.66	3.09
	97/62	short bead	2.73-6.43	7.33-10.08	2.95-4.19
			$\bar{x}$ = 4.45; σ = 1.0	$\bar{x}$ = 8.73; σ = 0.86	$\bar{x}$ = 3.6; σ = 0.34
208	194/66	short bead	3.05-6.91	7.22-10.09	1.85-4.61
			$\bar{x}$ = 5.01; σ = 0.85	$\bar{x}$ = 8.65; σ = 0.46	$\bar{x}$ = 2.75; σ = 0.43
V/(28)	97/62	barrel-shaped bead	11.53	9.9	3.2

canines, featuring a single hole located at the slightly tapered end (Fig. 1: a-f). A total of 31 pendants were found in Burial 208, several on the front of the skull and the rest behind it.

Beads:

– Disc beads – a total of three beads were found: one among the marble beads of a hip belt in the woman's burial, and two in the child's burial.

– Short beads constituted the majority in both burials. In the woman's burial, namely No. 208, they are associated exclusively with the hip belt (148 beads made of marble and two made of shell) (Fig. 1: g-m), while 26 beads of marble were found scattered in the child's burial, No. V(28) (Fig. 2).

– A long barrel-shaped bead – only one of this type – was found in the child's burial (Fig. 2: a).

The range of measurements for each discussed artefact is presented in Table 1, including the Mean $\bar{x}$ and Standard Deviation (σ). In the case of the short beads found in both burials, their mean length and width measurements, along with a low standard deviation, indicate that they are roughly the same in size. This observation may suggest a common origin.

Raw material identification

Shell beads

The use of low magnification reaching up to 80× facilitated the identification of shell ornaments among the stone/mineral ones. Within Burial 208, among the marble beads in the pelvic area, two beads were identified as having been made from bivalve shells (Fig. 1:

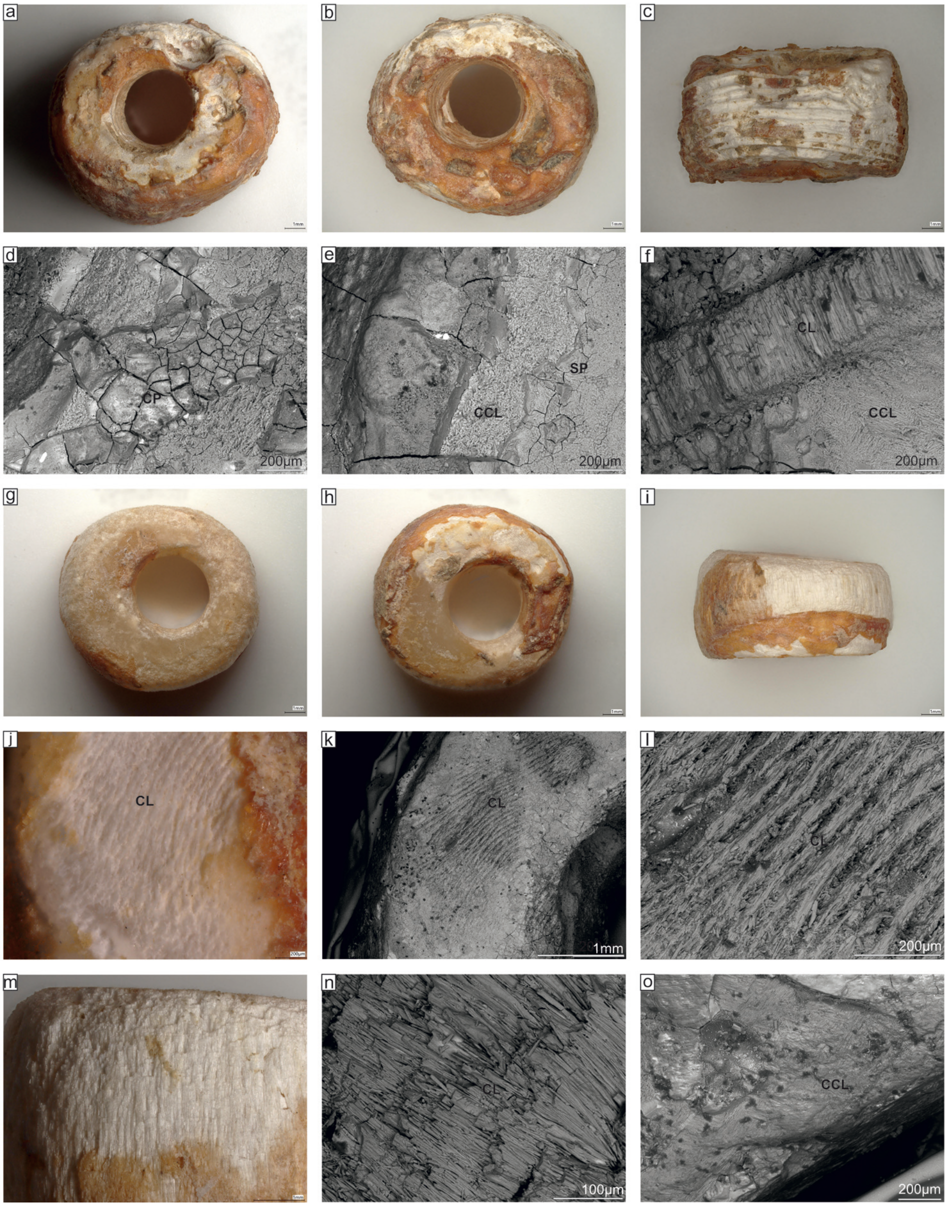


Fig. 3. Two *Spondylus* beads discovered in Burial 208. Bead 194_66_A: a-c – view from different sides; d – view of a bead surface with calcium phosphate (CP) residue; e – view of the bead microstructure: complex crossed foliated layer (CCL) and prismatic structures (SP); f – view of the bead microstructure: crossed lamellar layer (CL) and complex crossed foliated layer (CCL). Bead 194_66_B: g-i – view from different sides; j-n – crossed lamellar layer (CL); o – crossed foliated layer (CCL). Digital photographs: a-c, g-j, m and SEM microphotographs: d-f, k, l, n, o (photo A. Kurzawska)

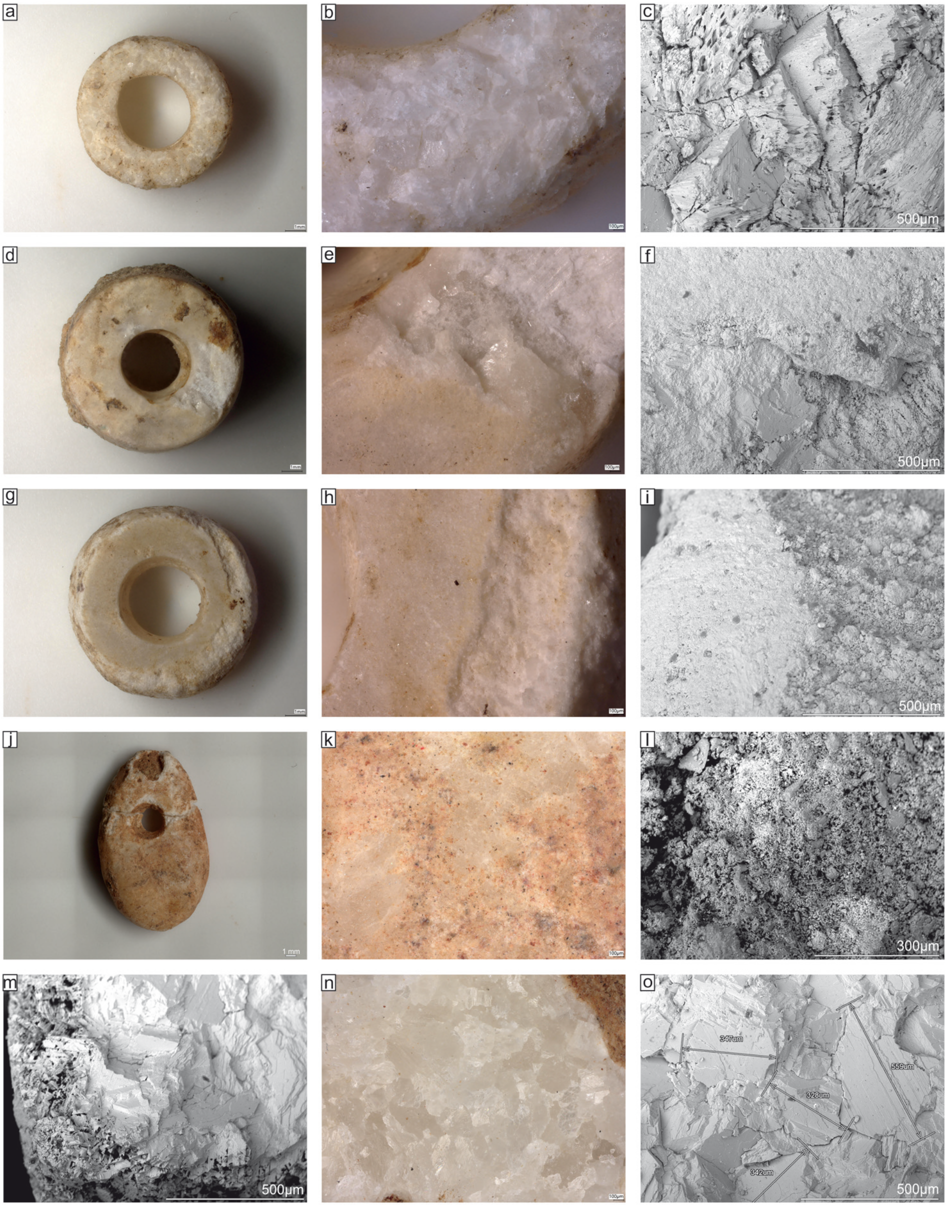


Fig. 4. Stone ornaments from discussed burials, examples of different grain size of crystals in marble: fine-grained marble with visible calcite crystals to the naked eye (bead 97_62_D – a, b, c; Bead 194_66_Z – d, e, f); very fine-grained marble (Bead 97_62_E – g, h, i); state of deterioration of marble (Pendant 193_66_T); heavily weathered surface (j, k, l); fresh cut (m, n, o). Digital photographs: a, b, d, e, g, h, j, k, n and SEM microphotographs: c, f, i, l, m, o

l-m, Fig. 3). Accurately classifying the genus was crucial for determining their provenance. For this purpose, a meticulous analysis of the microstructure of the shell beads was undertaken, followed by a comparative assessment against a reference collection, comprising microphotographs from previous analyses of shell artefacts held by the authors, as well as published studies (Gardelková-Vrtelová and Golej 2013; Sakalauskaite *et al.* 2020). Employing both digital microscopy and scanning electron microscopy (SEM), the microstructures of the beads were documented (Fig. 3).

We compared the microstructure of the beads and that of *Spondylus* shells, drawn by the potential shell thickness and the presence of similarly shaped and sized beads discovered in Neolithic burials in Central Europe, which were made from shells of this particular genus (Sakalauskaite *et al.* 2020). The *Spondylus* shell structure primarily encompasses the subsequent layers, as outlined by Gardelková-Vrtelová and Golej 2013:

1 – The outermost shell layer is composed of foliate calcite (CF).

2 – The middle shell layer consists of crossed lamellar aragonite (CL).

3 – The innermost shell layer is characterized by complex crossed lamellar aragonite (CCL) and prismatic aragonite (SP) which display irregular alternation with CL and CCL layers near the center.

Both beads (labelled as 194_66_A and 194_66_B) exhibit shell microstructures typical of *Spondylus* shells, including aragonitic prismatic structures (SP) (Fig. 3: e), crossed lamellar layers (CL) (Fig. 3: f, j, k, l, n), and complex crossed foliated layers (CCL) (Fig. 3: e, f, o). The foliate calcite, which constitutes the outermost layer of the shell, was not observed during the analysis of the beads. Based on the visible microstructure, it is highly possible that the beads were made from the thickest part of the valve. The outer calcitic layer, responsible for the shell's colouration, was notably absent in these beads. As a result, it is plausible that the beads were manufactured in this manner, suggesting they might have originally been white.

Although the dissolution of aragonite was visible on the bead surfaces, no recrystallization was observed. The distinctive yellow-orange colour relates to areas covered by calcium phosphate CaPO (CP) due to post-depositional processes (Fig. 3: a-d, h-j).

Stone ornaments

The vast majority of the ornaments were made of stone (in Burial 208: 31 pendants and 149 beads; in Burial V(28): 29 beads). They vary in their state of preservation, from those that still retain their polish to those that are significantly weathered. Proper identification of the raw material was sometimes challenging for this reason. Nevertheless, it can be stated without doubt that all were made of a carbonate rock.

The discussed stone ornaments were made from semi-translucent, monomineral, densely compact marble (crystalline calcite) with either a vitreous or dull lustre. Macroscopic observations, confirmed by crystal measurements using an SEM, classified the raw material as very fine to fine-grained saccharoidal marble (Fig. 4). The determination of grain size took into account the division used in the archaeometric study of marbles, as discussed by Antonelli and Lazzarini in 2015. This division slightly differs from the typical petrographic classification, in which the fine-grained category encompasses sizes up to 2 mm. Although in some beads and pendants, calcite crystals are easily visible to the naked eye (*e.g.*, Bead 97_62_D with measured crystals up to 638 μm in size) (Fig. 4: a-c), this is challenging within the very fine-grained category (as seen in Bead 97_62_E with crystals measuring 22.4-58.3 μm) (Fig. 4: g-i), especially for those that are heavily weathered (*e.g.*, Pendant 193_66_T) (Fig. 5: j-l).

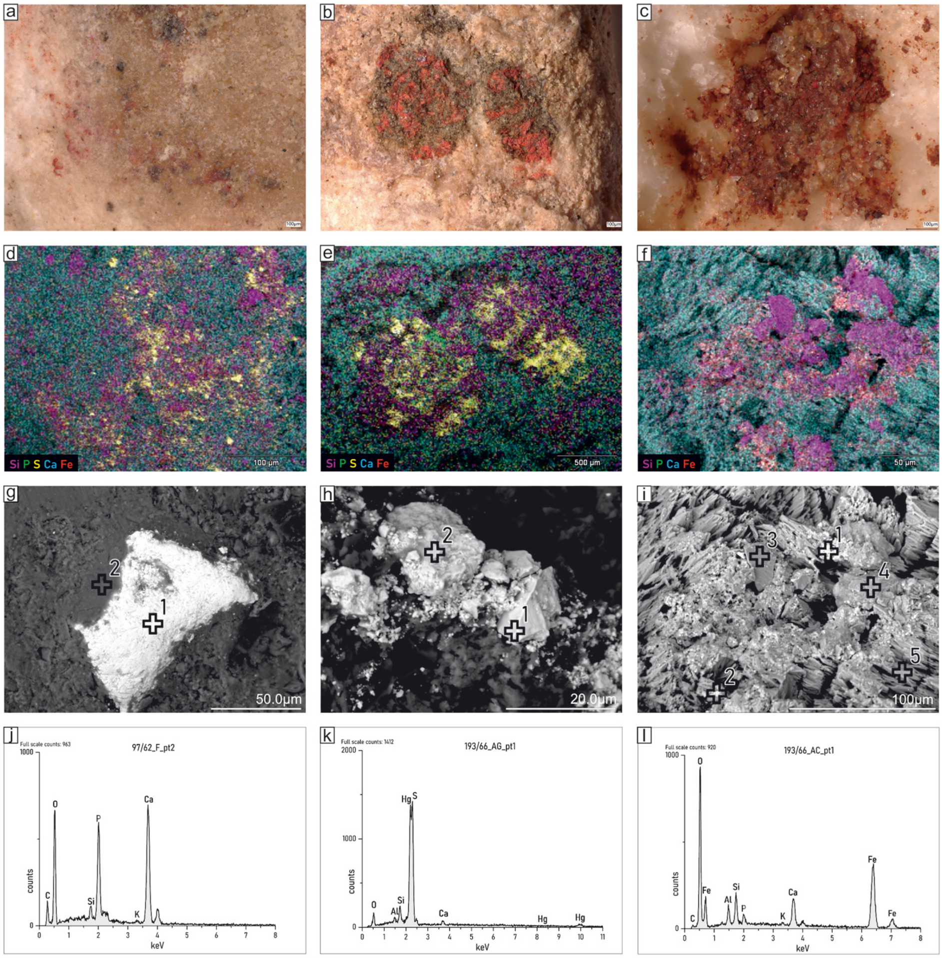
The staining of the surface of the artefacts was influenced by post-depositional processes associated with the long deposition of the artefacts in the grave in loess sediments. According to the Munsell charts, their colours were defined as follows: in a patinated state, they ranged from very pale brown to light yellowish-brown (10YR 6-8/2-4) or white to light pinkish-grey (5YR 7-8/1-2) (Fig. 4: j-k); on a surface not affected by weathering, they appeared as white/light grey (GLEY1 7-8/N) to light bluish-grey (GLEY2 8/10B) or very pale brown (10YR 7-8/1-2) (Fig. 4: a-b, d-e, g-h). A fresh cut reveals the pure white colour of marble (Fig. 4: n). The chemical composition of the raw material, as determined by non-destructive SEM-EDS analysis, indicates pure calcite marble (Fig. 5: n, m). No magnesium ions, indicating the presence of dolomite, were found in any of the analyzed objects.

Stone ornaments, particularly pendants, exhibit varying degrees of deterioration, evident through increased porosity, progressive granular disintegration, or the risk of breakage (Fig. 4: m). Similar to the shell beads, a brown (10YR 4-5/3) or yellowish-red to reddish-yellow/brown (5YR 5-6/4-6) substance, primarily composed of calcium phosphate (Fig. 5: j, m), was also detected on some of the stone ornaments.

Pigments

A red deposit was initially observed during the exploration of Burial 208, with the largest concentration located on and around the skull (Fig. 1). The highest quantity of this deposit was consequently found on the pendants discovered both on and behind the skull. Furthermore, during the analysis of the ornaments, traces of a red residue were also detected on the beads recovered from the pelvic area and on the sole barrel-shaped bead from the child's burial.

The substance on the ornaments exhibits various shades of red and brown, including reddish and brown nuances in colour. Within these residues, semi-quantitative analyses were conducted using SEM-EDS to determine the proportions of major elements (Fig. 5: m). While SEM-BSE images revealed the chemical diversity within the staining, EDS analysis of selected micro-areas (mapping) identified the presence of two distinct pigment compositions, as seen in the distribution of significant elements (Fig. 5: d-f). To a great degree, this division corresponds to the macroscopic colour variation. In areas identified as light red to dark red (10R 3-7/6-8) (Fig. 5: a-b), the results of the EDS analysis indicated the presence of mercury and sulphur peaks (Fig. 5: k) in samples 97_62_F_pt1, 193_66_



m Compound %

Elements: **major > 10%**; minor 3-10%; *traces < 3%*

	C	O	Na	Mg	Al	Si	P	S	K	Ca	Fe	Hg
97/62_F_pt1	*0.41*					*0.16*		**13.60**		*2.35*		**83.49**
97/62_F_pt2	4.21	**51.41**				*1.02*	**11.48**		*0.51*	**31.36**		
193/66_AG_pt1	*0.25*	7.68			*0.69*	*1.25*		**13.42**		*1.76*		**74.96**
193/66_AG_pt2	*0.33*	4.44			*0.69*	*1.33*		**12.19**		*1.41*	*1.64*	**74.98**
193/66_AC_pt1	*0.37*	**28.39**			*1.93*	3.60	*1.18*		*0.42*	6.67	**57.43**	
193/66_AC_pt2	*0.97*	**40.84**			3.64	6.29	*1.92*		*1.01*	8.62	**36.70**	
193/66_AC_pt3	*0.79*	**47.45**			*1.01*	**43.99**				5.54	*1.22*	
193/66_AC_pt4	*0.88*	**42.13**	*0.38*	*0.27*	**10.00**	**28.13**			**10.69**	4.64	*2.88*	
193/66_AC_pt5	*2.37*	**58.40**			*1.00*	*1.13*				**35.44**	*1.65*	

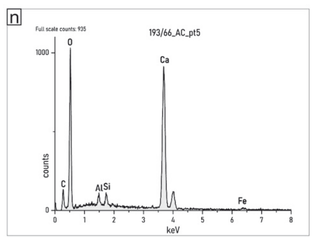


Fig. 5. Examples of microanalysis conducted on residues found on stone ornaments, specifically Bead 194_66_AB (a, d), Bead 97_62_F (g, j), Pendant 193_66_AG (b, e, h, k), and Pendant 193_66_AC (c, f, i, l, n). The analysis encompassed the examination of colour variations in different red pigments using a digital microscope (a, b, c). SEM-BSE images with chemical mapping (d, e, f), illustration of the elemental distribution of selected elements: silica (pink), phosphorus (green), sulphur (yellow), calcium (blue), and iron (red). Point analysis through EDS (g, h, i) and the corresponding spectra (j, k, l, n). Semi-quantitative results (major, minor, traces identified with SEM-EDS) obtained for the samples (m)

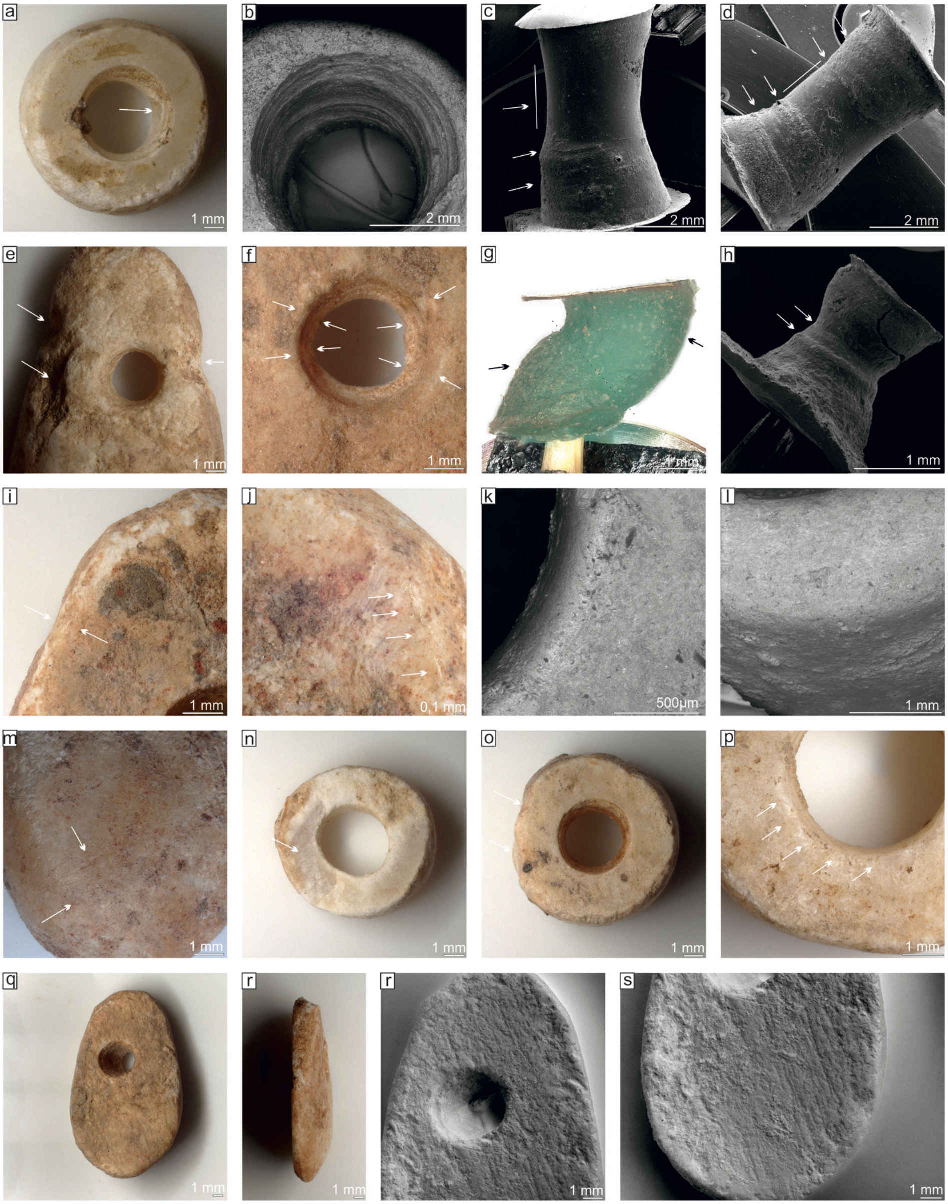


Fig. 6. Examples of microwear traces on beads and pendants from discussed burials: a-d – traces of drilling inside beads and on the silicone casts (straight lines and arrows point to microwear and usewear traces); e-f – usewear traces visible on a pendant's point shown by arrows; g – silicone cast of uneven drilled pendant from both sides; h – traces of drilling in pendant visible in the silicone cast; i-m – traces of usewear – polishing on the pendants (i-j, m) and beads (k-l, p) surfaces; n-o – traces of chipping visible on the surface (n) and edges of beads; q-s – traces of abrasion (grooves) and polishing on the pendant's surface

AG_pt1, and pt2, clearly indicating a cinnabar composition (Fig. 5: m). In contrast, the chemical composition of the darker-coloured areas (ranging from weak red to dusky/very dusky red and reddish/dark reddish brown – 2.5 YR 2.5 -4/2-3) (Fig. 5: c) is dominated by iron oxides (with Fe content ranging from 36% to 57%) with subordinate amounts of aluminosilicates (Fig. 5: i, l; 193_66_AC pt1 and 2). Regarding the morphology of these pigments as observed in the SEM images, the cinnabar appears to be more crystalline and crushed (Fig. 5: g-h), often fused with the calcium phosphate substance, while the iron compounds are in a more powdered and dispersed form (Fig. 5: i).

Microwear analysis

Various micro traces were observed during the analysis of the ornaments. The two *Spondylus* beads (Fig. 3), due to the chemical decomposition of calcium carbonate and the presence of residue on their surface, bore hardly any traces. In contrast, the ornaments made of marble exhibit traces attributed to the manufacturing process, as well as usewear traces produced by contact with string, skin, cloth, or leather to which the ornaments were attached, as well as contact with other ornaments (Fig. 6).

Beads

Concentric lines inside the perforations indicate traces of drilling (Fig. 6: a-d). Morphologically, the perforations appeared straight and biconical, with the latter being the most common. The manufacturing process involved drilling from both sides, clearly visible in the silicone cast (Fig. 6: c, d). Straight perforations, particularly those found in 16 beads (Burial V(28)) and 10 beads (Burial 208), may be indicative of use-wear resulting from subsequent extensive abrasion and polishing caused by the movement of a string (Fig. 6: a). As the beads were originally strung together, friction from the string may have smoothed the central, narrower part of the perforation (Fig. 6: c, d), suggesting that they were loosely strung. Chipping, visible as breakages on the edges and sometimes on the surface of the beads, is likely a result of the beads rubbing against each other during stringing (Fig. 1, Fig. 6: n, o), or contact with other hard material while, for instance, wearing the ornament. The smoothness and polish visible on some of the beads' edges (Fig. 6: k, l) may result from both final polishing in the manufacturing process and usewear, such as contact with soft material (cloth or leather).

Pendants

Manufacturing traces visible on the pendants include drilling (perforation by rotation) performed from both sides, resulting in morphologically biconical perforations that are visible on both the artefacts and in the silicone casts (Fig. 6: g, h). The biconical profiles of the perforations are clear and uneven, with drilling from both sides being sometimes uncentered (Fig. 6: g), at times more extensive, and meeting at a rather sharp angle (Fig. 6: h).

It is at this point that the hole possesses the smallest diameter. The traces of the manufacturing process are visible on the surface of the pendants as traces of abrasion (Fig. 6: r, s), suggesting the use of grinding and polishing in the manufacturing process. These traces typically consist of widely spaced scored lines going in the same direction. The polished surfaces of the pendants (Fig. 6: m, r) exhibit faintly visible lines going in various directions, and the edges display traces of wear (polishing) from contact with other materials. In cases where faint grooves are present, they are indicative of contact with harder materials.

Usewear traces such as chipping (Fig. 6: e), abrasion (Fig. 6: j), and polishing (Fig. 6: f, j) can be observed on both sides of the pendants (Fig. 6: i, j) and on the edges of the perforations (Fig. 6: f), indicating a different method of attachment (Fig. 6: e-g) beyond simple suspension. The pendants were most likely sewn onto a garment, such as a headband, the edge of headgear, or a hood, from both sides of the perforation.

DISCUSSION AND CONCLUSION

Sources of the Raw Material

Shell

Spondylus gaederopus is a well-known species that currently inhabits mainly the western part of the Mediterranean, including the Aegean Sea, the Adriatic Sea, and the Pacific Ocean (Poppe and Goto 2000). The origin of Neolithic ornaments in Europe made from this species has been widely discussed (Windler 2018, 2019; Bajnóczi *et al.* 2013; Todorova 2002). Due to uncertainties regarding the origin of *Spondylus* finds in Poland and their poor state of preservation, strontium isotope analysis ($^{87}Sr/^{86}Sr$) was performed, indicating their Quaternary age (Kurzawska *et al.* 2020). It was confirmed that the ornaments originated from areas around the Adriatic or Mediterranean Sea. All the *Spondylus* artefacts known in the area of Poland to date were either ornaments acquired through exchange/trade from the South, possibly the Aegean region, through the Carpathian basin communities, or they were brought to Poland by the first farmers (Kurzawska and Sobkowiak-Tabaka 2020). Chronologically, all of the *Spondylus* artefacts from Poland coincide with the area of the widest distribution of *Spondylus* ornaments in Europe between 5500 and 5000 BC (Windler 2019).

Marble

Determining the exact provenance of archaeological marbles is a challenging task at this stage of our research, given the limitations in our ability to follow the complete provenance procedure. However, the analytical results obtained thus far, along with archaeological data, allow us to propose and rule out potential sources of this raw marble material.

The nearest known outcrop of white marble is situated in the Śnieżnik Massif (Central Sudetes, SW Poland), where carbonate rocks appear in the Stronie Formation as assemblages of several separate long arrays of lenses along the distance of a few kilometers (see for example, Jastrzębski 2005; Gil *et al.* 2020). Based on differences observed in chemical composition and petrographic properties, several lithotypes of carbonate rocks have been recognized and distinguished by Koszela (1997). Among these, white calcite marbles characterized by a coarse and medium blastic texture with homogeneous and flake microstructures are described, while dolomite marbles are creamy and finely blastic. Significantly, the white purely calcite finely-blastic marble from which the Samborzec beads were made is not present.

The calcite marbles of the Stronie Formation are known to have been quarried since the 19th century for several varieties of marbles including the so-called "White Marianna" variety, nevertheless, within these outcrops, no traces of prehistoric exploitation have been found to date.

This outcrop was only mentioned by M. Doktor (Czekaj-Zastawny *et al.* 2009) as a potential source of raw material for the beads found at the burial site in Szczotkowice. However, this assertion lacked analytical support, as there was a deficiency in both petrographic and chemical analyses. Thus, it is probable that in his assumptions, he selected the nearest source of marble to Szczotkowice. Our exclusion of the Sudetes as the origin of the marble from Samborzec is based on the petrographic characteristics of marbles found in that region, including crystal size and the presence of dolomite. The finds from Samborzec exhibit significantly smaller crystals and lack the magnesium that would be indicative of dolomite within the composition.

Documented evidence of white marble mining in prehistory can be found in the Sazava region of the Czech Republic (Přichystal 2000). Recent research (Přichystal *et al.* 2019, Burgert and Přichystal 2022) has provided new petroarchaeological data concerning the raw material in this area. Two types of marble were identified within a single geological unit, the Šternberk-Čáslav Variegated Group in the Moldanubian Region. These are a calcite marble at the Bílýkámen site and dolomitic marbles around the town of Český Šternberk, located 7 km to the southeast. Consequently, these studies shed new light on craftsmanship in prehistory, particularly in the context of marble bracelets found at Neolithic sites. The stone assemblage in Samborzec exhibits many petrographic characteristics resembling Bílýkámen marble and the latter can therefore be considered a potential source. However, we cannot rule out more distant sources for the marble, such as the Balkans and Greece (Herz 1992).

Until now, marble ornaments have been discovered at just one other LBK burial site, located at Szczotkowice (Krauss 1964). These artefacts consist of 36 long barrel-shaped beads, remarkably similar in both type and dimensions to the one unearthed in the child's burial at Samborzec discussed here. Although it has previously been proposed that the white marble uncovered in Szczotkowice may have originated from the "Biała Marianna" deposit, nestled in the Sudety Mountains (Czekaj-Zastawny *et al.* 2009), considering new data, these suggestions should be revised. Comparable white stone ornaments in the area of Poland have also been identified at various archaeological sites linked to post-LBK communities, including Domasław, Site 10/11/12, Osłonki, Site 1, the Brześć Kujawski Site 4, and Krusza Zamkowa, Site 3. At Domasław, A. Wójcik conducted an analysis, identifying a total of 21 beads – comprising long cylindrical and short beads – macroscopically as carbonate rock. These beads exhibit a range of colours, from milky white through cream to grey, often featuring white and pink veins (Mozgała-Swacha and Murzyński 2017). In the cases of Osłonki and Brześć Kujawski, stone beads characterized by rectangular cross-sections, were identified as made from calcite. It was assumed that these beads may have reached these sites along with copper imports from the Czech Republic (Grygiel 2008). Recent, comprehensive research into the ornaments from burials at Krusza Zamkowa has shown that several disc beads (previously considered as white stones or calcite) were crafted from marble (Kurzawska *et al.* in prep.).

In light of the uniqueness of ornaments made from marble and white stones, along with the latest analysis, it appears increasingly likely that the raw material (marble), and perhaps even the ornaments themselves, were sourced from more distant locations, the closest possibly located in the Sazava region of the Czech Republic.

Pigments

The examination of the red residue discovered on the ornaments proved to be highly intriguing. In archaeological literature, the common assumption is that red pigments/colour, especially when in powder form, can be attributed to ochre. This approach however lacks precision and potentially leads to incorrect conclusions, as pointed out by Michera 1993 and Woźny 2002, 2007 in their research on the use of red dye in prehistory.

Our studies identified two types of red mineral pigments on the ornaments, namely: HgS crystals, interpreted as cinnabar, and iron oxides combined with aluminosilicates, the basic components of ochre. In the case of Burial 208, cinnabar was predominantly found on the pendants in the head area. The red pigment was however dispersed throughout the grave. Some beads from the belt also showed traces of cinnabar, albeit in smaller quantities. The distribution of these pigments across the artefacts appeared heterogeneous. Dark red ochre was found on only a few beads and one pendant, exclusively within the surface cavities of the ornaments. Regarding the beads from the child's burial V(28), any discolouration observed was not attributed to the presence of pigment but rather to post-depositional processes. A significant exception to this was a single barrel-shaped bead discovered under the skull. On its surface, amidst reddish-brown staining and micro spots of calcium phosphate residue, the presence of cinnabar was confirmed.

The extraction and use of cinnabar, a red mineral pigment composed of natural mercury sulphide (HgS), dates back to the Stone Age. Well-known Neolithic mining sites for cinnabar include Almaden in Spain, Monte Amiata and Spaccasasso in Italy, as well as quarries in the Balkans, including Idrija in Slovenia and Avala in Serbia (Gajič-Kvaščev *et* *al.* 2012; Maras *et al.* 2013; Mioč *et al.* 2004; Poggiali *et al.* 2017). The presence of mercury ore from the Šuplja Stena mine, located beneath Mount Avala near Belgrade, Serbia, along the trade route of the first farmers travelling through the Moravian Gate to Poland, suggests the possibility of the cinnabar's provenance. However, further analyses are required to confirm the hypothesis.

Possible sources located in Poland should be discounted due to the exceptionally rare occurrence of cinnabar within predominantly hydrothermal deposits. The most notable deposits linked to polymetallic uranium mineralization are the Kowary and Kletno deposits (Banaś and Mochnacka 1986; Mochnacka and Banaś 2000; Gil *et al.* 2020). Cinnabar identified at these sites is present only in trace amounts, typically as dispersed microcrystals within a network of quartz-calcite veinlets (Kowary) or embedded in veins or nests of secondary uranium minerals (Kletno). Obtaining a significant quantity of powder akin to that found in the woman's grave would not be viable from these locations.

Samborzec, Site 1 is situated on loess deposits, where finding red ochre is unlikely. Therefore, it is reasonable to assume that it was most likely acquired from other regions. In Poland, there are several potential source locations for red ochre, including the Tatras, the Sudeten Foreland, or bog ores in the lowlands. However, a more probable source can be found in the Rydno Complex within the Świętokrzyskie Mountains near Skarżysko-Kamienna, located approximately 100 km northwest of Samborzec. Although Rydno is recognized as a major mining centre for haematite ore in the Palaeolithic and Mesolithic periods, it cannot be ruled out that mining on a smaller scale continued during the Neolithic (Schild *et al.* 2011). Although haematite can be found within a reasonable distance, cinnabar was acquired possibly through trade or exchange from distant sources. It is widely acknowledged that valuable materials, typically those that are rare or require significant efforts in their acquisition, often are considered prestigious or of special symbolic meaning. Moreover, it is plausible that these Early Neolithic societies possessed an understanding of the distinct attributes of each mineral, indicating the deliberate cultural selection of specific pigments based on their intended use (Domingo *et al.* 2012).

Until now studies considering red pigments used throughout prehistory in Poland have primarily concentrated on items originating from sedimentary contexts, such as buildings, clay extraction pits, and ceramics (*e.g.*, Kościuk-Załupka 2023; Mioč *et al.* 2004). Therefore, considering the interesting results presented here as a case study of Samborzec burials, there is undoubtedly a need for more extensive investigations of the red pigments discovered in Neolithic burials.

The ornaments in a burial context

The discussed artefacts have been determined to come from two different burials, as mentioned earlier, namely Burial 208 and, surprisingly, a child's burial, V(28). Initially, the child's burial was classified as being associated with BBC communities, albeit with a degree of uncertainty. However, considering the contextual evidence, the orientation of the skeletal remains in the burial, the presence of identified marble beads, and their measurements (Tab. 1), the chemical match with red pigment (cinnabar), and the overall close similarities to the findings from woman's burial, we can now confidently associate this burial with the LBK remains (of phase I) at the site. Most of the short marble beads found in the child's burial (Fig. 2) are very similar to those found in the woman's pelvic area in Burial 208 (Fig. 1). Furthermore, several of them were discovered adjacent to each other (see Fig. 2) within the pelvic area of the buried child, possibly indicating a fragment of a similar ornament, such as a hip belt. The location of a barrel-shaped marble bead was mentioned as being positioned under the skull. The presence of red pigment – cinnabar – on the bead suggests that it might have been a head or neck ornament, similar to the marble pendants found with the woman in Burial 208 (the largest concentration of red pigment was usually found in specific areas of the skeletal remains, specifically around the head). The woman buried in Feature 208 was certainly adorned with two pieces of marble ornaments, namely: a head decoration made of marble pendants and a hip belt constructed of marble beads and two *Spondylus* beads. Unfortunately, it is unclear exactly in which part of the belt they were located. The discovery of beads made from *Spondylus* shells amidst marble ornaments is the second find of LBK ornaments in Poland in terms of raw materials, indeed exceptional in terms of typology, constituting a one-of-a-kind find within the territory of Poland. These previously undisclosed artefacts may now be incorporated into the limited catalogue of *Spondylus* ornaments uncovered in Poland (Kurzawska and Sobkowiak-Tabaka 2020). Both ornaments found in the woman's burial (the headdress and hip belt) showed traces of red pigment identified as cinnabar, with the largest amount found on the pendants. Similar LBK burials of women and children, adorned with ornaments made of *Spondylus* and marble, accompanied by the associated red pigment (although chemical studies were not conducted), were discovered at a cemetery in Vedrovice (Podborský ed. 2002). The presence of *Spondylus* ornaments and red pigment, either sprinkled or spread over the head, is more frequently encountered in burials from Central Europe (Hedges *et al.* 2013) and may be considered a distinctive element of different burial traditions within LBK communities (Jeunesse 1997).

Typically, specific raw materials and items made of them, particularly those obtained from distant regions – referred to as 'imports', such as *Spondylus* ornaments – have often been interpreted as symbols, found in burials indicating social status, prestige, or, in the case of children's burials, hereditary status (*e.g.,* Chapman and Gaydarska 2015). However, their roles were likely multidimensional, carrying deeper social messages beyond their decorative and symbolic functions, including religious dimensions (Borić 2015). Through ornaments and common customs (*e.g.*, in funerary rites), Neolithic communities living over a very wide area could express belonging to a shared tradition, beliefs, or ancestry (Rigaud *et al.* 2015). The unique ornaments found in burials discovered in Samborzec can be seen as manifestations of these well-established traits, serving as markers of membership in this tradition where the choice of raw materials, colour, and the type of decorations held specific significance. It seems evident that colour, particularly the bright and lustrous white, which bears a wide range of symbolic meanings across cultures (Vollmar 2009; Vitezović 2012), played a central role in the selection of raw materials, including white stones such as marble, as well as *Spondylus* shells, from which the outer layer of colour had been deliberately removed.

Acknowledgments

Special thanks to Piotr Włodarczak and Agnieszka Czekaj-Zastawny for providing us with materials and enabling our study, for their help and assistance. We also express our gratitude to two anonymous reviewers for their constructive comments. Many thanks are addressed to Paul McNamara for editing the English language version of this paper. This work was supported by the Faculty of Archaeology at Adam Mickiewicz University in Poznań (project no. Dec-26/WArch/2023).

References

Antonelli F. and Lazzarini L. 2015. An updated petrographic and isotopic reference database for white marbles used in antiquity. Rendiconti Lincei. *Scienze Fisiche e Naturali* 26, 399-413.

Baines R. K. 2012. *The Social Significance of Neolithic Stone Bead Technologies at Çatalhöyük*. Doctoral thesis, UCL (University College London).

Bajnóczi B., Schöll-Barna G., Kalicz N., Siklósi Z., Hourmouziadis G. H., Ifantidis F., Kyparissi-Apostolika A., Pappa M., Veropoulidou R. and Ziota C. 2013. Tracing the source of Late Neolithic Spondylus shell ornaments by stable isotope geochemistry and cathodoluminescence microscopy. *Journal of Archaeological Science* 40/2, 874-882.

Banaś M. and Mochnacka K. 1986. The two uranium deposits in the Polish part of the Sudety Mountains. In H. Fuchs (ed), *Vein Type Uranium Deposits* (Report of the Working Group on Uranium Geology Organized by the International Atomic Energy Agency, International Atomic Energy Agency – Technical Document), 361. Wien: International Atomic Energy Agency, 335-357.

Beck H. C. 1928. Classification and Nomenclature of Beads and Pendants. *Archaeologia* 77, 1-76.

Bonnardin S. 2009. *La parure funéraire au Néolithique ancien dans les Bassins parisien et rhénan*. Rubané, Hinkelstein et Villeneuve Saint Germain (= *Société Préhistorique Française, Mémoire* 49). Paris: Société Préhistorique Française.

Borić D. 2015. Mortuary practices, body and persons in the Neolithic and early-middle Copper Age of South-East Europe. In Ch. Flower, J. Harding and D. Hofmann (eds), *The Oxford Handbook of Neolithic Europe*. Oxford: Oxford University Press, 926-957.

Brilli M., Giustini F., Conte A. M., Lapuente P., Quarta G., Royo H., Scardozzi G. and Belardi G. 2015. Petrography, geochemistry, and cathodoluminescence of ancient white marble from quarries in the southern Phrygia and northern Caria regions of Turkey: Considerations of provenance discrimination. *Journal of Archaeological Science: Reports* 4, 124-142.

Budziszewski J. and Włodarczak P. 2009. *Kultura pucharów dzwonowatych na Wyżynie Małopolskiej*. Kraków: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.

Burchard B. and Włodarczak P. 2012. Złota culture graves at site 1 in Samborzec, Sandomierz District. *Sprawozdania Archeologiczne* 64, 269-310.

Burgert P. and Přichystal A. 2022. Marble as a material for the production of bracelets in Neolithic Central Europe. *Archäologisches Korrespondenzblatt* 52, 27-40.

Chapman J. and Gaydarska B. 2015. Spondylus Gaederopus/Glycymeris exchange network in Neolithic and Chalcolithic. In Ch. Flower, J. Harding and D. Hofmann (eds), *The Oxford Handbook of Neolithic Europe*. Oxford: Oxford University Press, 639-656.

Choyke A. M. and Bar-Yosef Mayer D. 2017. Introduction. In D. Bar-Yosef Mayer, C. Bonsall and A. M. Choyke (eds), *Not just for show. The archaeology of beads, beadwork and personal ornaments*. Oxford: Oxbow Books, UK, 1-6.

Czekaj-Zastawny A. 2016. Hunter-gatherers and the first farmers. In P. Włodarczak (ed.), *5500 – 2000 BC The Past Societies. Polish lands from the first evidence of human presence to the Early Middle Ages* 2, ed. P. Urbańczyk. Warszawa: Institute of Archaeology and Ethnology Polish Academy of Sciences, 107-124.

Czekaj-Zastawny A., Mitura P. and Valde-Nowak P. 2009. Kultura ceramiki wstęgowej rytej. In A. Czekaj-Zastawny (ed), *Obrządek pogrzebowy kultur pochodzenia naddunajskiego w neolicie Polski południowo-wschodniej (5600/5500-2900 BC)*. Kraków: Instytut Archeologii i Etnologii Polskiej Akademii Nauk, 175-216.

Czekaj-Zastawny A. and Oberc T. 2021. Chronologia osady. In A. Czekaj-Zastawny, A. Rauba-Bukowska and A. Kukułka (eds), *Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski Gwoździec stan. 2, gm. Zakliczyn*. Kraków: Instytut Archeologii i Etnologii Polskiej Akademii Nauk, 313-334.

Czerniak L. 2012. After the LBK. Communities of the 5th millennium BC in north-central Europe. In R. Gesler and V. Becker (eds), *Mitteleuropa im 5. Jahrtausend vor Christus. Beiträge zur Internationalen Konferenz in Münster 2010. Neolithikum und ältere Metallzeiten. Studien und Materialien 1*. Berlin: Lit Verlag Dr. W. Hopf, 151-174.

d'Errico F. and Stringer Ch. B. 2011. Evolution, Revolution or Saltation Scenario for the Emergence of Modern Cultures? *Philosophical Transactions of The Royal Society B Biological Sciences* 66(1567), 1060-9. https://doi.org/10.1098/rstb.2010.0340

Domingo I., Garcia-Borja P. and Roldan C. 2012. Identification, processing and use of red pigments (hematite and cinnabar) in the Valencian Early Neolithic (Spain). *Archaeometry* 54/5, 868-892.

Falci C. G., Cuisin J., Delpuech A., Van Gijn A. and Hofman C. L. 2018. New Insights into Use-Wear Development in Bodily Ornaments Through the Study of Ethnographic Collections. *Journal of Archaeological Method and Theory* 26, 755-805.

Gajić-Kvaščev M., Stojanović M. M., Šmit Ž., Kantarelou V., Karydas A. G., Šljivar D., Milovanović D. and Andrić V. 2012. New evidence for the use of cinnabar as a colouring pigment in the Vinča culture. *Journal of Archaeological Science* 39/4, 1025-1033.

Gardelková-Vrtelová A. and Golej M. 2013. The necklace from the Strážnice site in the Hodonín district (Czech Republic). A contribution on the subject of Spondylus jewellery in the Neolithic. *Documenta Praehistorica* 40/1, 265-277.

Gil G., Gunia P., Barnes J. D., Szymański M., Jokubauskas P., Kalbarczyk-Gil A. and Bagiński B. 2020. Origin of Talc and Fe-Ti-V Mineralization in the Kletno Deposit (the Śnieżnik Massif, SW Poland). *Minerals* 10/1, 13.

Gorelick L. and Gwinnett A. J. 1978. Ancient seals and modern science. *Expedition* 20(2), 38.

Gorelick L. and Gwinnett A. J. 1990. Innovative lapidary craft techniques in Neolithic Jarmo. *Archaeomaterials* 4/1, 25-32.

Groman-Yaroslavski I. and Bar-Yosef Mayer D. E. 2015. Lapidary Technology Revealed by Functional Analysis of Carnelian Beads from the Early Neolithic Site of Nahal Hemar Cave, Southern Levant. *Journal of Archaeological Science* 58, 77-88.

Grygiel R. 2008. *Neolit i początki epoki brązu w rejonie Brześcia Kujawskiego i Osłonek*. T. II. Cz. 3. Środkowy neolit. Grupa brzesko-kujawska kultury lendzielskiej. Łódź: Fundacja Badań Archeologicznych Imienia Profesora Konrada Jażdżewskiego, Muzeum Archeologiczne i Etnograficzne w Łodzi.

Hedges R., Bentley R. A., Bickle P., Cullen Ph., Dale Ch., Fibiger L., Hamilton J., Hofmann D. Nowell G. and Whittle A. 2013. The supra-regional perspective. In P. Bickle and A. Whittle (eds), *The first farmers of Central Europe. Diversity in LBK lifeways*. Oxford, Oakville: Oxbow Books, 343-384.

Herz N. 1992. Provenance determination of Neolithic to Classical Mediterranean marbles by stable isotopes. *Archaeometry* 34/2, 185-194.

Jastrzębski M. 2005. The tectonometamorphic evolution of the marbles in the Lądek-Śnieżnik Metamorphic Unit, West Sudetes. *Geologia Sudetica* 37, 1-26

Jeunesse C. 1997. *Pratiques funéraires au Néolithique ancien. Sépultures et nécropoles danubiennes (5500–4900 av. J.-C.)*. Paris: Éditions Errance.

Kadrow S. 2008. Gender-differentiated burial rites in Europe of the 5th and 4th millennium BC: attempts at traditional archaeological interpretation. *Analecta Archaeologica Ressoviensia* 3, 49-95.

Kamieńska J. 1963. *Field book of the excavated site 1 in Samborzec* [manuscript in the Institute of Archaeology and Ethnology PAS].

Kamieńska J. 1964a. Osady kultur wstęgowych w Samborcu. In S. Nosek (ed), *Studia i materiały do badań nad neolitem Małopolski*. Wrocław, Warszawa, Kraków: Wydawnictwo Polskiej Akademii Nauk, 77-189.

Kamieńska J. 1964b. Sprawozdanie z badań archeologicznych w Samborcu, pow. Sandomierz, w 1962 roku. *Sprawozdania Archeologiczne* 16, 35-38.

Kamieńska J. and Kulczycka-Leciejewiczowa A. 1970. The Neolithic and Early Bronze Age settlement at Samborzec, in the Sandomierz district. *Archaeologia Polona* 12, 223-246.

Kenoyer J. M. 1991. Ornament styles of the Indus Valley tradition: Evidence from recent excavations at Harappa, Pakistan. *Paléorient* 17/2, 79-98.

Knaf A., Guzzo Falci C., Habiba Toftgaard C. J., Koornneef J. M., van Gijn A., Brandes U., Hofman C. L. and Davies G. R. 2022. A holistic provenance and microwear study of pre-colonial jade objects from the

Virgin Islands: Unravelling mobility networks in the wider Caribbean. *Journal of Archaeological Science: Reports* 41, 103223.

Koszela S. 1997. Petrogeneza marmurów z południowo-wschodniej części metamorfiku Śnieżnika (Sudety). *Geologia Sudetica* 30, 59-115.

Kościuk-Załupka J. 2023. *Usage of ochre on the verge of neolithisation from the Near East to the Carpathian Basin*. Oxford: Archaeopress Archaeology.

Krauss A. 1964. Grób kultury starszej ceramiki wstęgowej ze Szczotkowic, pow. Kazimierza Wielka. In S. Nosek (ed), *Studia i Materiały do badań nad neolitem Małopolski*. Wrocław, Warszawa, Kraków: Zakład Narodowy im. Ossolińskich, 69-76.

Kulczycka-Leciejewiczowa A. 2008. Samborzec. Studium przemian ceramiki wstęgowej rytej. Wrocław: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.

Kurzawska A. and Sobkowiak-Tabaka I. 2020. Spondylus shells at prehistoric sites in Poland. *Sprawozdania Archeologiczne* 72/2, 41-66.

Kurzawska A., Sobkowiak-Tabaka I. and Jakubowski G. 2020. Miocene shells in the Late Neolithic and Early Bronze Age burials in Poland. *Geoarchaeology* 35, 952-973.

Kurzawska A. and Sobkowiak-Tabaka I. 2024. Uncovering the Tradition of Shell Ornaments in the Neolithic Poland. *Journal of Archaeological Science: Reports* 55, 104476.

Maras A., Botticelli M. and Ballirano P. 2013. Archaeometric investigations on cinnabar provenance and origin by X-ray powder diffraction: preliminary data. *International Journal of Conservation Science* 4, 685-692.

Margarit M., Mirea P. and Radu V. 2017. Exploitation of aquatic resources for adornment and tool processing at Magura 'Buduiasca'('Boldul lui Mos Ivanus') Neolithic settlement (southern Romania). *Quaternary International* 472, 49-59.

Micheli R. 2021. Similarities and Differences Between Italian Early Neolithic Groups: The Role of Personal Ornaments. *Open Archaeology* 7/1, 1274-1294.

Michera W. 1993. Uwagi o użytkowaniu czerwonego barwnika w polskim mezolicie i neolicie do około III tys. p.n.e. *Światowit* 37, 57-70.

Mioč U. B., Colomban Ph., Sagon G., Stojanović M. and Rosić A. 2004. Ochre decor and cinnabar residues in Neolithic pottery from Vinča, Serbia. *Journal of Raman Spectroscopy* 35/10, 843-846.

Mochnacka K. and Banaś M. 2000. Occurrence and genetic relationships of uranium and thorium mineralization in the Karkonosze Izera Block (the Sudety Mts, SW Poland). *Annales Societcitis Geologorum Poloniae* 70, 137-150.

Mozgała-Swacha M. and Murzyński T. 2017. Cmentarzysko kultury jordanowskiej ze stanowiska 10/11/12 w Domasławiu, gmina Kobierzyce, województwo dolnośląskie. In B. Gediga (ed), *Cmentarzysko ludności kultury jordanowskiej w Domasławiu, pow. wrocławski. Badania na autostradzie A4,* część XIV, zeszyt 19. Instytut Archeologii i Etnologii Polskiej Akademii Nauk: Wrocław, 7-134.

Munsell® Soil Color Charts: Year 2000 Revised Washable Edition. New Winsor, NY: GretagMacbeth.

Nieszery N. 1995. *Linearbandkeramische Gräberfelder in Bayern* (= *Internationale Archäologie* 16). Espelkamp: Marie Leidorf.

Oberc T., Czekaj-Zastawny A. and Rauba-Bukowska A. 2022. Radiocarbon dating for the Linear Pottery culture from the territory of Poland. In M. Grygiel and P. Obst (eds), *Walking among ancient trees. Studies in honour of Ryszard Grygiel and Peter Bogucki on the 45th anniversary of their research collaboration*. Łódź: Wydawnictwo Fundacji Badań Archeologicznych Imienia Profesora Konrada Jażdżewskiego, 183-212.

Podborský V. 2002. *Dvě pohřebiště Neolitického lidu s Lineární Keramikou ve Vedrovicích na Moravě*. Brno: Masarykovy univerzity.

Poggiali F., Buonincontri M. P., D'Auria A., Volante N. and Di Pasquale G. 2017. Wood selection for firesetting: First data from the Neolithic cinnabar mine of Spaccasasso (South Tuscany, Italy). *Quaternary International* 458, 134-140.

Poppe G. T. and Goto Y. 2000. *European Seashells. Vol 2. Scaphopoda, Bivalvia, Cephalopoda)*. Hackenheim: ConchBooks.

Přichystal A. 2000. *Stone raw materials of Neolithic-Aeneolithic polished artefacts in the Czech Republic: The present state of knowledge* (= *Krystalinikum* 26). Brno: Moravian Museum Brno, 119-136.

Přichystal A., Burgert P. and Gadas P. 2019. Marble from Neolithic quarries at the Bílý Kámen Hill near Sázava (Czech Republic) and its petrographic-geochemical characterization. *Geological Quarterly* 63/4, 811-821.

Rigaud S., d'Errico F. and Vanhaeren M. 2015. Ornaments reveal resistance of North European Cultures to the spread of farming. *PLoS One*, e0121166, https://doi.org/10.1371/journal.pone.0121166.

Rigaud S., Manen C. and García Martínez de Lagrán I. 2018. Symbols in motion: Flexible cultural boundaries and the fast spread of the Neolithic in the western Mediterranean. *PLoS One* 13(5), e0196488, https://doi.org/10.1371/journal.pone.0196488.

Sakalauskaite J., Plesseraud L., Thomas J., Albéric M., Thoury M., Perrin J., Jamme F., Broussard C., Demarchi B. and Marin F. 2020. The shell matrix of the European thorny oyster, *Spondylus gaederopus*: microstructural and molecular characterization. *Journal of Structural Biology* 211/1, 107497.

Schild R., Królik H., Tomaszewski A. J. and Ciepielewska E. 2011. *Rydno. A Stone Age Red Ochre Quarry and Socioeconomic Center*. A Century of Research. Warszawa: Instytut Archeologii i Etnologii PAN.

Séfèriadès M. L. 2010. Spondylus and long-distance trade in prehistoric Europe. In D. W. Anthony and J. Chi (eds), *The lost world of old Europe. The Danube Valley, 5000-3500 BC*. New York, Princeton, Oxford: Institute for the Study of the Ancient World at New York University, Princeton University Press, 179-186.

Siklósi Zs. 2013. *Traces of Social Inequality during the Late Neolithic in the Eastern Carpathian Basin* (= *Dissertationes Pannonicae ex Instituto Archaeologico Universitatisde Rolando Eötvös nominatae Budapestinensis provenientes* IV/3). Budapest: Eötvös Loránd University, Institute of Archaeological Sciences.

Todorova H. 2002. Die Mollusken in den Gräberfeldern von Durankulak. In H. Todorova (ed), *Durankulak, Band II. Die Prähistorischen Gräberfelder (Textteil)*. Sofia, Berlin: Deutsches Archäologisches Institut, 177-186.

Van Gijn A. 2017. Bead Biographies from Neolithic Burial Contexts: Contributions from the Microscope. In D. Bar-Yosef Mayer, C. Bonsall and A. M. Choyke (eds), *Not Just for Show: The Archaeology of Beads, Beadwork, and Personal Ornaments*. Oxbow Books, Oxford, 103-114.

Vitezović S. 2012. The white beauty – Starčevo culture jewellery. *Documenta Praehistorica* 39, 215-226.

Vollmar K. 2009. *Das grosse Buch der Farben*. Krummwisch: Königs-furt-Urania Verlag GmbH.

Windler A. 2018. Der Austausch von Spondylus gaederopus in Europa zwischen 5500 und 5000 v. Chr.: eine ökonomische Analyse (= *Der Anschnitt Beiheft* 40). Bochum: Verlag Marie Leidorf.

Windler A. 2019. The Use of *Spondylus gaederopus* during the Neolithic of Europe. *Journal of Open Archaeology Data* 7, 7. http://dx.doi.org/10.5334/joad.59

Włodarczak P. 1999. Cmentarzysko w Samborcu, woj. świętokrzyskie na tle innych znalezisk kultury ceramiki sznurowej z Wyżyny Sandomierskiej. *Sprawozdania Archeologiczne* 51, 119-144.

Woźny J. 2002. Symbole, wierzenia i rytuały „ludów leśnych” w pradziejach ziem polskich In W. Łysiak (ed.), *II Ogólnopolska Konferencja pt. Las w kulturze polskiej: materiały z konferencji, Gołuchów 2001*, t. 2. Poznań: Wydawnictwo „Eco”, 119-130.

Woźny J. 2007. Środowisko i wierzenia religijne. Czerwona ochra w rytuałach społeczeństw archaicznych. In A. Kowalczyk (ed.), *Procesy i zachowania społeczne w przestrzeni geograficznej*. Bydgoszcz: Wydawnictwo UKW, 101-121.