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SICKLES OF THE FUNNEL BEAKER CULTURE IN THE LIGHT OF USE-WEAR AND RESIDUE ANALYSIS

ABSTRACT

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The aim of this paper is to present new data on the use of plants and on flint management by Funnel Beaker societies. Studies of usewear and residues on flint tools from the Polwica-Skrzypnik site complex located in SW Poland included microscopic analyses of traces, starch and phytoliths, and adhesives. According to the usewear analysis, most of the tools were used as sickle inserts. The production of sickles was mainly based on good-quality imported flint material, but local groups also supplemented their needs with local flint. The identified phytoliths can be assigned to the grass and sedge families Poaceae and Cyperaceae, respectively, and to the subfamily Panicoideae of Poaceae. Microscopic traces indicate that inserts were re-sharpened during use and recycled by modifying them into other morphological and functional tools, such as hide scrapers. FTIR and GC-MS analyses show that the resinous substance preserved on the surfaces of the flint tools is wood tar, obtained by a process of pyrolysis of the bark of Betulaceae trees.

Keywords: TRB, sickles, usewear, phytoliths, wood tar
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INTRODUCTION

The Funnel Beaker (TRB) cultural tradition developed in the 4th and 3rd millennia BC and covered the area from the present-day Netherlands, Denmark and southern Scandinavia, across Germany and Poland, to western Ukraine. It is characterised by a multifaceted economy combining elements of both producing and gathering food, but primarily based on farming and husbandry as the major subsistence strategies. The great diversity of the material culture is one of the consequences of the dispersion. It followed from the local cultural substrates, environmental conditions and raw material accessibility. However, some of the elements become standardized in this period, and this particularly concerns flint tools, such as sickle inserts. Sickles evolved in Central Europe from a Neolithic curved sickle with more than two small flint pieces inserted obliquely or an L-shaped sickle with one insert positioned at a low angle, to an Eneolithic sickle with one large blade inserted laterally. Maria Gurova (2014a; 2014b) describes this phenomenon as "a shift in sickle morphology and mode of use" in the 4th millennium BC, connecting with a new technology of blade production, based on high quality flints.

The presence of long blades, carefully selected and retouched, and often recycled also characterizes TRB lithic inventories from Poland (Balcer 1975; 1983; Ginter and Kozłowski 1990; Domańska 1995). Such good-quality products likely arrived via long-distance import. However, local production of flint tools, including sickle inserts, is also documented. M. Nowak (2017) points to the importance of erratic flint and the use of small blades and flakes, and a bipolar technique as well. TRB assemblages from Little Poland (Małopolska) and the Lublin region, with a macrolithic industry (Lech 1981; Balcer 2002; Libera and Zakościelna 2006) differ from those from the Kuyavia region, where a medium-sized blade technology predominates (Domańska 1995; Małecka-Kukawka 1992). This situation is due to access to many types of flint sources, differing in quality and the size of the flint nodules, including good-quality Chocolate and Świeciechów flint, extracted with mining methods.

SW Poland is an area located outside the outcrops of good-quality resources. TRB flint tool production is poorly recognised due to the scarcity of lithic materials (Romanow *et al.* 1973; Wojciechowski 1973; Lech 1997; Cholewa 1998). Over the last few decades, opinions on the small quantity of flint assemblages were dominated by the assertion that the Neolithic people had to import lithics from other territories (Lech 1986; Wojciechowski 1988; 2000). Currently, however, this phenomenon is linked with the state of field survey. The fact is that most of the Neolithic materials in this area are mixed and not easy to separate (see Lech 1997). As a consequence of contextual problems, some of the TRB flint artefacts could have been included in the assemblages of earlier cultural traditions. In particular, this applies to implements made locally from erratic flint acquired nearby the settlements.

In this paper, we would like to focus on TRB sickles. The main questions to consider are about the production and use of sickles, and how technical innovations influenced the

Fig. 1. Polwica-Skrzypnik site complex, SW Poland. Edited by P. Dulęba

general flint management strategies in the area of SW Poland. Was production based on local resources, or were the blanks imported from workshops located near the outcrops of better-quality flint materials? Can combined analytical methods of study tell us more about the use of sickles than we know from usewear traces alone? Can any differences in tool use be noted based on raw materials? Are there differences in post-use treatment between particular types of functional tools? We applied four methods of analysing traces and residues, which helped us to determine the functions of lithic implements and the hafting mode, as well as to improve our knowledge on plant exploitation in that time. Our studies are based on flint materials from the Polwica-Skrzypnik site complex in SW Poland. The assemblage is not numerous, but has great research value, because it includes tools with macroscopically visible residues — unique to the archaeological sites located in Poland. Lithic parts of sickles covered with glue, and complete, hafted tools composed of lithic inserts and organic handles belong to the most exclusive finds in Neolithic Europe (Vogt 1951; Georgiev 1961; Behm-Blanke 1963; Hayek *et al.* 1991; Anderson *et al.* 1992; Sauter *et al.* 2000; Bosch *et al.* 2006; Flors *et al.* 2012; Linton 2012).

THE POLWICA-SKRZYPNIK SITE COMPLEX

Polwica -Skrzypnik is a multicultural archaeological site complex in the Oława district, SW Poland. It includes three sites previously identified as Polwica 4 and 5, and Skrzypnik 8 (Fig. 1). The site is located in the Wrocław Plain, on the slopes of a barely visible prominence, 145-150 m a.s.l. This area is covered by clay deposits of the Odra glacial period. In the northwest corner of the site complex there is a small depression formed as a result of glacial melting. The drainage system of this region is composed of the direct and indirect tributaries of the Oder, with Żuławka stream located about 1.2 km southwest of the site.

An archaeological rescue survey was carried out from 1997-2000 by the Archaeological Museum in Wrocław, under the supervision of Prof. B. Gediga from the Institute of Archaeology and Ethnology of the Polish Academy of Sciences, in advance of the A4 highway construction. The site yielded relics of settlement and sepulchral structures from the Neolithic, the Bronze Age, the Iron Age, the Migration Period and the Middle Ages (Dobrakowski *et al.* 2000; 2001).

The remains of the Neolithic settlement are distributed in the western part of the excavated area, which covered 26.400 sq m (Kulczycka-Leciejewiczowa and Noworyta 2009, Fig. 78). According to object-based chronology and radiocarbon dates (Table 1), the earliest finds come from the middle Neolithic and are identified with the Linear Pottery culture (LBK). Afterwards, this area was occupied by the societies of the Lengyel-Polgar culture (LPC), the Funnel Beaker culture (TRB) and the Globular Amphora culture (GAC). TRB is represented by 76 pits, as well as fragments of pottery and other finds retrieved from the cultural layers or pits of younger chronology. Functional interpretation of most of the site structures is complicated. Some of them are remnants of storage pits, houses and fireplaces. There is also a shallow pit of probably ritual function (Kulczycka-Leciejewiczowa and Noworyta 2009).

Imprints and charred remains of plants in daub from storage pits belong to emmer (*Triticum dicoccun*), einkorn (*Triticum monococcum*) and barley (*Hordeum vulgare*), as well as weeds, such as brome (*Bromus),* corn cockle *(Agrostemma githago)* and fat hen (*Chenopodium album*) (Lityńska-Zając 2009a). Cereal processing is confirmed by 8 querns or quern fragments, and animal husbandry is documented by 450 fragments of cattle bones and less numerous bones of pig and sheep/goat (Krupska *et al.* 2009).

LITHIC MATERIALS

Amongst the rich collection of archaeological materials retrieved from the Polwica-Skrzypnik site complex, lithic tools are not numerous. They are represented by 48 specimens: 21 artefacts of the TRB, 17 artefacts of the GAC, 1 tool of the Unetice cuture and 10 pieces of undetermined tradition. General results of the raw material and typo-techno-

Table 1. Polwica – Skrzypnik, SW Poland. Flint artefacts of the TRB (A, B, C – tools selected for the analysis: A – FTIR; B – GC-MS; C – starch and phytolith)

No.	Tool type	Pit no. () acc. Kulczycka-Leciejewiczowa, Noworyta 2009	Raw material	Pit function	Pit chronology	Working edge	Worked material	Hafting traces	Figure
1	endscraper	S8/2163	erratic flint	storage pit	Lusatian culture	left lateral and distal	cereals and hide	-	3:4
2	endscraper	S8/1812 (61)	erratic flint	pit-house?	TRB (4545+-35 BP)	right lateral	cereals	hafting polish	3:5
3	retouched blade 1 (C)	S8/2106 (79)	erratic flint	ritual	TRB	right lateral	cereals	-	2:1
4	retouched blade 2	S8/2106 (79)	erratic flint	ritual	TRB	right lateral	cereals	hafting polish	2:2
5	retouched blade 3 (A)	S8/2106 (79)	erratic flint	ritual	TRB	right lateral	cereals	hafting residues	2:3
6	retouched blade 4	S8/2106 (79)	erratic flint	ritual	TRB	right lateral	cereals	-	2:4
7	retouched blade	S8/2038	erratic flint	pit-house?	Lusatian culture	left lateral	cereals	hafting residues?	2:5
8	retouched blade	S8/1657	erratic flint	undetermined	prehistory	right and left lateral	cereals	hafting polish	2:6
9	retouched blade	S8/cultural layer	erratic flint	cultural layer	-	right lateral	soft material	-	3:1
10	retouched blade (C)	P4/66 (26)	erratic flint	fireplace	TRB	right and left lateral	cereals	-	2:7
11	retouched blade	S8/1539	Volhynian flint	household?	Lusatian culture	right lateral	cereals	hafting polish	2:8
12	retouched blade	S8/2106e (79)	erratic flint	ritual	TRB	right lateral	cereals	-	2:10
13	retouched blade	P4/471	erratic flint	fireplace	Lusatian culture	left lateral	soft material	hafting polish	3:3

Table 1 cont. Polwica – Skrzypnik, SW Poland. Flint artefacts of the TRB (A, B, C – tools selected for the analysis: A – FTIR; B – GC-MS; C – starch and phytolith)

No.	Tool type	Pit no. () acc. Kulczycka-Leciejewiczowa, Noworyta 2009	Raw material	Pit function	Pit chronology	Working edge	Worked material	Hafting traces	Figure
14	retouched blade	P4/825 (34)	erratic flint	fireplace	TRB, LPC	left lateral	hard material	-	3:2
15	retouched blade	P4/100c	erratic flint	pit-house	Lusatian culture	right lateral	cereals	-	2:11
16	retouched blade (A,B,C)	S8/2169 (84)	erratic flint	well	GAC (3860+-40 BP)	right lateral	cereals	hafting residues	2:9
17	arrrowhead	P4/82 (18)	Volhynian flint	household?	TRB (4080+-35BP)	-	no traces	-	3:6
18	blade	S8/1854 (68)	erratic flint	household?	TRB	-	no traces	-	-
19	splintered flake	S8/1812 (61)	erratic flint	pit-house?	TRB (4545+-35 BP)	right lateral	cereals	-	3:7
20	splintered flake	S8/cultural layer	erratic flint	cultural layer	-	-	no traces	-	-
21	flake	S8/2163	erratic flint	storage pit	Lusatian culture	-	no traces	-	-

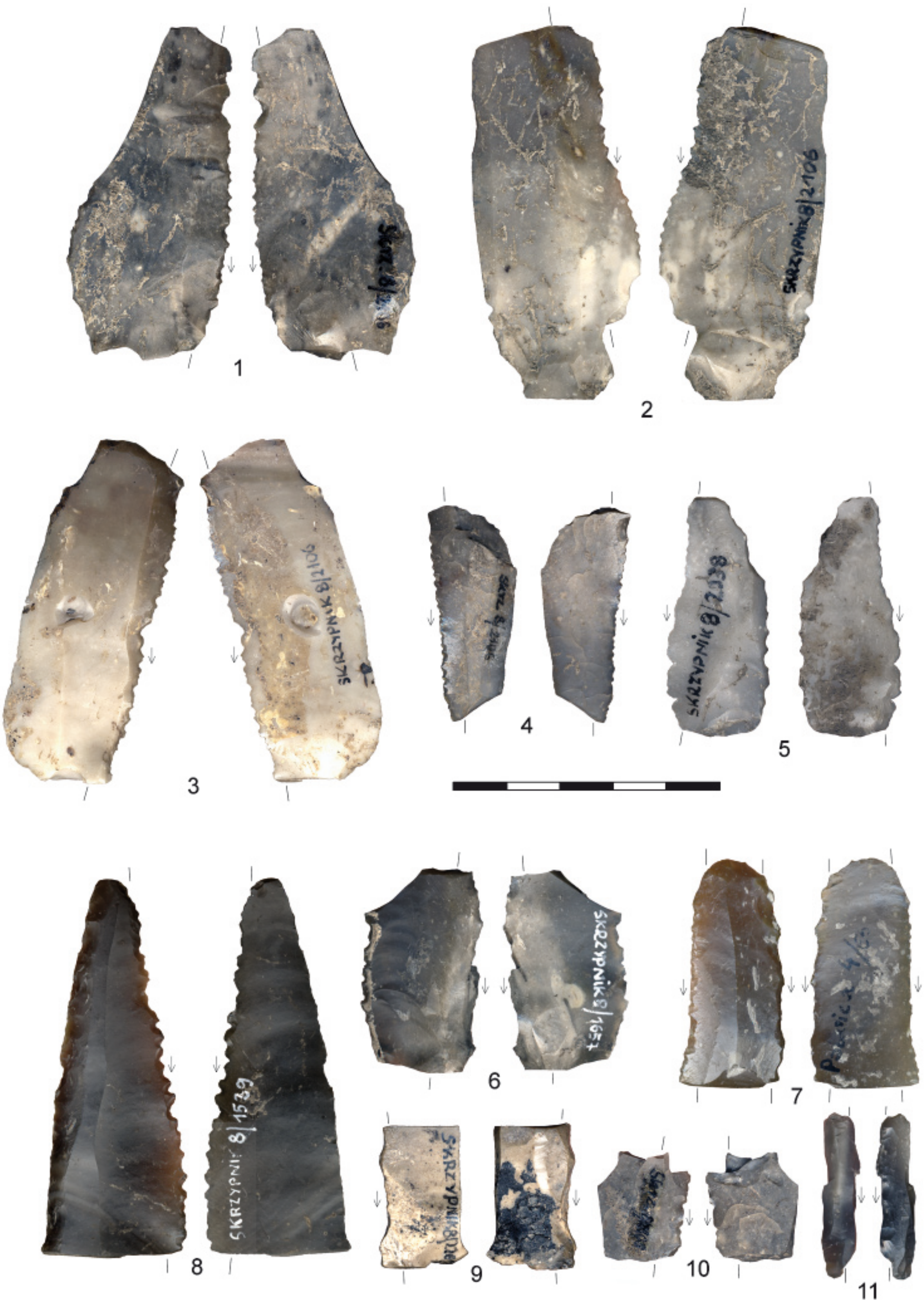


Fig. 2. Polwica-Skrzypnik, SW Poland. TRB flint tools: 1-11 – retouched blades. Dashed lines mark range of usewear traces, arrows show direction of movement. Photo by N. Lenkow

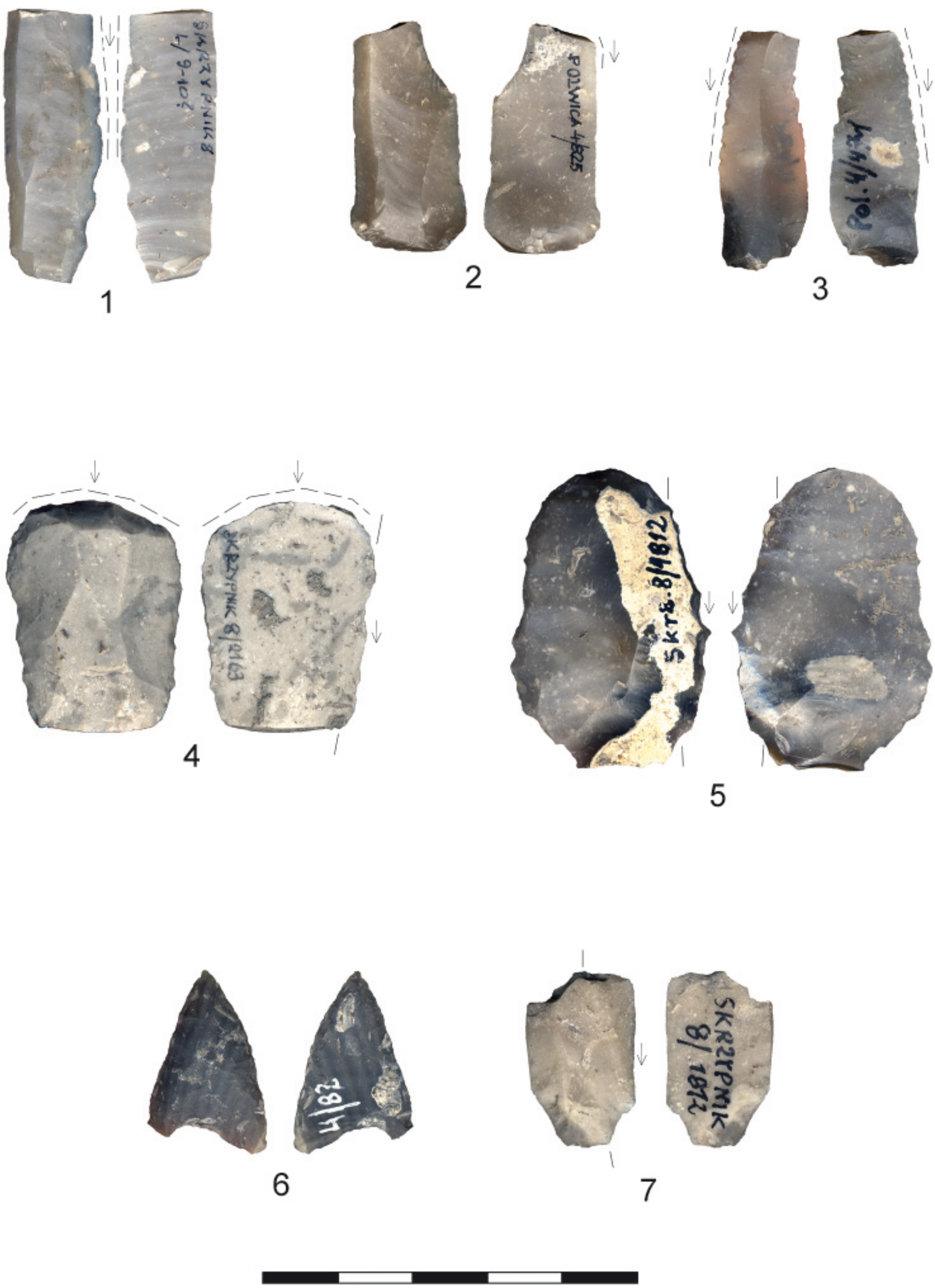


Fig. 3. Polwica-Skrzypnik, SW Poland. TRB flint tools: 1-3 – retouched blades; 4-5 – endscrapers; 6 – arrowhead; 7 – splintered flake. Dashed lines mark range of usewear traces, arrows show direction of movement. Photo by N. Lenkow

logical analyses of the tools have already been published (Bronowicki 2009). J. Bronowicki suggests that the majority of the TRB lithic tools were made from erratic flint, most probably in the workshops located on the Głubczyce Plain, ca. 120 km from the site. Two pieces (a retouched blade and an arrowhead) were made from Volhynian flint. The deposits of this good-quality raw material are located ca 500 km east from the site.

The manufacture of flint tools was based on blades detached from the single platform core. Two different kinds of blades were selected for retouching: long and wide blades, and middle-sized blades, both with straight profiles.

Most of the TRB flint assemblage is comprised of retouched tools, including 2 end-scrapers, 14 retouched blades and 1 arrowhead, followed by a small group of blanks: 1 blade and 3 flakes, including 2 splintered flakes (Table 1).

Retouched blades outnumber all the tools in this assemblage (Fig. 2:1-11; 3:1-3). There are unilateral and bilateral retouched blades, with a retouched distal part in two cases and a pointed distal part in one case. At least 6 of them were made from macrolithic blades (maximum length – 72 mm, maximum width – 27 mm). Their lateral edges were prepared by pronounced denticulated retouch, in contrast to the middle-sized blades with tiny, semi-abrupt retouch. None of the retouched blades were preserved in their complete form. Distal or both distal and proximal parts are missing in most cases, and four tools have their lateral parts broken off as well.

Endscrapers represent the secondary forms, modified from large retouched blades (Fig. 3:4-5). The heart-shaped arrowhead represents an asymmetric form. All the edges were modified with flat retouch on the dorsal side and semi-steep retouch on the ventral side (Fig. 3:6).

The chronological determination of the flint tools was based on morphometric and technological characteristics, as well as on contextual data. Ten artefacts come from pits with TRB pottery – a household, a pit-house, a ritual feature and a fireplace. One lithic implement was found in a pit containing pottery of the TRB mixed with potsherds of the LPC. Seven artefacts come from pits of younger chronology: storage pits, houses and a fireplace of the Lusatian culture (6 pieces), and a well of the GAC (1 piece). Additionally, 2 pieces were retrieved from the cultural layer in the southwestern part of the excavated area.

Negatives of two of the retouched blades are covered by a blackish substance. This fact was missed at the previous stage of analysis, and provides an opportunity for obtaining more information about the complex technology of tool production.

ANALYTICAL METHODS

All of the flint artefacts were subjected to usewear analysis to identify the functions of the tools and their relative length of use. We used a Nikon Eclipse LV100 (up to 400x) metallographic microscope and an Olympus SZX9 (up to 57x) stereomicroscope. Prior to the microscopic observations, and after the extraction and preparation of the residue samples, flint artefacts were cleaned for two minutes in water in an ultrasonic tank. Usewear analyses were supported by experiments designed to demonstrate the efficiency of sickles with a single blade hafted laterally, and to examine the development of sickle gloss.

As both the cutting of cereals and of wild siliceous plants can produce plant polish of similar texture, three flint tools were selected for starch and phytolith analysis. These types of microresidues have been successfully extracted from different types of artefacts, including pottery (e.g. Saul *et al.* 2013), obsidian artefacts (e.g. Kealhofer *et al.* 1999), and grinding implements (e.g. García-Granero *et al.* 2016). However, the preservation of phytoliths is often affected by different environmental conditions (Madella and Lancelotti 2012). As phytolith analysis has not been applied to artefact studies in this research area, the feasibility of extracting phytoliths on flint tools is still uncertain. Therefore, we began with small number of TRB sickles from the Polwica-Skrzypnik site complex to assess the state of preservation of phytoliths. Two retouched blades that were analysed come from pits without any admixture of younger archaeological materials. They show the most intensive traces of use and are well preserved. A third sample was selected due to the macroresidues attached to its surface and its intensively worn-out working edge. We expected that these implements were in use for a relatively long time, which could have increased the chance of depositing microresidues. Phytoliths were extracted following the procedure outlined by Kealhofer *et al.* (1999) with slight modifications. Firstly, distilled water was used to rinse the flint tools in separate plastic beakers. The purpose of this procedure is to remove the adjacent soil on the artefacts. These "first wash" samples were collected for contamination control. Then "second wash" samples were collected after a ten-minute sonic cleaning of the artefacts. Phytoliths were separated using a heavy liquid LTM (lithium metatungstate) with a specific gravity of 2.35. After removal from the sediment matrix, the phytoliths were mounted on slides, viewed, counted and photographed at 400x magnification. Identification of phytoliths was undertaken when possible by the use of reference material at Leiden University, as well as published documents (e.g. Madella *et al.* 2005; Twiss 1992; Powers 1992; Mulholland and Rapp 1992; Piperno and Pearsall 1998).

Two flint tools with macroscopically visible blackish adhesives (Table 1, nos. 5 and 16) were selected for macroresidue analysis by Fourier Transform infrared spectroscopy (FT-IR) — a screening technique. Afterwards, a sample of the resinous substance from one of them (Table 1, no. 16) was subjected to gas chromatography coupled with mass spectrometry (GC-MS). This part of the analysis was focused on determining the type of adhesive used to attach flint inserts to hafts. The GC-MS procedure applied and the instrumentation used in this study have already been published by Łucejko and colleagues (Łucejko *et al.* 2017). FTIR was carried out with the use of the Thermo Nicolet 380 spectrometer with DTGS detector. A small amount (1 mg) of the sample was taken and mixed with spectral pure potassium bromide (sample: KBr 1:200) and was analysed as a micropellet. The FTIR absorbance spectrum was collected in the range between 4000 and 400 cm^{-1}, with a resolution of 2 cm^{-1}.

Due to the contextual problems at the site, it was necessary to confirm the Neolithic age of the macroresidue analysed by GC-MS. The chronology of the resinous substance was determined with the AMS radiocarbon dating method in the Poznań Radiocarbon Laboratory.

RESULTS

Traces of use

Most of the lithic implements exhibit very pronounced traces of use. This includes 14 retouched blades, 2 endscrapers and a splintered flake (Table 1). Harvesting implements outnumber all of the used tools in this group (Fig. 2:1-11; 3:4-5, 7). Traces of cutting domestic cereals are very uniform and do not differ between particular tools. The artefacts show an intense, well-developed gloss on one or two lateral edges. Smooth and bright polish forms a narrow, compact band along the edge, with continuous topography both on and near the highly rounded edge. Depressions, including comet-shaped pits, are very abundant and densely spread over the polished area. Striations are tiny, short and narrow, indicating the cutting of stalks rather in their middle or lower section (Fig. 4:1-6). Scars are not numerous and are barely visible due to preparation of the edges by denticulate retouch. Negatives of deliberate and use retouch are filled with polish. In a few cases, retouch scars removed portions of sickle gloss, which means that rounded, blunted edges were resharpened during use. In one case, after the right lateral edge was worn out, the opposite side was prepared for cutting activity (Fig. 2:7), and in other two cases distal parts were retouched (Fig. 3:4). Without exception, traces run parallel to the main axis. Gloss invasiveness rarely exceeded 0.5 cm and reached approximately 1 cm in the proximal parts of the two largest retouched blades. Traces indicate a long duration of use, and some of the edges are completely worn out. Hafting traces in the form of spots of polish or slight rounding and more continuous hafting polish, as well as residues of bitumen were recorded on seven tools.

As was mentioned, there are no completely preserved retouched blades in this assemblage. The relations between gloss and broken extremities indicate post-use destruction, thus there were no signs of the deliberate removal of proximal or distal parts of a blade. In most cases, post-depositional factors are responsible for the loss, which is not significant. There were also other reasons, related to the intentional modification of tools. Endscrapers exemplify well the preparation of new forms for performing different functions (Fig. 3:4-5). Sickle inserts made from large retouched blades were considerably shortened by retouching the distal parts of the tools. One of the resulting endscrapers was then used for scraping hide. In the five most damaged cases, dehafting or retooling could have been responsible for fragmentation (Fig. 2:6, 9, 10-11; 3:7).

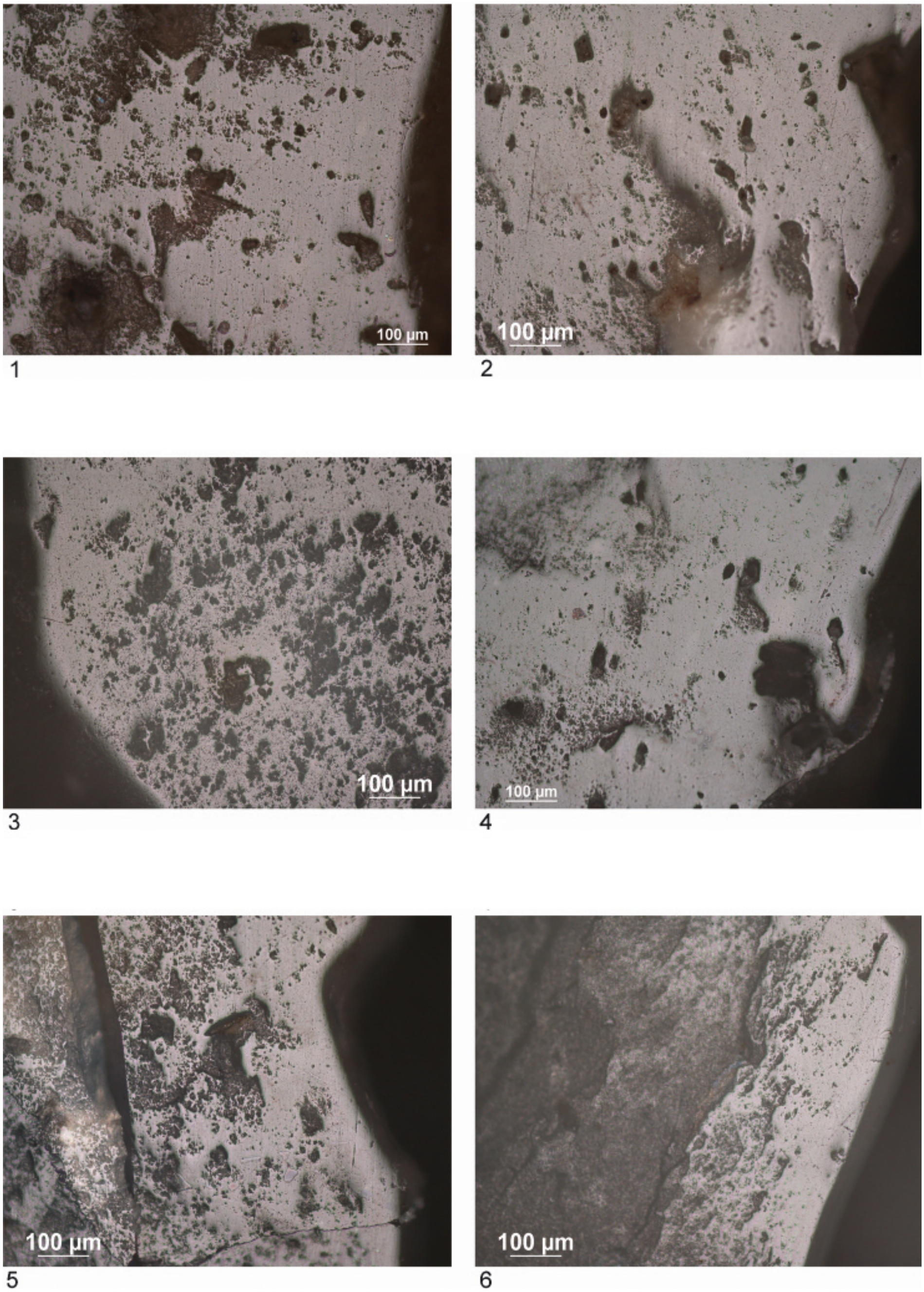


Fig. 4. Polwica-Skrzypnik, SW Poland. Sickle gloss on TRB flint tools. Photo by B. Kufel-Diakowska

Despite the fact that the artefacts with sickle gloss are not complete forms, we can see that sickle inserts were produced mainly from long and wide blades, on which the right, left or both lateral edges were modified by denticulate retouch. Nevertheless, the medium-sized blades were also retouched in a similar way and used for cutting cereals (Fig. 2:4-5).

Two retouched blades bear traces of cutting meat or fresh hide (Fig. 3:1, 3). The working edges of the tools are slightly rounded, with parallel, greasy polish on and near the edge. One retouched blade was used for working hard, most probably animal material (Fig. 3:2). Abrasive traces concentrate on a protruding edge on the distal part of the blade. All three tools were made from medium-sized blades of erratic flint. Intentional retouch is limited to the passive parts of the tools in two cases. In one case, the cutting edge was also prepared by tiny denticulate retouch, and hafting traces have been recorded in this example.

Starch and phytoliths

Phytoliths were successfully retrieved from all three tools subjected to such analysis. Normally, the "first wash" is supposed to remove the loose sediment on the tool, and the "second wash" will possibly provide residues that are related to tool use (Molino and Cuthrell 2011). In this study, phytoliths were not found in the "first wash" samples. In contrast, 12 phytoliths were recovered from the "second wash" samples. This result suggests that the recovered phytoliths originated from the artefacts rather than the adjacent soils. Most of the phytoliths were recovered from tool nos. 3 (n=2) and 10 (n=9) (Table 1). Only one phytolith was discovered on flint tool no. 16.

Four types of phytoliths were identified, including elongate-echinate, smooth elongate, long cell, and bilobate (Fig. 5). The two phytoliths discovered on flint no. 3 were identified as elongate-echinate long cell phytoliths from Poaceae (Fig. 5:a-b). The nine phytoliths discovered on flint tool no. 10 included one smooth elongate phytolith (Fig. 5:c), one unidentified oblong phytolith (Fig. 5:d), three long cell phytoliths from Poaceae or Cyperaceae (Fig. 5:e-g), and four bilobate phytoliths from subfamily Panicoideae of Poaceae (Fig. 5:h-j). One elongate-echinate phytolith was found on flint tool no. 16 (Fig. 5:k). Some of the discovered phytoliths appear damaged or partly dissolved (e.g. Fig. 5: a, f-j), suggesting the initial phytolith assemblage was affected during post-depositional processes.

Resinous substance

Two artefacts with sickle gloss display a blackish substance attached to the surfaces. The first one is most interesting due to the considerable amount of residue. It is a proximal fragment of the retouched blade, with its left part broken off and highly reflective sickle gloss on its right lateral edge. A thick layer of residue covers most of its dorsal surface (Fig. 2:9). Due to the younger context of deposition (a well of the GAC) and the fact that there are also probable wood tar pits from the Iron Age recorded at the other parts of the site

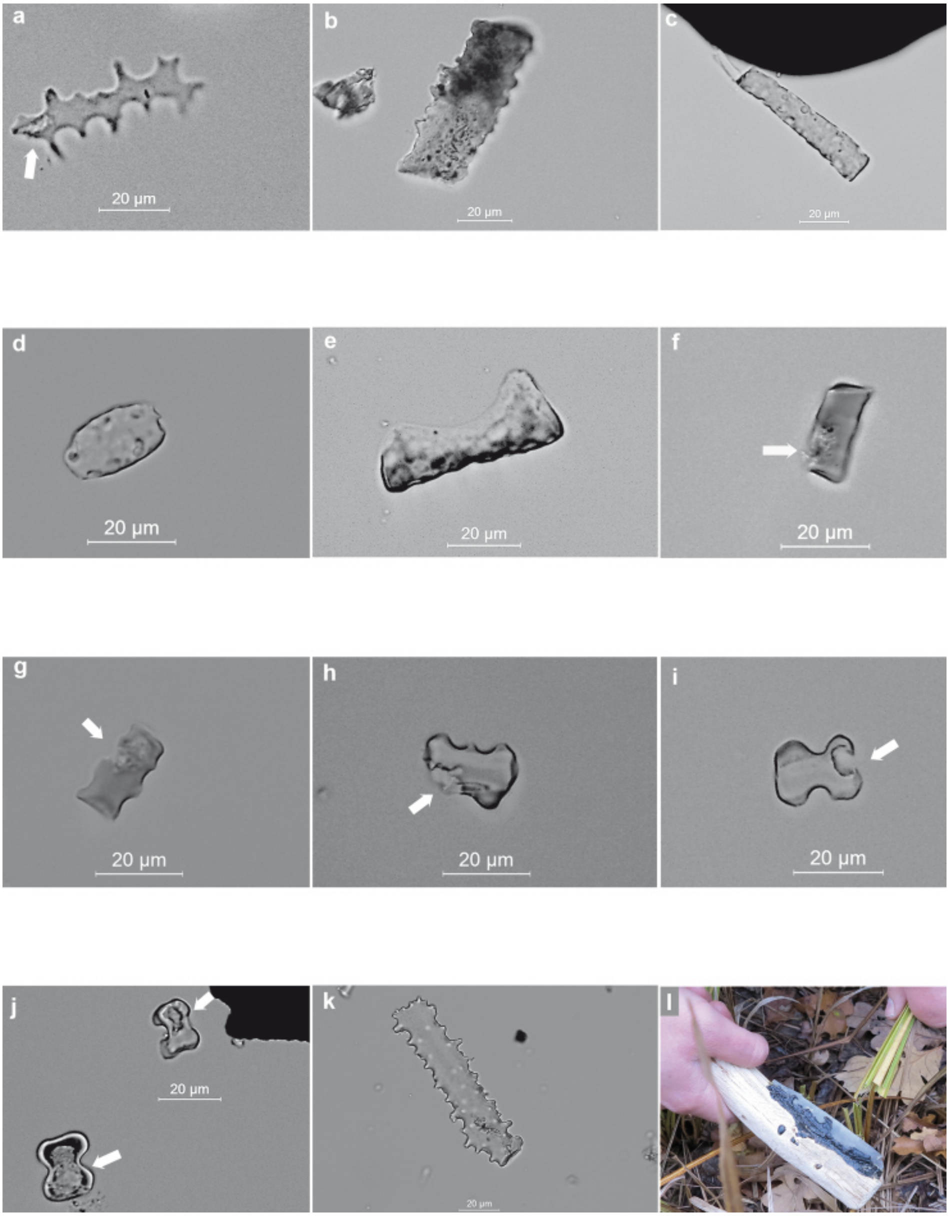


Fig. 5. Polwica-Skrzypnik, SW Poland. Phytolith morphotypes found on the three flint tools. a, b – phytoliths from artefact Strz. 8/2016 (a – elongate echinate; b – weathered, possibly from elongate echinate); c to j – phytoliths from artefact Polwica 4/66 (c – smooth elongate; d: unidentified, possibly an oblong phytolith; e, f, g – long cell; h, i, j – bilobate); k – elongate echinate phytolith from artefact Skrzypnik 8/2169; the arrows point out damaged features on the phytoliths. Experiment: cutting reed with the replica of a plant-cutting tool (l). Photo by W. Li

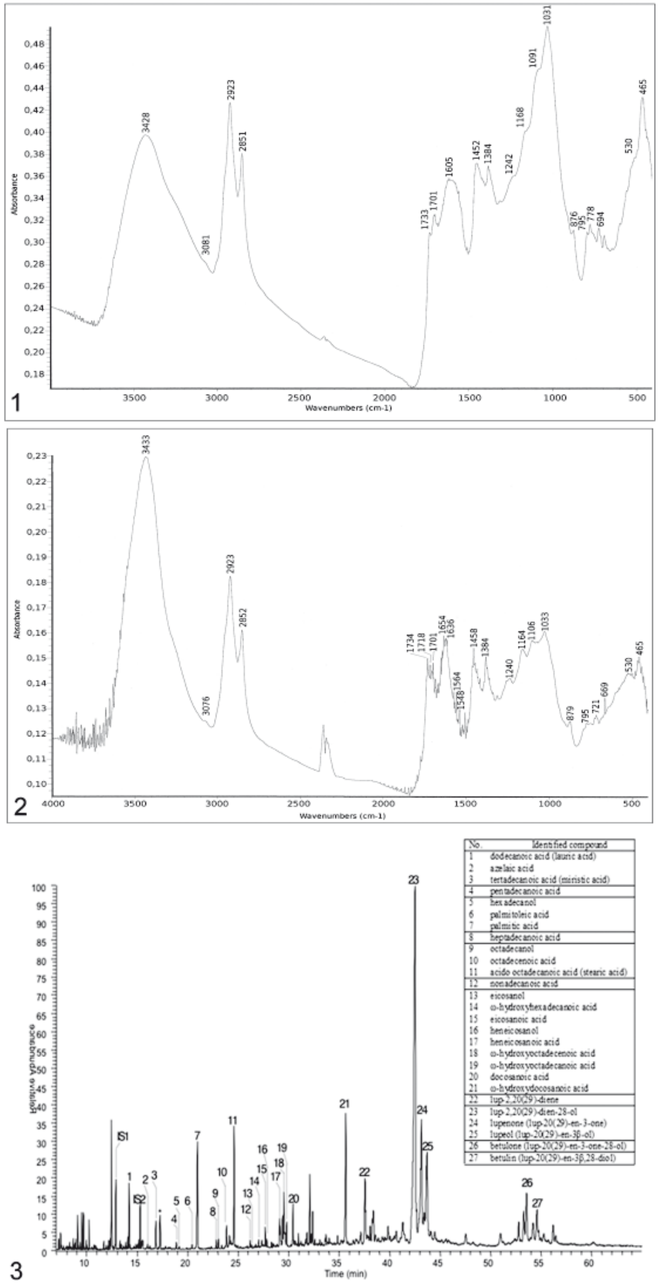
(T. Gralak, personal communication), the residue was subjected to C14 dating. The age of the resinous substance is dated to 4675 ± 35 BP (Poz-100277) (3525-3366 BC after calibration, using OxCal 4.3.2, Bronk Ramsey and Lee 2013) and correlates with the late phase of the TRB settlement in SW Poland (Kulczycka-Leciejewiczowa 1997; Dreczko 2017; 2018), although it is older than the radiocarbon dates from the animal bones at the Polwica-Skrzypnik site complex (Kulczycka-Leciejewiczowa and Noworyta 2009). Thus, the tool either found its way inside the well accidentally or was intentionally relocated from its original place of discard.

Infrared spectroscopy of the sample shows analytical signals for both organic and inorganic materials (Fig. 6:1). The main inorganic compound is located in the 1030 cm^{-1} region and is connected with silicates (Si-O band) from clay minerals (Luxan and Dorrego 1996). The other Si-O peaks from quartz are observed at: 795, 778, 694 and near 530 cm^{-1} (Shillito *et al.* 2009; Saikia and Parthasarathy, 2010). These inorganic signals are the consequence of contamination of the sample by clay and soil. For archaeometric identification, other peaks are more important. Absorptions due to the presence of uncharacteristic OH stretching vibrations were detected in the region around 3400 cm^{-1} (at 3428 cm^{-1}) and at 1242 cm^{-1}. The next significant signals were located in the range 2800-3000 cm^{-1} (peaks from carbon-hydrogen bands). The most important are peaks at 2923 and 2851 cm^{-1}, which are the stretching vibrations due to methyl ($-CH_3$) and methylene ($-CH_2$) groups in hydrocarbon skeletons.

Other bands in the spectrum are those in the region 1450-1380 cm^{-1}, due to the $-CH_2$ and $-CH_3$ bending vibrations (1383.9 and 1451.5 cm^{-1}). This indicates that the sample has both saturated (alkanes) and unsaturated (alkenes) hydrocarbons, as well as an aromatic structure (a signal at 1605 cm^{-1} and a very weak peak at 1487 cm^{-1}). The next identified peaks provide information about the other elements of the sample's structure. A stretching band of a carboxylic group at 1701 cm^{-1} and a methyl ester signal at 1733cm^{-1} are present.

All identified analytical signals confirm plant material: wood tar or pitch, obtained from thermal processes of wood (Font *et al.* 2007; Łucejko *et al.* 2012). The presence of two peaks at 2922 and 2852 cm^{-1} suggest raw-materials of birch (Shillito *et al.* 2009), because of triterpenoids present in *Betula* bark (Orsini *et al.* 2015; Ribechini *et al.* 2015). The resinous products from the *Pinaceae* family were excluded (Colombini *et al.* 2005; Duce *et al.* 2015; Font *et al.* 2007; Izzo *et al.* 2013).

The GC-MS analysis of the same blackish substance allowed the establishment of its chemical composition (Fig. 6:3). Triterpenoids with a lupane skeleton, lup-2,20(29)-dien-28-ol, lupenone, lupeol (lup-20(29)-en-3â-ol), lup-2,20(29)-diene, betulone (lup-20(29) en-3-one-28-ol) and betulin (lup-20(29)en-3â,28-diol), are the main constituents of the sample. In addition, a series of linear alcohols ranging from 16 to 22 carbon atoms, a series of linear carboxylic acid fatty acids ranging from 12 to 22 carbon atoms and a series of ů-hydroxycarboxylic fatty acids ranging from 16 to 22 carbon atoms are also present. The molecular profile determined by the GC-MS confirms unequivocally that the material on



No.	Identified compound
1	dodecanoic acid (lauric acid)
2	azelaic acid
3	tertadecanoic acid (miristic acid)
4	pentadecanoic acid
5	hexadecanol
6	palmitoleic acid
7	palmitic acid
8	heptadecanoic acid
9	octadecanol
10	octadecenoic acid
11	acido octadecanoic acid (stearic acid)
12	nonadecanoic acid
13	eicosanol
14	ω-hydroxyhexadecanoic acid
15	eicosanoic acid
16	heneicosanol
17	heneicosanoic acid
18	ω-hydroxyoctadecenoic acid
19	ω-hydroxyoctadecanoic acid
20	docosanoic acid
21	ω-hydroxydocosanoic acid
22	lup-2,20(29)-diene
23	lup-2,20(29)-dien-28-ol
24	lupenone (lup-20(29)-en-3-one)
25	lupeol (lup-20(29)-en-3β-ol)
26	betulone (lup-20(29)-en-3-one-28-ol)
27	betulin (lup-20(29)-en-3β,28-diol)

Fig. 6. Polwica-Skrzypnik, SW Poland. FTIR spectrum of black resinous sample extracted from flint tool nos. 16 (1) and 5 (2). Chromatogram obtained in the GC/MS analysis of the sample from flint tool no. 16 (3). Total ion current chromatogram of the resinous sample (the acidic and alcoholic species are present as TMS-derivatives). Labels refer to the table. Edited by B. Miazga, J. Łucejko

the flint tool is tar obtained by a pyrolysis-type process on bark of the *Betulaceae* family of trees, which includes birch (Colombini *et al.* 2006; Ribechini *et al.* 2011).

The second tool selected for the residue analysis was a slightly heated, completely retouched blade, with semi-steep retouch on its distal end and denticulate retouch on its right lateral edge. There are vast patches and small spots of blackish adhesives on the left lateral edge and on fragments of the dorsal surface of the tool. Highly reflective sickle polish is visible on its right lateral edge (Fig. 3:3). The FTIR analyses of the black deposit on the flint tool were much more difficult due to the small amount of the residue on the object and its poor state of preservation. The extracted sample was less than 1 mg. The infrared spectrum (Fig. 6:2) is similar to that obtained for the previously described sample, and also suggests the organic character of this residuum. The most important analytical signals are: 2936.6 and 2852.5, and 1458 and 1338 cm^{-1} from methyl and methylene groups. The other signal belongs to aromatic structures (about 1600 cm^{-1}), a carboxylic group (1701 cm^{-1}) and esters (1734 cm^{-1}). All these peaks are characteristic for triterpenoid resins (Shilito *et al.* 2009), present in pitch and wood tar.

DISCUSSION

The results of the analysis direct our attention to four aspects of the research. First of all, the possible provenience of flint blades made from erratic raw material requires explanation. As written above, Bronowicki (2009) claims that flint nodules or blanks were imported from Upper Silesia, ca 120 km southeast of the site. This statement is not supported by the macroscopic characterisation of the implements. Moreover, Bronowicki himself, as well as other researchers, mentioned several times that erratic flint resources in the area of the Wrocław Plain are larger than was previously thought, with available flint nodules more than 10 cm in diameter (Bronowicki and Bobak 1999; Wiśniewski 2006). In the Polwica-Skrzypnik site complex, two different kinds of blades were selected for retouching: long, wide blades and middle-sized blades. The differences in metric characteristics are considerable, but not enough to suggest that the two groups of blanks were produced in workshops located next to different outcrops. We may only suppose that the required dimensions of large blades for sickles might have exceeded the capacity of local nodules, which were nonetheless appropriate for producing middle-sized blades. In this assemblage, there is only one cortex blade and no flakes or other waste products, but at the other TRB sites from the Wrocław Plain, local flint tool production is confirmed by the presence of small blades and flakes, as well as bipolar products (Romanow *et al.* 1973; Wojciechowski 1973; Lech 1997).

The next problem, which is integrally related to the first one, concerns the use of tools. We can see from this study that metric, technical and probably raw-material features were important factors in the production of tools of a particular function. Large blades made from better-quality raw materials, including Volhynian flint, were modified by denticulate retouch and used for harvesting cereals. They were often resharpened in the course of field work or modified into another tool type, as noted in other regions as well (Balcer 1975; Małecka-Kukawka 2000). The scale of recycling of sickle insets was large compared to other tools. Sparsely retouched medium-sized blades made from erratic flint were used for working animal materials. This assemblage is an example of a dichotomy in flint-tool manufacturing: the production of large sickle inserts based on non-locally made blades, knapped in specialised flint workshops and modified with denticulate retouch; and probably local production of middle-sized blades used for domestic activities. The lack of large sickle inserts was complemented by locally produced blades of smaller dimensions. Two examples of medium-sized blades with denticulate retouch were used as sickle inserts (Fig. 2:4-5). Such a manner of flint management is closer to that seen in Kuyavia, where people also had access to local erratic flint resources, and tried to establish some fraction of production independent from the import of Chocolate flint (Domańska 1995; Małecka-Kukawka 1992).

The presence of phytoliths is the third aspect of this research. It should be mentioned that such an analysis has not been preceded by similar study related to the residues on tools in Poland. Phytolith analysis showed a broader range of plant species cut with sickles than was previously revealed in palaeobotanical studies. In addition to phytoliths from Poaceae or Cyperaceae, phytoliths from subfamily Panicoideae of Poaceae were also recorded, which means that cereal cultivation near the Polwica-Skrzypnik site complex may also have included broomcorn millet (*Panicum miliaceum),* recorded at a few TRB sites so far (Lityńska-Zając 2009b). The same sickles were probably used for harvesting cereals and wild siliceous plants, such as sedges or bulrush. Plants were cut together with culms, which is suggested by the texture of usewear traces and confirmed by additional data from daub with imprints and the charred remains of stems and straw (Krupska *et al.* 2009).

The last interesting aspect we would like to consider is the hafting mode of sickles. The fact that large blades were intensively recycled may suggest that sickles were made as composite tools at the site. Remains of tar made from the bark of *Betulaceae* trees via a process of pyrolysis were identified with the use of FTIR and GC/MS analysis. These are the first cases of flint tools with macroscopically visible adhesives, used to attach flint sickle inserts to handles, which have been confirmed at Neolithic sites in SW Poland. The locations of both usewear traces and the adhesive suggest that only the very edge was available for cutting plants, and the majority of a flint specimen was mounted in a haft. Certainly, the reconstruction of a complete sickle is not possible, because there are no hafts preserved at the TRB sites in this region. However, the most probable model of a TRB sickle from Polwica-Skrzypnik was a tool with one blade inserted laterally, mounted tightly with wood tar in an elongated or short wooden haft. Experiments conducted by one of the authors (B. K-D.), using both types of sickles, do not show any significant differences in efficiency or in the development of gloss on the cutting edge. A sickle with a short haft was slightly less efficient than a sickle hafted in a long handle, but this opinion is only based on the subjective impressions of the experimenter and requires more independent experimental studies.

CONCLUSION

Our knowledge about the use of plants by societies identified with the Funnel Beaker culture in Poland is limited due to the scarcity of archaeobotanical data. Detailed studies of secondary sources such as traces and residues on agricultural tools bring valuable information to this area of study. We analysed twenty-one flint tools used and discarded by people identified with the TRB. Despite the small number of implements in the assemblage from the Polwica-Skrzypnik site complex, the artefacts demonstrated the potential to provide a more detailed understanding of the use of tools. Two different kinds of blades were selected for retouching: long, wide blades and medium-sized blades. Large blades made from better-quality raw materials, including Volhynian flint, were modified by denticulate retouch and used for harvesting cereals, while middle-sized blades were slightly retouched and used for other domestic activities, such as cutting soft animal materials. Phytolith analysis of three flint inserts with intense sickle gloss showed that the following plant families were cut with sickles: the Poaceae or Cyperaceae family, and subfamily Panicoideae of Poaceae. A blackish resinous substance, identified through the use of FTIR and GC/MS analyses as wood tar made from bark of *Betulaceae* trees, and previously considered as residue of a younger age, was demonstrated to be a Neolithic adhesive. Our results indicate that the combination of usewear studies along with residue analysis is a valuable tool for studying prehistoric material culture.

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