RECREATING ARTEFACTS AND ANCIENT SKILLS FROM EXPERIMENT TO INTERPRETATION

Edited by
Monica Mărgărit and Adina Boroneanț

CETATEA DE SCAUN

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FOREWORD

"If we hope to achieve the aim of reconstructing culture history, we must develop means for using archaeological remains as a record of the past and as a source of data for testing propositions which we set forth regarding past events".
(L. Binford 1968. 11)

Early archaeological experiments focused on replicating ancient structures or artefacts using materials, tools and techniques allegedly used by people in the past. Experiments were employed when conventional methods of archaeology no longer worked, attempting to test, explain and ultimately reconstruct crafting practices, technical facilities, and work methods.

At present, experimental archaeology has long passed its infancy, and much has changed since its 19th century debut (e.g. Evans, 1872). It was during the 1950s that S.A. Semenov (1964) innovated the field of functional analysis, and since then experimental archaeology was recognized as essential to usewear studies and its impact slowly but steadily extended over other archaeological fields of study. The number of publications has increased significantly, triggered by conferences and workgroups on experimental archaeology and use-wear analysis (e.g. Alonso *et al*. (eds.) 2017; Beyries *et al.* (eds.) 2021, as the most recent).

But, comparatively speaking, experimental archaeology plays a rather a marginal role, still, despite its immense potential for reconstructing the past and the strides it has made in asserting and developing itself: if early experimentations were mainly 'replicative' focusing on obtaining the exact aspect of specific archaeological artefacts/structures, at present, particular attention is given to the scientific framework of the archaeological experimentation, focusing on the design and control of the experiments for testing specific hypotheses about past activities. At the moment, experimental archaeology and use-wear analysis are combined in order to better understand the multifaceted aspects of an object's life, among which manufacture and use are usually seen as the most significant.

This volume focuses on the role and means of archaeological experimentation in understanding the processes involved in the design, manufacture and use of past artefacts. We set out looking for contributions that would test existing theoretical hypotheses but also others that bring forth innovative approaches. When asking for contributions, we suggested the five stages of an experimental approach as main-themes: 1. Selection and acquisition of raw materials, identical to those present in the archaeological assemblages. 2. Production of replicas following the technological transformation schemes identified by the direct study of archaeological items. 3. Experimental use as indicated by the publications/ethnographic comparisons or as suggested by the morphology/use-wear evolution of the archaeological items. 4. Microscopical analysis of use-wear patterns. 5. Comparison of experimental data with archaeological data in order to validate the existing hypotheses on their manufacture and use by the human communities. A second aim was for the invited authors to come from various archaeological backgrounds and cover a broad spatial and temporal interval.

As a result, this volume comprises 17 studies organized in three sections, dictated by the various aspects of experimental archaeology they represent: from the more traditional experimental replication, understanding and interpretation of artefact functionality, and relatively recent (and less trodden) directions in experimental archaeology. It also comes to show that experimental archaeology is as well suited for Palaeolithic studies as it is for the Neo-Eneolithic and the Bronze Age. Although most papers refer geographically to Europe, interesting contributions take us to Argentina and Australia.

The seven papers falling into the section *Experimental replication* present experimental projects dealing with: animal butchering techniques in the Middle Paleolithic (Marie-Cécile Soulier, Sandrine Costamagno, Emilie Claud and Marianne Deschamps); ivory processing during the Aurignacian period (Wulf Hein); reconstruction of prehistoric boats (Grzegorz Osipowicz, Justyna Orłowska, Justyna Kuriga, Alicja Bieniek, Dominik Chlachula, Jeljer Huisman, Hildegard Müller, Tabea Müller, Matteo Orsi, Marijn Rudolphie, Claudio Simoni, Sanne Smit, and Dorota Wojtczak); Eneolithic fibre production (Ana Ilie); manufacture and use of arrowheads during the Eneolithic (Ion Torcică and Marius Gheorghe Barbu, Mihaela Maria Barbu and Ioan Alexandru Bărbat); Bronze Age pottery making (Angie Wickenden).

The following section - *Paths to functionality* - debuts with an overview of the prehistoric projectile points (Jean-Marc Pétillon, Pierre Cattelain), followed by contributions on the use of different types of personal adornments (Monica Mărgărit; Leïla Hoareau, Sylvie Beyries; Ekaterina N. Golubeva, Madina Sh. Galimova and Vera N. Bakhmatova), grinding technology as triggered by rock properties (Vesna Vučković); functionality of shell and lithic tools inferred from microwear traces (Romina Silvestre, Natacha Buc, Daniel Loponte and Alejandro Acosta).

The final section - *Fresh approaches to experimental interpretation* - brings forth four experimental programs that had employed methodologies less frequently undertaken: inferring functionality of skin working tools by the study of microscopic animal residues (Elspeth Hayes, Nina Kononenko); identification of vessel manufacturing techniques using computed tomography (Vasile Opriş, Adina Boroneanț, Marta Petruneac, Mihaela Golea, Marin Focşăneanu, Robert Sîrbu and Clive Bonsall); ascertaining the function of the *bucchero* incense burners (Darya A. Derzhavets) or re-discussing the results of fire use in the manipulation of the dead (Yannis Chatzikonstantinou).

Hopefully, the present collection of works will convince once again of the importance of archaeological experiments and their significant contribution to the understanding of the human life- and deathways of the past. It also makes a convincing plea, we believe, for interdisciplinarity and the use of new techniques and methods pertaining to the physical and chemical sciences, but not only. Last but not least, it shows that there are almost no limits to testing archaeological hypotheses by means of well developed, science-based experiments.

We would like to thank all contributors who answered our call, and with patience and goodwill helped us complete this volume in less than a year. Each paper was submitted to external reviews. Therefore, our gratitude goes to our colleagues who anonymously reviewed the contributions, offering comments and suggestions that improved the overall content of the volume.

The Editors

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RECONSTRUCTING PREHISTORIC BOATS. A REPORT ON TWO EXPERIMENTS CARRIED OUT DURING THE FIRST INTERNATIONAL CAMP OF EXPERIMENTAL ARCHAEOLOGY, TORUŃ 2021

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Recreating artefacts and ancient skills: from experiment to interpretation

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Abstract: This article reports on two main archaeological experiments that were conducted during the first International Camp of Experimental Archaeology, which took place in August 2021 at Golub-Dobrzyń, close to Toruń, Poland. During the two weeks of this event, its participants, divided into two groups, carried out the reconstruction of two archaic boats: a dugout and a leather-covered boat known from ethnographic contexts mostly as the so-called skin-on-frame canoe. All work was carried out using exclusively techniques and tools known in the Stone and Bronze Ages. Also, this article presents a first discussion on the characteristics of use-wear traces created on the experimental tools.

Keywords: experimental archaeology, traceology, dugout boat, leather-covered boat, Stone Age, Bronze Age.

1. Introduction

Experimental archaeology in Poland has a tradition of over 100 years since the first works on this field were published by Stefan Krukowski at the beginning of the 20th century (Krukowski 1915). At the Institute of Archaeology of the Nicolaus Copernicus University in Toruń (IA NCU), this research tool was used for the first time by Kazimierz Żurowski in the 1970s, to study the methods possibly used to soften prehistoric osseous raw materials (Żurowski 1974). Almost simultaneously, works in the field of experimental archaeology were also carried out by Andrzej Kola and Gerard Wilke, who focused their interest on the production of Medieval crossbow bolts (Kola and Wilke 1975). In 1995, Jolanta Małecka-Kukawka and a group of students participated at the Traceological Camp in Izhevsk, organised by the Russian Academy of Sciences. As a result of the cooperation established during this event, in April 1996, a two-week traceological course was organised for the first time at the IA NCU.

Of key importance for the development of experimental archaeology at the IA NCU was the foundation of the Laboratory of Traceology in 2008. The Laboratory has largely focused the experimental work carried out in our center on the creation and development of a base of experimental tools made of various raw materials, to be used as comparative material for the traceological analysis of the prehistoric artefacts. This database is currently one of the largest, if not the largest in Poland. Its development was also possible thanks to the commitment of the members of the Society for Experimental Prehistoric Archaeology (SEPA), a student organisation founded in 1998 at our Institute.

Since the beginnings of the SEPA, its members have dedicated great effort to engage in numerous scientific experiments with the aim to reconstruct the human lifeways in prehistoric times. These works were focused two fold: to solve more general problems connected to different techniques/methods of production/ processing of different raw materials in prehistory (Orłowska 2015, 2016; Osipowicz 2005a, 2005b, 2007), as well as to answer very specific questions linked to the technology and function of specific artefacts (Orłowska and Osipowicz 2017; Orłowska 2018a, 2018b, 2019, 2021; Osipowicz *et al.* 2019, 2020a, 2020b, 2020c, 2020d, 2020e). Over the more than 25 years of SEPA's existence, its members have organised several experimental camps, dedicated to time and resource consuming experiments (Osipowicz *et al.* 2015).

The latest initiative in the field of experimental archeology proposed within the IA NCU is the publication of the quarterly newsletter *Experimental Archaeology at the Nicolaus Copernicus University. The Newsletter.* The first issue was released in 2018. The Newsletter is published on the Internet (via www. academia.edu and www.researchgate.net) and contains short papers describing past and present projects in experimental archaeology, conducted at the Nicolaus Copernicus University.

1.1. The International Camp of Experimental Archeology, Toruń 2021

One of the most recent significant undertakings initiated and organised by the employees of the Institute of Archeology NCU was the *International Camp of Experimental Archeology, Toruń 2021*. The Camp took place on August 16-28, 2021 and was held at the castle in Golub-Dobrzyń, Poland. During two weeks, participants of the event (students from Italy, Switzerland, Netherlands, Namibia, Czech Republic and Poland), divided into two groups, undertook two complex archaeological experiments, with the purpose of creating and testing replicas of two archaic boats: a dugout and a leather-covered boat known more from ethnographic contexts, as the so-called skin-on-frame canoe. All work was carried out exclusively using techniques and tools known in the Stone and Bronze Ages.

From a scientific perspective, the main goal of both experiments was to supplement the IA NCU's experimental tool reference collection with macrolithic heavy-duty tools and with specimens used for activities requiring large-scale supportive processes, such as burning (in the case of wood) and soaking in lye (for removing hair from hides). The experiments carried out during the Camp also yielded the first tools for traceological studies regarding the function of prehistoric metal tools, to be developed in our center in the future.

This paper presents the results of the two main experiments carried out at the Camp, and offers a first glance on the characteristic of the use-wear traces left on the tools used during these works.

2. The experimental making of a dugout boat

2.1. Archaeological background

Log boats are units hollowed out from the complete or half-cut trunk of a tree. Ethnographic sources confirm their use in many regions of the world (Pydyn 2011. 251). The simplicity of this type of units and the relatively less complex set of tools necessary to produce them, made them one of the oldest types of boats used by man. Unlike many other types of simple water transport, dugouts are known from relatively numerous archaeological contexts dating to the Stone Age (Pydyn 2011. 251). The oldest European find of this type is a log boat from the Pesse swamp in the Netherlands (van Zeist 1957), dated to 8265±275 BP (uncal). It is estimated that ca 300 units of this type have been found in Poland. At the same time, only 5 of them are dated to the Neolithic and early Bronze Age (up to 1300 BC; Ossowski 1999. 177-211). The construction method of dugouts depended primarily on their purpose, local tradition, and available material. Ethnographic sources show that both, deciduous and coniferous trees were used to make them. Both, the hard and durable trees, e.g., oak, were chosen, as well as the soft and easy to handle, e.g., poplars (Ossowski 1999. 50).

2.2. An overview of the experimental work to date

Log boats are not only the oldest archaeological evidence of watercraft but possibly also the most replicated one (Menotti 2012, 301). The number of experiments carried out over the years showed that the prehistoric boats of this type could have been made in many ways, from applying the different types of burning techniques, to the use of tools made of stone, metal or even bone (Christensen 1990). Many experiments on this field carried out until now were focused on the reconstruction of boats from specific periods using tools and techniques known in the given eras, for example the Mesolithic (Moses 1987; Christensen 1990), Neolithic (Christensen 1990; Martić 2012) or Bronze Age (Strachan 2010). Amongst the many experiments, one of the most interesting is the attempt to replicate the Late Bronze Age log boat found at Roseninsel on Lake Starnberg, Germany. The 13.40 meters long and 70 cm wide replicated oak dugout was successfully launched in 2000 and showed a carrying capacity of ten people (Schobel 2001). An interesting example of the experimental testing of prehistoric log boat replicas are the two voyages in dugout canoes called the Monoxylon Expeditions, that took place between Aegean and Mediterranean islands in 1995 and 1998 (Tichý 2000, 2001). As an inspiration for this project served, among others, the Neolithic log boat discovered in Lake Bracciano, replicated with Stone Age tools and techniques. A different example here can be the Prometheus Project, which aimed to investigate a debated aspect of prehistoric log boat construction - the use of fire (Watts 2014).

2.3. Materials and tools

As possible raw material for our dugout boat, we have prepared two tree trunks, one from European ash (*Fraxinus excelsior*) and the second from poplar (*Populus*). The trunk of the poplar was about 8 meters long and 90 cm in diameter. It had been cut four years before the Camp started. During this time, it was exposed to changing weather conditions. The ash trunk was about 6 meters long and 80 cm in diameter. Unfortunately, it was not perfect having a large knot in the middle, the remains of one of the tree's main branches. This trunk was exposed to weathering for two years.

Figure 1. Examples of experimental tools used in the making of the dugout boat.

In view of the project, we prepared 27 different tools, which were replicas of known prehistoric artefacts. The set included:

- eight antler adzes (Fig. 1A). The tools were made mainly from the proximal end of red deer antler beams. The working edges were cut to create the characteristic bevelled blade oriented perpendicularly or slightly obliquely to the line of the haft. For the fastening of the handle, the perforation, mostly 2–2.5 cm in diameter, was carried out in the butt part of the tools. All handles were made from deciduous tree wood.

- two T-shaped antler axes (Fig. 1B). The tools were made from the central part of the red deer antler beam. The area left after removing the trez tine was perforated to insert the handle. Working edges were cut to create the characteristic bevelled blade that was set parallel to the line of the handle. All handles were made from deciduous tree wood.

- two polished flint axes (Fig. 1C). The semi-products of the axes were made from Baltic-erratic flint by a skilled flintknapper. Their working edges were polished on a plate of sandstone. The shafts for the axes were made from oak roots.

- five antler-sleeved tranchet axes made of flint (Fig. 1D). The axes were prepared by a skilled flintknapper from Baltic-erratic flint. They were fixed in sleeves made of red deer antler and mounted on handles made of deciduous tree wood.

- two bronze adzes (Fig. 1E) and two bronze axes (Fig. 1F). These tools were prepared especially for the needs of the Camp by a skilled caster. They are replicas of Bronze Age socketed and flanged axes/adzes. All tools were mounted in handles made of oak tree.

- an iron adze (Fig. 1G). Similarly to the tools described above, this one was also prepared especially for the need of the Camp by a skilled blacksmith. It is a replica of an Iron Age socketed adze. It was mounted in a handle made of oak tree.

- four wooden wedges. These tools were made from pine wood. They had a bevelled working edge and a blunt end.

- two wooden mallets (Fig. 1H) made of beech tree.

2.4. Description of the experiment

Stage 1 - Processing the outer part of the trunk (removing the bark, the soft outside of the wood and the rotten fragments of raw material)

This stage of the work was carried out without using techniques supporting raw material processing (burning). Its purpose was to test the quality of the raw material used, remove its damaged fragments and pre-shape the boat. In the beginning, we chose the poplar trunk for the dugout, which has much better properties, i.e. straightness, uniform thickness, considerable length and, above all, lesser hardness of the wood. We started the work on the trunk by removing the rotten parts of the wood and checking its general condition (the bark had been removed earlier). Wooden wedges and antler adzes, hit with wooden mallets, were used. Unfortunately, after removing a few layers of the decaying wood, we noticed that the trunk was no longer suitable for constructing a dugout. Therefore, we stopped working on this trunk and started peeling the bark from the second (ash) tree trunk. The same tools as for the first trunk, i.e. wooden wedges and antler adzes, were used for this activity. The work was effective, and the peeled bark came down in long patches (Fig. 2A). The trunk turned out to be well preserved. Once the bark ended, it was time to prepare the top of the trunk for the firing process. To do this, first, we flattened it, and then we chiseled a groove along the entire length of the trunk. We performed these activities using a flint axe (Fig. 2B) and the antler adze used as a chisel/wedge. This stage took about 2 hours.

Stage 2 - Treatment of the inner part of the trunk

At this stage, burning was started as processing method. It consisted in placing (initially) glowing charcoals inside the groove made earlier and later, after a few firings, inside the shaped boat. Wood-burning was maintained with an air blow, and the charred fragments were removed with replicas of various prehistoric tools. The sides of the boat were protected with a layer of wet clay and sand, which prevented them from burning (Fig. 2C). This also helped also with forming the shape and thickness of the dugout. To spread the fire along the length of the trunk, pine and beech wood chopped into small pieces were used (Fig. 2D).

The first "burning episode" lasted about 1 hour 30 minutes. Subsequently, the coal and the fuel remains were removed (they were moved to a nearby fire for re-use). When the fired surface cooled down slightly, we proceeded to remove the charred layer of wood inside the boat with a flint tranchet and the antler adzes (Fig. 2E). We found the work of roughly chiseling the burnt raw material and then removing its remains by scraping as the most effective. The process of "cleaning out" the part of the trunk being processed took about 20 minutes. After its completion, we started firing anew. During the first day, we performed the described activities three more times (burning, removing the charred surface, protecting the boat walls with clay).

Figure 2. Photographic documentation during the experimental making of a dugout boat: A - Removing the bark from the ash tree trunk; B - Chiselling and flattening of the trunk using a flint axe; C - Protecting the external sides of the dugout with clay; D – Heat spread along the length of the trunk; E - Removing the charred layer of wood with a flint tranchet and antler adzes; F - Removing charred wood from the inside of the boat with flint tranchets; G - The next stage of the firing; H - Removing charred wood with the help of Bronze Age and early Iron Age tool replicas; I - Removing (trimming and scraping) the burned wood.

We conducted our experiments in a very windy place (deforested edge of a large river valley). In the early stages of the firing wind had a negative impact on the burning process making the fire more difficult to control. To solve the problem and to protect the nearby located buildings from the accidental transmission of fire, we have decided to construct a windscreen. It was made of wooden poles stuck into the ground at some distance from each other, and reed mats were stretched between them.

Our work schedule for the next couple of days was similar to the one described above. We started the day around 9:00 am by lighting a fire inside the trunk, which usually lasted for about half an hour. Then a 1.5 hour burning process (Fig. 2G) took place, followed by: (1) removing the embers and unburnt pieces of wood (fuel), (2) a 15-20 minute break for the surface to cool down, and (3) removing (chopping and scraping) burned wood. The last of these activities usually took about 20-30 minutes, with the involvement of 2 to 4 people. Every day, we were able to carry out 3 to 4 such cycles, which resulted in the removal of approx. 6-8 cm of wood layer. We finished the work every day around 18:00.

As time went on, we started to work with metal axes and adzes, replicas of tools from the Bronze Age and the early Iron Age (Fig. 2H). They turned out to be very effective as they made deeper cuts inside the processed wood thus triggering an increasing depth of fire penetration during the burning process. We decided to permanently include the tools mentioned above in our works due to the high hardness of the ash wood and the associated firing efficiency lower than expected in the stone tools (on average, after 1 hour 30 minutes of the burning process, it was possible to remove only approximately 2 cm of the burnt wood layer).

Unfortunately, after six days of work, we noted that the firing of the trunk was advancing much slower than assumed, generating the risk of not being able to finish the dugout before the end of the Camp. The reason for the delay was the much greater hardness of the ash wood compared to the poplar, which originally was designed to be used in the experiment and which was considered as a basic raw material for a dugout when we planned the schedule of our work. For this reason, we decided to shorten the processed trunk by about 1.5 m. This decision was difficult, but unfortunately, necessary for the boat to be finished on time. At the beginning of the second week, the trunk was half hollow (Fig. 2I). That day, we decided to remove the windscreen because natural wind blow appeared to be invaluable for the burning process at this level.

Stage 3 - Treatment of the outter surface of a trunk

When the burning out of the inner part of the dugout was close to an end, we decided to start the process of shaping the beak and stern of the boat. We lit two small fires at both ends of the trunk (Fig. 3A). The firing took about an hour, followed by the removal of the burnt material (Fig. 3B). This process was repeated several times during that day. At the same time, we have treated some bottom and side elements of the boat to give it a more streamlined shape and to level the boat's curvature (Fig. 3C). The dugout boat was finished after 11 days of work (Fig. 3D).

3. Experimental making of a leather boat

3.1 Archaeological background

Besides rafts, leather boats are one of the oldest means of water transport. Archaeological sources, however, do not provide much data on the methods of building and operating units of this type; hence their reconstruction is often based on ethnographic data and more modern finds. However, this does not change the fact that they were probably used at the end of the Pleistocene (Pydyn 2011. 236). In terms of construction, leather boats refer to bark, cane, or wicker units. They could be built as skeletal, and shell units; the first of these techniques is better confirmed by sources (Pydyn 2011. 237). The most numerous categories of leather boats include small round, oval, elliptical and square or rectangular units. They were common in various geographical regions (Hornell 1946. 93-172; Johnstone 1980. 26-44; McGrail 1987. 173-191). The skins of many animal species were used to make their plating, e.g. in the United Kingdom and Ireland, they were primarily cowhides, while in the Arctic zone, deer, caribou, whale, seal and sea lion skins were used (McGrail 1987, 176).

Figure 3. Photographic documentation of the experimental making of a dugout boat: A - Shaping the dugout's beak and stern parts with the help of small fires at both ends of the trunk; B - Hewing the burnt area of the boat with bronze axes; C - Hewing the bottom of the boat with a bronze axe; D - Camp participants with finished dugout.

3.2. An overview of the experimental work to date

The great majority of the reported reconstructions of the leather-covered boats were built using modern methods. One can find many examples of this type of project on the Internet, based to a greater or lesser extent on historical or ethnographic finds. However, many of these projects have also some scientific value. One of the more interesting and earlier experiments on this type was aimed at making the *umiak* and was carried out by the National Museum of Canada, Ivugivik in 1960 (Arima 1961). Another interesting experiment was inspired by the Bronze Age rock-carved ships from Scandinavia and aimed to build and test a leather boat replicating those depicted on rock carvings, with methods and tools available in that period (Johnstone 1972; Marstrander 1976). The last experiment that is worth mentioning was aimed at the construction of a skin-on-frame canoe (Groom *et al*. 2019a) and a skin-on-frame coracle (Groom *et al*. 2019b). It was developed at the Kierikki Stone Age Centre in Finland. Both units were built with prehistoric techniques; however, modern metal tools were also used in the process.

3.3. Materials and tools

Plant materials in the shape of willow (*Salix* sp.) branches necessary to build the skeleton of a boat were collected from the nearest forests. To cover the boat we have used red deer (*Cervus elaphus*) skins, sewn together with strings made of pig intestines.

For the needs of this project, two replicas of a Neolithic flint axe and a stone axe were prepared. Also, we have used two Bronze Age axe replicas (one shaft hole axe and one flanged), analogous in shape to the ones described in the case of the experimental dugout boat making. In addition, flint tools were prepared, including six knives made on blades and three end-scrapers that were hafted in wooden handles, a bifacial knife, an end-scraper wrapped in leather, and finally, a deer rib with unretouched flint inserts. The collection of tools to be used in the experiment was supplemented by bevel-ended osseous tools made of long deer bones (two made of fresh bones, two made of bones aged for about a year) and a dozen of awls and point-type tools made of cattle bones (two awls, eight spindle-shaped point-type tools of different lengths and two specimens of this type with a thick base/handle and a small thin point).

3.4. Description of the experiment

Stage 1 - Making a boat frame

The construction of the boat began with a frame, on which leather sheathing was supposed to be stretched later. In the first stage of the work, preparing the necessary wooden raw material i.e. straight willow branches, was the most important. To cut them off, replicas of Neolithic and Bronze Age axes were used. Initially, due to the experimenters' lack of skill, the work with these tools was difficult and ineffective. The difficulties resulted, among others, from the fact that the branches had to be cut at some distance from the ground, which resulted in the "bouncing" of the axes due to the high elasticity of willow branches. However, as time passed, the process became more effective as the participants became more experienced (Fig. 4A-B). During this stage, the branches needed for the construction of the frames used later to stretch and clean deer hides were also cut off. All branches were cleaned of leaves by hand. A flint knife, which was used occasionally to incise the bark, also proved to be helpful in this operation. The result of this stage of work was the acquisition of about 80 large willow branches with a diameter of 3 to 5 cm and numerous twigs for plait.

After obtaining the materials necessary to build the boat's skeleton, we delineated its shape on the ground. The works started with drilling two holes at a distance of 4 m, where two larger branches (approx 2.5 meter long) were placed, constituting the future keel (Fig. 5 - marked with red line). With the help of a string connecting them, the main axis of the boat's hull was marked out. In its middle point, the maximum width of the hull was marked, which was 1.4 m (70 cm from each side of the keel). At the ends of this line, in the drilled holes, two long branches of about 1.8 m were inserted. This way were obtained the two perpendicular axes of the boat's symmetry. Then, symmetrically, every 25-28 cm around the entire perimeter of the future boat were drilled holes, where branches building the boat's frame were placed (Fig. 4C). There were 17 branches on each side - 34 branches in total on both sides. The boat's sides were woven to a height of about 28 cm along its entire circumference with willow twigs (Fig. 4D). In the next step, the two largest branches forming the keel were tied and connected to the woven parts of the boat sides. Eight branches were used on each side of the keel to form four longitudinal "boat frames" of the skeleton (cf. Fig. 5 - marked on the green; Fig. 4E). Both the bow and the stern of the boat were secured with poplar bast, and their structure was strengthened by tying a series of willow twigs so that the plating would not be broken in the future when reaching the shore (Fig. 4F). The skeleton constructed this way was turned inner side up. Then the braided lines on the sides were completed, strengthened, and finished by tying them with a poplar bast (Fig. 4G). From the bow and stern, two beams 1.5 m long and approx. 3 cm thick were added to strengthen the frame. Later, 17 branches of about 70-100 cm in length and 2 cm thick were attached to the bottom part of the boat to create the frame of the boat floor. The frame was covered with two mats made of the willow twigs (Fig. 4H).

Stage 2 - Preparation of hides necessary to cover the boat

To cover the skeleton of the boat, eight deer hides were required. Due to the limited time we had for our Camp, we have decided to prepare six of them in advance. The remaining two were processed during the Camp. Two frames were constructed from previously cut willow branches, on which fresh deer hides were stretched (Fig. 4I). These hides had to be cleaned of the remains of flesh (Fig. 4J). A bifacial knife, two end scrapers, three knives made of flint blades, and four bevel-ended bone tools were used for this task.

Flint knives were used for preliminary cutting off the meat remains, while the end scrapers were mostly used to precise remove the fat. In turn, the work with the bone bevel-ended tools (that were the most useful here) consisted of hitting the taut hide from the top to the bottom at approximately 45 degrees, which resulted in the systematic removal of the layer of flesh.

What is worth noticing, in the case of the two bevel-ended tools made of old bones, is the significant blunting of the working edges observed already after 2 hours of work. The blunting hindered the effectiveness of cleaning the hides. Therefore, it was decided to cut these working edges off (these fragments were saved for traceological analysis) and prepare new ones on the sandstone plate. Then, processing continued. Notably, there is a difference in the durability of the working edge between the tools made from old bones and the one made from fresh bone, where, despite the 4 hours of working, no blunting of the edge was noticed.

Figure 4. Photographic documentation of the experimental making of a leather boat: A - Cutting the branches with a bronze axe; B - Shortening the branches with a flint axe; C - Outline of the future skeleton during the construction; D - The skeleton during construction - bending branches; E - Complete general construction of the skeleton; F - The bow and the stern of the boat secured with poplar bast and strengthened with willow twigs; G - Finishing the sides of the boat with a poplar bast; H - Mats made of willow twigs for securing the floor of the boat; I - Stretching the hides on the wooden frames; J - Cleaning the hide with a flint knife.

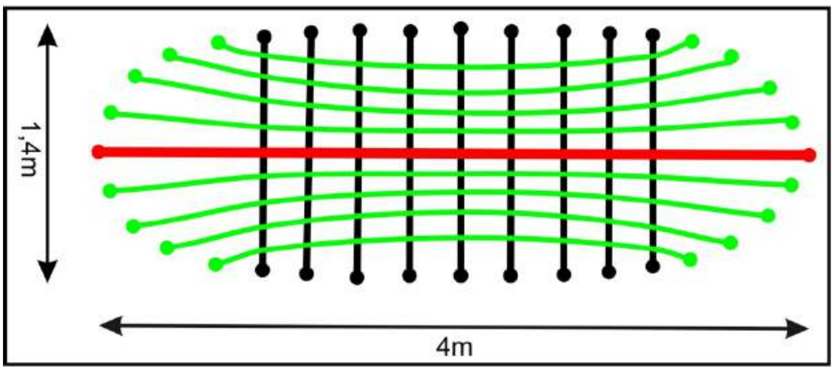

Figure 5. Leather boat skeleton diagram. Red line – keel of the boat; green lines - longitudinal "boat frames" of the skeleton; black lines – perpendicular "boat frames" of the skeleton.

After the hides had been thoroughly cleaned of the remains of fat and flesh, they were put into lye (a mixture of water and ash) for three days. Then, the hides were thoroughly rinsed and stretched on a debarked poplar trunk, where hair was removed by the use of a deer rib with flint inserts and two flint end scrapers (Fig. 6A). The work consisted in scraping the hides with the above-mentioned tools (with and against the grain). The rib-tool created some problems during work because one of the composite inserts was slightly higher. It resulted in an uneven removal of the hair on different parts of the working edge. To fix this problem the insert had to be retouched. After 3 hours of work, another insert cracked and was replaced. The work with the tool finished 40 minutes later. Removing the hair was not an easy process because in certain places hair was still strongly attached to the hides. This was probably caused by the insufficient alkalinity of the lye solution that we used. Unfortunately, due to the limited time that we had at the Camp, it was not possible to repeat the leaching process.

Figure 6. Photographic documentation of the experimental making of a leather boat: A - Removing hair with a tool made of a rib with flint insets; B - Sewn hides on the skeleton; C - Making holes in the hides with a bone point-like tool; D - Twisting the dried pig intestines; E - Sawing the hides with a string made of intestines; F - Stretching sawn hides on the boat's skeleton and connecting them to it with a string; G - Finished leather boat during drying.

Stage 3 - Covering the frame of the boat with hides

The first aim of this stage was to sew together previously prepared hides. They were tried on to the skeleton in pairs and sawn together (Fig. 6B). To obtain the proper shape of the plating, hides were cut with a flint knife. Holes in the hides were used to connect them together and were made along their edges with the bone awls and point-like tools, approximately 1 cm one from each other and from the edge of the hide (Fig. 6C). Significant differences between the tools used in this activity were noticed. The most effective were the tools with a thick base/handle and a small, thin point, while long needles and awls broke very quickly at the tip or at the middle of its length and had to be repaired many times by grinding on the sandstone. The working time of the tools usually ranged from 2 to 35 minutes. In the case of two tools, the working time was 1 and 2 hours. Their working edges had to be sharpened (ground on the sandstone) every 5-15 minutes of use. The two most effective tools (characterised by thick bases and small points) worked for 3 and 6 hours without significant repairs. It is worth noting here that the small size and the shape of these two made it possible to make holes using a combined piercing and drilling technique. On the others, only drilling was possible due to the way tools were hold in the hand (making it impossible to apply higher pressure force).

After the holes were made, the hides were sewn together using dried and twisted intestines (Fig. 6D). Sewing began with two hides forming the bow plating to which other parts were subsequently attached, keeping one direction of the central seam. Dried and well twisted intestines were relatively easy to thread through the holes by hand without the use of needles (Fig. 6E), but there were situations when the intestines got wet from the hides and required the tip to be trimmed with a flint knife. Eight hides sewn together resulted in a seam with a total length of 11.5 m. Its creation was exhausting and required the work of a few people. Sheathing prepared this way was stretched on the boat's skeleton and connected to it with a natural string (Fig. 6F). Then, it was left to dry (Fig. 6G). After 11 days of work, the boat was finished (Fig. 7).

Stage 4 - Impregnation

Due to the limited duration of the Camp, impregnation of the boat was not possible at the place, however, it will be done very soon. The plan is to seal the boat's seams with tar and to impregnate it with animal oil. For now, the boat is kept dry, which prevents its destruction.

4. Discussion

Both experiments conducted during our Camp were a great platform to increase our general knowledge on the usefulness and possible applications of the specific techniques, raw materials, and tools that were used. It gave us the great possibility to discuss their possible applications in different types of activities that could have been conducted in prehistory.

In the case of the dugout boat the entire work lasted 11 days, with at least four people working seven to eight hours each day. The finished dugout is 415 cm long, with an average width of 50 cm, a height of 60 cm and a depth of 50 cm. It was necessary to use approx. 8 m^3 of wood as firing fuel for its completion.

Figure 7. Camp participants with finished leather boat.

Undoubtedly, the most important information that was obtained by this experiment is the one relating to the key importance of the hardness of wood used to make the dugout for the effectiveness of the burning technique, as well as of the penetration capabilities and damage resistance of the stone and metal tools used. Of course, we were fully aware of the differences in the efficiency of processing soft and hard wood with tools similar to those used in prehistory. However, basing our knowledge on the previous experience in this field, concerning primarily the production of small items (e.g. wooden containers), we did not realise how crucial the hardness of the raw material can be for the progress made during the making of a large object, such as a log boat.

During the work, it was also observed that the presence of large knots can be a factor facilitating the processing of hardwood. At least in the case of our trunk, they were characterised by a greater softness of the raw material, which facilitated its penetration both by fire and tools.

It was also crucial to properly protect the dugout walls with clay. In principle, after each firing, the layer of previously applied clay had to be removed and replaced with a new one. The reason was that the fire penetrated the free space forming between the dry and fired clay and the wood to be protected. We have ignored it in the initial stages of burning out the boat. As a result, one of its sides burned through in the upper part.

Working with many different types of tools allowed us to initially classify them in terms of effectiveness and assess their advantages and disadvantages. Bronze tools should undoubtedly be considered the most useful, although they were not without minuses. They tended to move (rotate) on the shaft and fall out (despite the use of ties, ropes, and copper wire, which were intertwined through their ears and attached to the shafts). Antler adzes also proved to be very useful as scrapers of charred wood. Flint axes, on the other hand, were excellent for splitting firewood.

In the case of the leather-covered boat, due to the complexity of the experiment, it was necessary to divide the work, so the steps described above were sometimes performed at the same time. It can have the influence on the real time necessary to create such a boat if someone would like to repeat our experiment with a smaller group of people. After "decompressing" the skeleton, the boat has the dimensions 4.2 m length by 1.75 m width and 70 cm depth. The whole structure is relatively light, and three people can easily carry it. We are not sure how many people will be able to use the boat, however, we think that at least four people will be able to do it.

The list of the observations made during this experiment is also quite long, however, their correct understanding and interpretation require some time and verifications. At this moment, as one of the more interesting, we can point out a difference that was observed in the durability of the working edges between bone tools made of "old" and fresh raw material. Of course, we need to test it statistically and verify these observations (both experimentally and traceologically), however, our observations suggest a very fast degradation of the osseous raw materials and consequently, their limited usefulness for the creation of tools, only a few months after the removal from the animal body (even if the post-deposition conditions were as it seems quite neutral). It can be an important argument in the discussion on the reliability of the suggestions present in the archaeological literature assuming the possibility of re-using even very old bone raw material in prehistory (for example, David and Pelegrin 2009; Osipowicz *et al*. 2020e). More about the reliability of this experiment we will be able to report after testing the boat, a great and real verification of the materials, tools, and technologies used to its creation.

The main scientific goal of the experiments carried out during the described Camp was to supplement the comparative base of experimental tools kept at IA NCU with macrolithic products and tools used for activities requiring supporting processes, that can change the characteristics of the well-known use-wear traces, making them look different. This goal has been achieved to the extent planned. Some of the tools used during the camp (e.g. axes) were intensively used without major repairs throughout its entire duration, which guarantees the damage caused on their working edges will be an excellent comparative basis for prehistoric products and will allow us to verify our previous knowledge on various aspects of using this type of form (based on previous experiments). Others, such as the metal tools used in the experiments (or the scraper made of a cow's rib with flint inserts) are the first experimental products of this kind in our collection, which will certainly contribute to the development of new directions of microscopic studies at IA NCU (including, above all, the traceology of metal products).

The traceological analysis of the tools used during the Camp has just begun, therefore a more precise characterization of the use-wear traces created on their surface is impossible at the moment. However, some examples of the observed usage damages can be found in Fig. 8. At the microphotographs presented there, various types of "contamination" are also readable. Their presence is not due to our sloppiness. It is a result of the deliberate decision to give up cleaning the experimental products from the organic debris deposited on their surface during the experiments. These tools will become an element of a new comparative base created at our Institute, namely the base of organic and inorganic "residues" that deposit on the surface of tools used for various activities, as the result of post-depositional processes (and in other circumstances). Thanks to the appropriate multifaceted physicochemical studies, this database will allow us to significantly increase the probability of the correctness of our interpretations on the subject of pre-and post-deposition biography of prehistoric products.

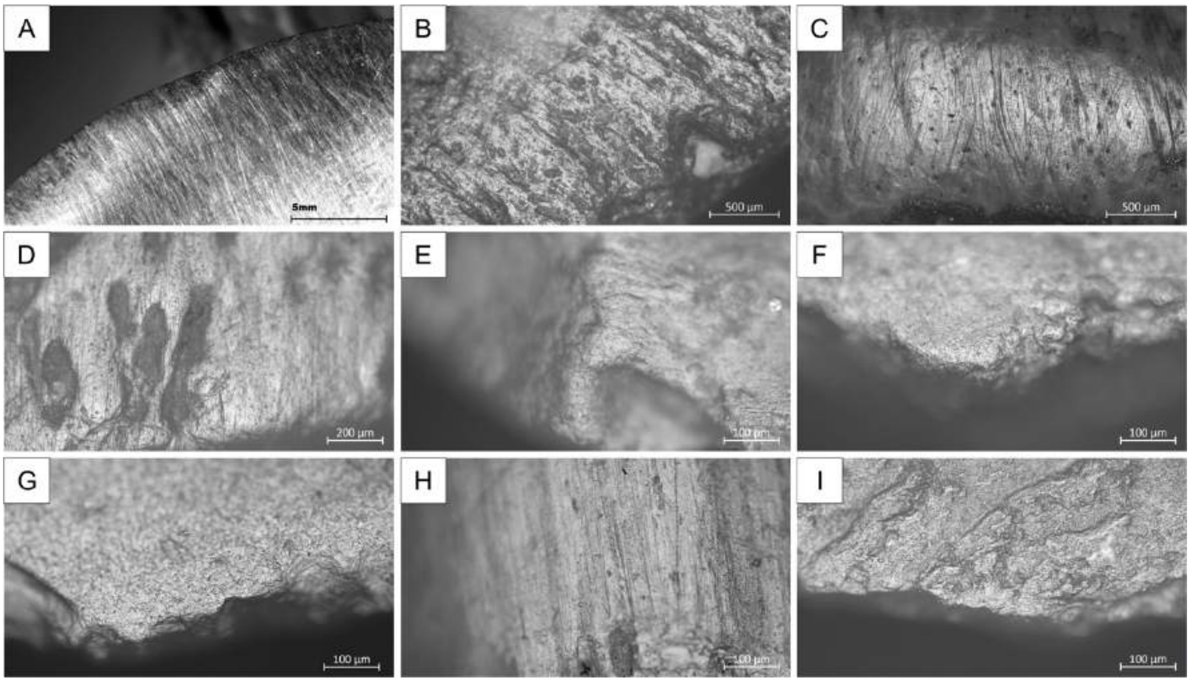

Figure 8. Examples of the use-wear traces observed on: A – bronze adze used to chiselling and scraping charred wood; B – flint polished axe used for cutting wood; C – antler adze used for chiselling and scraping charred wood; D - the bone bevel-ended tool used to remove flesh from deer hide; E - flint bifacial tool used for cutting hide deer hide; F – flint scraper used for scraping red deer hide; G - Flint inset from the composite tool used to remove hair from the deer hide; H - point-like tool used for the perforation of hides; I - flint knife used to cut pig intestines. Fig. A: SMZ-745T microscope fitted with a DeltaPixInvenio 6EIII, Fig. B – I: Zeiss Axioscope 5 Vario microscope fitted with an Axiocam 208 camera. Photo G. Osipowicz.

6. Conclusions

The described experiments were our first attempt at reconstructing boats. During the project, we learned a lot both about the tools required and the process of production, which is very specific. We will certainly use this knowledge in future projects that we are already planning. We have also learned a lot about the organization of such complicated experiments, knowledge that will be used during the Second International Camp of experimental Archaeology, that we plan for the near future.

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