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Roman Bone Artefacts – First Steps Towards a New Approach

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To date, archaeologists often use a typological approach to assess the functions of bone artefacts from the Roman period. In some of these assigned typological groups, certain artefacts do not have a clear definition. This study aimed to assess whether use-wear analysis combined with experimental archaeology could be applied to bone artefacts from the Roman period as an aid in identifying the function of these artefacts. Artefacts of the Roman site

Augusta Raurica, Switzerland, were examined employing the use-wear approach and compared with experimentally reproduced and used replicas. These replicas were experimentally crafted from bone using lathes, files, knives, horsetail (_Equisetum telmateia_) and leather. During the experimental reproduction, many interesting observations about the different methods and raw materials were made. There was a significant difference observed between the use of cooked and raw bone material. The replicas of Roman bone artefacts were used on wax tablets made from wood and beeswax. They can produce legible letters on the wax and even left traces on the wood. The traces left on Roman bone artefacts' replicas were similar to two artefacts typologically classified as _stili_. This preliminary study produced some interesting results but also left many open questions in need of further examination.

> “ The metal tools used left clear traces. However, it would be interesting to compare the previous traces with further traces produced by replicas of Roman tools. The sanding and polishing with horsetail and leather were very efficient, but we could find no such traces on the archaeological artefacts.

Introduction

In Roman sites, bones are often among the most common finds. They can provide information about the diet, economy, social life, or craftsmanship during the Roman period (Schmid, 1968, p.185; Mikler, 1997, pp.113-114; Deschler-Erb, 1998, p.18; Deschler-Erb and Schibler, 2012, p.38). During the Roman era, a high diversity of objects were manufactured from bones, antlers, teeth and horns. Among such objects were spoons, combs, writing implements, spindles, and sword hilts (MacGregor, 1985, pp.1-23; Deschler-Erb, 1998, p.119; Jung, 2013, pp.2-4). Bone, antler, teeth, or horn artefacts were crafted or repaired in manufacturing workshops (for example, Bertrand, 2008, pp.102-112; Deschler-Erb and Gostenčnik, 2008, pp.300-305; Feugère, Forest and Prévot, 2008, pp.32-33). They might even be manufactured or repaired in self-production (Mikler, 1997, pp.113-114; Obmann, 1997, p.63; Jung, 2013, p.15) or by seasonal- or part-time craftsmen (Frosdick, 2008, p.120). Manufacturing workshops are characterised by a high find density of semi-finished products and waste (Deschler-Erb, 1998, p.194). Such Roman manufacturing workshops have been documented in _Augusta Raurica_ (Deschler-Erb, 1998, pp.269-282). _Augusta Raurica_ is a Roman site located on the southern bank of the Rhine River in Switzerland near Basel (See Figure 1). It was founded as a Roman colony and was occupied from the 1st to 4th century AD (Schwarz, 2004, p.358; Berger, 2012, pp.17-31).

The manufacture and function of Roman bone artefacts are usually determined by applying multiple approaches. Observing traces, semi-finished products, and factory waste help researchers understand Roman bone artefacts' manufacture. The collaboration between researchers and modern professional bone artisans is another insightful approach (compare Béal, 1983, pp.20-34; MacGregor, 1985, p.115; Deschler-Erb, 1998, pp.93-110; Gostenčnik, 2005, pp.289-348; Jung, 2013, pp.17-39; Barbier, 2016). The results show that the archaeological bone artefacts were manufactured by the use of multiple techniques and various tools, like saws, files, knives, chisels, or lathes (see Deschler-Erb, 1998, pp.93-110; Picod, 2004, pp.71 -75; Gostenčnik, 2005, pp.289-348; Jung, 2013, pp. 17-39; Barbier, 2016, p. 6).

Pictorial evidence, the context (Stephens, 2008, pp. 117-119), or the comparisons with similar artefacts from different materials (Gostenčnik, 2005, p. 31) can help determine their function. Furthermore, researchers traditionally use a typological approach to assess the function of an archaeological artefact. This approach, however, has its limits, as was already discussed elsewhere (Deschler-Erb, Müller, and Wojtczak, 2021, p.414). Nevertheless, studies using those methods show that the Romans used various objects for all kinds of activities (see MacGregor, 1985, pp.1-23; Deschler-Erb, 1998, p.119; Jung, 2013, pp.2-4).

In Deschler-Erb, Müller, and Wojtczak (2021), we presented a new approach to assess Roman bone artefacts: combining experimental archaeology and use-wear analysis. This method is used to determine the manufacture and function of bone artefacts, often from prehistoric contexts. Use-wear analysis requires cross-referencing of the observed surface. In many studies, a cross-reference is done with the surface of experimentally reproduced replicas (Semenov, 1970, pp.143-195; Newcomer, 1974; Olsen, 1984; Legrand, 2007; Wojtczak and Kerdy, 2018). Even though applying use-wear analysis on Roman bone artefacts is a new approach, bone artefacts from Roman contexts have already been studied with the help of experimental archaeology (Stephens, 2008; Volken, 2015; Barbier, 2016).

Within the framework of a Bachelor thesis (Müller, 2018), four archaeological rod-shaped bone artefacts from *Augusta Raurica* (See Figure 2) were assessed by means of use-wear analysis. Two of those artefacts were typologically classified as *spindles*. The other two artefacts were typologically classified as *stili* (for more information, see Deschler-Erb, Müller, and Wojtczak, 2021, pp.416-420). The main questions were: Can the functions of the artefacts be assessed with the help of use-wear analysis? Do these functions correspond to the functions attributed to the artefacts by the typological approach? Are multiple uses detectable?

In this paper, we focus on the experimental production of the replicas as the results of the use-wear analysis were presented elsewhere (Müller, 2018; Deschler-Erb, Müller and Wojtczak, 2021).

Method

During this study, several steps were carried out, which included preparations, training, multiple experiments and examination:

1. Preparations (See *Preparations for experimental work*) included:

    - Learning how to use a modern lathe at the Drechselstube Neckarsteinach (< www.drechselstube.de > [Accessed: 22.03.2021]), Germany.
    - Learning how to carve bone and produce Roman bone replicas at the bone workshop Ars Asta (ARS ASTA - Römisches Knochenhandwerk < www.ars-asta.de > [Accessed: 22.03.2021]), Darmstadt, Germany. Artisan A. Dingeldey specialises in the reconstruction of roman bone artefacts.
    - Constructing a wooden lathe with a fiddle bow drive.
    - Harvesting and drying giant horsetail. The giant horsetail was used for sanding the replicas of Roman bone artefacts.
    - Preparing bovine metatarsi.
    - Practising the manufacture of replicas of Roman bone artefacts by producing many replicas, including several failed attempts.
    - Harvesting and preparing wax, followed by building replica wax tablets.

2. The experimental reproduction of manufacturing traces and replicas from bovine metatarsi by using a saw, a wooden lathe with fiddle bow drive, knife, drawknife and files (See *The experimental manufacture of replicas*).
3. The methods of the Low-Power approach (Semenov, 1970, p.22; Tringham et al., 1974, p.175; Odell and Odell-Vereecken, 1980, pp.89-90) had to be learned to examine the traces of manufacture on replicas and archaeological artefacts (see Deschler-Erb, Müller and Wojtczak, 2021, pp.418-419).
4. The experimental use of the replicas (see *The experimental use of replicas*).
    - We focus on experiments with regard to writing implements-*stili.* Two replicas were experimentally used to examine the traces left by writing on wax tablets and smoothing the wax. These experiments were conducted because two archaeological artefacts were typologically classified as *stili.* The distal ends were used to write on wax tablets, while their proximal end was used to smooth the wax on the wax tablets.
    - A third replica was used for scraping on plain wood with the distal and proximal end to examine the difference a fine layer of wax makes in comparison.
5. The replicas and archaeological artefacts' surfaces were examined for traces of use (see Deschler-Erb, Müller and Wojtczak, 2021).

Preparations for experimental work

Tools used for the manufacture of Roman replicas

As mentioned above, many manufacturing workshops from the Roman times are known. But only a few discoveries of tools in context with the manufacture of bone, antler, horn, or tooth artefacts are known (Deschler-Erb, 1998, pp.93-94; Gostenčnik, 2005, pp.290-291). Two such rare examples are from Maastricht, NL, and Urach, D. In Maastricht, a saw fragment was discovered that might have been used to work antler in the 5th century AD (Dijkman and Ervynck, 1998, p.17). Equally from the 5th century AD, a complex interpreted as a workshop was found on the *Runder Berg bei Urach*. Next to two antler fragments with tool traces, tools like chisels and knives were excavated (Koch, 1994, pp.24-27). Multiple hypotheses could explain the lack of such findings: the tools were possibly used to work various materials and not just bones or antlers (Jung, 2013, pp.14-15). Furthermore, it could be possible that the artisans were part-time or migrant artisans who took their tools with them and only left the semi-finished products and waste (Frosdick, 2008, p.120).

More information about the manufacture of bone, antler, horn, and tooth artefacts is known by observing the traces of manufacture on archaeological artefacts. Traces of files, saws, knives, drawknives, and lathes have been observed (Schmid, 1968, pp.185-192; Gracie and Price, 1979, pp.21-25; MacGregor, 1985, p.115; Béal, 1983, pp.23-25; Deschler-Erb, 1998, pp.185-192, Gostenčnik, 2005, p.298; Jung, 2013, pp.17-39; Barbier, 2016, p.6). Through such technological analysis, it is assumed that the Romans already had used lathes to work bone artefacts (for example, Gostenčnik, 2005, pp.314-318). Even though there are neither pictorial representations of Roman lathes nor have preserved lathes been found (Deschler-Erb, 1998, p.98), multiple lathes from Roman times have been reconstructed and used. Such experimentally used lathes with a fiddle bow drive have been rebuilt, for example, by Ch. Picod (2004, pp.73-74), A. Dingeldey (Jung 2013, pp.28-29) and M. Barbier (2016, pp.47-53). Most of them are rebuilt with a fiddle bow drive, though other systems might be possible as well (Böcking, Gérold and Petrovszky, 2004, pp.212-213). A further construction variation is the clamping method. Based on experimental work and studies of the waste material, multiple clamping methods could have been used in Roman times. For example, clamping the workpieces between two metal spikes (Deschler-Erb, 1998, fig.157.1; Jung, 2013, fig.12; Barbier, 2016, fig.208) or the use of wooden chucks (Deschler-Erb, 1998, fig.157.2; Picod, 2004, fig.2-5; Jung, 2013, fig.16-17).

One of the authors (HM) learned how to process bones and use a lathe for the experiments in this study. Various modern lathes and one wooden lathe with a fiddle bow drive were used during this stage. Additionally, a simple wooden lathe with a fiddle bow drive made out of wood scraps, mainly of fir wood, was built to use for the experimental reconstruction of the replicas. The bows were made out of ash, hazel, and willow branches (See Figure 3).

The previously mentioned lack of metal tool artefacts associated with the manufacture of bone artefacts stands in contrast with the many Roman metal tools known (Mutz, 1968; Gaitzsch, 1980; Hanemann, 2014). Some of those archaeological tools show different characteristics than modern tools, as can be seen with files. Although files from Roman times display various cross-sections – like square, half-round, or round – they differ in the cut from modern files. Modern files often have double cuts, while in Roman times, the files mostly had single-cuts and double cuts seemed only to appear accidentally (Gaitzsch, 1980, pp.49-54). Ideally, it would have been better to use replicas of Roman metal tools to manufacture replicas of roman bone artefacts experimentally. But since this study was preliminary and based on a limited time frame and budget, it was decided to use modern tools: chisel, knife, drawknife, saw, and file (See Figure 4).

The last step in the manufacture of bone artefacts is often described as grinding and polishing the final product. There are various methods - such as the use of potash, pumice, or sandstone - that might have been used to grind and polish objects in Roman times. However, there is hardly any archaeological evidence (MacGregor, 1985, p.58; Deschler-Erb, 1998, p.102; Jung, 2013, pp.37-39). But through Pliny the Elder, who wrote in *Naturalis Historia* that fish skin (9,40: translated in Rackham, 1967, pp.190-191) and radishes (19,87: translated in Rackham, 1961, pp.476-477) could be used for polishing ivory, we get a brief insight of what a Roman artisan might have used to polish bone or in this case, ivory objects. In more recent times, dried horsetail stalks containing silicic acid have been used to polish ivory and other materials (Eipper, 2002, pp.37-38). Multiple researchers have proposed that the Romans might have used horsetail (MacGregor, 1985, p.58; Picod, 2004, p.75; Jung, 2013, pp.37-39). Furthermore, the use of leather to polish the objects is listed as another possibility (Jung, 2013, p.39).

We wanted to investigate whether the grinding and polishing techniques could be detected on the archaeological artefacts in the absence of reliable evidence. So, the replicas in this study were sanded with dried giant horsetail (*Equisetum telmateia*) collected from a forest in Central Switzerland (See Figure 5) and polished with scraps of tanned cowhide.

Bone – the raw material to produce Roman replicas

A striking amount of Roman bone artefacts made of metatarsi from either bovine or horses were discovered (Deschler-Erb, 1998, pp.71-74; Gostenčnik, 2005, p.299; Feugère and Prévot, 2008, p.233). Less is known about the handling of bones in the Roman period. There is some debate about whether the Romans processed the bones raw or after degreasing by cooking them (Jung, 2013, p.21; Barbier, 2016, p.5). Some researchers even suggest that the bones were soaked in water (Schmid, 1968, p.185; MacGregor, 1985, p.63) or other liquids (Gostenčnik, 2005, pp.297-299; Barbier, 2016, p.5). All of those methods have their advantages and disadvantages concerning factors like storability and processability. For example, degreased bones are easier to store, get less stained and greasy, but are more brittle than raw bones (Deschler-Erb, 1998, pp.94-96; Gostenčnik, 2005, pp.297-299; Jung, 2013, p.21).

For the experiments presented in this paper, bones of different origins and preparation methods were used. Firstly, blanks from boiled and bleached metatarsi from Argentinian bovines and equines were processed. These blanks were used to practise how to work with bones and produce replicas on a lathe. Both raw and cooked cow metapodials were processed to manufacture the replicas used for writing on wax. Those metapodials were carved out of legs from modern cow breeds (See Figure 6.1) collected from a butcher in Switzerland. The metapodials were carved out and cooked in water and soft soap (See Figure 6.2). For a better degreasing process, the epiphyses of the metapodials were sawed off using a bandsaw. The bone marrow was extracted with a stick and water, and the metatarsi were cooked again in water and soft soap (See Figure 6.3). The second batch of cow metatarsi was processed raw. For this purpose, the epiphyses were sawed off, and the bone marrow extracted in the same manner as before. With the help of electrical saws, the raw and cooked bones were sawn into blanks. Those blanks (See Figure 6.4) were later experimentally processed into replicas.

Production of replicas of Roman wax tablets

In a later stage of the study, replicas of roman bone artefacts were used to write and scrape wax tablets (see *The experimental use of replicas*). But first, replicas of wax tablets had to be produced. During Roman times, such wax tablets were made of ivory or wood and were covered with a fine layer of a wax mixture (Büll, 1977, pp.786-787). Various types of wood were used in Roman times to make wax tablets: For example, in *Tasgetium* – a roman settlement in eastern Switzerland (See Figure 1) developed in the first century AD (Brem and Leuzinger, 2005, p.33) – tablets made out of fir, spruce, maple, and beech were found (Hartmann, 2011, p.126). In *Vindonissa* – a legionary camp in northern Switzerland (See Figure 1) founded in 14/16 AD (Trumm, 2015, p.93) – tablets made out of fir, spruce, maple, and possibly also larch were found (Fellmann, 2009, pp.109-111). In *Augusta Raurica,* only a tiny fragment of a wax tablet was found. The wood is not yet appropriately analysed (Fünfschilling and Ebnöter, 2012, p.164). Chemical analysis of wax mixtures on wax tablets from different roman sites showed a mixture of resin and charcoal from bone or wood blended with the wax. Even ochre was found in some wax mixtures (Büll, 1977, pp.809-812).

Poplar wood was used to create the frames for the replicas of wax tablets used in the experiments presented in this paper. Due to the lack of an authentic recipe, pure beeswax was used for this first experiment. The wax was obtained by melting honeycombs (See Figure 7.1) from a farm in central Switzerland. Rainwater was heated (60-90°C), the combs were added and dissolved. The mixture of honeycombs and rainwater was sieved and left to cool down until the cold, hard wax could easily be removed. In fresh rainwater, the hard wax was heated up again and strained through a fine-mesh sieve. After sieving, the cooled wax was dried in the sun (See Figure 7.2). The wax was melted in a water bath (60-90° C), and a thin layer (1 mm) was poured onto the wood tablets. Between the experiments, the fine layer of wax on the tablets was melted and restored. The most efficient way was to put the wax tablets into the oven (65°C) until the wax was melted.

The experimental manufacture of replicas

A total of nine experimentally reproduced replicas were created. Additionally, numerous failed attempts were made during the learning and training of replica manufacturing (see Deschler-Erb, Müller and Wojtczak, 2021, Fig.4). Before the replicas were created, different studies on the manufacture of roman bone artefacts were consulted (see Béal, 1983, pp.20-34; MacGregor, 1985, p.115; Deschler-Erb, 1998, pp.93-110; Gostenčnik, 2005, pp.289-348; Jung, 2013, pp.17-39; Barbier, 2016). One of them included the first observation of the four archaeological artefacts used in present investigations (Deschler-Erb, 1998, pp.39,75-76).

Replica *G* and *I* were produced to be used as writing implements on replicas of Roman wax tablets. Both replicas were made of blanks from metatarsi of adult bovine from a modern breed from Switzerland. While replica *G* (length 138.5 mm, max. width 9.9 mm) was made out of a cooked metatarsus (See Figure 8), replica *I* (length 132 mm, max. width 11.9 mm) was made from a raw metatarsus (See Figure 9).

The blank for replica *G* (See Figure 8.1) was prepared on an electric lathe to remove a large part of the excess material (See Figure 8.2), and the proximal end was formed into a spatula using a file. Whenever a file was used, the blank was rested on a work block with a notch (See Figure 8.5). The workpiece was held with the left hand, while the right worked the file over the workpiece. A new wooden chuck had to be produced on an electric lathe to fix the blank into the lathe with a fiddle bow drive. The chuck was worked out so that the workpiece could be secure in it with the rectangular proximal end (See Figure 8.6). There are no references for this approach, but the workpiece was more manageable to shape due to the better grip in a rectangular notch. With the blank set between the chuck and the tailstock (See Figure 8.7), the fiddle bow was moved with the left hand to rotate the chuck and the blank.

Contrary to electric lathes, lathes with fiddle bow drives turn the chucks with the blank alternately in opposite directions. The tool was held against the blank only when the chuck with the blank turned counter-clockwise. When turning, the right hand and the tool were supported on the palm resting surface. Excess material was removed, and the desired shape was turned into the workpiece, including the thickening just before the distal end. The chisel was held straight or angled slightly upwards at an angle up to 30° (See Figure 8.8) . Only the shaft and the distal end were produced by using a chisel. The notches were turned into the workpiece by tilting the chisel (See Figure 8.9). A file was used to define the shape. The left hand turned the chuck and the blank while the right hand guided the file over the workpiece (See Figure 8.10). Gradually, the replica was adapted to its shape. The distal end was turned only slightly. Slowly, the material was removed at the shaft and at the distal end to alter the form (See Figure 8 .11). While the distal end was turned, the bone broke (See Figure 8.3). The broken tip had to be sharpened with a file. Also, the proximal end had to be filed because a part broke off. When filing the distal end, the file was held in the right hand, and a work block supported the workpiece. The workpiece was rotated clockwise, while the tip was filed as evenly as possible. The more angular shape of the proximal end was filed with the workpiece resting on the work block without rotating (See Figure 8.4).

The big blank of replica (See Figure 9.1) was clamped into a vice and prepared with a drawknife (See Figures 9.2 and 9.6). Similarly to replica *G*, the proximal end was formed into a spatula using a file and, after this, secured into the same chuck. The workpiece was fixed into the wooden lathe with a fiddle bow drive, set between the chuck and the tailstock. The blank (See Figure 9.3) was thick and uneven. Combined with the slow drive of the fiddle bow drive, the workpiece and the chuck got stuck. An electric drill was attached to the chuck, and the abundant excess material was removed (See Figure 9.7). This decision was made due to the still little experience in using this instrument and in order to be able to continue further work. After this, the workpiece was reworked regularly with the fiddle bow drive (See Figure 9.8), and the traces of the electronic drill disappeared.

The goal was to produce the identical replica as replica *G*. Even though the blank was worked and formed in the same manner as replica *G;* it was not possible to create the exact shape due to the brittle bone. The distal end broke multiple times. The result was a slightly thicker shape (See Figures 9.4 and 9.9). The distal and proximal ends were reworked with the file on a work block like replica *G* (See Figure 9.10). During this stage, the proximal end of replica *I* broke off (See Figure 9.5).

All the other replicas were produced in similar manners. All nine replicas were sanded with dried horsetail and polished with leather (See Figure 10).

For comparison, different kinds of traces – by knife, drawknife, and saw – were produced. Saw traces were made during the manufacture and were found on waste (See Figure 11.1). A further blank was clamped into a vice, and a drawknife was pulled over the blank with both hands (See Figure 11.3). A third blank was held in the left hand, while a knife was pushed over the blank with the right hand (See Figure 11.2).

The experimental use of replicas

Replica *G* and *I* were used for writing on as well as smoothing out replicas of wax tablets. Each replica was used the same way as a pencil on a piece of paper: The replicas were fixed between thumb, index, and middle finger. During the writing, the distal ends pierced through the wax and scraped on the wood. As seen in the wax tablets from *Vindonissa* (Speidel, 1996, p. 9), the text also carved itself into the wood. The proximal ends were placed on the tablets and pulled over the wax to smooth out the wax. It only had contact with the wax and did not pierce through the wax scraping over the wood.

Each replica was used in stages and documented in between those stages. The replicas were used for nine hours of writing and three hours of smoothing out the wax (See Figure 12).

An additional experiment was conducted with replica *A*. The proximal end of replica *A* was used to scrape a dried piece of birchwood for three hours (See Figure 13). This experiment was performed to compare the traces left by wood to the traces left by a combination of wood and wax. The replica was held like the replicas in the experiments on the wax tablets.

Discussion

The results of the use-wear analysis are already presented elsewhere (Müller, 2018, pp.40-75; Deschler-Erb, Müller and Wojtczak, 2021, pp.418-421). Summarised, it showed that the use-wear analysis could be applied to bone artefacts from Roman contexts. Traces of knives, draw knives, files, and the use of a lathe were found on the archaeological artefacts and confirmed a previous study (Deschler-Erb, 1998, pp.39,75-76). The conformity of the typological approach and the macro-wear analysis was shown in two cases. Two archaeological artefacts typologised as *stili* (writing implements) showed similar traces to replicas experimentally used as writing implements (see Deschler-Erb, Müller and Wojtczak, 2021, pp.418-421).

During the experiments, many notable observations arose. For one, experimentally reconstructing a replica and the time management often depended significantly on the production of suitable blanks. Bones only provide a limited thickness for the blank. If the blank was uneven or incorrectly clamped, there was a high risk of failing because there was not enough material on one side. The production of big blanks proved to be time-consuming. Even though the problem of a lopsided lack of material was avoided, the fiddle bow drive did not have enough force, and the blank became stuck on the chisel. It was worth investing more time in producing suitable and even blanks, for these were easier to clamp and turn on the lathe with fiddle bow drive. It was easier to fix a rectangular proximal end into a chuck than a round one. The rectangular end had a better grip, and this led to a regular turning movement.

Further, the treatments, like degreasing or not, have an impact on the processability of bones. According to previous studies (like Deschler-Erb, 1998, pp.94-96; Jung, 2013, p.21), the cooked bone should have been the more brittle bone to process. But in this study, the boiled bone was very easy to work with, and the raw bone was more brittle. During the processing of bone material, it has become apparent that there are many factors that influence its condition and usability for tool manufacturers.

The drawknife turned out to be a very efficient tool to work with bones. But the workpiece has to be clamped to use the drawknife. A vice is not very optimal since it promotes breaking of the bone. Furthermore, sanding with dried horsetail and polishing with leather was very efficient, even though we could not distinguish traces or polishes of horsetail or leather on the four assessed archaeological artefacts. It is recommended to remove the branches before horsetails are dried.

Many questions are left open. The wax mixture is one of these questions. The content and the composition could have different influences on the traces. The experiments showed that a small layer of wax (1 mm) is more than enough to write. During the experiments, the text carved itself into the wood, which shows that writing implements from bones are strong enough to produce such traces on the wood.

After the experimental use as writing implements on wax tablets, the surface of replica *G* showed contamination, while the surface of replica *I* remained white (See Figure 14). The contamination of the surface of replica *G* seems to be attributed to the cooking of the raw material. Replica *I* had more fat, which appears to protect the surface against contamination.

Conclusion

The presented investigation has shown that with the help of experimental archaeology, many novel observations were noted. The experiments demonstrated how complex the production of Roman bone objects could be. The selection of the raw material proved crucial. Cooked and uncooked bones behaved differently during experimental reproduction and use. While the boiled bone was very easy to work with, the raw bone was more brittle. Conversely, the raw bone replicas were in better condition after use compared to those made from cooked bone.

The Romans may have taken advantage of these different properties and selected the raw material depending on the production and use of the objects. However, we are not yet in a position to prove this working hypothesis, and further experimentation is needed.

The metal tools used left clear traces. However, it would be interesting to compare the previous traces with further traces produced by replicas of Roman tools. The sanding and polishing with horsetail and leather were very efficient, but we could find no such traces on the archaeological artefacts. Since there are many possible sanding and polishing methods, it would be essential to produce a wider variety of these types of traces and compare them with similar studies (for example, Olsen, 1988; Furger, 2020).

The reproduced replicas of Roman bone artefacts were instruments used for inscribing on a wax tablet. They can produce legible letters in the wax and even left traces on the wood. The experiments proved that not only metal writing implements could be used to write on wax tablets. The Romans probably used *stili* made from bone as well.

All in all, the study did not just show that the use-wear analysis could be applied to bone artefacts from Roman contexts. It also showed the practicality of Roman bone *stili*, the pros and cons of different methods of working bones and the raw material itself. Additional experimentation and studies could produce further interesting insights.

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use wear analysis

Country Switzerland

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Gallery Image

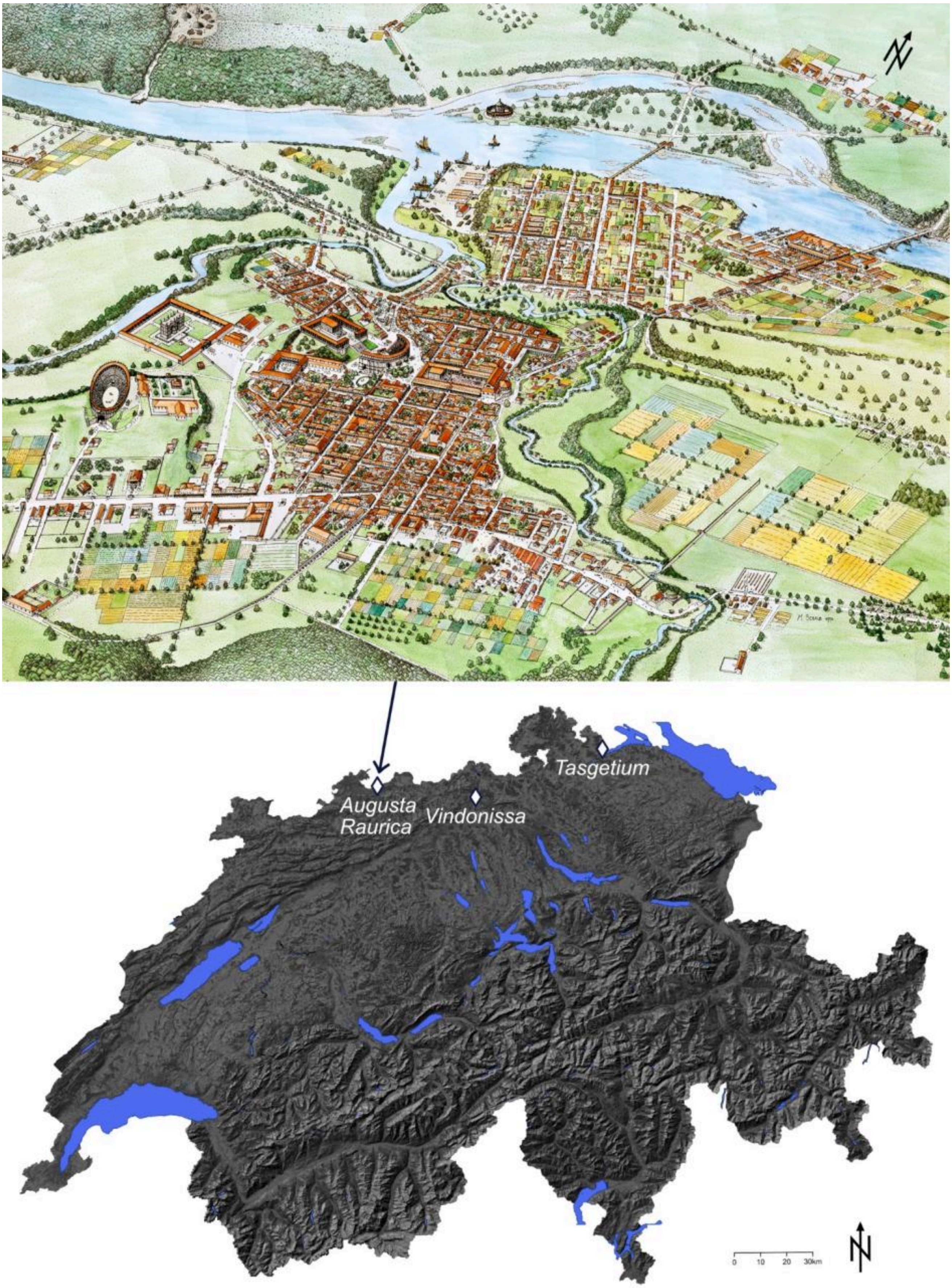

FIG 1. RECONSTRUCTION DRAWING BY MARKUS SCHAUB, AUGUSTA RAURICA. MAP COMPILED BY H. MÜLLER BASED ON WWW.MAP.GEO.ADMIN.CH AND WWW.GEOVIEW.BL.CH ACCESSED 14TH MAY 2021.

FIG 2. FOUR ARTEFACTS WERE EXAMINED. THE ARTEFACTS 334 (INV.-NR. 1974.8430, LENGTH 174 MM, MAX. WIDTH 9 MM) AND (INV.-NR. 1907.897, LENGTH 204 MM, MAX. WIDTH 7 MM) WERE TYPOLOGICALLY CLASSIFIED AS SPINDLES. THE ARTEFACTS 848 (INV.-NR. 1980.14635, LENGTH 101 MM, MAX. WIDTH 8 MM).AND 856 (INV.-NR. 1980.1440, LENGTH 156 MM, MAX. WIDTH 9.1 MM) WERE TYPOLOGICALLY CLASSIFIED AS STILI (SEE DESCHLER-ERB, MÜLLER AND WOJTCZAK, 2021, PP. 416-418). PHOTO BY HILDEGARD MÜLLER.

FIG 3. A SIMPLE WOODEN LATHE WITH A FIDDLE BOW DRIVE WAS BUILT TO PRODUCE REPLICAS. PHOTO BY HILDEGARD MÜLLER.

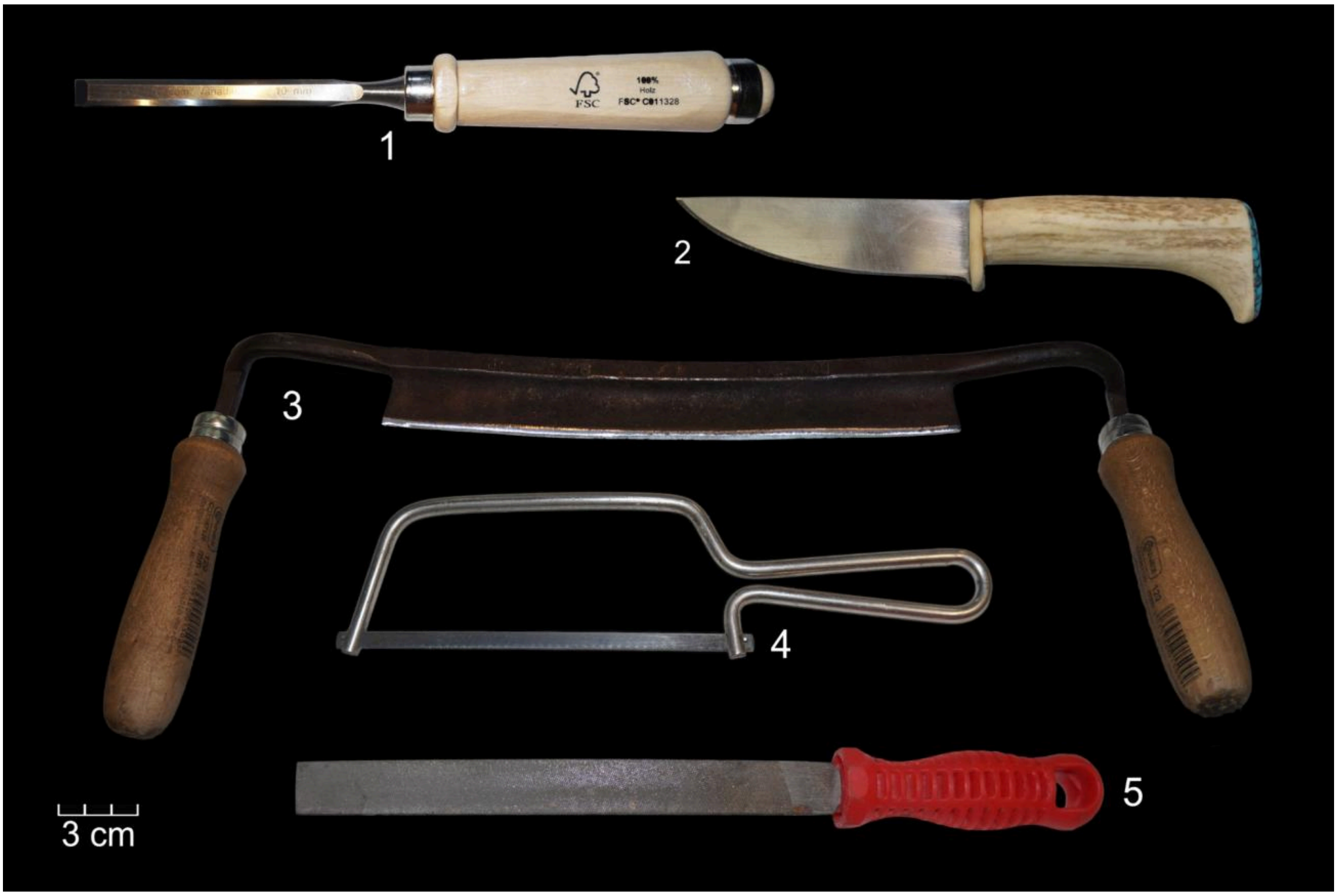

FIG 4. FOR THIS STUDY, MODERN METAL TOOLS WERE USED TO REPRODUCE MANUFACTURING TRACES EXPERIMENTALLY. THE FLAT CHISEL WAS 10 MM WIDE AND HAD A WEDGE ANGLE OF 45° (1). THE KNIFE'S BLADE WAS 107 MM LONG, 30 MM WIDE, AND HAD A STRAIGHT SPINE AND A CONVEX CUTTING EDGE (2). THE BLADE OF THE DRAWKNIFE HAD A SLIGHT CURVATURE, WAS 29 MM WIDE AND 208 MM LONG (3). THE USED METAL SAW HAD

A 152 MM LONG BLADE WITH A WAVY TOOTH SET (4). THE FILE WAS 200 MM LONG, 20 MM WIDE AND HAD DOUBLE CUTS (5). PHOTOS BY HILDEGARD MÜLLER.

FIG 5. HORSETAIL (EQUISETUM TELMATEIA) WERE COLLECTED AND DRIED TO SAND BONES. PHOTO BY HILDEGARD MÜLLER.

FIG 6. METAPODIALS WERE CARVED OUT OF HIND- AND FRONT LEGS FROM COWS (1). THE FIRST BATCH WAS DEGREASED IN BOILING WATER AND SOAP (2). AFTER THE EPIPHYSES OF THE METAPODIALS WERE SAWED OFF AND THE BONE MARROW WAS EXTRACTED, THEY WERE COOKED AGAIN FOR A BETTER DEGREASING PROCESS (3). WITH THE HELP OF ELECTRICAL SAWS, BLANKS WERE PRODUCED (4). PHOTOS BY HILDEGARD MÜLLER.

FIG 7. HONEYCOMBS (1) WERE MELTED. AFTER MELTING AND SIEVING THE WAX MULTIPLE TIMES, IT WAS DRIED IN THE SUN (2). PHOTOS BY HILDEGARD MÜLLER.

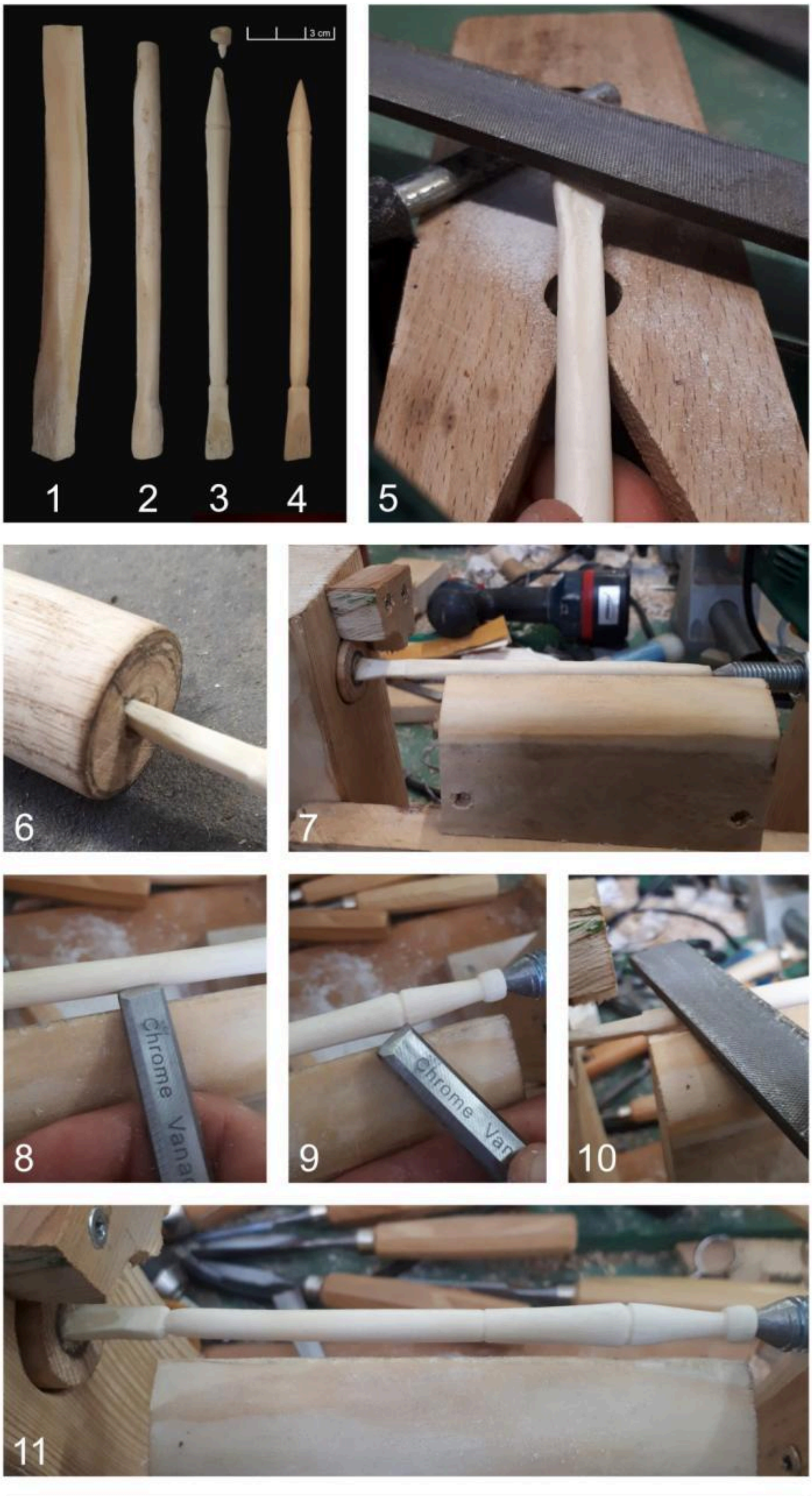

FIG 8. A BLANK FROM A CATTLE METATARSUS (1) WAS PREPARED ON AN ELECTRIC LATHE TO REMOVE EXCESS MATERIAL (2). THE PROXIMAL END WAS FORMED INTO A SPATULA BY USING A FILE (5). A NEW WOODEN CHUCK WAS PRODUCED TO SECURE THE RECTANGULAR PROXIMAL END OF THE WORKPIECE (6). THE WORKPIECE WAS FIXED INTO THE LATHE (7) AND WORKED WITH A CHISEL WHEN THE WORKPIECE TURNED COUNTERCLOCKWISE. THE TOOL (CHISEL) WAS HELD STRAIGHT OR ANGLED SLIGHTLY UPWARDS AT AN ANGLE UP TO 30°. THE CUTTING EDGE WAS HELD PARALLEL (8) OR AT AN ANGLE OF 30° TO THE WORKPIECE. WITH AN ANGLE OF 30°, THE RIGHT

CORNER OF THE CUTTING EDGE COULD CUT NOTCHES INTO THE WORKPIECE (9). A FILE (10) WAS USED TO DEFINE THE SHAPE (11). THE DISTAL END BROKE, AND THE PROXIMAL END WAS SLIGHTLY DAMAGED (3). WITH A FILE, THE ENDS WERE FIXED. AFTER SANDING AND POLISHING, REPLICA G WAS FINISHED (4). PHOTOS BY HILDEGARD MÜLLER.

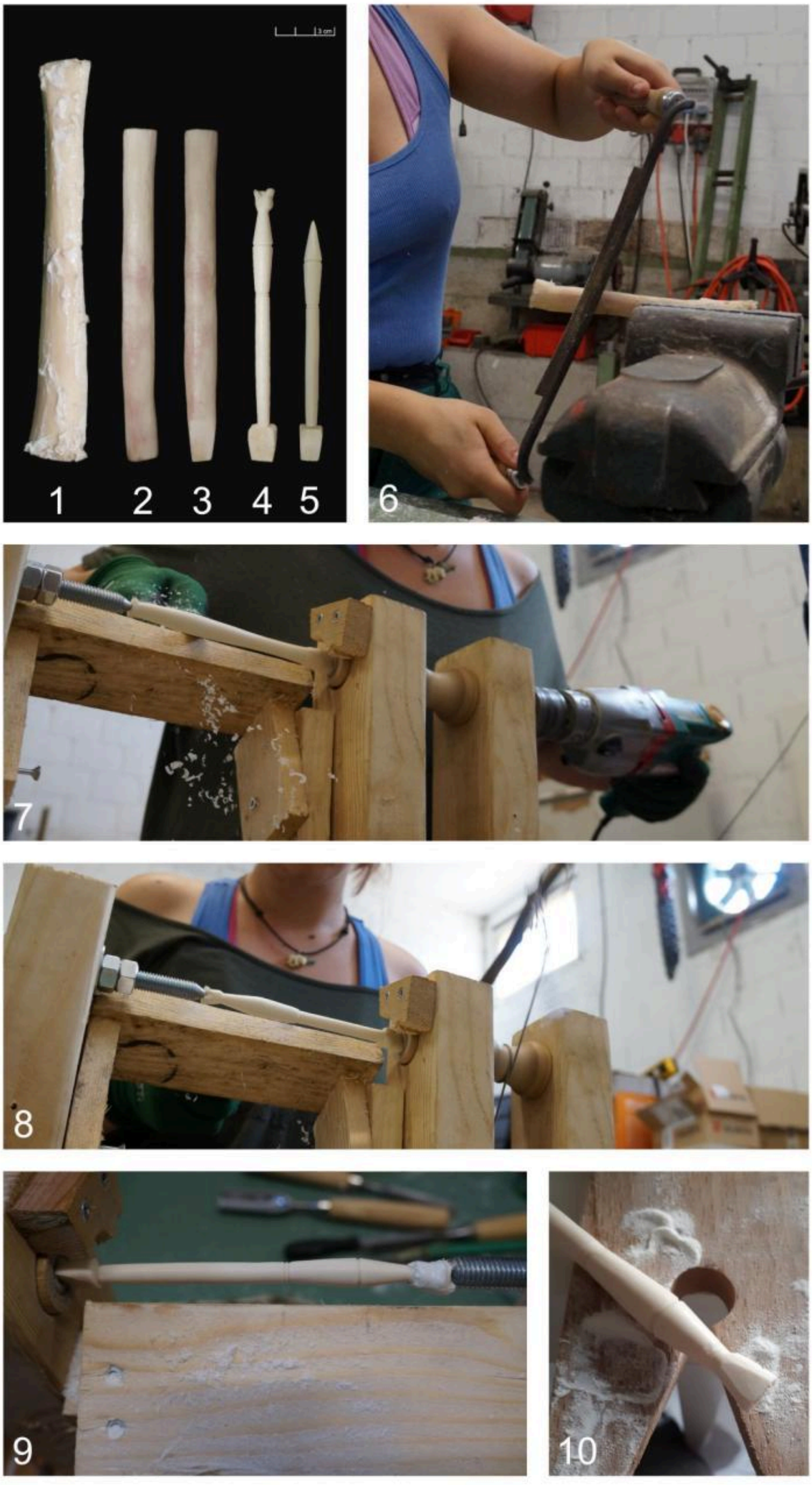

FIG 9. A BIG BLANK (1) WAS SAWN OUT OF A RAW METATARSUS OF AN ADULT BOVINE FROM A MODERN BREED FROM SWITZERLAND TO PRODUCE REPLICA I (5). THE WORKPIECE WAS CLAMPED INTO A VICE AND WORKED WITH

A DRAWING KNIFE (2, 6). THE PROXIMAL END WAS FORMED INTO A SPATULA USING A FILE AND SECURED INTO THE WOODEN LATHE WITH A FIDDLE BOW DRIVE. THE UNEVEN AND THICK WORKPIECE (3) GOT STUCK ON THE SLOW LATHE. WITH AN ATTACHED ELECTRIC DRILL, THE ACCESS MATERIAL COULD BE REMOVED (7), AND THE WORKPIECE COULD BE REWORKED LIKE REPLICA G WITH A FIDDLE BOW DRIVE (8). THE PLANS TO PRODUCE AN IDENTICAL REPLICA AS G WERE INTERRUPTED BY THE BONE'S BRITTLENESS (9). THE RESULT WAS A SLIGHTLY THICKER SHAPE (4). THE DISTAL AND PROXIMAL ENDS WERE OVERWORKED WITH A FILE (10). DURING THIS STAGE, THE PROXIMAL END OF THE REPLICA I BROKE OFF. REPLICA I (5) WAS SANDED WITH DRIED HORSETAIL AND POLISHED WITH LEATHER. PHOTOS BY HILDEGARD MÜLLER.

FIG 10. THE REPLICAS WERE SANDED WITH DRIED HORSETAIL (1) AND POLISHED WITH LEATHER (2). PHOTOS BY HIL-DEGARD MÜLLER.

FIG 11. SAWTRACES WERE PRODUCED DURING THE MANUFACTURE AND WERE FOUND ON WASTE (1). THE KNIFE WAS PUSHED WITH THE RIGHT HAND OVER THE BLANK HOLD BY THE LEFT HAND (2). THE DRAWING KNIFE WAS PULLED WITH BOTH HANDS OVER THE BLANK FIXED IN A VICE (3). PHOTOS BY HILDEGARD MÜLLER.

FIG 12. EACH REPLICA WAS USED FOR NINE HOURS OF WRITING (1) AND THREE HOURS OF SMOOTHING (2) ON THE WAX TABLETS. PHOTOS BY DOROTA WOJTCZAK.

FIG 13. THE PROXIMAL END OF REPLICA A WAS USED TO SCRAPE WOOD FOR THREE HOURS. PHOTO BY HILDEGARD MÜLLER.

FIG 14. AFTER NINE HOURS OF WRITING AND THREE HOURS OF SMOOTHING WAX, THE SURFACE OF REPLICA G SHOWED CONTAMINATION, WHILE THE SURFACE OF REPLICA I WAS STILL WHITE. PHOTOS BY HILDEGARD MÜLLER.