A Swiss Army Knife from the Upper Paleolithic? Experiments on Non-Projectile Uses of Backed Pieces

Ein Schweizer Taschenmesser des Jungpaläolithikums? Experimente zu nicht jagdwaffenbezogenen Verwendungen von Rückenmessern

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ABSTRACT

Backed lithic artifacts are an important part of the Upper Paleolithic tool kit, and are often among the most abundant categories of lithic tools found at Magdalenian and Gravettian sites. Often these tools are exclusively referred to as projectiles, and indeed many – if not most – backed pieces may have been parts of composite projectile heads, mounted laterally onto organic points (e.g., Allain and Descouts 1957; Allain 1979; Abramova 1982; Bergman and Newcomer 1983; Leroi-Gourhan 1983; Plisson 1985; Nuzhnyi 1993; Christensen and Valentin 2004; Sano 2009; Langlais 2010; Araujo-Igreja 2011; Tomasso et al. 2018). Experiments of varying comprehensiveness concerned with the use of (Magdalenian) backed pieces as projectile inserts have confirmed the effectivity of this setup (e.g., Moss and Newcomer 1982; Pétillon et al. 2011; Gauvrit Roux et al. 2020). However, backed pieces sometimes also served other purposes like cutting, sawing, shaving, scraping or perforating (Moss and Newcomer 1982; Moss 1983; Owen 1988; Piel-Desruisseaux 1998; Christensen and Valentin 2004; Taller et al. 2012). The modular technological system involving these lithic artifacts is highly versatile, mobile and dynamic as there are numerous possibilities of use

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and as the small lithic inserts are easy to transport and the composite tools themselves are easy to maintain and repair. Here, we present the results of an experiment where different tasks were carried out using backed pieces hafted in a wooden handle or operated handheld. The design of the handles loosely follows examples found at Canadian Dorset sites where bladelets comparable in size to Magdalenian backed pieces were hafted and used as knives (Owen 1988, 88ff.). We tried out the tools in various activities (cutting, perforating and carving/whittling) on a set of worked materials (wood, antler, marine shell, smoked meat, dried, semi-tanned hide, and tanned leather). After the completion of these tasks, the applicability, durability and usefulness of the setup were evaluated and the lithic inserts were checked microscopically for use-wear traces.
Keywords: Lithic Artifacts, backed pieces, experimental archaeology, use-wear analysis, trace formation, Upper Paleolithic, Jurassic Chert, Radiolarite

ZUSAMMENFASSUNG

Rückenretuschierte Steinartefakte stellen im Jungpaläolithikum Europas ab dem Gravettien, aber noch viel stärker im Magdalénien regelhaft einen bedeutenden Anteil an den lithischen Werkzeuginventaren. Teils werden diese Artefakte pauschal als schneidende Einsätze in Komposit-Geschossspitzen angesprochen, die seitlich an einer Spitze aus organischen Rohmaterialien befestigt worden waren (z.B. Allain und Descouts 1957; Allain 1979; Abramova 1982; Bergman und Newcomer 1983; Leroi-Gourhan 1983; Plisson 1985; Nuzhnyi 1993; Christensen und Valentin 2004; Sano 2009; Langlais 2010; Araujo-Igreja 2011; Tomasso et al. 2018), und in der Tat mag dies der erstrangige Verwendungszweck gewesen sein, der im Übrigen auch experimentell überzeugend bestätigt werden konnte (z.B. Moss und Newcomer 1982; Pétillon et al. 2011; Gauvrit Roux et al. 2020). Allerdings scheinen die rückenretuschierten Artefakte teils auch anderen Zwecken wie Schneiden, Bohren, Schnitzen, Schaben oder Sägen gedient zu haben (Moss und Newcomer 1982; Moss 1983; Owen 1988; Piel-Desruisseaux 1998; Christensen und Valentin 2004; Taller et al. 2012), und einige dieser nicht mit der Jagdwaffentechnologie in Zusammenhang stehenden Verwendungsarten werden im Rahmen der hier präsentierten Studie experimentell überprüft. Die rückenretuschierten Steinartefakte sind zweifelsohne Teile einer modularen Technologie, die in hohem Maße mobil, vielseitig und dynamisch einsetzbar ist. Es sind zahlreiche Verwendungsmöglichkeiten vorstellbar, und das System insgesamt ist leicht zu transportieren, zu warten und zu reparieren; gleich ob als Projektilbewehrung einer organischen Geschossspitze oder geschäftet in einem Holzgriff zur Verwendung als messerartiges Werkzeug. Die experimentelle Nutzung rückenretuschierter Lamellen und Klingen, geschäftet in einem Holzgriff als Komposit-Werkzeug für verschiedene Arbeiten, wird in diesem Aufsatz vorgestellt; ein Teil der Rückenelemente wird hierbei auch einfach in der Hand gehalten, also ungeschäftet verwendet. Durchgeführte Aufgaben beinhalten das Schneiden von gegerbtem Leder, von trockener, halbgegerbter Haut (Schuhmacherleder) und geräuchertem Fleisch, das Beschnitzen von Holz (Weide, Wacholder) und Rengeweih, sowie das Durchbohren verschiedener Materialien (Holz, Rengeweih, Leder, halbgegerbte Haut, marine Molluskenschalen). Da der Ausgangspunkt für die hier behandelte Fragestellung in der Auseinandersetzung mit dem Jungpaläolithikum der Schwäbischen Alb liegt

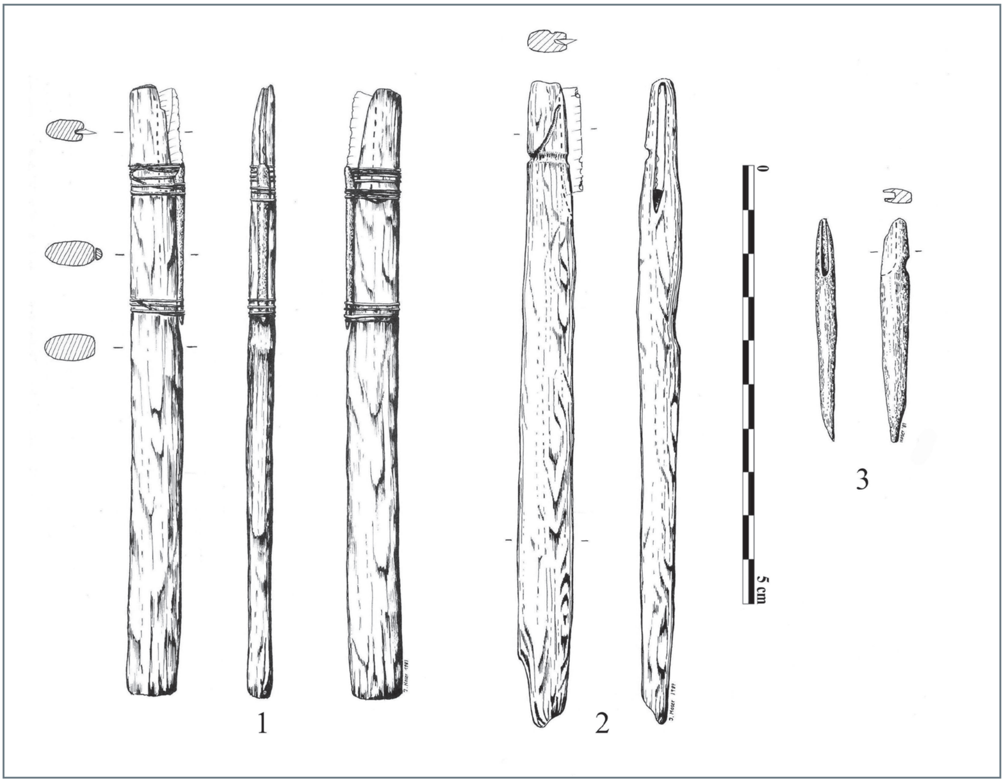
(Magdalénien und Gravettien; vgl. Taller et al. 2012, 2019; Taller 2014, Taller und Conard 2016, 2019, im Druck), finden nur Materialien Verwendung, die entweder gesichert oder zumindest sehr wahrscheinlich den Bewohnern Südwestdeutschlands im späten Pleistozän zur Verfügung gestanden haben. Dieser Anspruch beschränkt sich dabei nicht nur auf die bearbeiteten Materialien, denn auch die von den gravettien- und magdalénienzeitlichen Menschen in der Region hauptsächlich verwendeten lithischen Rohmaterialien in Form von lokalen und regionalen Jurahornsteinen und Radiolariten kommen ausschließlich zum Einsatz. Die Gestaltung des Holzgriffes für das Komposit-Messer orientiert sich grob an archäologischen Funden aus der holozänzeitlichen Dorset-Periode der kanadischen Arktis, wo Lamellen als Schneidewerkzeuge in einem Griff geschäftet worden waren (Owen 1988, 88ff.). Nach Beendigung der experimentellen Arbeiten werden Einsetzbarkeit, Haltbarkeit und Nützlichkeit des Komposit-Werkzeuges evaluiert, und die lithischen Einsätze werden, auch mikroskopisch, auf durch den Gebrauch entstandene Spuren untersucht.
Schlagwörter: Steinartefakte, rückenretuschierte Stücke, Rückenmesser, experimentelle Archäologie, Gebrauchsspurenuntersuchung, Jungpaläolithikum, Jurahornstein, Radiolarit

Introduction

This paper reports the results of an experiment where replicas of Upper Paleolithic backed pieces were hafted individually in a knife-like configuration and used for different tasks alongside hand-held backed lithics. The goal was to test the efficacy of this setup in different craft activities and to provide reference material for further functional study of the assemblages from the Swabian Jura (southwestern Germany) by using exclusively local and regional raw materials.

Backed pieces are common artifacts in Gravettian and particularly Magdalenian lithic tool assemblages in Europe. At Magdalenian sites that have been excavated recently using modern techniques including water screening or fine sieving of the sediments, backed pieces are often the dominant tool category (e.g., Schmidt 1912; Leesch 1997; Bullinger 2000; Christensen and Valentin 2004; Pétillon et al. 2011; Bolus 2012; Julien 2014; Taller 2014; Maier 2015). This means that these artifacts and the connected technologies must have been of considerable importance for Magdalenians and their technological strategies. Therefore, a closer look at this tool category and its possible uses is not only justified but essential in order to gain insights into the viability of the technologies that these hunter-gatherers applied. The same is true for the Gravettian.

When functional studies have been carried out on backed artifacts (in these cases mainly, but not exclusively, from Magdalenian contexts), they have usually detected quite varied uses. Besides the predominant use as projectiles, for instance cutting, scraping, sawing or perforating a range of materials has been reported (see e.g., Moss and Newcomer 1982; Moss 1983; Owen 1988; Piel-Desruisseaux 1998; Christensen and Valentin 2004; Robertson et al. 2009; Taller et al. 2012).The layout of the experiment presented here in terms of the selection of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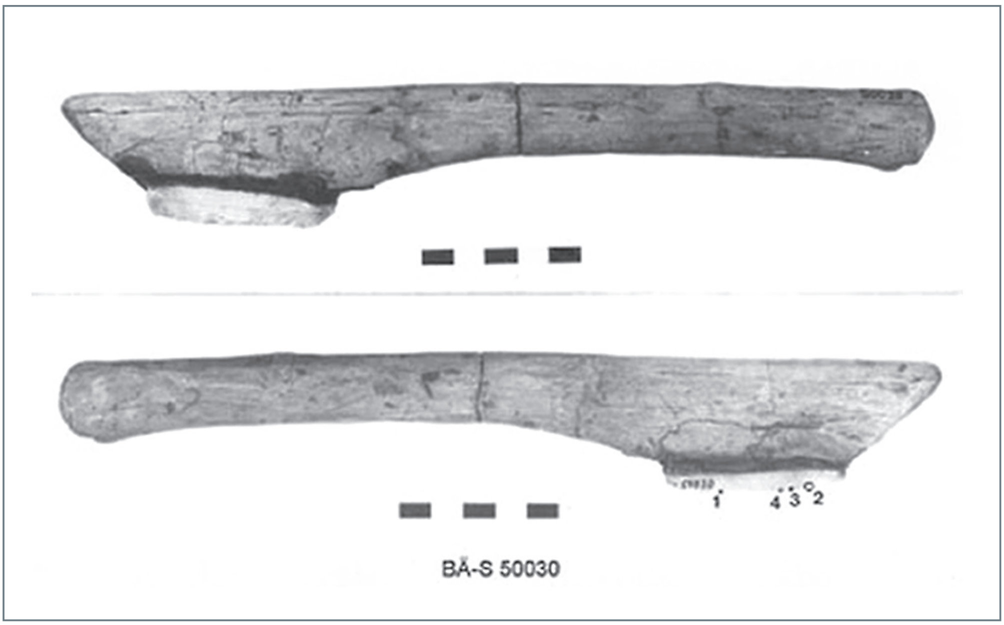
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activities is based on the results of these earlier use-wear analyses as well as a variety of organic artifacts that may have been produced wth the help of such or similar tools (Taller 2018).

In order to be used as a cutting device or for carving, a backed lithic generally has to be hafted in some kind of handle, although with some exceptions (see below). Since fully preserved hafted knives are not known from Upper Paleolithic contexts, we used here the archaeological finds from the Dorset Culture (Canada, Prehistoric Arctic; see Owen 1988: 189) as models for hafted lithic cutting devices. In this design, a small lithic implement was set in a groove at the end of a wooden or antler handle (Fig. 1). Other comparable examples of composite knives with lithic cutting edges, albeit neither from Upper Paleolithic contexts nor involving backed pieces, have been found at a Holocene site in the Baikal area (Zavituchina 1985) as well as at the Swiss Neolithic site Burgäschisee-Süd (Pawlik 1995) (Fig. 2).

Even though the evidence of non-projectile uses of Upper Paleolithic backed pieces is relatively scarce to date, the data available to us suggests that these tools may have served in varied tasks. We therefore hypothesized here that they could be interpreted as the Upper Paleolithic equivalent of the Swiss Army knife, i.e. a multifunctional and mobile tool. The backed pieces form a part of a modular tool design where damaged elements can be replaced with relative ease. Their small size also makes them easily transportable. Backed pieces of dimensions known from the Magdalenian or Gravettian are very light (usually <1g). The wooden handles tested here weigh only c. 10–30g, and the glue (of which not a lot is needed; see below) can be transported easily when dry. If composite tools equipped with backed lithics are perceived as a part of personal equipment as well as an almost certainly curated technology (sensu Binford 1979), their presence in the archaeological record can also be taken as an indication of the existence of other technologies since the transport of all the materials needed for the manufacture and maintenance would necessitate the use of some sort of a carrying device, like a bag, a pouch or a basket. In addition to the likely existence of leather bags, plant-based basketry and woven fabrics seem to have been known from the Gravettian onwards (Adovasio et al. 1996; Soffer and Adovasio 2004) and can be viewed as possible materials and technologies for the manufacture of containers in the Eurasian Upper Paleolithic.

Fig. 1: Hafting scenarios for bladelets in the Dorset Culture of the Canadian Arctic and Greenland (2500–1000 BP), taken as an inspiration for experimental knives used in the present study (modified after Owen 1988).

Abb. 1: Schäftungsszenarien für Lamellen aus der Dorsetkultur der Kanadischen Arktis und Grönlands (2500–1000 BP), die als Anregung für die in der vorliegenden Studie benutzten experimentell erzeugten Messer gedient haben (verändert nach Owen 1988).

Fig. 2: Composite knife setup from the Neolithic of Burgäschisee-Süd (modified after Pawlik 1995).

Abb. 2: Kompositmesser aus dem Neolithikum von Burgäschisee-Süd (verändert nach Pawlik 1995).

Finally, if the many examples of very fine Upper Paleolithic workmanship (such as e.g., the figurative art of the Aurignacian, the Gravettian Venus figurines, the many finely carved and decorated Magdalenian spear throwers, harpoons and objects of mobile art) are considered, it is clear that such perfectly crafted objects indicate the development of tools that allowed precise control over the application of force.

Since the present experiments were designed with an eye on the Magdalenian and Gravettian of the Swabian Jura, and since the main lithic raw materials used there in the Upper Paleolithic are local and regional Jurassic cherts as well as radiolarites from the Danube and Iller gravels, these siliceous materials were employed exclusively in the experiment to ensure maximum comparability and information gain. To date little experimental work has been done to understand to what extent, and after how much time of use, wear traces form on lithic artifacts made from these materials (but see Xhauflair 2014 on the use of radiolarite in a Southeast Asian context). Our experiments can therefore be considered the first ones that are directly adapted to the raw material situation in the Upper Paleolithic of the Swabian Jura.

In the context of studies focused on flint, many very useful experiments have already been conducted for the use of backed pieces and other lithic artifacts as parts of composite projectiles (e.g., Moss and Newcomer 1982; Yaroshevich et al. 2010; Pétillon et al. 2011; Chesnaux 2014; Rots 2016; Tomasso et al. 2018; Gauvrit Roux et al. 2020). Regarding other uses of backed lithics, only the experiments by Moss and Newcomer (1982) and, published very recently, Groman-Yaroslavski et al. (2020) are known to us. Interestingly, some of our findings correspond well with the observations made by Groman-Yaroslavski et al. (2020) and thus encourage further research in this direction.

Research goal

The main goal of this study and experiment was to test the suggested composite multi-purpose tool setup (a backed bladelet hafted in a grooved wooden handle with the aid of a compound adhesive) under real life conditions and thus confirm or falsify its applicability. In addition, the experiments also yielded an initial use-wear reference collection for the possible non-projectile uses of Upper Paleolithic backed pieces. Importantly, the lithic tools used in the experiment form the first functional reference sample for southwestern German cherts and regional radiolarite. Initial observations on use-wear formation on these lithic raw materials are presented here. Besides the backed pieces that are the main focus here, also non-backed lithic artifacts, e.g., burins and blades from preparation, were produced within the same context in view of future studies.

Materials

All materials used in the experiments were available in southern Central Europe during at least parts of the Upper Paleolithic. Only local and regional lithic raw materials (Jurassic cherts and radiolarite) were utilized for the manufacture of the backed pieces. In this context, we need to mention that the Jurassic chert used here is of a comparably fine-grained texture. Of different kinds of wood, juniper and willow were chosen, as *Juniperus communis* and *Salix* seem to have been available at least temporally to Upper Paleolithic occupants of southern Central Europe (see Riehl et al. 2014; Duprat-Oualid et al 2017). The wood was worked in a fresh state.

Other worked materials included reindeer antler, marine shell (documented for the Swabian Magdalenian, see Rähle 1981, 1994), smoked meat, partially tanned dry hide with a raw core beneath the tanned outer layer (very hard material, used, e.g. for making shoes) and tanned, softened leather. Tanning of hides is difficult to demonstrate archaeologically, and it can be debated whether our choice to use tanned leather instead of raw hide is archaeologically accurate. Nevertheless, given the abundant evidence of hide processing in the Upper Palaeolithic record and the appearance of e.g. sewing needles by the Magdalenian, there is reason to assume that Gravettian groups had reasonable knowledge of the qualities of animal hides and most likely also of ways to improve these qualities. While a link with hide-processing cannot be demonstrated, it is interesting to note that remains of *Arctostaphylos* sp. (bearberry) have been identified in the Gravettian layers of Hohle Fels, and there is ethnographic evidence of the use of this plant in tanning (Riehl et al. 2014).

A possible exception in terms of Upper Paleolithic availability might be beeswax, which was used as a plasticizer in the compound hafting glue in the experiment reported here. The only reliable evidence for use of beeswax in the Pleistocene in the region north of the Alps comes from the Final Paleolithic site of Bergkamen in Westphalia, Germany and dates to ca. 13,000 cal BP (Baales et al. 2017). Possible evidence for use of beeswax at European sites south of the Alps also dates to the end of the Pleistocene and the Paleolithic. At the Dalmeri rockshelter (Trentino region, northeastern Italy), an Epigravettian site dating to between 13,200 and 13,000 cal BP, slabs of stone with haematite painting on them have been found. The pigment was fixed and bound with a material that was most likely beeswax (Dalmeri et al. 2009). From the same region, there is also evidence of use of beeswax in a compound glue. Different rockshelter sites dated to the late Mesolithic and early Neolithic in the Trentino region have yielded microliths hafted to wooden shafts using an adhesive made from vegetal bitumen, beeswax and powdered haematite (Cristiani et al. 2009).

Other indications of honey gathering and therefore in all probability also the collection of wax in pre-Neolithic Europe are the examples of rock art from the Spanish Mesolithic site Cuevas de la Araña, where the gathering of honey is depicted (Dams and Dams 1977). Evidence of the harvesting and use of honey and beeswax increases drastically only in the European Neolithic (Roffet-Salque et al. 2015). In South Africa, however, beeswax seems to have been in use in the Middle Stone Age from about 40,000 years ago onwards (d'Errico et al. 2012).

The hafting agent we used in the experiment was a compound glue of pine resin and beeswax, tempered with charcoal. The mixing ratio was approximately 60 % resin and 40 % beeswax. Several experimental compounds have been made with resin and beeswax as the main components (e.g., Barton and Bergman 1982; Moss and Newcomer 1982, Bergman and Newcomer 1983; Cattelain and Perpère 1993; O'Farrell 2004; Pétillon et al. 2011; Coppe and Rots 2017; for a comprehensive overview of these and other mixtures used in archaeological experiments, see Gaillard et al. 2015, table 1).

The resin for the adhesive in our experiment was harvested in a local forest near Tübingen exclusively from injured *Pinus sylvestris* (Scots Pine) trees. The resin was cleaned of larger pieces of bark which adhered to it and then liquefied in a small pot in 10–20 seconds over a camping gas stove with an output of 1,250 W. Then the beeswax was added and immediately melted into the already fluidized resin. After that, the mastic was tempered with ground charcoal and poured into the groove of the wooden handle, after which the backed piece was pressed in. This needed to happen fast as the glue dried and hardened almost immediately once removed from the stove. Since it also was easily reheatable and showed no apparent loss of function even after being liquefied multiple times, the adhesive can be considered well suited for transport and mobile use. For the composite knives manufactured in this experiment, only a very small amount of glue (ca. 1–3 ml) was necessary to haft one backed lithic. The configuration can therefore be considered economical in terms of raw material use.

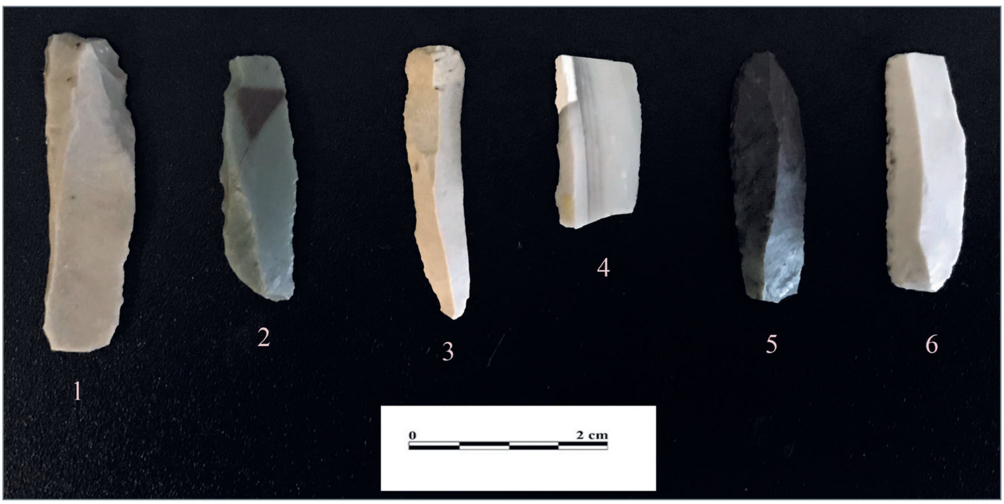


Fig. 3: Selection of backed pieces made for the experiment. 1–2, 5: Radiolarite; 3–4, 6: Jurassic Chert (photo: A. Taller).

Abb. 3: Auswahl für das Experiment hergestellter rückengestumpfter Artefakte. 1–2, 5: Radiolarit; 3–4, 6: Jurahornstein (Foto: A. Taller).

Experimental setup, protocol and implementation

First, a stock of backed pieces was made to carry out the experiments (n=30; Fig. 3), with enough spare blanks (>40 bladelets and blades) to produce further implements when needed. The lithic blank production was carried out by Dr. Hannes Napierala and the lead author with reindeer and red deer antler hammers and small, hard hammerstones. The backs were made by pressure flaking using a red deer antler tine. The mean length of the backed pieces is

Fig. 4: Experimentally made objects. 1 (top): juniper wood handle (made earlier in order to test the first setup), (lower two): handles made from willow wood; 2: small leather bag with antler button; 3: perforated marine bivalve shell; 4: antler projectile point (photos: A. Taller).

Abb. 4: Experimentell hergestellte Objekte. 1 (oben): Griff aus Wacholderholz (bereits vorher gefertigt, um die erste Konfiguration zu testen), (Mitte und unten): Griffe aus Weidenholz; 2: kleiner Lederbeutel mit Geweihknopf; 3: durchlochte Meeresmuschelschale; 4: Geschossspitze aus Geweih (Fotos: A. Taller).

29.3 mm, they have an average width 9.6 mm, and the average thickness amounts to 3.4 mm. There is a clear overrepresentation of lithic artifacts made from Jurassic chert (ca. 63 % Jurassic chert vs. 37 % radiolarite), which is attributed to the fact that good quality radiolarite is hard to find today in the region and only one usable nodule was available to us.

For the composite setup, one backed piece was set in a grooved wooden handle (Fig. 4.1). These handles were designed to be as thin as possible in the active part of the arrangement, i.e., where the backed bladelet was hafted. This helped to ensure maximum manoeuvrability of the composite tool's active end during the different activities and tasks. However, in order to have an arrangement that is sufficiently robust for the tasks at hand, the backed piece needed to be set as deep as possible into the groove, which, considering the small dimensions of the lithic artifacts, meant that the protrusion of the edge was sometimes only a few millimetres. Therefore, the composite tool was not practical for some tasks (e.g., some whittling/carving works, cutting meat), which means that we might have to consider different modes of hafting and/or use (transverse, working like a chisel, or an Ulu). Some tasks (e.g., perforating, cutting of food items) were done with handheld artifacts.

The goal here was to manufacture actual artifacts in order to test the tools under real life conditions. This choice was made to gain the maximum amount of information about the usability of backed artifacts in different tasks (see Keeley 1980). One wooden handle of juniper wood was made before the actual experiment started. In this handle, one backed piece was glued into the groove with the composite adhesive described in the "materials" section. With this instrument, three other handles (one in juniper wood and two in willow wood) were made, using a different lithic insert each time. These handles were then equipped with backed lithics and used in the subsequent experiments. In the course of the experiments, altogether 27 backed lithics were used, 24 of these in the manufacture of the objects mentioned in Table 1 and partly pictured in Fig. 4. Three backed pieces were wasted earlier in an unfruitful attempt to carve dry antler (see below). Given the successfully completed tasks, this does not seem excessive, especially when considering that I (AT) am not an expert craftsman in this field; an artisan from the Upper Paleolithic would have completed the tasks much better, much faster, and without wasting as many lithic implements.

Following the lack of success in working dry antler, the blank for the antler point made in the experiment (Fig. 4) was soaked in water for 24h prior the experiment and was also soaked repeatedly for shorter periods during the shaping process whenever the material became too hard to work. Some of the tools were used in a combination of motions to complete the task at hand. Particularly the wood-working tools represent a mix of gestures as they were used in whittling as well as in making the groove and in cutting the handle to its desired length.

Table 1 summarizes the uses of the different setups. Most tasks were carried out using tools in both Jurassic chert and radiolarite.

Material worked	Aim	Hafted	Backed pieces needed for completion of the task
Willow wood	Manufacture of wooden handle (two made)	Yes	2
Juniper wood	Manufacture of wooden handle and small wooden fork	Yes	1
Leather	Cutting of blank and cord for a small leather bag	Yes	1
Leather	Perforating the leather blank (12 holes)	No	1
Leather	Cutting of a protecting pad for the hand	Yes	1
Willow wood	Perforating the bases of the wooden handles (3 holes)	No	2
Reindeer antler	Perforating a small antler disc to make a button (2 holes)	No	2
Reindeer antler	Making an antler projectile point from an antler splinter	Yes	3
Raw hide	Cutting a cord	Yes	5
Raw hide	Perforating the cord to create a loop	No	1
Marine shell	Perforation to create a pendant	No	3 (with 5 borer tips)
Smoked meat	Cutting	No	2

Table 1: Materials and tasks of the experiment.

Tabelle 1: Im Rahmen des Experiments bearbeitete Materialien und ausgeführte Arbeiten.

After use, the lithics were taken out of their handles (often warming of the adhesive was necessary) and cleaned first using acetone and then in an ultrasonic cleaning tank in a mixture of water and liquid detergent. In many cases this was not enough, and the remaining residual material had to be removed with diluted (3 %) acetic acid and/or NaOH (also 3 %) and ultrasonication in water in between. Use-wear features were examined under both low and high magnification using standard procedures (see e.g., Semenov 1964; Tringham et al. 1974; Lawrence 1979; Keeley 1980; Odell and Odell-Vereecken 1980; Odell 1981; Vaughan, 1985) and two different microscopes, an Olympus SZX7 stereomicroscope (magnifications 8–56×) with oblique lighting and an Olympus BX53M metallurgical microscope (magnifications 50–500×) with incident lighting. The wear traces were photographed under high magnification using an Olympus UC90 microscope camera and StreamEssentials software. The low magnification images are composed of individual photos captured with StreamEssentials and stacked in Helicon Focus Lite. The analysis of production and hafting wear features (see Rots 2010a, b) is in progress and the discussion here is limited to use-wear in the strictest sense.

Results

The knife setup seemed well suited for the tasks executed here. Small knives are very practical for many different activities, such as for carving delicate objects and for fine work of any description in general. It is no coincidence that whittling knives in use today usually have very fine and small (steel) blades. Especially with a hafting arrangement such as the one used here,

Fig. 5: Carving juniper wood with the experimental knife (photo: A. Taller).
Abb. 5: Schnitzen von Wacholderholz mit dem experimentell hergestellten Messer (Foto: A. Taller).

high accuracy and control over the movement and application of force is possible when working with the edge. On the whole, the proposed setup worked well, but there were also a few setbacks and problems.

In the course of the experiments it became clear that standardization is very important for the joint between the lithic implement and the groove in the wooden haft. While the composite knife could be used in a reliable, steady and durable way on almost any material when the hafting arrangement was good (see Figs. 5 and 6), it was almost impossible to complete a task if certain parameters on the side of the lithics and/or the groove in the handle were not properly met. Straightness, thickness/diameter, and regularity of the back of the piece as well as the working edge all played a crucial role. When the degree of standardization was not high enough, the backed pieces came loose very easily and/or the working edges were not usable to their full potential. This is also something that needs to be considered for future experimental designs in this area of research. Some of the objects that were created during the experiments are pictured in Figure 4.

Whittling, carving and perforating wood (Figs. 4.1,5) worked well and the backed lithics showed considerable endurance in these tasks. For instance, the willow wood for the handle could be worked for 1.5–2 h until the object was finished using a single backed piece. The (slightly smaller) handle of juniper wood was finished in 46 min, and after that the hafted

Fig. 6: Cutting of semi-tanned hide (photo: A. Taller).
Abb. 6: Schneiden halb gegerbter Tierhaut (Foto: A. Taller).

backed piece was used for a further 19 min to carve a small fork, also of juniper. These findings are similar to those reported by Groman-Yaroslavski and colleagues (2020) who found that the backed pieces were in a perfectly functional condition even after a considerable time of wood working (1000 strokes, working time 45–60 min). In our experiment, the cutting of the groove in the handles (which was later deepened using a lithic burin) was straightforward. Perforating the wooden handles using hand-held tools was comparably easy, although the three holes (made with two different backed pieces) took ca. 40 min to finish.

The hafted backed pieces used to carve and whittle wood show edge damage that varies in characteristics according to the relative hardness of the wood and is oblique or transverse in orientation. The damage on the radiolarite tool used for working willow for two hours (RM [Rückenmesser] 1) is particularly light and consists of bending-initiated scars that are relatively shallow and mostly small (Fig. 7a). The polish on this piece is notably discontinuous and limited. This may be partly the result of the chipping of the edge during work but raw material qualities may also play a role. The best-developed patches have a plant-like appearance (Fig. 7b). The Jurassic chert tool (RM 4) used for 1.5 hours shows considerably more continuous polish that has wood-like characteristics, but is mostly limited to a narrow band on the outermost edge and is therefore not very diagnostic (Figs 7c, d). The linearity of the microwear is not very pronounced on either tool, but the continuous, non-invasive polish on the Jurassic

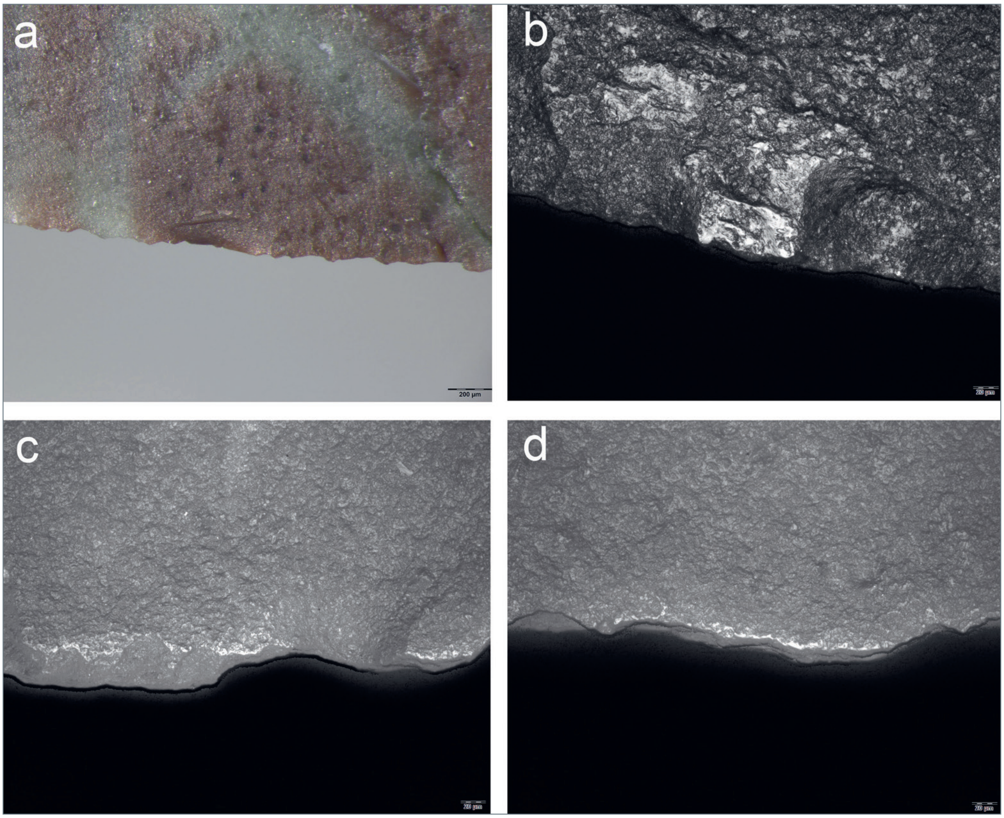


Fig. 7: a) A small bending-initiated scar from working willow on backed piece RM 1 (radiolarite) used for two hours. Original magnification 56×, scale bar 200 µm; b) Polish from working willow on RM 1 (radiolarite) used for two hours. Original magnification 500×, scale bar 20 µm; c) Polish from working willow on RM 4 (Jurassic chert) used for 1.5 hours. The polish is bright and more or less comparable to wood polish on flint in its texture and distribution. Original magnification 500×, scale bar 20µm; d) Polish from working willow on RM 4 (Jurassic chert) used for 1.5 hours. The polish forms a narrow band on the edge and is less characteristic than that shown in 7c. Original magnification 500×, scale bar 20 µm (photos: N. Taipale).

Abb. 7: a) Kleine, durch Biegen beim Bearbeiten von Weidenholz verursachte Aussplitterung auf Rückenmesser RM 1 (Radiolarit), benutzt über zwei Stunden. Originalvergrößerung 56×, Maßstab 200 µm;
b) Negative kleiner, bei der Bearbeitung von Weidenholz entstandener Biegebrüche an RM 1 (Radiolarit) durch die Bearbeitung von Weidenholz, benutzt über zwei Stunden. Originalvergrößerung 500×, Maßstab 20 µm;
c) Politur auf RM 4 (Jurahornstein) durch die Bearbeitung von Weidenholz, benutzt über 1,5 Stunden. Die Politur ist hell und in ihrer Textur und Verteilung mehr oder weniger vergleichbar mit Holzpolitur auf Feuerstein. Originalvergrößerung 500×, Maßstab 20 µm; d) Politur auf RM 4 (Jurahornstein) durch die Bearbeitung von Weidenholz, benutzt über 1,5 Stunden. Die Politur bildet ein schmales Band an der Kante und ist weniger charakteristisch als die in 7c gezeigte. Originalvergrößerung 500×, Maßstab 20 µm
(Fotos: N. Taipale).

Fig. 8: Edge angle of the lithic vs. possible working angle of the whole composite tool (photos: A. Taller).
Abb. 8: Schneidenwinkel des Steinartefakts vs. möglicher Arbeitswinkel des kompletten Kompositwerkzeugs (Fotos: A. Taller).

chert piece is consistent with dominantly transverse motion. The radiolarite tool likewise shows a transverse or oblique tendency, but also an isolated location with longitudinally oriented, flat polish. The perforators used on wood both fractured during use. They are triangular in cross-section and show a characteristic pattern of bending-initiated edge damage that is present on edges and the dorsal ridge and is consistent with rotative use motion. The distal fragments were not analyzed under high magnification at this stage as they are small-sized and difficult to manipulate.

The thickness of the composite tool's head limited its use potential in woodworking and other tasks to an extent. This is because it did not allow for a working angle that would actually correspond to the edge angle of the backed lithic (Fig. 8), and thus prohibited very fine work. For instance, the configuration pictured in Fig. 8 shows a backed lithic with an edge angle of about 45°. However, if the complete setup is considered, the minimum working angle was closer to 65°. This posed problems also when cutting up smoked meat, for which task larger, handheld backed pieces were consequently used. Similar limitations have also been observed by Groman-Yaroslavski and colleagues (2020) in their comparable experiment.

The cutting of the soft leather blank and cords worked well and was achieved very quickly. On the whole, the manufacture of the complete bag took only about 20 min (plus the time needed to perforate the antler button; Fig. 4.2). A leather pad for hand protection during knapping or working with sharp tools was cut out in 26 min. The chert piece used for cutting soft leather for 12 minutes shows bending-initiated, mostly shallow scarring that is sometimes clearly oblique in orientation (Fig. 9). The microwear on the tool consists of subtle rounding, discontinuous hide-like polish, and rare spots of brighter, flatter, striated polish indicative of

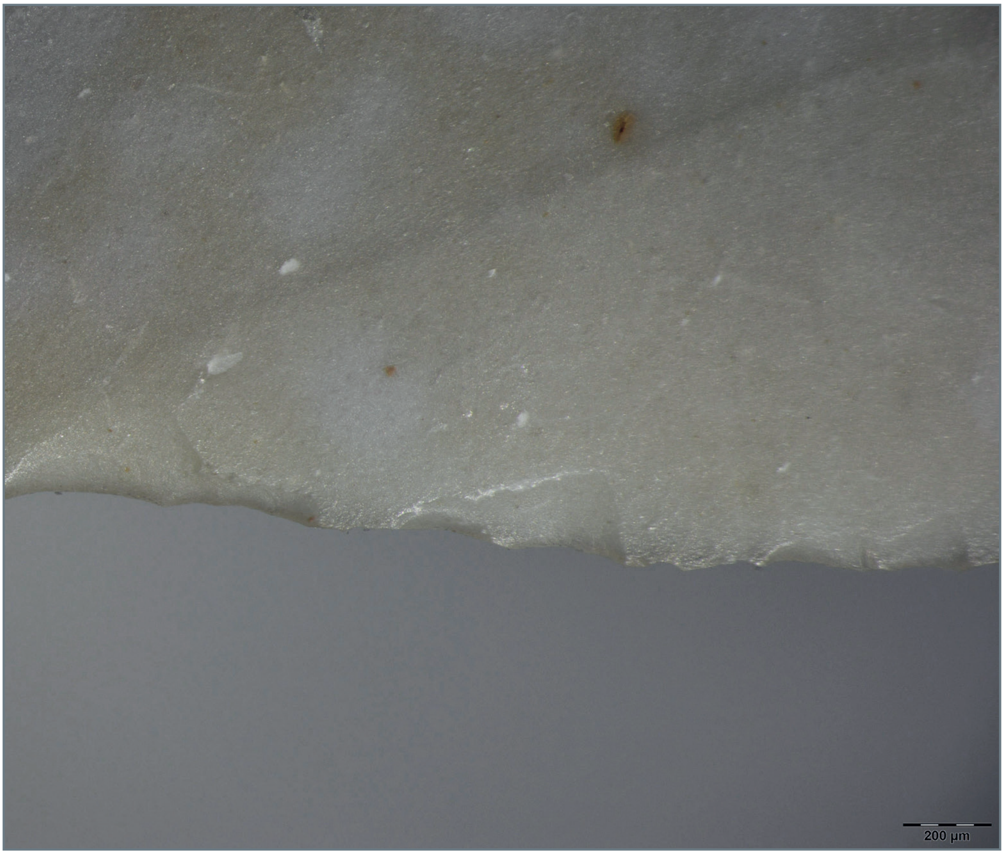


Fig. 9: Bending-initiated, partly obliquely oriented scarring on RM 5 (Jurassic chert), used for cutting soft leather for 12 minutes. The lighting has been adjusted in the image editing software to enhance the visibility of the scars and the chert therefore appears darker than it is in reality. Original magnification 40×, scale bar 200 µm (photo: N. Taipale).

Abb. 9: Teilweise schräg orientierte, durch das Schneiden weichen Leders entstandene Aussplitterung in Form von Biegebrüchen an RM 5 (Jurahornstein, Arbeitsdauer 12 Minuten). Die Beleuchtung wurde mit Bildbearbeitungssoftware angepasst, um die Sichtbarkeit der Aussplitterungen zu verbessern. Dadurch erscheint der Hornstein dunkler als er tatsächlich ist. Originalvergrößerung 40×, Maßstab 200 µm (Foto: N. Taipale).

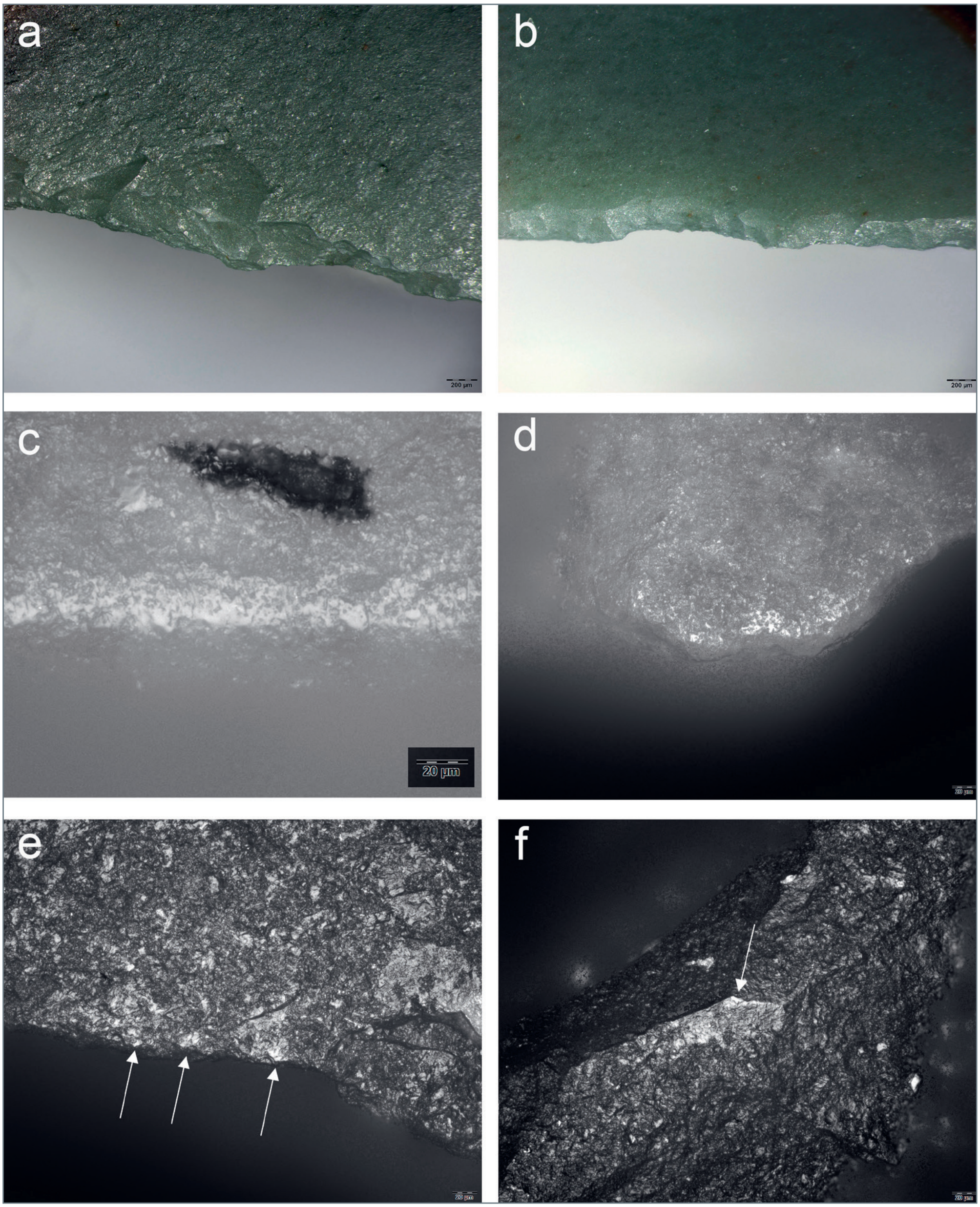
hard contact material, most probably the small chert chips that came off the edge during work. The perforator used on soft leather exhibits infrequent, small but relatively deep bending-initiated scars on the acute-angled and fragile edge at the tip. Under magnification, the most prominent edge portions show rounding and polish.

Working antler in the way proposed here (see Fig. 4.4) was feasible, but took a considerable amount of time and also inflicted much more substantial damage to the lithic working edges than wood-working. The antler splinter for the point had been soaked in water for about 24 h, which was an absolutely necessary step of preparation, as an earlier ineffective attempt with dry material had shown. Even as the soaked antler dried during the course of the work, carving and cutting became increasingly difficult, and the motion necessary to remove material became more like scraping than actual carving/whittling, until ultimately the workpiece had to be re-soaked. The manufacture of the projectile point took more than two hours (134 min), and it is clear that longer initial soaking would speed up the manufacturing process.

Due to the hardness of the worked material, the wear traces caused by working antler are dominated by scarring. Regardless of the lithic raw material, the scars are typically discontinuous, rather invasive, shallow, and often step-terminated on the surface that was in primary contact with the antler whereas the opposite aspect shows continuous scarring that is dominantly feather-terminated and resembles marginal retouch (Fig. 10a, b). This asymmetrical pattern is consistent with the relatively low working angle but is also influenced by surface convexities. The Jurassic chert tool (RM 2) that was used for two hours presents well-developed polish at one location that is directly comparable to antler polish on flint (Fig. 10c). The polish is at places associated with edge rounding that is clearly more pronounced than on the wood-working tools (Fig. 10d). In contrast, the polish on the radiolarite artifact (RM 3) is much more limited in both extension and development (Fig. 10e). This tool was used almost as long as its Jurassic chert counterpart (1.5 hours), a duration that can be assumed lengthy enough to allow characteristic polish to develop. While the chipping of the working edge can be partly responsible for the lack of diagnostic polish, the option that the properties of radiolarite affect use-wear formation should be considered and investigated through further experimentation. Perforating the (dry) antler button (Fig. 4.2) took about 20 min per hole, which seems relatively long, especially when considering that these holes were quite small with a diameter of ca. 2.5 mm. The radiolarite tool used for this task shows prominent chipping and abrasion on the tip. Very limited smooth polish that can be observed on rare occasions on the highest ridges resembles bone polish seen on flint tools, but is extremely restricted in extension (Fig. 10f). The chert tool used in the same manner represents a slightly coarser variety than the other experimental tools, which is reflected in the wear pattern. Macrowear is dominated by scarring whereas abrasion comparable to that observed on the radiolarite tool is nearly absent here. Some polish is visible on high points but it is always very limited and uncharacteristic.

The working of dried semi-tanned hide was equally difficult as the force needed to cut into the very hard material was considerable and again caused massive wear and splintering on the lithic edges, which often left them unusable. As a result of this, the cutting of a strap of hide with a length of about 40 cm took almost 1h and wasted five backed pieces; moreover, one of the pieces snapped in two while in the haft. Sometimes cutting the hide was more a sawing movement than actual cutting.

The wear on the radiolarite tool (used for 12 min) consists of bending-initiated, partly obliquely oriented scarring. Some of the scars are rather deep and retouch-like, consistent with the relative hardness/resistance of the material, and are accompanied with partial rounding visible under low magnification. The polish on this piece is partly very bright and


a
b
c
20 µm
d
e
f

localized (Fig. 11a). While radiolarite chips rubbing against the edge during work may be partly responsible for this pattern, the worked material itself can also be considered hard enough to cause high localized friction. The chert tool (used for 25 min) shows comparable traces as well as polish that reaches relatively far behind the edge but is limited to the highest spots of the surface microtopography and is undiagnostic in appearance even though the direction of work is sometimes visible as rare striations. Perforating the semi-raw hide wore out two borer-tips and caused bending-initiated scarring and some rounding and polish on topographic high spots and ridges (Fig. 11b).

The perforation of a thick and hard marine bivalve shell was another demanding task for the lithic tools, and took almost three quarters of an hour and wasted five lithic borer ends (for one hole with a diameter of about 2 mm; Fig. 4.3). The Jurassic chert tool used in this task shows scarring with bending or removed initiations and abrupt terminations as well as relatively well-developed, nearly smooth rounding of the outermost tip. The polish that has been located so far is bright, flat, partly striated (longitudinal) and consistent with hard worked material, but it is unclear whether it is caused by direct contact with shell or represents flint-on-flint friction. One of the radiolarite borers (BO [Bohrer]1) shows dominantly longitudinally oriented striations that likewise are caused by either the worked material itself or chips that came off the tip (Fig. 11c). These features seem to derive from movement with which the tool was pushed against the worked material. Under low magnification, the tip of this tool has a crushed appearance (Fig. 11d) and is rounded in its distalmost part similarly to the Jurassic chert tool.

Fig. 10: a) Invasive abruptly terminating scarring on the ventral aspect of the working edge of RM 3 (radiolarite), used for working soaked antler for 1.5 hours. Original magnification 32×, scale bar 200 µm; b) Retouch-like dorsal scarring on RM 3 (radiolarite), used for working soaked antler for 1.5 hours. Original magnification 32×, scale bar 200µm; c) Polish on RM 2 (Jurassic chert), used on soaked antler for two hours. The polish is located on the termination of a scar and is comparable in characteristics to antler polish on flint. Original magnification 500×, scale bar 20µm; d) Edge rounding and polish on RM 2 (Jurassic chert), used on soaked antler for two hours. Original magnification 500×, scale bar 20µm; e) Limited polish (indicated with arrows) on RM 3 (radiolarite) from working soaked antler for 1.5 hours. Original magnification 500×, scale bar 20µm; f) Limited polish (arrow) on BO 6 (radiolarite), used for perforating dry antler for 25 minutes. The polish is restricted to the highest ridge. The larger reflective area below it is a partial radiolarian (natural surface feature). Original magnification 500×, scale bar 20µm (photos: N. Taipale).

Abb. 10: a) Invasive, abrupt endende Aussplitterungen auf der Ventralfläche der Arbeitskante von RM 3 (Radiolarit), benutzt zur Bearbeitung gewässerten Geweihs über 1,5 Stunden. Originalvergrößerung 32×, Maßstab 200 µm; b) Retuscheartige dorsale Aussplitterungen an RM 3 (Radiolarit), benutzt zur Bearbeitung gewässerten Geweihs über 1,5 Stunden. Originalvergrößerung 32×, Maßstab 200 µm; c) Politur auf RM 2 (Jurahornstein), benutzt auf gewässertem Geweih für zwei Stunden. Die Politur befindet sich am Ende einer Aussplitterung und ist in ihren Charakteristika mit Geweihpolitur auf Feuerstein vergleichbar. Originalvergrößerung 500×, Maßstab 20µm; d) Kantenverrundung und Politur auf RM 2 (Jurahornstein), benutzt auf eingeweichtem Geweih für zwei Stunden. Originalvergrößerung 500×, Maßstab 20µm; e) Begrenzte Politur (mit Pfeilen angezeigt) auf RM 3 (Radiolarit) von der Bearbeitung gewässerten Geweihs über 1,5 Stunden. Originalvergrößerung 500×, Maßstab 20µm; f) Begrenzte Politur (Pfeil) auf BO 6 (Radiolarit), benutzt zum Durchlochen trockenen Geweihs über 25 Minuten. Die Politur ist auf den höchsten Grat beschränkt. Der größere reflektierende Bereich darunter ist eine partielle Radiolarie (natürliches Oberflächenmerkmal). Originalvergrößerung 500×, Maßstab 20µm (Fotos: N. Taipale).

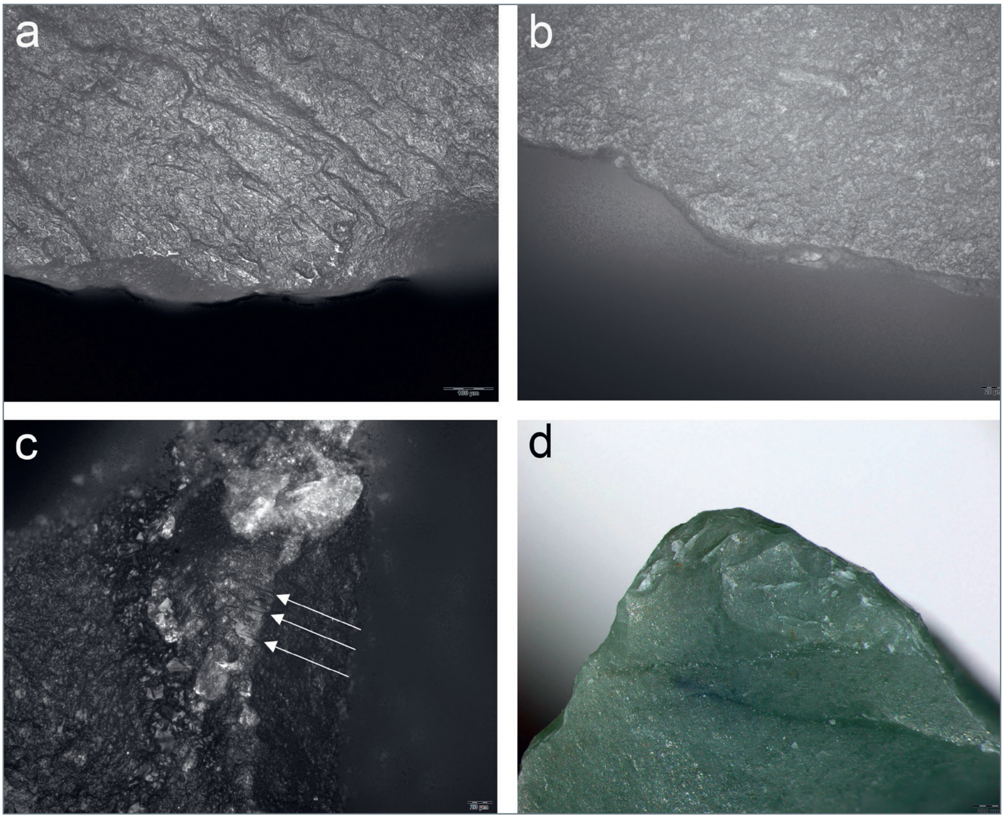


Fig. 11: a) Bright polish on high points of surface microtopography on RM 6 (radiolarite), used for cutting partially tanned rigid hide for 12 minutes. The polish may be influenced by small chips that came off the tool edge and became embedded in the worked material. Original magnification 200×, scale bar 100µm; b) Edge rounding and polish from perforating partly tanned rigid hide on BO 9 (Jurassic chert), used for 11 minutes. Original magnification 500×, scale bar 20µm; c) Longitudinally oriented linear polish and striations (indicated with arrows) on the tip of BO 1 (radiolarite), used for perforating a marine shell for 40 minutes. The wear features are caused by either direct contact with the shell or by the chips that came off the tip during work. Original magnification 500×, scale bar 20µm; d) Crushing (small abruptly terminating scars) on the tip of BO 2 (radiolarite), used for perforating marine shell for ca. 40 minutes. Original magnification 32×, scale bar 200 µm (photos: N. Taipale).

Abb. 11: a) Helle Politur auf hohen Stellen der Oberflächen-Mikrotopographie auf RM 6 (Radiolarit), benutzt zum Schneiden teilweise gegerbter starrer Tierhaut für 12 Minuten. Die Politur könnte durch kleine Absplisse beeinflusst sein, die sich von der Werkzeugkante gelöst haben und in das bearbeitete Material eingebettet wurden. Originalvergrößerung 200×, Maßstab 100µm; b) Kantenverrundung und Politur vom Durchlochen teilweise gegerbter starrer Tierhaut auf B0 9 (Jurahornstein), benutzt für 11 Minuten. Originalvergrößerung 500×, Maßstab 20µm; c) in Längsrichtung orientierte flächige Politur und Striationen (durch Pfeile angezeigt) an der Spitze von BO 1 (Radiolarit), benutzt zum Durchlochen einer Meeresmuschel über 40 Minuten. Die Gebrauchsspuren sind entweder durch direkten Kontakt mit der Muschel verursacht oder durch Absplisse, die sich während der Arbeit von der Spitze gelöst haben. Originalvergrößerung 500×, Maßstab 20µm; d) durch kleine, abrupt endende Aussplitterungen stark beschädigte Bohrerspitze (BO 2, Radiolarit), benutzt zum Durchlochen einer Meeresmuschel über ca. 40 Minuten. Originalvergrößerung 32×, Maßstab 200 µm (Fotos: N. Taipale).

Cutting smoked meat (pork) without bone was a simple enough task for the backed knives, but the efficiency of the composite setup was hampered by the relatively low protrusion of the cutting edge. The tool worked fine when cutting thin slices into pieces, but proved problematic when a deeper incision was necessary (see Fig. 8), and the task was eventually carried out with bigger, handheld backed pieces. These tools were only used for a short period of time (4–5 min each). When observed with the stereomicroscope, they show limited, discontinuous scarring with both bending and cone initiations. Some scars are broad and shallow while others are small and better-defined. Under magnification, the Jurassic chert knife shows limited bright polish on some ridges and scar terminations that is potentially influenced by the small chips that came off the edge during work. Parts of the edge show subtle rounding, but clear meat polish is absent. The microwear on the radiolarite tool consists of rare longitudinal striations and limited abrasion that appears to have longitudinal orientation but is difficult to distinguish with certainty from the somewhat variable natural surface features.

Discussion and conclusion

The examination of the experimental tools under the microscope has shown that both raw material varieties (Jurassic chert and radiolarite) are suitable for combined low and high magnification use-wear analysis. Due to the generally fine grain of the Jurassic chert we used, the edge damage patterns on the two lithic materials are broadly comparable both to each other and to flint. In contrast, the observations on the single perforator in coarser chert suggest that internal variability within this raw material needs to be properly accounted for in archaeological applications, and direct analogies between fine and coarse varieties should be avoided at least until they can be justified experimentally. The near absence of macroscopic rounding on the above-mentioned perforator indicates that coarser varieties of Jurassic chert may be less susceptible to the formation of abrasive wear, which can be expected to lead to slower polish formation on microscale.

The first observations on the current sample point to a possible difference in polish formation between Jurassic chert and radiolarite. The antler-working tools are the most illustrative example. Whereas the fine-grained Jurassic chert developed after prolonged use polish very similar to that seen on flint tools, the corresponding traces on the radiolarite tool are discontinuous and limited in comparison. A recent analysis of archaeological radiolarite tools from Hohle Fels (Taipale 2020) has shown that polish development on this raw material can range from completely absent to extensive even when only tools with relatively pronounced low magnification wear are compared. While part of the archaeological observations can be explained by differential preservation of microwear, it appears that there are also particularities in polish formation on radiolarite that need to be understood before drawing parallels between archaeological radiolarite and flint/chert tools. These particularities would be best addressed through systematic experiments where parameters such as edge morphology, working angle, and duration of tool use are carefully controlled for. In the current experimental setup, the primary aim was to replicate real-life tool use situations, which limits the scope of conclusions in terms of use-wear formation. In addition, particularly the chipping of acute-angled edges of the lithic tools used here is a factor that has had a currently unknown effect on polish formation. Because the process of chipping is affected by both edge morphology and the details of tool use, it can be expected to vary slightly from tool to tool, which means that the tools discussed above may not be strictly comparable even if the worked material and the duration of use is the same or similar. The observations here must therefore be considered preliminary and examined critically in the context of controlled experiments where edge morphology and load conditions are kept constant.

The amount of force applicable with the composite setup was surprising, although it clearly depended on the quality of the hafting arrangement, which needed to be highly standardized both on the side of the backed lithics as well as the groove in the handle. While it was not difficult to de-haft the lithic implements, the composite tools had to be warmed regularly for this purpose, as the adhesion of the glue held the backed pieces in the groove so strongly that the extraction of the implement with purely mechanical means was often impossible, at least without the danger of causing severe damage to either the wooden haft, the stone artifact, or both. This finding might relate to an observation made by Moss and Newcomer who note that at Pincevent, backed pieces were often found next to or even in hearths, which suggests that "…the hearth played a part in fitting and reusing the bladelets from a haft" (Moss and Newcomer 1982: 293).

The handheld perforators also functioned well, and since in their case only the tip was used, the lateral part could still theoretically serve as a cutting edge. For archaeological artifacts, a dual function seems thus possible for such pieces. While the back is not a mandatory modification if the tool is meant for hand-held use, the backed part functioned well as a rest for the forefinger during the work, and can therefore be considered an advantage. The same applies to the handheld artifacts used for cutting.

The experiments proved that the proposed configuration works well for different tasks, and the possibility that backed pieces were parts of modular tool kits and not exclusively used as projectile inserts should be taken into consideration when working with Upper Paleolithic stone tool assemblages. The advantages of tools such as the ones tested here become even more evident when the lightweight, easily transportable, and parsimonious nature of the arrangement is considered. All that is needed are a wooden handle, a number of backed pieces, and a bit of glue, which is equally easy to transport in its solid state. That being said, it is necessary to bear in mind that there are also limitations to the setup proposed here. The thickness of the distal part of the handle combined with the limited protrusion of the lithic cutting edge can make tasks that require low working angles difficult or even impossible to complete. The relative lack of protrusion of the working edge can also be problematic if a deep incision into the material (e.g., meat) is necessary.

Consequently, even though the overall setup worked well, our hypothesis that backed pieces could function as highly versatile tools ("Swiss Army knives") cannot be fully confirmed by the observations made in these initial experiments. The current insights would rather suggest that if hafted this way, backed elements could serve in particular tasks including wood-working, antler-working, and cutting of leather and/or hide. For other purposes, different hafting modes or hand-held use would be required.

Groman-Yaroslavski et al. (2020) tested a transverse hafting arrangement experimentally and their archaeological sample suggested that the small lithics were mainly used in transverse actions. The same authors also experimented with hand-held backed pieces. Based on our experience, the handheld application seems a conceivable alternative in case delicate work is required. Hand-held use also provided a maximum degree of flexibility in terms of tool movement and working angles, which can be considered relevant for certain craft activities. In such use, the backed part of the artifact can serve as a comfortable support for the forefinger during work.

It is conceivable that the presence of a modular technology involving backed pieces in the Swabian Upper Paleolithic during the Gravettian mirrors a reaction of Pleistocene hunter-gatherers to a changing climate and environment from ca. 35 ka cal BP onwards, with declining temperature and insolation (e.g., Clark et al. 2009; for a discussion related to archaeology see Maier and Zimmermann 2017), a development that later culminated in the Last Glacial Maximum. Swabia was uninhabited from the end of the Gravettian around 31 ka cal BP until about 16 ka cal BP presumably because of the harsh climatic conditions. This phase of climatic cooling probably coincided with a declining availability of food resources as the result of changes in the geographical range of prey animal species. This might well have necessitated a more mobile and reliable toolkit that is easy to maintain and repair (Taller and Conard in press). With Magdalenians, who recolonized the Swabian Jura after the Gravettian hunters following a hiatus of about 15 ka, the technology of composite tools involving backed lithics reaches its apex and backed pieces are often the dominant category among lithic tools.

In this context, understanding the variability in hafting and use of backed elements on both sides of the LGM is crucial for a better view of long-term technological change and the factors that can trigger it. The first step in this direction is the experimental replication of the archaeological artifacts and the testing of different hafting and tool use scenarios to gain insights into the mechanical properties of hand-held and hafted backed elements as well as the opportunities and limitations linked to such designs. This kind of work also provides the necessary reference material for the examination of archaeological artifacts from a functional point of view. The results presented here represent the initial testing of one hafted tool design documented in a more recent, arctic archaeological context as well as the preliminary trials in hand-held use of backed pieces. We plan to continue in this line of experimentation, and among our future aims is the fabrication of more complex artifacts relevant to the archaeological contexts we are examining. We also intend to incorporate hafting wear in the analytical procedure (see Rots 2010a) and aim at complementing our current actualistic experiments with more controlled ones to better understand use-wear formation on the local raw material varieties. All these aspects can be considered relevant for increasing the accuracy of archaeological interpretations.

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