Reverse engineering of sewing with needle-and-thread: an interpretation of complementary technology at Aghitu-3 Cave, Armenia

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Zusammenfassung

Reverse Engineering des Nähens mit Nadel-und-Faden: eine Interpretation komplementärer Technologie in der Aghitu-3-Höhle, Armenien

In diesem Beitrag dekonstruieren wir ein einzelnes Fundstück aus der Höhle Aghitu-3 im armenischen Hochland und ordnen es in einen breiteren Verhaltenskontext ein. Bei dem besagten Fund handelt es sich um eine Knochennadel mit Öhr aus dem archäologischen Horizont IIId, einer jungpaläolithischen, etwa 29 000 Jahre alten Schicht. Durch sog. Reverse Engineering *der zahlreichen Prozesse, die mit der Herstellung und Verwendung dieses Fundstücks verbunden sind, erhalten wir einen Einblick in die Interaktion des frühen modernen Menschen mit seiner Umwelt. Zu diesen Prozessen gehören die Herstellung von Stein- und Knochenwerkzeugen, die Bearbeitung von Häuten, die Verarbeitung von Fasern, das Zusammensetzen von Kleidungsstücken und deren Verzierung mit Muscheln.*

Die Menschen des Jungpaläolithikums verwendeten in einer sog. Community of Practice *ein Netzwerk aus breitem Wissen und Know-how, verschiedenen Praktiken, Rohmaterialien, Halbfertigprodukten und Werkzeugen. Mithilfe des Kognigramm-Ansatzes stellen wir fest, dass der Fund einer Nadel mit Öhr als ›Nadel-und-Faden‹ gelesen werden muss – als komplementäres Werkzeugset, dessen zwei getrennte und auswechselbare, aber voneinander abhängige Elemente miteinander interagieren, konzeptionell vergleichbar mit Pfeil-und-Bogen. Ein spezifisches Merkmal dieses Werkzeugsets ist die Übertragung seines Verbrauchsteils, des Fadens, durch den unterstützenden Teil, die Nadel, auf die zugeschnittenen Teile aus Leder oder Stoff. Dadurch entsteht ein zusammengesetztes Artefakt, ein Komposit mit neuen Eigenschaften, die über die der Grundelemente hinausgehen. Der hier angewandte deduktive Ansatz hilft, den verborgenen Makrokosmos hinter einem exemplarischen archäologischen Fund zu verstehen.*

Schlagwörter Jungpaläolithikum, Knochennadel mit Öhr, Knochenwerkzeuge, Muschelperlen, Kognigramm

Summary

In this paper, we deconstruct a single find from Aghitu-3 Cave in the Armenian Highlands and expand it within a broader behavioural context. The find in question is an eyed bone needle from archaeological horizon IIId, an Upper Palaeolithic layer dated to about 29 000 years ago. By reverse engineering the numerous processes associated with the manufacture and use of this find, we gain insight into how early modern humans interacted with their environment. Such processes include the production of stone and bone tools, hide working, processing fibres, assembling garments, and decorating with shells.

In a community of practice, Upper Palaeolithic humans applied a network of broad knowledge and know-how, diverse practices, raw materials, semi-finished products, and tools. Using the cognigram approach, we assert that the find of an eyed needle must be read as needle-and-thread, a complementary tool set whose two separate and exchangeable, yet interdependent elements interact with each other, conceptually comparable to a bow-and-arrow. A specific characteristic of this tool set is the transfer of its consumable part, the thread, through the enhancing part, the needle, to the tailored pieces of leather or fabric. This creates a composite artefact with new emerging qualities beyond those of the basic elements. The practice of deduction used here helps us understand the hidden macrocosm behind an exemplary archaeological find.

Keywords Upper Palaeolithic, eyed bone needles, bone tools, shell beads, cognigram

Introduction

Evidence for the manufacture and use of clothing in the Palaeolithic is rare. Its importance for the year-round survival of humans under Ice Age conditions from Central Europe to East Asia, and in particular for the expansion of humans beyond 50° of northern latitude, is undisputed. Here, our research group aims to contribute one facet to the study of Upper Palaeolithic sewing based on our work at an archaeological site named Aghitu-3 Cave, where we began

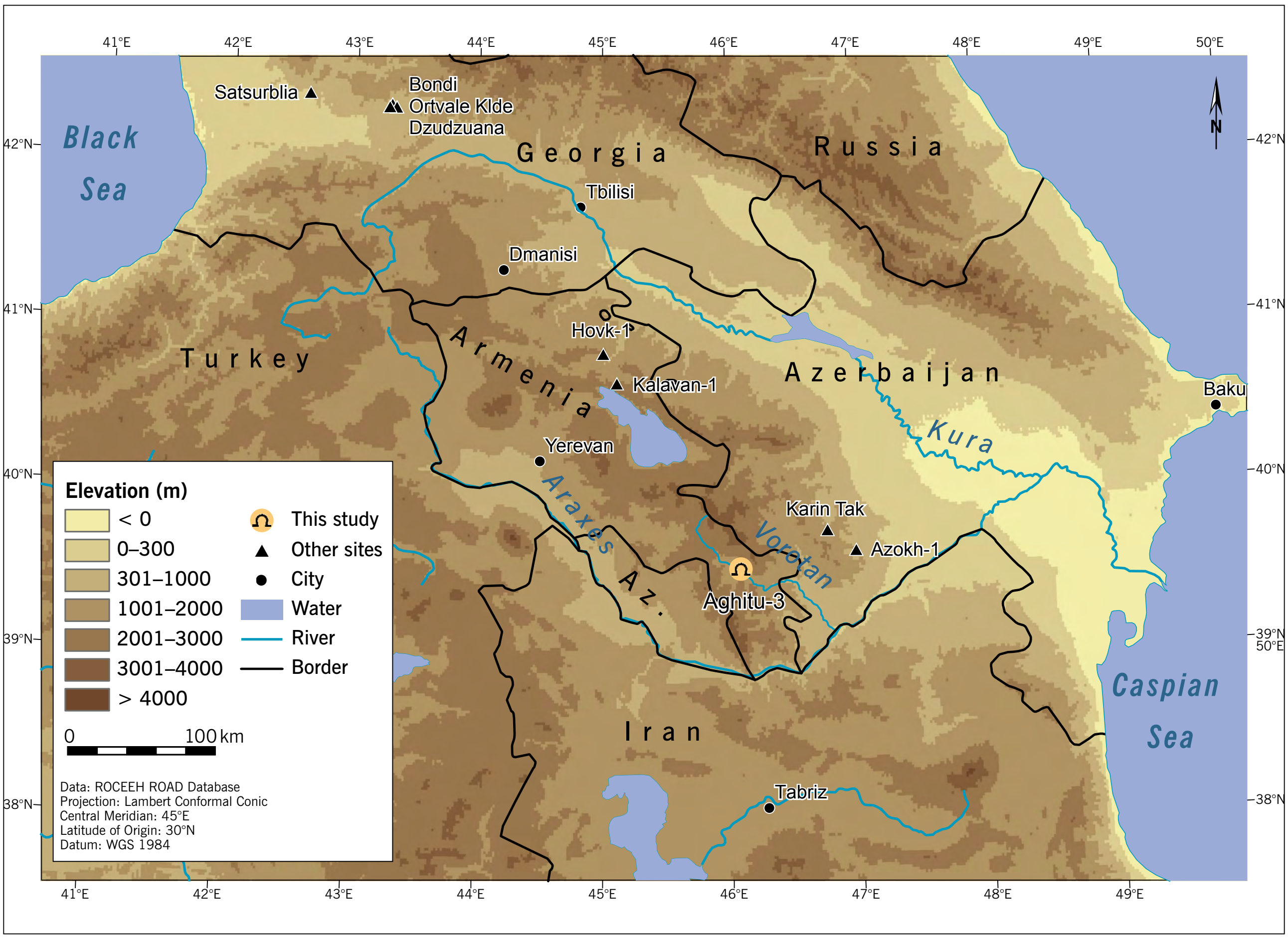


Fig. 1 Location of Aghitu-3 Cave, Syunik Uplands, in the Armenian Highlands showing its relationship to regional archaeological sites.

Abb. 1 *Lage der Aghitu-3-Höhle, Hochland von Syunik, im armenischen Bergland mit Darstellung ihrer Beziehung zu regionalen archäologischen Fundstellen.*

excavations in 2009. The site is located in the Syunik province in southern Armenia at an elevation of 1601 m and a latitude of N 39.5° (Fig. 1–2). The stratigraphic sequence of the site provides a remarkably detailed record of human habitation during the Upper Palaeolithic, covering the period from 40 000 to 24 000 years ago. One exceptional find is an eyed bone needle found in archaeological horizon (AH) IIId, which dates to about 29 000 years ago based on calibrated radiocarbon dates of charcoal and bone (Kandel et al. 2017).

We hope this article succeeds in illustrating how a simple needle can open a much larger web of understanding about Palaeolithic life. We use details about the site and augment them with information taken from a broader archaeological context to reconstruct the process of making clothing with a needle. Using the cognigram approach, we emphasise the function of needle-and-thread as a specific, complementary tool set. By doing so, we explore the world that the needle reveals, Upper Palaeolithic lifeways in general, clothing, and technological sophistication in particular. By reverse engineering the many processes involved in making and using the needle, we aim to establish a greater connection between the material remains discovered at this archaeological site and the everyday activities of Upper Palaeolithic people.

Bone tools for sewing

Archaeologists distinguish two groups of bone tools which they associate with sewing. On the one hand, awls are pointed tools without an eye for threading. They are generally made of animal limb bones, either naturally pointed ones or elongated shafts. The pointed distal ends were shaped and maintained during their use by whittling and grinding, whereas the proximal ends may not be modified at all. Use-wear of the tips of such tools indicates that already in late Neanderthal contexts, awls were heavily used to puncture soft tissues such as hides and leather (d'Errico et al. 2003). These pointed tools, potentially in combination with puncture boards (Doyon et al. 2023), are perfectly well suited for making different kinds of clothing on their own.

On the other hand, eyed needles (e.g. Gilligan 2019), as their name suggests, possess a perforation that allows the threading of different kinds of fibres. In the combined process of puncturing and pulling threads through the perforations, these tools can be used for different sewing purposes such as stitching layers together and attaching ornaments to clothing, but also for weaving, netting, and basketry, among other possibilities. Eyed needles are generally made from fragments of long bones that have been worked all over. Needles for sewing are significantly smaller and thinner than

Fig. 2 Aghitu-3 Cave in 2008 before excavation began. The opening of this basaltic cave is about 18 m wide, 11 m deep, and 6 m high.

Abb. 2 *Die Aghitu-3-Höhle im Jahr 2008 vor Beginn der Ausgrabungen. Die Basalthöhle ist etwa 18 m breit, 11 m tief und 6 m hoch.*

awls, and their use is different, enabling finer detailed work. Even though awls and eyed needles are both clearly associated with the production of clothing and accessories, experimental archaeologists readily agree that such tools are in no way prerequisites for making clothing (D. Olthoff, pers. comm.; Klek 2012; see IJsveld/Olthof in this volume).

Two synthetic studies over the past decade have advanced our understanding of when eyed needles first came into use and where they occurred. At the heart of these studies is the investigation of needles and their relationship to tailored clothing. F. D'Errico et al. (2018) brought together a list of global sites showing that the earliest eyed needles occurred in Asia about 45 000 years ago. These were associated with the Early Upper Palaeolithic of the Caucasus and Central Siberia. I. Gilligan et al. (2024) furthered this trend by expanding the list of sites with needles between c. 45 000 and 25 000 years ago, as the technology became established in Asia.

The archaeological evidence for eyed needles is surprisingly rare. Worldwide, fewer than 20 localities are currently known from the period between 45 000 and 25 000 years ago, and these are scattered widely across Asia. As we see in Fig. 3, eyed needles first appear at two locations in Central Asia between 45 000 and 35 000 years ago and expand across Asia in two steps from 35 000 to 25 000 years ago. The first step reaches Central and Eastern Asia, while the second spreads into Western Asia. Two additional sites, one in Slovenia and the other in Spain, suggest that eyed needles arrived in Europe after 30 000 years ago (Gilligan et al. 2024). Following this initial phase of development, eyed needles become more frequent in the archaeological record of Eurasia during the Last Glacial Maximum (LGM, c. 26 000 to 20 000 years ago). Only after the LGM at the end of the Palaeolithic (18 000–14 000 years ago) did they become a common feature of archaeological sites all over Eurasia (Stordeur-Yedid 1979; Lázničková-Galetová 2010; Zhang et al. 2016).

One of the oldest eyed bone needles stems from Denisova East Chamber in the Altai Mountains of Siberia (Russia). Even though it is broken at the tip and the eyelet, it measures 52.6 mm long, 2.0–2.5 mm wide, and 2.2–1.1 mm thick; the preserved part of the eyelet is 0.8 mm in diameter (Shunkov et al. 2020). Another outstanding assemblage of eyed needles comes from the Yana site in the far north of Siberia. The Yana needles show various shapes with a length spanning from less than 50 to more than 100 mm and apparently different cross-sections. The thickness of the proximal part ranges from 2.0–2.5 up to 7.9 mm, a span that defines the maximum hole size left in the fabric that was worked with these implements. The needles and fragments from Yana

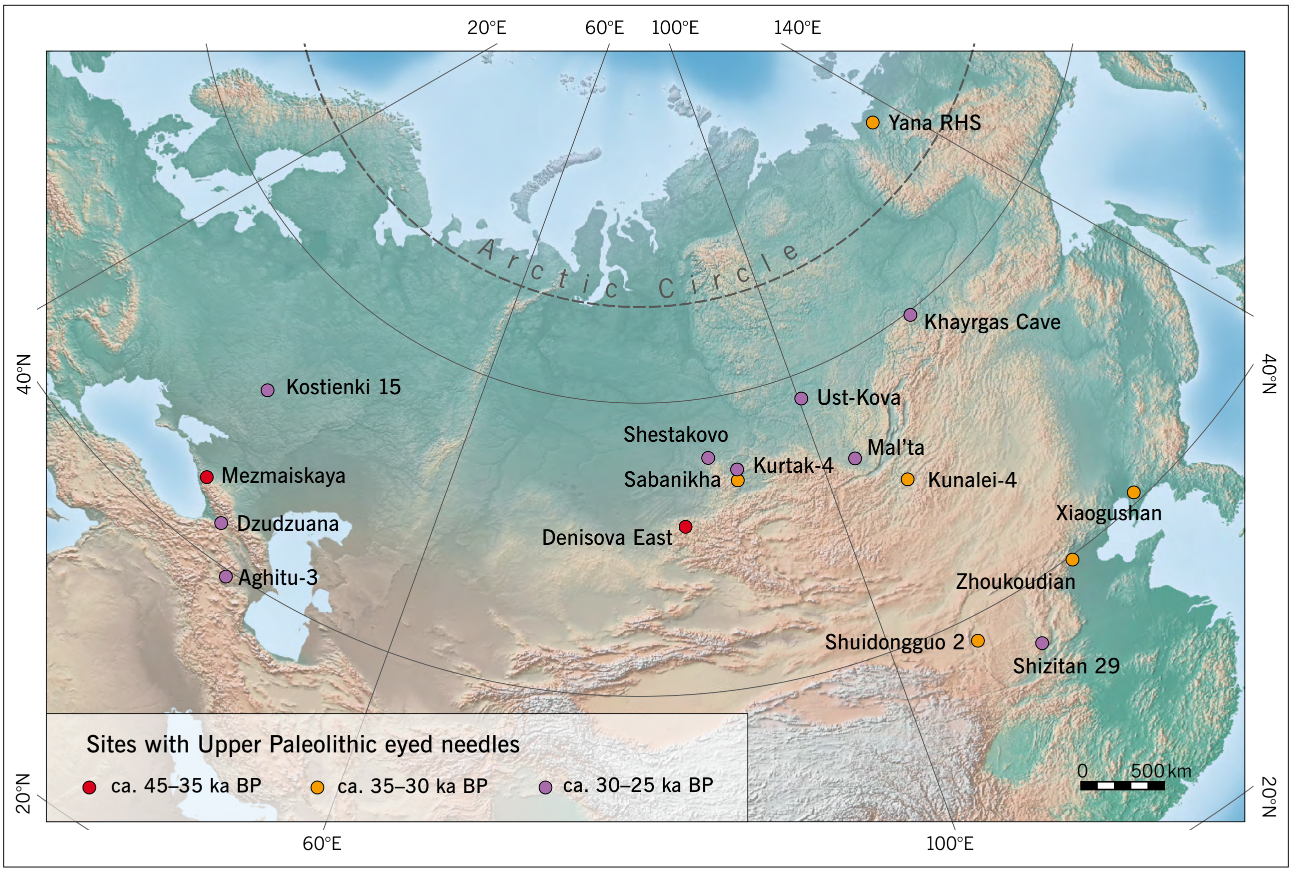


Fig. 3 Mapping of Upper Palaeolithic eyed bone needles in Asia showing the progression of their distribution over time.

***Abb. 3** Kartierung jungpaläolithischer Knochennadeln mit Öhr in Asien, die die chronologische Verbreitung zeigt.*

indicate that these tools were extensively used and maintained by reshaping the tips and drilling new eyes (Pitulko/Pavlova 2022).

With a length of 18.5 mm and a width of 2 mm, the eyed bone needle from Aghitu-3 is considerably smaller than those of the Denisova and Yana assemblages. Part of the needle's eyelet and point were missing, suggesting it was discarded in a broken state. Thus, the full length of the needle is not known. Similar to the sites mentioned above, its eye is less than 1 mm in diameter (Fig. 4). The find truly represents the proverbial needle in a haystack, found through meticulous sieving and sorting of each bucket of sediment during the excavation. Even though the needle is incomplete, we can learn much about past human behaviour from this exceptional artefact.

Since needles are quite small, it is seldom possible to identify the animal species to which the bone belonged. Relatively recent and innovative analytical methods such as ancient DNA and ZooMS (Zooarchaeology by Mass Spectrometry) make it possible to identify the species used to make needles (Pelton et al. 2024). Still, it is not customary to subject such small and rare objects to destructive forms of testing, so for now we cannot say from which animal the needle at Aghitu was fabricated. Nor could we carry out microscopic studies to better understand how the needle was made or used. However, based on macroscopic observations, we can say that the needle shows traces of whittling as well as polish, likely from manufacture and use.

The site of Aghitu-3 Cave

The cultural layer AH IIId, in which the needle was found, yielded over 3000 stone artefacts made of obsidian and chert. The approach to knapping focused on creating cores and knapping them from a single direction, so-called unidirectional bladelet cores (Fig. 5,1). Many of the blanks were then modified by retouching the edges to form differently shaped tools. Most of the tools at Aghitu consist of laterally retouched and backed bladelets (Fig. 5,4–9), suggesting that people focused on preparing hunting equipment. In addition, some of the tools were further modified into drills, which would have been helpful in perforating bone. Other tools include scrapers (Fig. 5,2) and burins (Fig. 5,3), as well as notches and denticulates (Kandel et al. 2017).

Using portable X-Ray Fluorescence (pXRF) to differentiate the obsidian sources, the team determined that about 8% of the obsidian present in AH III at Aghitu-3 travelled long distances, up to 250 km, to get there (Kandel et al. 2017; Frahm et al. 2019). Such studies show us that people were highly mobile, or at least had contact with other groups who ranged over equally broad territories. Most of the obsidian (~92%) was found within the nearby Vorotan River basin from sources up to 30–40 km away.

More than 1400 animal bones come from layer AH IIId, mainly of equids (horse) and caprines (sheep/goat) (Kandel et al. 2017; Bertacchi et al. 2021). The faunal remains are associated with the stone artefacts and tell us what animals the

Fig. 4 Eyed bone needle from Aghitu-3 Cave, layer AH IIId, measuring 1.85 cm in length and 0.2 cm in maximum width, broken at base and point.

Abb. 4 *Knochennadel mit Öhr aus der Aghitu-3-Höhle, Schicht AH IIId, 1,85 cm lang und 0,2 cm breit, an Basis und Spitze abgebrochen.*

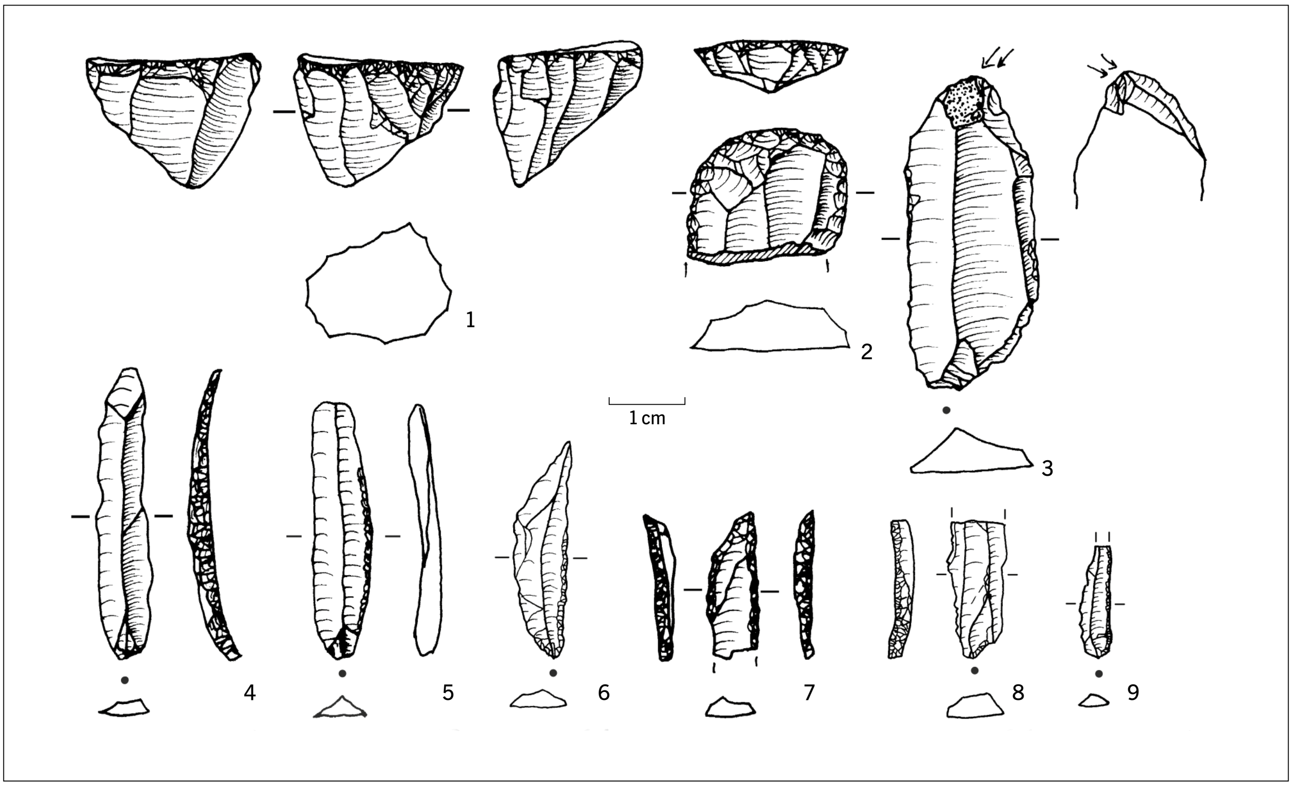


Fig. 5 Examples of stone artefacts made of obsidian and chert from Aghitu-3 Cave, layer AH III: 1 core; 2 scraper; 3 burin; 4–9 retouched bladelets.

Abb. 5 *Beispiele für Steinartefakte aus Obsidian und Silex aus der Aghitu-3-Höhle, Schicht AH III. 1 Kern; 2 Kratzer; 3 Stichel; 4–9 retuschierte Lamellen.*

Fig. 6 Complete pointed bone awl from Aghitu-3 Cave, layer AH IIId, measuring 12 cm in length and 1.1 cm in maximum width.

Abb. 6 *Vollständige spitze Knochenahle aus der Aghitu-3-Höhle, Schicht AH IIId, 12 cm lang und maximal 1,1 cm breit.*

inhabitants of Aghitu hunted and ate. The age of the animals and their state of tooth wear helps us to determine that the site was likely occupied during the warmer seasons, probably in spring and early summer. In addition to the eyed needle, further organic artefacts from AH IIId include a bone awl (Fig. 6) and a bone point (Fig. 7). We interpret several perforated shell beads (Fig. 8) made from the freshwater snail *Theodoxus pallasi* as ornaments, in some cases stained with ochre residues.

Evidence from microarchaeological studies indicates that AH III contains complex combustion features (Kandel et al. 2017). This supports prolonged and repeated occupations at the site. Additionally, a wide array of scientific analyses covering sedimentary ancient DNA (ter Schure et al. 2022), micromammals (Rey-Rodríguez et al. 2024), isotopes, charcoal, and pollen, among other categories, have contributed to synthetic studies about the regional climate and environment between 40 000 and 24 000 years ago (Kandel et al. 2017).

Reverse engineering of sewing with needle-and-thread

By reconstructing the activities associated with and examining the ideas that stand behind the tiny bone needle, we start to understand how a superficially simple artefact can encompass an entire world of entangled humans, their knowledge and practices, raw materials, semi-finished products, and tools (cf. Hodder 2011). In addition to the sphere of

Fig. 7 Bone point from Aghitu-3 Cave, layer AH IIId, measuring 10.9 cm in length and 0.5 cm in width, with broken base.

Abb. 7 *Knochenspitze aus der Aghitu-3-Höhle, Schicht AH IIId, 10,9 cm lang und 0,5 cm breit, mit abgebrochener Basis.*

the eyed needle and the other bone tools, its context comprises the spheres of different lithic tools, hides/leather (or fabric), fibres/thread, the assemblage of the garment, and its decoration (for summary see Tab. 1).

Lithic tools

Different lithic tools for cutting, whittling, drilling, and grinding are prerequisites for manufacturing highly modified bone tools such as awls, lissoirs, and especially needles. Raw materials with adequate qualities for modification and use must first be acquired. Tools to knap the desired tool forms, such as burins, scrapers, notches, denticulates, or drills, comprise unmodified hammerstones and bone retouchers. All types of cutting stone tools are present among the finds of AH IIId and are made of obsidian and chert.

Bone tools

To make a needle as well as other bone tools, a person first had to collect an animal bone from a fresh carcass – perhaps

Fig. 8 Examples of perforated shell beads of the freshwater gastropod, *Theodoxus pallasi*, from Aghitu-3 Cave, layer AH III.

Abb. 8 *Beispiele für durchlochte Muschelperlen der Süßwasserschnecke* Theodoxus pallasi *aus der Aghitu-3-Höhle, Schicht AH III.*

hunted, perhaps scavenged. Flat ribs were taken as blanks for producing lissoirs (Soressi et al. 2013), and fragments of diverse bones could be used with minimal modification as retouchers. For awls and needles, people usually selected long limb bones; tibias and metapodials were favoured to produce needles because these bones are naturally straight and solid. Sharp stone tools like burins (Fig. 5,3) were needed to extract the blank of the needle from the long bone. With these, parallel grooves could be cut into the bone to prepare the basic elongated pre-form of the needle (Hoffman 2002; Lázničková-Galetová 2010; Fig. 9). Freed from the bone, the blank was probably carved into its desired shape using flakes or retouched pieces such as scrapers, notched artefacts, or denticulates. After thinning the butt end, a pointed stone drill was needed to pierce the bone from both sides to create the eyelet. The needle was then smoothed, perhaps on a grinding stone or another flat hard surface using sand or grit as an abrasive, until the desired roundness and smoothness were achieved. Finally, the tip was sharpened through abrasion.

Hide/leather

Needles are tools used to join pieces of textiles or treated animal skins. As one possibility in the macrocosm of a needle with an eyelet, we concentrate here on the processing of hides and leather as an example. From Palaeolithic contexts, we know little about the techniques and materials used to transform fresh animal skin into durable and wearable hides or leather. Ethnographic and experimental work provides insights into potential fabrication processes (Hurcombe 2014; Klokkernes 2022). Raw skin or a pelt must be acquired by hunting; its qualities differ significantly depending on animal species, the season of the hunt, the sex and age of the prey, and the part of the body. The best quality can be gained in late summer to autumn when holes made by insects such as eclosing botflys are healed and the fresh winter pelt is grown (Osborn 2014); the occupation of Aghitu-3 in spring and summer makes the processing of hides at another location plausible.

	Activity	Raw material	Tools used	Product	Tool behaviour (Haidle et al. 2015)	Reference
Stone tools	acquisition	lithic with flaking qualities	–	–	–	
	acquisition	lithic with grinding qualities	–	–	–	
	acquisition	pebble as hammer stone	–	–	–	
	knapping	lithic with flaking qualities	hammer stone, bone retoucher	cutting stone tools such as burins, scrapers, notches, denticulates, drills	simple	
Bone tools	acquisition	bone of different shape for retoucher, lissoir, punch board, awl and needle	–	–	–	
	acquisition	polishing material	–	–	–	
	whittling and grinding, polishing	long bone	cutting stone tool like scraper and grinding stone, polishing material	awl	simple	Pitulko/Pavlova 2022
	incising, thinning and reshaping by whittling and grinding, polishing, drilling	long bone	different cutting stone tools (like burin, scraper, notch, denticulate), drill, grinding stone, polishing material	eyed needle	simple	Pitulko/Pavlova 2022
	thinning and reshaping by grinding	rib	grinding stone	deflesher/lissoir with smooth ogival tip		Soressi et al. 2013
Additional	unspecified	unspecified	unspecified	equipment like hunting weapons, containers, frames, sewing patterns	simple, potentially **composite** or **complementary**	Haidle 2009; Lombard/Haidle 2012
Hides/leather	acquisition/hunt	prey	hunting weapons, cutting stone tool	raw skin	simple, potentially **composite** or **complementary**	Haidle 2009; Lombard/Haidle 2012
	drying (or smoking), cleaning: removal of remaining meat, fat and connecting tissues, optional removal of hair	raw skin	possibly fire, cutting stone tool, stone scraper or bone deflesher/lissoir (smoother), hard ground or frame	stabilised raw skin	simple	Hurcombe 2014, 81; Klokkernes 2022
	acquisition	tanning substance: brain, urine, vegetable or bark, smoke, oil, ochre	possibly container, cutting or pounding stone tool, water, fire, smoking fuel	–	simple	Hurcombe 2014, 80–87; Klokkernes 2022
	tanning, rinsing, softening/oiling	tanning substance, stabilised raw skin	possibly container, water, lissoir (smoother)	tanned and soft hides	**compound**	Hurcombe 2014, 80–87; Klokkernes 2022

	Activity	Raw material	Tools used	Product	Tool behaviour (Haidle et al. 2015)	Reference
Fibres/thread	acquisition	fibre plants (flax, nettle, bast of trees)	possibly cutting stone tool, bark peeler	–	none or simple	
	extracting fibres, cleaning, aligning	fibre plants (flax, nettle)	possibly pounding tool such as wooden mallet, water/dew or scraper	fibres	simple	Hurcombe 2014, 56–57
	acquisition	dye plant	possibly cutting stone tool	–	none or simple	
	preparation	dye plant	possibly container, water, pounding tool	dye	simple	
	dying	dye fibres	possibly container	dyed fibres	**compound**	Hurcombe 2014, 66–67 note 28
	spinning, plying, twisting	dyed plant fibres	–	thread	–	Jørgensen et al. 2023
Assembling garment	tailoring according to patterns and wearer	tanned hides	cutting stone tool	tailored pieces of tanned hide	simple	
	punching	tailored pieces of tanned hide	awl and punch board	tailored pieces of tanned hide with holes for seam	simple	Doyon et al. 2023
	sewing	tailored pieces of tanned hide (with holes?)	eyed needle-and-thread	garment	**composite, complementary**	Osborn 2014; Siebrecht et al. 2023; Nomokonova et al. 2024
Decoration	acquisition	(shells of) freshwater snails	–	–	–	
	cleaning from animal tissue and dirt (optional)	(shells of) freshwater snails	potentially twig as probe; fire; water	clean shells	simple	
	perforation (optional)	shells	stone tool for drilling or grinding	perforated shells	simple	
	application according to patterns	perforated shells, garment	eyed needle-and-thread	garment with ornaments	**composite, complementary**	

Tab. 1 The context of the eyed bone needle comprises various spheres including stone and bone tools, hides/leather (or fabric), fibres/thread, the assemblage of the garment, and its decoration. This table summarises the respective activities, raw materials, tools used, products, and tool behaviour related to making an eyed bone needle.

Tab. 1 *Der Kontext der Knochennadel mit Öhr umfasst verschiedene Bereiche, darunter Stein- und Knochenwerkzeuge, Häute/Leder (oder Stoff), Fasern/Faden, die Zusammenstellung des Kleidungsstücks und seine Verzierung. Die Tabelle fasst die jeweiligen Tätigkeiten, Rohstoffe, verwendeten Werkzeuge, Produkte und das Werkzeugverhalten im Zusammenhang mit der Herstellung einer Knochennadel mit Öhr zusammen.*

In the first step, the raw skin – laid on the bare ground or stretched in a frame – must be cleaned of meat, fat, and connecting tissues with the help of stone or bone tools and then dried or smoked to prevent rotting. For the tanning process, two additional components are needed: 1) substances such as brain, urine, extracts from vegetables or bark, smoke, oil, or ochre; and 2) a variety of implements including containers, cutting and pounding tools, and fire plus smoking fuel as material (Hurcombe 2014; Klokkernes 2022). During the tanning process, the raw skins are infused by the tanning substance: both form an inseparable compound material with new qualities, which can then be further processed into products such as garments, bags, and tents.

Fibres/thread

To join pieces of textiles or treated animal skins, materials of animal origin such as tendons, sinew, or leather strips can be used; alternatively, various plant fibres can serve as

Fig. 9 Example of an eyed bone needle made experimentally from the tibia of a juvenile pig.

***Abb. 9** Beispiel einer experimentell hergestellten Knochennadel mit Öhr aus dem Schienbein eines jungen Schweins.*

thread in the sewing process. In contrast to the lack of data about hide-working, some (sparse) evidence in Palaeolithic contexts sheds light on the processing of plant fibres.

From a Neanderthal context at Abri Maras, Dép. Ardèche (France), dating between 52 000 and 41 000 years ago, we recognise potential remains of z-twisted, three-ply thread made from the fibrous layer of the inner bark (bast), likely of conifers (Hardy et al. 2020). An ivory baton with grooved holes from the southern German site of Hohle Fels, Alb-Donau-Kreis District, implies that people were making rope about 35 000 years ago (Conard/Malina 2016; Conard/Rots 2024). From the Georgian site of Dzudzuana in the southern Caucasus, we see evidence for spun, twisted, and dyed flax fibres about 29 000 years ago (Kvavadze et al. 2009; Bar-Yosef et al. 2011), contemporaneous with the occupation of AH IIId at Aghitu-3. Sedimentary ancient DNA studies at Aghitu-3 revealed evidence of plants that provide dyes and fibres, strengthening previous findings about Upper Palaeolithic plant use in this region (ter Schure et al. 2022). From Pavlovian contexts in Moravia, the use of plant fibres dating between 32 000 and 29 000 years ago has been reported (Adovasio et al. 2001). At Dolní Věštonice I and II, and at the nearby site of Pavlov I, both South Moravia region (Czech Republic), up to 27 000-year-old imprints of interlaced twisted strings have been preserved on fired clay fragments (Adovasio et al. 1996). The clay imprints show different types of twining. The authors identified cordage with knots, plaited basketry and woven textiles, »[…] and the fineness of some of the weaves suggest [sic] […]« that they were »fully flexible cloth fabrics« (Adovasio et al. 2001, 58). Although some authors doubt this (Valoch 2007; cf. Soffer/Adovasio 2014), similar finds from the Russian Far East, dated to the boundary between the Pleistocene and Holocene, confirm the original interpretation (Hyland et al. 2002). Evidence of working with (plant) fibres stems from Ohalo II in Israel about 19 000 years ago (Nadel et al. 1994) and several sites in Europe and Russia (Soffer et al. 2000a). O. Soffer et al. (2000b) provide an overview of the depiction of dress elements of Gravettian female figurines. These examples all suggest that people at the time of the Aghitu needle had the necessary know-how to make rope and thread.

Potential materials for sewing thread include plant components, such as blades of grass and other natural fibres, and animal products, such as thinly cut strips of hide and prepared sinews. Following the contemporaneous evidence from the geographically close Dzudzuana Cave, we reconstruct thread made of dyed plant fibres. Both fibres and dye-producing plants are the desired materials and must be acquired and processed according to their characteristics and with the appropriate equipment (see, for example, Hurcombe 2014). The fibres need to be extracted, cleaned and aligned; liquids or pastes are made from the dye-producing plants. During the dying process, the fibres are infused by the dying substance: both form an inseparable compound material, which can then be spun, plied, and twisted in a multitude of ways (cf. Jørgensen et al. 2023).

Assembling the garment

To achieve the desired result, the pieces of tanned hide must be tailored into a garment according to patterns and the dimensions of the anticipated wearer (Osborn 2014). Different techniques may then be used to join the pieces together. To pierce two or more thick layers of tanned hide or leather, it can be advantageous to use an awl – potentially in combination with a punching board (Doyon et al. 2023) – as an awl is much stronger and more resilient than a fragile needle. Then, the parts can be seamed together with needle-and-thread (variant 1). If the pieces of hide are pierced only with an awl, without additionally using needle-and-thread (variant 2), smaller holes may result, as they are not widened by the proximal end of the needle, which is broader due to the eyelet. In this case, however, experimental archaeologists suggest that the ends of the thread must be stiff, as when using unsoftened sinew, for example (R. Walter, pers. comm.). In a third variant, an eyed needle is used with thin and flexible thread without the necessity of piercing with an awl, as reconstructed in the cognigram shown in Fig. 10a. The technique of sewing with eyed needle-and-thread can vary significantly depending on purpose or tradition (Siebrecht et al. 2023; Nomokonova et al. 2024).

Needle-and-thread represents a complementary set of separate yet interdependent tools (comparable to bow-and-arrow, see Lombard/Haidle 2012), with the needle acting as an enhancing element, while the thread serves as a consumable element. Both elements are exchangeable and can vary in their properties and capacities. The application of the consumable element, the thread, is actively augmented by the enhancing element, the needle, which is handled and controlled by the user. The diameter of the eyelet of the needle – and thus the width of its proximal end and the width of the holes produced – corresponds to the thread size and quality; needle-and-thread have to be chosen together to suit the purpose. A specific characteristic of the needle-and-thread complementary set is the transfer of the consumable part, the thread, to the tailored pieces, thus creating a composite artefact with new emerging qualities beyond those of its three basic elements.

Decoration

Another composite, which can be realised with the help of the needle-and-thread tool set, is the decoration of the garment with appliqués. At Aghitu-3, people used shells of freshwater snails, which they likely cleaned of animal tissue and adhering dirt, and perforated using punches or drills. In a process of complementary tool use similar to the assembling of garments, several components – clothing, shells, thread, plus a meaningful pattern – could be combined to create a composite with new emerging qualities beyond those of its basic elements (Fig. 10b).

Why would a needle be advantageous?

Sewing experiments show that neither eyed bone needles nor awls are required to manufacture even complex clothing (D. Olthof, pers. comm.; Klek 2012; see IJsveld/Olthof in this volume). The experimental archaeologist R. Walter (pers. comm.) reports that a sinew thread with a dry, stiff end can easily be pushed through holes prefabricated in hides with an awl. However, needles may be advantageous in using different sewing materials or to create specific qualities along the seams. Even if a tailored piece is perforated with an awl, flexible and thin plant-based thread, for instance, is difficult to insert. Here, the advantage of using an eyed needle lies in its ability to draw the thread more easily through the holes. If eyed needles are not used, the thread must be pushed through the holes using the awl[1]. Thus, eyed needles can help to draw thin and flexible thread through prefabricated holes, to avoid an additional piercing step in thin hides, or to make stitches that do not perforate all of the layers of the pieces to be joined. Inuit seamstresses do not puncture the layers completely but push »the needle within the internal layers of the hide being sewn« (Siebrecht et al. 2023, 84). By using only eyed needles, they avoid holes in the outer layer of the garment, thus keeping the seams watertight and windproof.

The climate of the Late Pleistocene (130 000–12 000 years ago) was marked by large fluctuations in temperature and precipitation, with continental and alpine glaciers repeatedly advancing and retreating. Life without clothing would be difficult to imagine in large parts of continental Asia, especially during peak glacial intervals. In general, this also holds true at northern latitudes, at high elevations, and during the winter. Certainly, some kind of garment was required for protection against the environment[2].

Simple types of open clothing like a cape require an animal skin – which, however, has to be treated in an elaborate process to make it durable and comfortable (see above) – and the means to pierce it, for example, by using a large, robust bone awl. Yet simple clothing does not insulate its wearer as well as tailored and multi-layered clothing. Although making such garments does not imperatively require delicate tools such as eyed needles, these would have enabled the use of advanced techniques to create seams as well as affix ornaments to clothing, as the shell beads from Aghitu-3 suggest (Fig. 8). Clearly, advanced sewing work was of critical importance for human expansion above 50° of latitude, and survival in the Arctic or under Eurasian glacial conditions, just as it was highly valued in historical Siberia for the manufacture of dwellings, bed sets, storage bags, clothing, and footwear (Osborn 2014; Nomokonova et al. 2024).

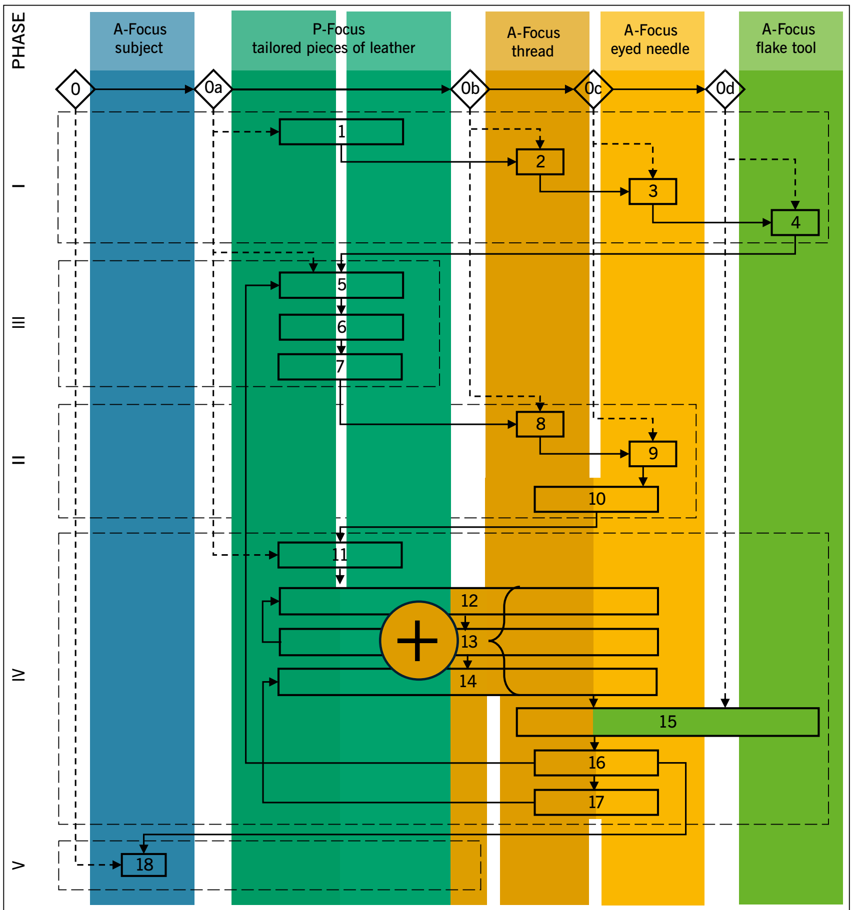
Discussion and conclusion

Gilligan's excellent research[3] explores the development of clothing. He unfolds various facets, such as the genetic divergence of human body lice and head lice as an indicator of clothing as separate habitat, the production of simple (draped) versus complex (layered and tailored) clothing, and aspects of thermodynamic regulation in cold climates.

1 In German, the word *pfriemeln* relates to *Pfriem* = awl, which implies an uncomfortable process.

2 Hosfield 2016; Osborn 2014; Gilligan 2007; Gilligan 2010; Gilligan 2017; Gilligan 2019; Gilligan et al. 2024.

3 Gilligan 2007; Gilligan 2010; Gilligan 2017; Gilligan 2019; Gilligan et al. 2024.



Assemblage of garment with eyed needle-and-thread
0. Perception of basic need: clothing
0a. Perception of sub-problem 1: tailored pieces of leather needed
0b. Perception of sub-problem 2: thread needed
0c. Perception of sub-problem 3: eyed needle needed
0d. Perception of sub-problem 4: flake/cutting tool needed

Phase I: Providing necessary items for sewing
1. Providing tailored pieces of leather
2. Providing thread
3. Providing eyed needle(s)
4. Providing flake/cutting tool

Phase II: Preparation of tailored pieces for sewing
5. Picking up two tailored pieces that are to be joined together
6. Correctly orienting the sides and aligning the edges of the pieces
7. Determining edge section to be be joined

Phase III: Preparation of needle-and-thread
8. Selecting appropriate thread
9. Picking up the eyed needle
10. Threading the thread into the eye of the needle

Phase IV: Joining the tailored pieces by sewing them together
11. Picking up the correctly aligned pieces at the edge to be joined
12. Inserting the needle into the leather at a sufficient distance from the edge and to the appropriate depth (depending on the desired seam and stitch pattern)
13. Drawing the thread through and tighten

Repeat step 12 and 13 several times until seam of this edge section is closed

14. Sewing the thread at the end of the seam
15. Cutting off loose thread end
16. Removing thread remains from eye of the needle
17. Threading the second loose thread end into the eye of the needle

Repeat step 14–16 one time for second loose thread end
Repeat Phase II–IV until all seams are closed

Phase V: Satisfaction of need
18. Possessing clothing

a

Fig. 10a–b Cognigrams of (a) sewing a garment and (b) assembling a garment and shell ornaments with the complementary tool set of eyed needle-and-thread, showing the different attention foci (A = active: subject and tools, P = passive: objects), actions, and effects of tools on other foci. In the sewing process, the eyed needle and thread function as a complementary tool set (depicted as { in the graphic), joining together the tailored pieces resp. the garment and shell ornaments with the thread (depicted as + in the graphic) to form a new composite entity with new qualities[4].

Abb. 10a–b *Kognigramme (a) des Nähens eines Kleidungsstücks und (b) der Zusammenfügung eines Kleidungsstücks und von Muschelornamenten mit dem komplementären Werkzeugset Nadel-und-Faden, das die verschiedenen Fokussierungen (A = aktiv: Subjekt und Werkzeuge, P = passiv: Objekte), Handlungen und Auswirkungen von Werkzeugen auf andere Schwerpunkte zeigt. Beim Nähvorgang fungieren die Nadel mit Öhr und der Faden als komplementäres Werkzeugset (in der Grafik als { dargestellt), das die zugeschnittenen Teile bzw. die Kleidungs- und Muschelornamente mit dem Faden zu einer neuen zusammengesetzten Einheit mit neuen Eigenschaften verbindet (in der Grafik als + dargestellt)*[5].

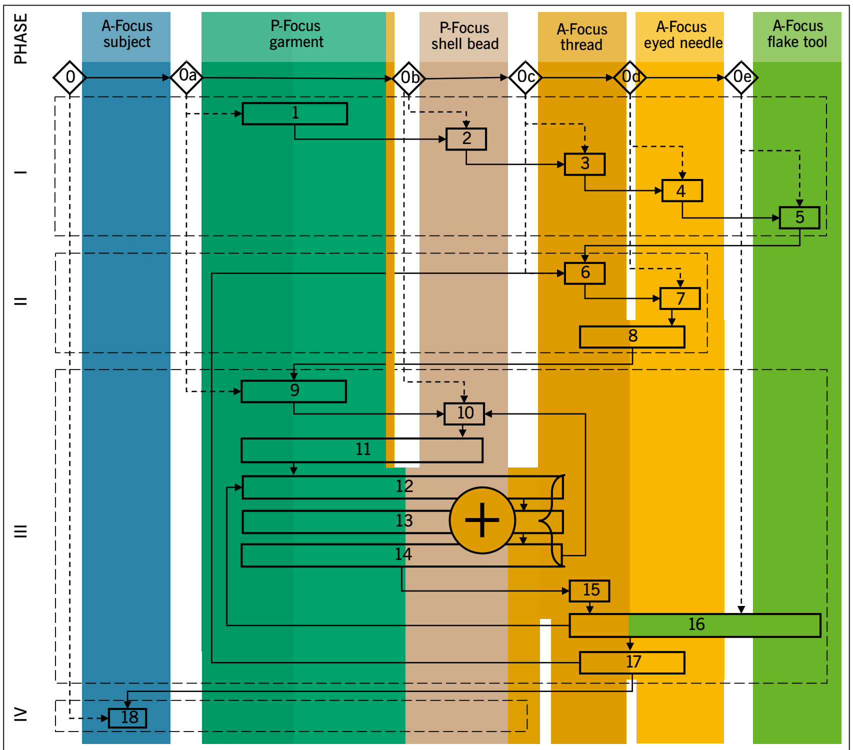
His comprehensive work on the subject also examines the toolkits required to fabricate clothing, especially stone and bone artefacts, while delving into the social and psychological aspects of clothing as well.

The case study of the eyed bone needle from Aghitu-3 highlights a single archaeological find, which must be read in its conception as well as its function as a complementary set of needle-and-thread, comparable to that of a bow-and-arrow set (cf. Lombard/Haidle 2012). Within the broader archaeological context, which includes stone tools, a bone awl, evidence of the use of plant fibre and dye, and possible decoration with shells, the needle additionally allows us to reconstruct a vast network of performances. These are associated with numerous raw materials, tools, products, and activities well beyond the narrow purview of sewing. Each of these elements was backed by knowledge of qualities and locations, seasonal or specific, and other limitations and legitimations; these include know-how of techniques and procedures and are based on acquired skills.

The basis for the development and maintenance of such an entangled corpus of performances must have been a community of practice (CoP) which incorporated several genera-

4 This simplified cognigram is not based on a specific example but represents foci and actions that are generally seen as part of the process; for details about cognigrams see Haidle 2023.

5 Dieses vereinfachte Kognigramm basiert nicht auf einem bestimmten Beispiel, sondern stellt Aufmerksamkeitsfoki und Aktionen dar, die allgemein als Teil des Prozesses angesehen werden; weitere Informationen zu Kognigrammen s. Haidle 2023.



Assemblage of garment and ornaments with eyed needle-and-thread

0. Perception of basic need: clothing with shell ornaments needed
0a. Perception of sub-problem 1: garment needed
0b. Perception of sub-problem 2: shells with holes needed
0c. Perception of sub-problem 3: thread needed
0d. Perception of sub-problem 4: eyed needle needed
0e. Perception of sub-problem 5: flake/cutting tool needed

Phase I: Providing necessary items for sewing
1. Providing garment
2. Providing shells with holes
3. Providing thread
4. Providing eyed needle(s)
5. Providing flake/cutting tool

Phase II: Preparation of needle-and-thread
6. Selecting appropriate thread
7. Picking up the eyed needle
8. Threading the thread into the eye of the needle

Phase III: Attaching shells to garment by sewing them together
9. Picking up the garment
10. Picking up a shell
11. Placing the shell at a position to be decorated
12. Inserting the needle into the leather to the appropriate depth
13. Drawing the thread through (leaving a long enough end for final knotting) and tightening
14. Inserting the needle in the hole of the shell, drawing the thread through

Repeat step 10 and 14 several times until the shell is fixed

15. Fixing the ends of the thread with a knot
16. Cutting off loose thread ends

Optional: Repeat step 12 to 16 for more shells. If thread is too short, go on with step 17 and then repeat from Phase II on.

17. Removing thread remains from eye of the needle

Phase IV: satisfaction of need
18. Possessing clothing with shell ornaments

b

tions and expanded across the boundaries of the daily core group. Although the central process of sewing and manufacturing tools for this activity is generally associated with women (Osborn 2014; Siebrecht et al. 2023; Nomokonova et al. 2024), we do not know who was responsible in the Eurasian Upper Palaeolithic (cf. Owen 2005). Regarding the broader context, it is likely that both sexes were involved in the manufacture of clothing.

Similar to recent examples of situated learning documented by J. Lave and E. Wenger (1991), the CoP likely encompassed all ages, from very young children to older people. According to their affiliation with age and sex categories, as well as individual capacities, the CoP members were involved in the performances with different motivations, targets, contributions, and legitimations. Corresponding to their distinct possibilities and positions within the group, the CoP members exchanged material, conceptual, and social resources such as assistance, work, care, knowledge, know-how, skills, role models, equipment, and orchestration. Through continuous individual development and social transmission, the network of performances could be maintained and adjusted to meet new environmental or cultural requirements.

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Source of figures

1 C. Sommer, ROCEEH, using data from ROAD (Kandel et al. 2023)
2 A. Kandel, ROCEEH
3 C. Sommer, ROCEEH, using data from Gilligan et al. 2024
4 D. Arakelyan, NAS
5 E. Ghasidian, University of Tübingen
6–8 D. Arakelyan, NAS
9 Experiment: M. Khodabakhshi Parizi; photo: H. Jensen, University of Tübingen
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