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Flint awls at the Mesolithic site of Star Carr: Understanding tool use through integrated methods

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ABSTRACT

The form and macroscopic wear of Mesolithic awls has been used to infer function, which has become an aspect of established typologies. However, verification of form/function relationships are needed to ensure typologies are robust. This paper presents the results of GIS and microwear analysis of 54 flint awls excavated from the Early Mesolithic site of Star Carr, UK, in conjunction with results from experimental research on awl use. Results expand on previous findings that awls were used for a range of activities at Star Carr, reflected in the different worked contact materials identified; including mineral, wood, bone, and hide. The experimental programme provided important insights into macroscopic tip modification of awls working with different contact materials for different lengths of time. Rates of tip snapping were found to be high in the Star Carr sample. GIS plots of awl location integrated alongside the microwear results show that the majority of awls were recovered from the west of the site, with clusters composed of different contact materials. The proximity of hide and shale working may suggest the production of clothing with appliqué beads. The combination of microwear, experimental archaeology, and GIS is applicable to other Mesolithic sites and holds potential to expand our knowledge of the spatial structuring of tool-using behaviours. Moreover, combined use of these methods has enabled greater understanding of awl typologies: providing a means to independently assess the relationship between tool morphology and use.

1. Introduction

Mesolithic flint awls - defined here as a diverse category of tools united by having partially or fully bilaterally retouched edges that converge to a point, making the tool well suited to piercing and/or drilling tasks - have been found in variable densities at sites across Britain in England (Conneller et al., 2018b; Jacobi, 1978; Berridge and Roberts, 1986; Dumont, 1983, 1988, 1989; Johnson and David, 1982; Radley and Mellars, 1964; Smith and Harris, 1982; Waddington and Pedersen, 2007; Wymer, 1962), Northern Ireland (Dumont, 1988; Woodman, 2015), Scotland (Morrison, 1982; Pirie et al., 2006; Wickham-Jones et al., 2017), and Wales (Jacobi, 1980; David, 1989; David, 2007; David and Walker, 2004; Lillie, 2015; Nash, 2012). They form a relatively minor, though persistent, component of formal tool assemblages across Britain and the continent. Few sites in Britain have large quantities of this tool, and most are early Mesolithic in date. Of sites with small lithic assemblages (<5000 pieces) only Broxbourne 102 has more than 10 awls; of larger sites (>5000 pieces) only Star Carr (184), The Nab Head (44), Kinloch (56) and Oakhanger VII (178) have more than 20 awls (Conneller, 2021). Of these sites, The Nab Head and Star Carr have notable evidence of bead production. Awls are also recovered from continental European Mesolithic sites, though in lower quantities, possibly due to a greater prevalence of using bone awls (Svoboda, 1983; Marquebielle, 2011; Bergsvik and David, 2015; Price et al., 2011; Alcade and Saña, 2017; Terberger et al., 2015). The tools making up the category of flint awls have attracted debate regarding use and typological organisation. A variety of terms are used across the European Mesolithic to describe tools within this category, including: awl, piercer, borer, zinken, bec, perforator and mèche de foret (Ballin, 2021). Though some of these types (zinken, mèche de foret) have precise

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Fig. 1. Location of Star Carr.

typological definitions and others (such as the distinction between awls and borers) are generally followed, use of some of the terms can vary between different researchers.

The category of Mesolithic flint awls is a useful microcosm in which to explore some of the challenges affecting attempts to organise stone artefacts more generally. Like other lithic tool types, historically in the awl category it was common that terms used to define form were simultaneously used to infer function. For example, piercers and awls were suggested to reflect a piercing action, while borers and drill bits were suggested to be used in a drilling action. Similarly, within Mesolithic research, size has sometimes been used to define categories, and the likely contact material; for example, smaller awls have been linked to drilling tasks and larger awls to piercing tasks (Berridge and Roberts, 1986, 18; Dumont, 1986; Jacobi, 1976), while some have argued that larger awls were used for drilling bone and smaller awls for drilling stone (Nash, 2011). Microwear results challenge this, with no clear correlations in tool size based on material reported. Instead, flint awl/drill contact materials reported via microwear have been found to be diverse, including hide, hide and mineral, wood, plant, bone and stone (Conneller et al., 2018b; Dumont, 1988; Schmitt, 1998; Schmitt et al., 2009; Semenov, 1964). Rarely, however, have the differences in contact materials been explored spatially to better understand connected or divergent activities using awls, likely because the method is time consuming to carry out and relies on good levels of preservation, resulting in small sample sizes.

This paper presents results of microwear and spatial analysis of 54 flint awls from the Early Mesolithic site of Star Carr (UK) excavated between 2004 and 2015. The sample was examined using microwear analysis, supported by a dedicated experimental archaeological awl reference collection. The microwear results were then spatially plotted using GIS (Geographic Information System) software. The results suggest that awls were used on a variety of contact materials at Star Carr, with some limited spatial patterning in the use of particular materials (bone, hide and mineral). The combination of using microwear to assess use, combined with high resolution spatial analysis, provides important insights that contribute to ongoing debates surrounding awl function and typological categorisation.

2. Site background

2.1. Introduction to the site

Star Carr (Fig. 1) is an Early Mesolithic site located to the south-western shore of palaeolake Flixton, North Yorkshire (UK), dating to between c. 9300–8500 cal BC. The site was occupied over a period of 800 years and includes 41,820 pieces of knapped flint (Conneller et al., 2018b), found both within and around post-built structures and activity areas on the dryland (Taylor et al., 2018a), and in wetland areas that included large timber platforms (Bamforth et al., 2018). Excellent organic preservation has allowed for the recovery of a diverse faunal

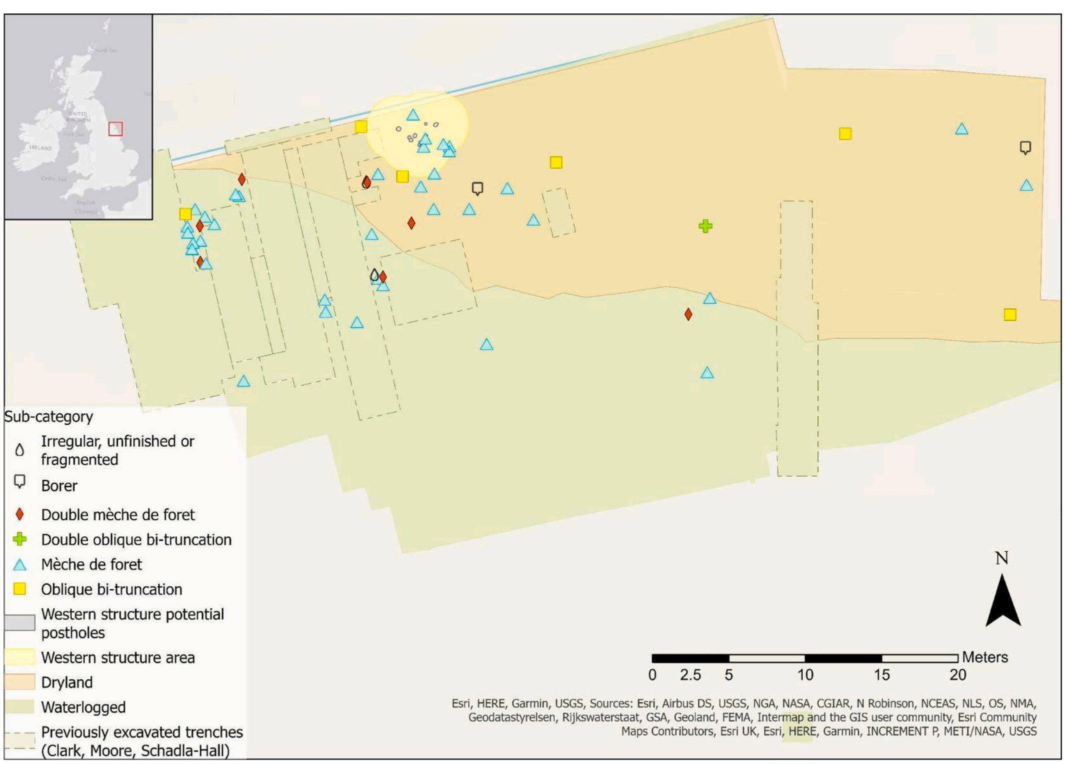

Fig. 2. Map to show Clark's area, western structure area and location of the analysed awls (with inset to show Star Carr in UK). See Milner et al. 2018a for further information about excavation.

Fig. 3. Micrograph of Dumont's analysis depicting SC53, a borer used to work possibly shale. Note the striations (Dumont 1988, 453).

Table 1
Classification of flint awl tip breakage based on the Star Carr assemblage.

Classification	Definition
0 - unmodified to the naked eye	Tip appears unused with no visible modification (e.g. crushing or removals).
1 - rotational minor removals	Diagonal removal at the very tip, indicating a rotational motion of use (i.e. drilling). Still functional.
2 - rounding and/or removals	Micro-removals and/or abrasion at the very tip, microchipping may or may not be visible. Still functional.
3 - resharpened tip snap from use	Snapping largely localised at the tip, resharpens the tool creating an angular edge so continued use is possible. Rounding and/or polish may be removed. Still functional.
4 - snapped	Severe shearing of the entire tip leaving an almost straight profile. No longer usable.

assemblage dominated by red deer (Knight et al., 2018a), preserved wooden artefacts (Taylor et al., 2018c), and a range of bone and antler tools, including 192 barbed points and 23 antler headdresses (Elliott and Milner, 2010; Elliott and Little, 2018; Little et al., 2016). The site is also home to one of the largest and most diverse assemblages of personal ornaments in the British Mesolithic, including shale beads (33) and pendants (2), amber pendants (3), animal teeth pendants (2), and processed bird bone possibly consistent with bead production (Milner et al., 2016; Needham et al., 2018).

2.2. Awl use and spatial patterning

A total of 183 awls have been excavated from the site, 114 by Grahame Clark between 1949 and 1951 across three connected trenches positioned in proximity to the lakeshore (Fig. 2). These awls lack 3D find locations but were recorded by trench and grid square. Based on the available published information, nine awls were excavated from cutting I, where finds location was given (Clark et al., 1949, 65), and a further 42 examples from cutting II and cutting III, with no find's location specified (Clark et al., 1950, 114; Fig. 2).

Excavations by the Star Carr Project (2004–2015) expanded east and south. Seventy awls were recovered, found in greatest quantity immediately to the east of Clark's trenches in the vicinity of a small group of postholes (henceforth referred to as the western structure), which likely dates to around 9300 or 8800 cal BC (Conneller et al., 2018b, 517; Milner et al., 2018b, 240; Bayliss et al., 2018, 73).

John Dumont (1988) carried out a programme of microwear analysis on a sample of awls excavated by Clark to investigate their use, along with other tools from the site. In total, Dumont (1983, 1988, 1989) analysed 27 awls of which 14 showed use, consistent with: bone (8), wood (1), hide (1), and indeterminate materials (4). Of those examples where contact material was unclear, three showed macroscopically observable edge rounding and striations which Dumont suggested might be consistent with working shale (Dumont 1988, 78; Fig. 3). Due to the lack of 3D spatial data for awls and mèche de foret excavated by Clark, Dumont's results cannot be used to assess spatial patterning in materials worked.

A second microwear study by one of the authors (Aimée Little) investigated the use of awls excavated between 2004 and 2015 (see Conneller et al., 2018b). The sample incorporated awls from across the site, including the vicinity of the western structure, and the area surrounding Clark's excavations. Of the 19 awls sampled, 17 showed traces of use in varying motions and on different contact materials, consistent with: drilling mineral (6), piercing hide/mineral (2), cutting/scraping (siliceous) plant (3), drilling bone (4), drilling/sawing an indeterminate hard material (1), an indeterminate use (1), and unused examples (3) (Conneller et al., 2018b, 515). However, the small sample size provides only limited insights regarding spatial patterning in use, especially given the range of contexts the sample incorporates.

The results of studies by Little and Dumont are comparable, suggesting awls were used on a range of contact materials and in different motions, dominated by drilling. Based on the range of contact materials and motions identified in these studies, it has been suggested that awls were used as multi-functional craft tools at Star Carr (Conneller et al., 2018b, 516). However, spatial patterning building from a larger microwear sample is required to understand the range of uses and the presence and extent of any patterning across space in these uses. This would then allow a clearer appreciation of how the working of materials might be connected or reflect particular activities.

3. Material and methods

3.1. Overview

This paper presents results of microwear and spatial analysis of a sample of 54 flint awls excavated between 2004 and 2015, including reanalysis of tools previously published as part of the Star Carr Project (Conneller et al., 2018b). All objects where convergent retouch had been used to produce a point were defined as awls. Awls were re-examined as a group and sub-types refined. Three sub-types were identified. The most common of these are the elegant bilaterally retouched forms known as mèche de foret, of which 44 were recovered. These are defined as lanceolate and more or less parallel in form, shaped through entire or partial abrupt, bilateral retouch, with one, or more rarely two pointed ends (Brinch Petersen, 1966). Other types were rare: nine awls were defined as oblique bi-truncations, with the point formed by two convergent oblique truncations only, without the lanceolate form and attention to trimming of some part of parallel laterals characteristic of mèche de foret. One piece was more irregularly and more minimally retouched to form a thick point on a sturdy support and was defined as a borer. Each awl was cleaned, analysed macroscopically for tip modifications and microscopically for wear associated with use. A programme of Experimental Archaeology was used to create a reference collection of

Table 2
Showing the range of experimental tools used, the typology of the tools used, the length of tool before and after use, the working gestures used, angle of working in use, whether additives were used, the contact material, number of perforations created, time taken to create perforations, and any notable observations collected during working.

Awl no.	Typology	Length before (mm)	Length after (mm)	Working gesture	Contact material	No. of perf.	Time used (mins., secs.)	**Wear category**	Notes / macroscopic observations
1	Mèche de foret	61	61	Freehand, 0°, single direction, dry, uni-directional	shale	1	3 mins. 24 secs.	1	Single direction inefficient
2	Mèche de foret	61	61	Freehand, 0°, single direction, dry, uni-directional	shale	5	7 mins. 48 secs.	1	Single direction inefficient
3	Mèche de foret	55	55	Freehand, 0°, multi-direction, dry, uni-directional	shale	1	1 mins. 7 secs.	1	Multi-direction efficient
4	Mèche de foret	61	61	Freehand, 0°, multi-direction, dry, uni-directional	shale	5	4 mins. 48 secs.	1	Multi-direction efficient
5	Mèche de foret	58	57	Freehand, 0°, multi-direction, dry, uni-directional	shale	20	27 mins. 09 secs.	2	Single direction inefficient
6a	Mèche de foret	62	61	Freehand, 0°, multi-direction, dry, uni-directional	shale	40	59 mins. 10 secs.	1	Rounding after 20 perforations, chipping/ flaking after 27 perforations
6b	Mèche de foret	61	61	Freehand, 0°, multi-direction, dry, uni-directional	shale	18	58 mins. 55 secs	2	Same tool as 6a, used for longer. Inefficient due to heavy tip rounding and wear
7	Mèche de foret	61	60	Freehand, 0°, multi-direction, water added, uni- directional	shale	20	33 mins. 04 secs.	2	Large spall removed from tip after 1 perforation
8	Mèche de foret	55	53	Freehand, 0°, multi-direction, water added, uni- directional	shale	40	87 mins 39 secs.	2	Multi-direction efficient, fine paste increased tip rounding
9	Mèche de foret	59	56	Freehand, 0°, multi-direction, dry, uni-directional	bone	5	28 mins. 16 secs.	2	Significant flaking from tip. Original tip became ineffective. Required grip adjustment to use a sharp edge formed by flaking
10	Mèche de foret	58	56	Freehand, 0°, multi-direction, dry, bi-directional	bone	1	18 mins. 45 secs.	3	Significant flaking of the tip. Complete rotational snap of the tip as two sides of the perforation joined up
11	Mèche de foret	59	56	Freehand, 0°, multi-direction, dry, bi-directional	bone	3	67 mins. 02 secs.	3	Significant tip chipping and flaking
12	Mèche de foret	39	37	Freehand, 0°, multi-direction, dry, bi-directional	amber	2	34 mins. 08. secs.	2	Tip rounding with increasing use
13	Mèche de foret	62	62	Freehand, 0°, multi-direction, dry, bi-directional	amber	3	63 mins. 58 secs.	1	Tip rounding with increasing use
14	Mèche de foret	42	41	Freehand, 0°, multi-direction, dry, bi-directional	amber	1	60 mins. 04 secs.	2	Some spalling of tip and edges. Tip rounding with increasing use
15	Mèche de foret	43	43	Freehand, 0°, multi-direction, dry, bi-directional	hide	23	29 mins. 56 secs.	2	No chipping or flaking, but rounding of the tip
16	Mèche de foret	45	44	Hafted, 0°, multi-direction, dry, uni-directional	shale	16	29 mins 55 secs.	1	Single direction inefficient
17	Mèche de foret	33	31	Freehand, 0°, multi-direction, dry, bi-directional	teeth	2	68 mins. 51 secs.	2	Extensive tip chipping and flaking
18	Mèche de foret	50	49	Freehand, 0°, multi-direction, dry, bi-directional	wood	1	39 mins. 37 secs.	2	Very small chips removed from the tip. Tool became noticeably hot to the touch
19	Mèche de foret	51	50	Freehand, 0°, multi-direction, dry, bi-directional	wood	3	79 mins. 11 secs.	2	Very small chips removed from the tip. Tool became noticeably hot to the touch
20	Mèche de foret	44	41	Freehand, 0°, multi-direction, dry, bi-directional	jet	1	17 mins 45 secs.	2	Heavy tip damage. Tip rounding
21	Mèche de foret	55	53	Freehand, 0°, multi-direction, dry, bi-directional	jet		46 mins. 37 secs.	2	Heavy tip damage. Tip rounding

flint awls drilling a range of material to inform the microwear analysis. The results were plotted spatially using GIS. Protocols for each method are detailed in turn below.

3.2. Macroscopic analysis: Length and tip modification

The length of each awl was measured to assess the relationship between tool length and function. Measurements were taken using digital calipers rounded up to the nearest mm. With the aim of standardising terminology used in functional analysis of flint awls, five categories of tip modification were developed and assigned: (0) unmodified to the naked eye; (1) rotational minor removals, (2) rounding and/or removals, (3) resharpened tip snap from use, (4) snapped. Diagnostic observations are detailed in category definitions outlined in Table 1. These observations were informed by modifications to tip morphology during experimental drilling for a range of durations and contacts materials.

3.3. Microwear analysis and cleaning

Low and high-power microscopy were used to observe the archaeological and experimental awls (van Gijn, 1990; Jensen, 1988; Odell, 2001; Vaughan, 1985; Yerkes and Kardulias, 1993). An Olympus SZ61 stereomicroscope and Olympus LC30 camera were used for low power observations (<100× magnification), alongside an Olympus BX53M with an Olympus DP74 camera for high power observations (100–400× magnification). Archaeological and experimental pieces were cleaned in an Ultrawave U300 ultrasonic tank for 10 min in individual bags containing washing detergent and water to remove dirt/grease from tool surfaces (Keeley, 1980). Some of the awls at Star Carr evidenced iron oxide staining linked to the depositional context (Croft et al., 2018; High et al., 2018), a chemical cleaning protocol was used in some cases in an attempt to remove it. Applicable artefacts were placed in a separate bag containing potassium hydroxide (KOH) solution (0.1 M) inside the sonic bath and cleaned for 10 min. After rinsing, they were placed in the sonic bath for 10 min, within bags containing hydrochloric acid (HCl) solution (0.6 M). All tools were then rinsed in water for 10 min using the sonic bath (Evans et al., 2014; van Gijn, 2010).

If a polish was not observed, where possible, other types of wear traces (e.g. edge removals, tip rounding) were used to identify the hardness of the material (e.g. soft, medium or hard), and motion of use. Although not as specific, contact material hardness can help to limit the range of possible materials worked.

The extent of polish was recorded as undeveloped or developed. Undeveloped polish relates to a tool that was not used for a sufficiently long time to observe a well-developed polish, or a tool that was used but areas of polish have been removed from continued use through microremovals at the tip. Through comparisons with the experimental tools, it was possible to identify developed polish on the archaeological awls. Owing to the motion of use and the occurrence of removals at the tip from use, assessments of intensity of use and development of polish are presented with caution.

3.4. Experimental archaeology

An experimental archaeological reference collection of utilised awls was produced to support microwear analysis and the identification of contact materials, working actions, and intensity of use (Table 2). The reference collection includes examples of working shale, amber, seasoned wood, dry bone (red deer), teeth (red deer), and hide (red deer) with ochre inclusion, expanding on previous work by Needham et al. (2018). Awls were used freehand with the tool tip perpendicular to the material in each experiment. Working gestures varied between single direction rotation and multi-direction rotation, and working materials from one or two faces based on thickness. Replica flint awls were commissioned from an experienced flint knapper and were stored in individual plastic bags after production and prior to experimentation. Experimental awls were made from black, fine grained, glasslike flint. Chemical testing has not been used to establish specific provenance of flint sources at Star Carr, but the flint selected for experiments was in keeping with the archaeological awls (Conneller et al., 2018b). A core with one platform was prepared with hard and soft direct percussion after which blades were detached by direct and indirect soft percussion. All blades were made before the next phase, retouching into awls, started. Some extra blades were made to prepare for blades breaking during retouching. Retouching into awls was started with hammer and anvil retouching using two hammerstones. Each awl was finished by pressure flaking with an antler flaker. Taking into account all phases of work (making the core, producing blades, retouching into awls) the production time of one awl is c. 4–5 min. At the end of each experiment the awl was placed in a new, individual plastic bag.

3.5. Spatial analysis using GIS

As most awls excavated by the Star Carr Project (2004–2015) had associated x, y, z GPS coordinates, their position could be spatially mapped using GIS. ArcGIS Pro software was used to create maps of the site and to plot individual awls spatially. Maps were created of awls using microwear data establishing probable contact material. This allowed for the recognition of spatial patterning associated with specific uses of archaeological awls. Height data was not considered in dryland areas due to the presence of bioturbation in the soil profile. Unfortunately, there are similar issues in the 'Bead Area', which though an area of fen car peat, is located adjacent to the ditch of the canalised River Hertford. As a result, the peat is highly desiccated and cracked, which has led to movement of artefacts within the profile. However, elsewhere, wetland areas preserve more than 800 years of human activity in stratigraphic sequence, as elucidated by a high-precision Bayesian model of more than 200 radiocarbon dates (Bayliss et al. 2018). Here contexts and height data enabled the separation of awls from diachronic activity episodes (Conneller et al., 2018b; Taylor et al., 2018b).

4. Results

4.1. Macroscopic results

4.1.1. Length

The length of each awl was measured, and the results are presented in Fig. 4. The data reveals only a modest difference in length of tool relative to contact material. Awls used in working wood are the largest tools, while the smallest tool was used to work bone. While it has been suggested that larger awls were likely used to work bone and smaller

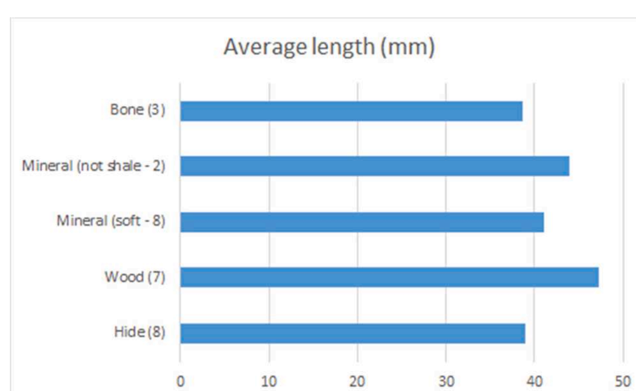

Fig. 4. Graph showing the average length of awls based on contact material group.

awls used on mineral at Star Carr (Nash, 2011), the data suggests the opposite is true. Awls for working mineral are modestly larger than those used to work bone. Tools are in the main of a similar length regardless of the contact material worked and by extension, length can be said to be a weak predictor of function at Star Carr.

4.1.2. Tip modification

An initial observation of the awls with the naked eye revealed 42 with some degree of tip modification, of which 12 had severe tip snapping which would prevent continued use for drilling or piercing tasks (shown in Fig. 5). The experimental results suggested that this severity of tip snap is unlikely to occur even when working with hard contact materials such as dry bone. Duration and intensity of use as well as hafting may be additional pertinent factors. The loss of awl tips may influence the quantity of tools displaying usewear. As the awl tip is the primary contact area used in working, it is probable that several the snapped awls were used and wear traces are now lost, leading to an underrepresentation of working traces in the sample.

Fig. 5. SC92936, a mèche de foret from Star Carr, classified as a group 4 type tip modification (snapped) with hypothetical reconstruction of the complete tool.

4.2. Microwear results

4.2.1. Overview

All 54 awls were cleaned, with 19 requiring additional chemical cleaning. Microwear traces from use were observed on 43 awls (35 mèche de foret, seven oblique bi-truncations, one borer), of which 27 were diagnostic (22 mèche de foret, four oblique bi-truncations, one borer) thus enabling identification of contact materials. Post-depositional surface modification (PDSM) was observed on 41 awls, including iron oxide deposits and staining, metallic striations and flat, dull polish not related to use. However, PDSM did not always interfere with the identification of polish. In 18 cases, diagnostic polish from use could be discerned despite the presence of PDSM. As adhering iron oxide deposits obscured some microwear traces, it is probable that the range of contact materials is underappreciated and where contact material can be discerned, the interpretation is necessarily tentative. Where microwear polish was identified, it was largely located at the distal end, associated with protruding retouched areas on the dorsal aspect. No definitive hafting wear traces were observed on the analysed awls.

The results of microwear analysis are presented below, grouped by contact material, and presented alongside a GIS map to understand the spatial distribution by material type. The dryland extent in the map depicts what the site is likely to have looked like during the main phase of occupation (c.8800 cal BC), but as the palaeolake gradually became infilled the once open water became peat and was used for certain small-scale tasks (Taylor et al., 2018b). A summary results table of awls identified as used on soft, medium, hard indeterminate and indeterminate materials, as well as not used, can be found in Supplementary Material 1.

4.2.2. Mineral

From the 8 awls identified as used to work soft mineral, six are mèche de foret, two are double mèche de foret and two are oblique bi-truncations (Table 3). As perforated shale was excavated from the site near a number of the mèche de foret, together with comparable experimental working traces, it seems likely that the soft mineral traces are from shale. One mèche de foret and one oblique bi-truncation evidenced traces of a harder mineral, likely amber, which was also found at Star Carr (Needham et al., 2018). However, they are found on the opposite side of the site to the amber pendants, c. 40 m away, possibly reflecting transport of the awls, the amber, or both (Fig. 6); refits of other types of

Table 3
Results from awls used on mineral.

Finds number	Awl type	Length (mm)	Cleaning	Tip modification	PDSM	Contact material	Extent of polish
82401	Oblique bi-truncation	45	Soap	2	FeO staining and flat dull polish	mineral (not shale, possible amber)	undeveloped
90515	Mèche de foret	43	Soap	1	FeO staining and flat dull polish	mineral (not shale, possible amber) drilling	undeveloped
99551	Mèche de foret	45	Soap	1	n/a	soft mineral drilling	undeveloped
96336	Double mèche de foret	38	Soap and chemical	1	FeO deposits	soft mineral? drilling	undeveloped
97607	Oblique bi-truncation	26	Soap and chemical	4	n/a	soft mineral	developed
113581	Mèche de foret	44	Soap and chemical	2	Considerable FeO staining and metallic striations	soft mineral?	undeveloped
114679	Mèche de foret	29	Soap	4	n/a	soft mineral?	undeveloped
92402	Mèche de foret	30	Soap	1	FeO deposits	soft mineral drilling	developed
93991	Mèche de foret	60	Soap	2	n/a	soft mineral	developed
94227	Double mèche de foret	56	Soap	1	FeO deposits and metallic striations	soft mineral drilling	undeveloped

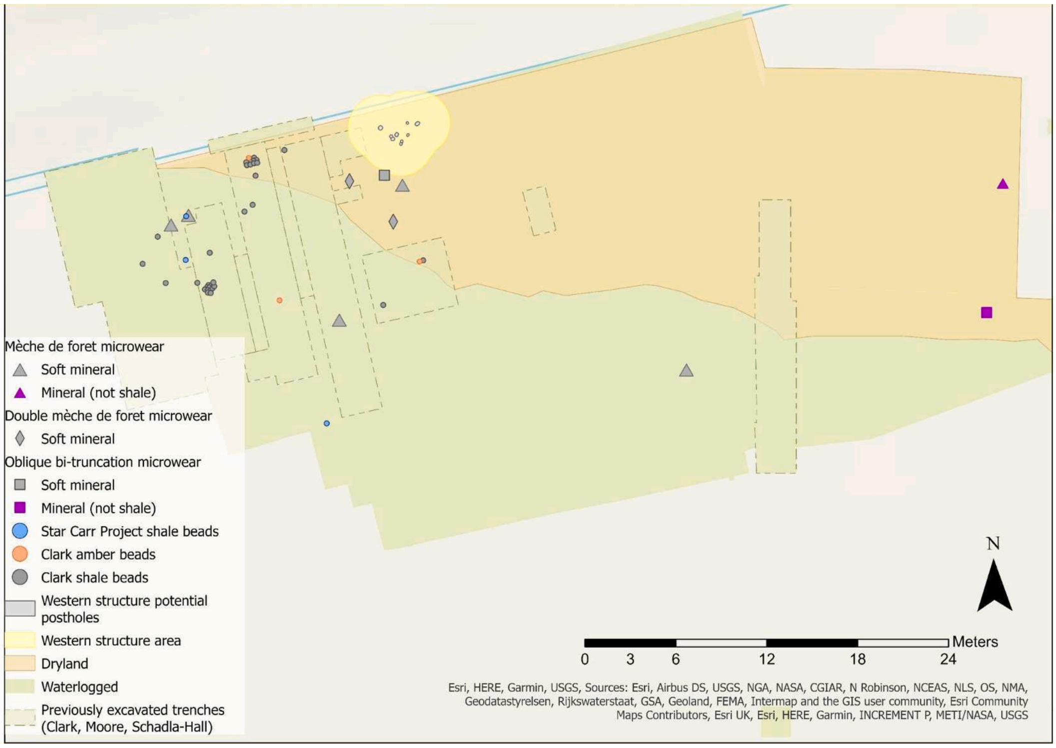

Fig. 6. Distribution of microwear results from awls interpreted as used on mineral and soft mineral (shale), along with shale and beads excavated from the site.

lithic tools confirm connections between these two areas (Conneller et al., 2018a). The mèche de foret, including double mèche de foret, typically exhibited rotational minor removals at the working tip, consistent with their use as a drill using a rotational working action. There are three examples of well-developed soft mineral polish (Fig. 7), but more typically the awls showed limited polish development. This may be because shale is soft and polish development is slow as a result. Further, the rotational action used in drilling can cause micro removals at the tip, removing areas of more developed polish, making awls appear less utilised.

There are clear similarities in the features of the experimental mèche de foret used to drill shale freehand for 1 h and the developed archaeological polish on SC93991. Experiments of working shale freehand with a mèche de foret have shown that in excess of 40 shale beads can be made in 1 h with the same tool. This quantity should be taken as a minimum estimate as the shale being drilled during experimentation was typically thicker than the beads recovered from Star Carr. This suggests that one awl alone could have easily produced the surviving assemblage of shale beads (33) found at Star Carr.

4.2.3. Animal

4.2.3.1. Hide and hide with mineral. Of the 8 awls identified as used to work hide and hide and mineral, five were mèche de foret, two were double mèche de foret, one was an oblique bi-truncation (Fig. 8; Table 4). Hide and mineral refers to the working of hide with a mineral additive, such as ochre, which has been documented to aid the softening and tanning of hide (Dubreuil and Grosman, 2009; Rifkin, 2011). These awls show evidence of both developed and undeveloped polish, with developed examples exhibiting similar characteristics to an experimental awl used to pierce/drill dry hide for 30 min (see Fig. 9). The most frequently observed tip modification during experimental hide and mineral working was rounding and/or removals; this is consistent with microwear observations of heavily rounded working edges (see Fig. 9). Owing to the properties of hide and from experiments, a degree of rotational motion when using an awl can help to widen the perforation. Spatially, indirect evidence of hide working is spread across different areas of the site - in both the dryland and the wetland periphery (see Fig. 8). Unlike the other contact materials, awls used for hide working cluster within the footprint of the western structure features, with three awls found in proximity, possibly suggesting this was an area with a particular focus on this task.

4.2.3.2. Bone. Bone working was identified on three awls; all of which were mèche de foret (Table 5). The spatial distribution of two of the mèche de foret correlates with the bone material found in this area by the Star Carr Project (see Fig. 10), which included 560 specimens of bone (including modified pieces) and antler (Knight et al., 2018b, 146). However, none of the bones or antler recovered by the Star Carr Project evidence drilling; rather, analysis of the bone assemblage indicates it is the product of practices of formal deposition into the lake waters (Knight et al., 2018b, 137). The third mèche de foret located to the east of the other two mèche de foret, though in close horizontal proximity, is much higher in the sequence. While the deposition of the two earlier mèche de

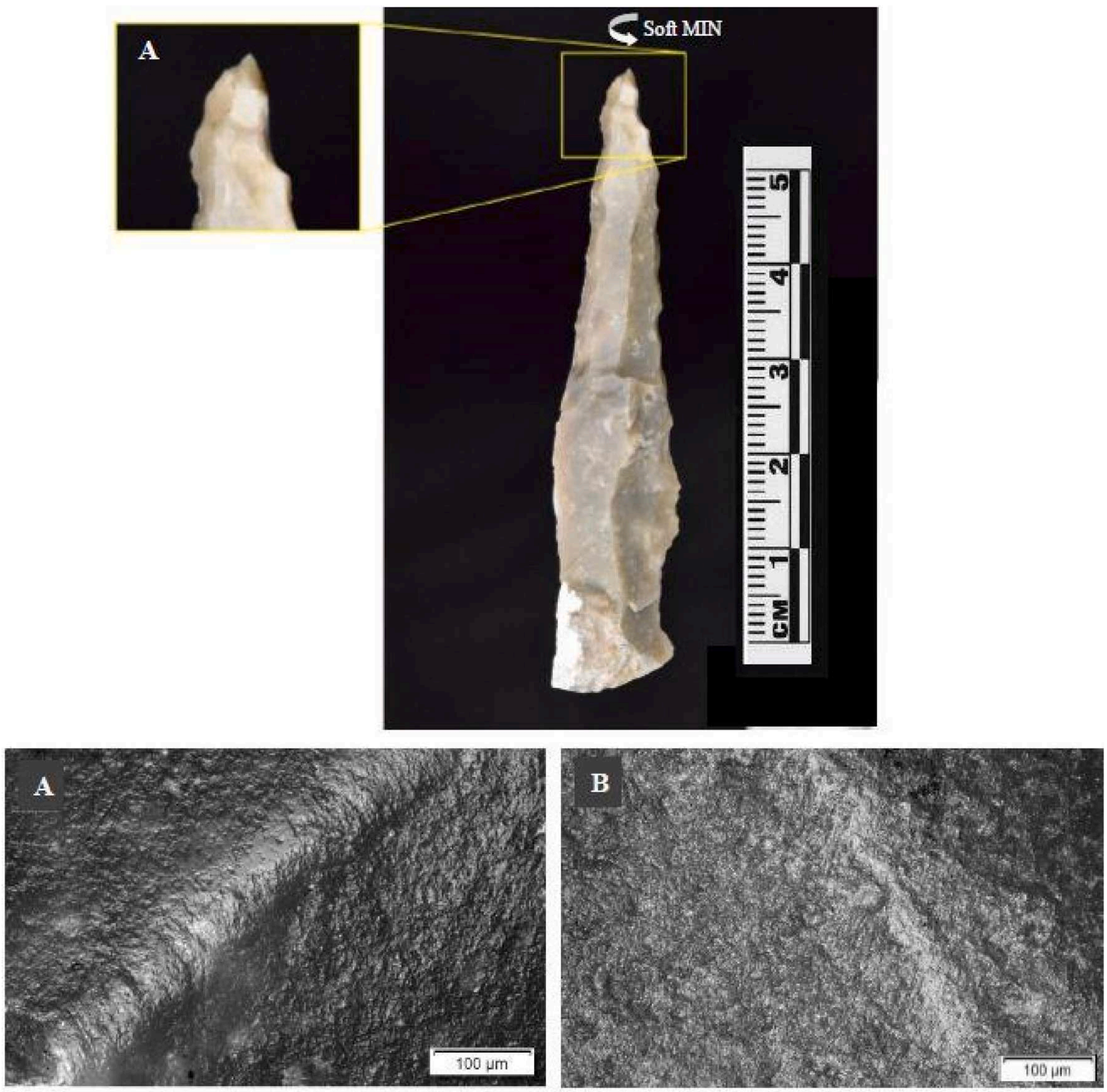

Fig. 7. A - SC93991 an archaeological mèche de foret interpreted as used for drilling shale, 200× magnification. No wear was observed on the ventral aspect; B - experimental mèche de foret used for 1 hr to drill 40 shale beads freehand, 200× magnification.

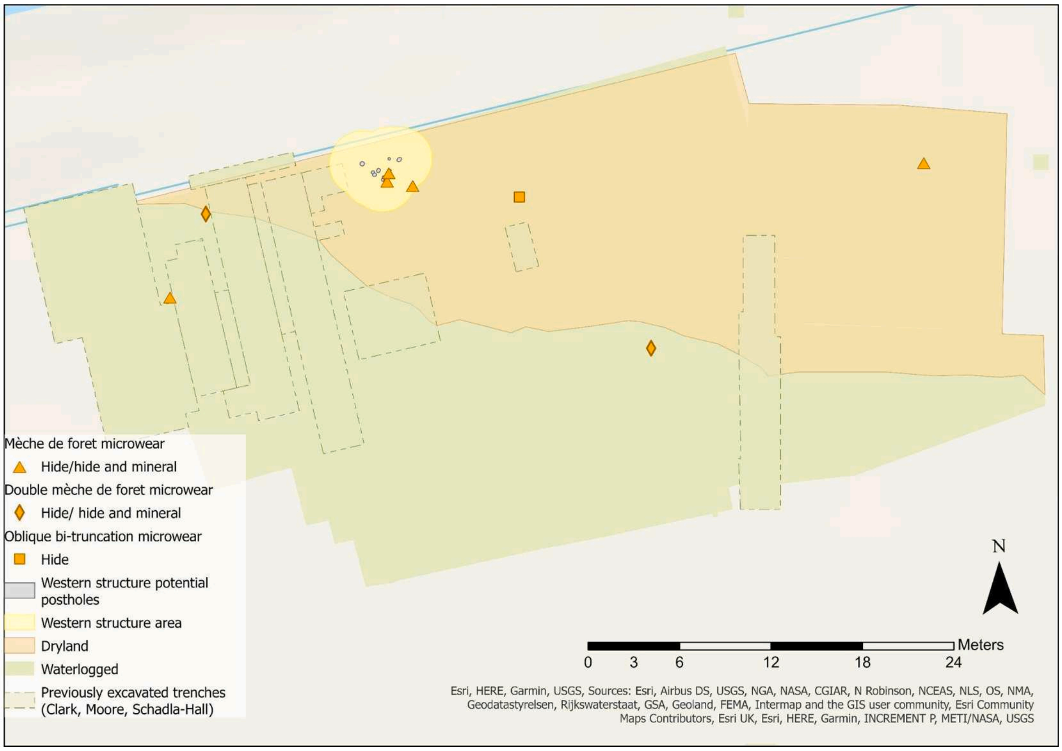

Fig. 8. Distribution of awls interpreted as used to work hide and hide and mineral.

Table 4
Results from awls used on hide or hide with mineral.

Finds number	Awl type	Length (mm)	Cleaning	Tip modification	PDSM	Contact material	Extent of polish
82724	Mèche de foret	47	Soap and chemical	1	n/a	hide + mineral drilling/ piercing	undeveloped
85366	Mèche de foret	35	Soap and chemical	4	n/a	hide	developed
96249	Mèche de foret	36	Soap	2	Metallic striations	hide + mineral	undeveloped
113564	Double mèche de foret	51	Soap	2	FeO deposits and flat dull polish	hide	undeveloped
115294	Mèche de foret	30	Soap	4	FeO deposits	hide	developed
109731	Oblique bi-truncation	38	Soap	2	Flat dull polish	hide	developed
91454	Mèche de foret	41	Soap	1	n/a	hide (+additive) drilling/ piercing	developed
94395	Double mèche de foret	34	Soap	2	FeO staining	hide + mineral	undeveloped

foret took place around 8800 cal BC, the third piece belongs to some of the latest activity two to three centuries later, when this had developed into an area of fen carr. Based on the edge damage on the mèche de foret, it is likely they were used in a rotational motion as a drill. The mèche de foret generally have developed polish and show similarities with an experimental mèche de foret used to drill dry bone for 1 h (see Fig. 11).

4.2.4. *Vegetable*

4.2.4.1. Wood. Of the 6 awls used on wood, four were mèche de foret, one was a double oblique bi-truncation, and one was a borer (Table 6). As shown in Fig. 12, the awls are spatially spread across the site although there is a main cluster to the south of the western structure area. Both developed and undeveloped polish was observed, although the

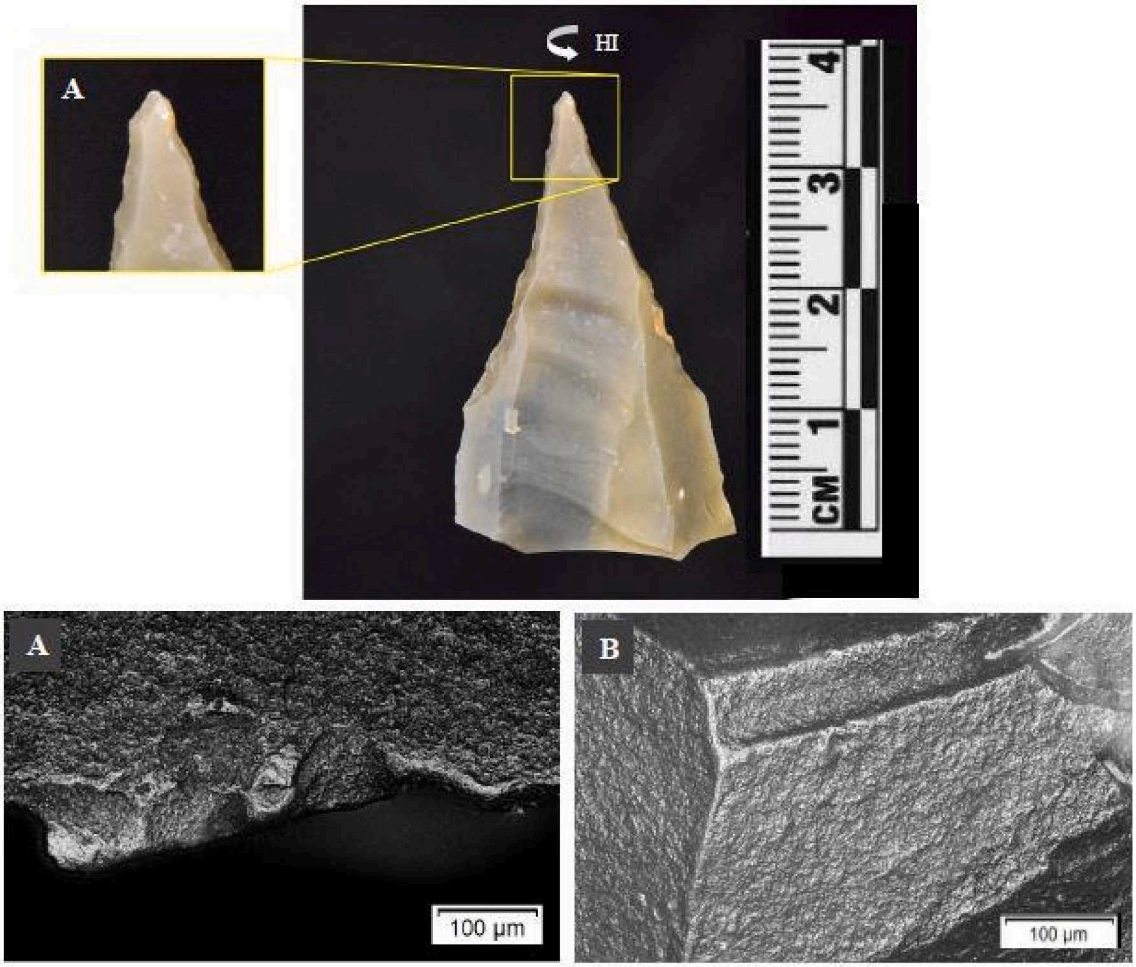

Fig. 9. A - SC109731 an oblique bi-truncation interpreted as used for piercing hide, 200× magnification. No wear was observed on the ventral aspect. Note the area of tool A's edge to the right side of the image showing clear rounding; B - experimental mèche de foret used for 30 mins to pierce dry hide with red ochre freehand, image taken on the ridge of the dorsal, 200× magnification.

developed examples appeared to have a less intense polish to the experimental tool used to drill seasoned wood for 40 min; it is possible that the Star Carr awls were used for a shorter duration (see Fig. 13). Awls associated with working wood are largely found to the west of the site but are most frequent in the vicinity of the structure. There is no evident patterning by tool type. Experimental drilling of seasoned wood showed a close correlation to the analysed archaeological awls used, although it is feasible that other wooden materials may have also been drilled.

Table 5
Results from awls used on bone.

Finds number	Awl type	Length (mm)	Cleaning	Tip modification	PDSM	Contact material	Extent of polish
96471	Mèche de foret	31	Soap	2	FeO staining	bone	developed
116369	Mèche de foret	41	Soap	2	FeO deposits	bone	developed
116995	Mèche de foret	44	Soap and chemical	1	FeO deposits	bone drilling	undeveloped

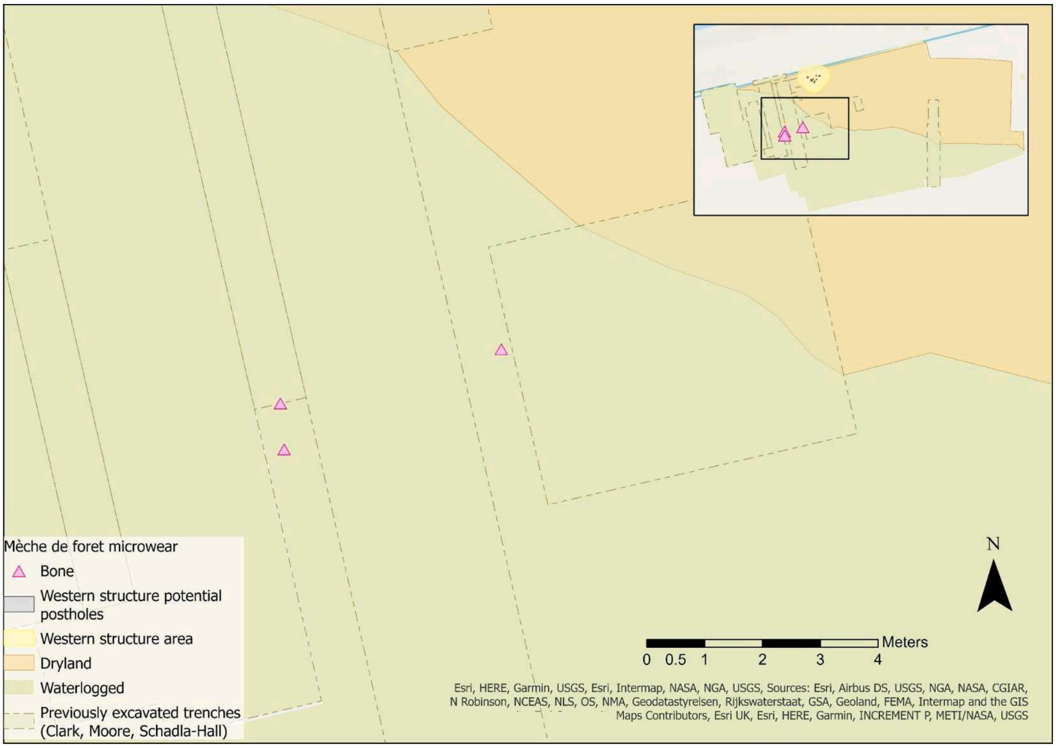

Fig. 10. Distribution of mèche de foret interpreted as used to work bone.

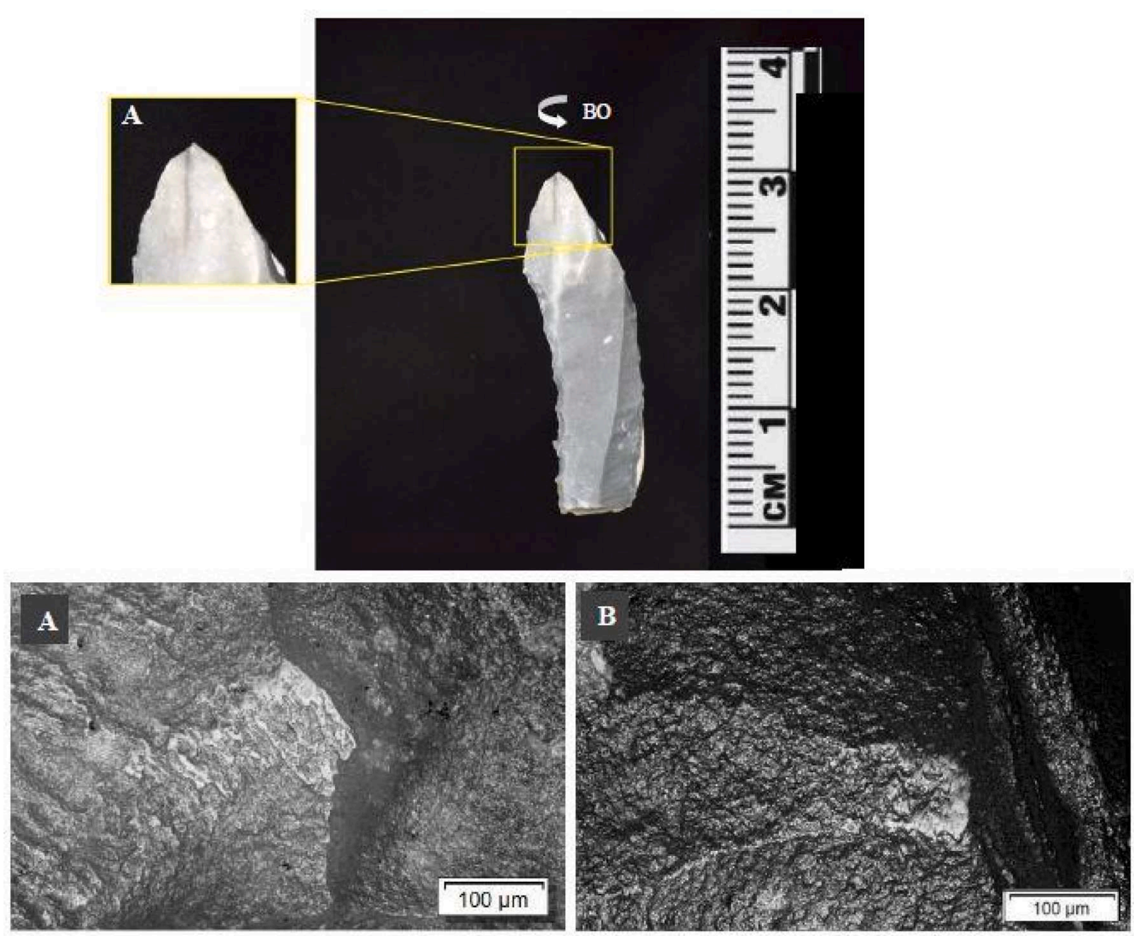

Fig. 11. A - SC96471 a mèche de foret interpreted as used to drill bone, 200× magnification. No wear was observed on the ventral aspect; B - experimental mèche de foret used to drill dry bone for 1 hr, 200× magnification.

Table 6
Results from awls used on wood.

Finds number	Awl type	Length (mm)	Cleaning	Tip modification	PDSM	Contact material	Extent of polish
94622	Mèche de foret	42	Soap and chemical	1	FeO deposits	wood drilling	developed
95321	Double oblique bi-truncation	81	Soap	1	FeO staining and flat dull polish	wood (one tip only) drilling	developed
110685	Mèche de foret	37	Soap and chemical	2	FeO staining	wood	undeveloped
93521	Borer	34	Soap	1	Flat dull polish	wood drilling	developed
94298	Mèche de foret	54	Soap	2	n/a	wood	undeveloped
97145	Mèche de foret	36	Soap	2	n/a	wood	developed

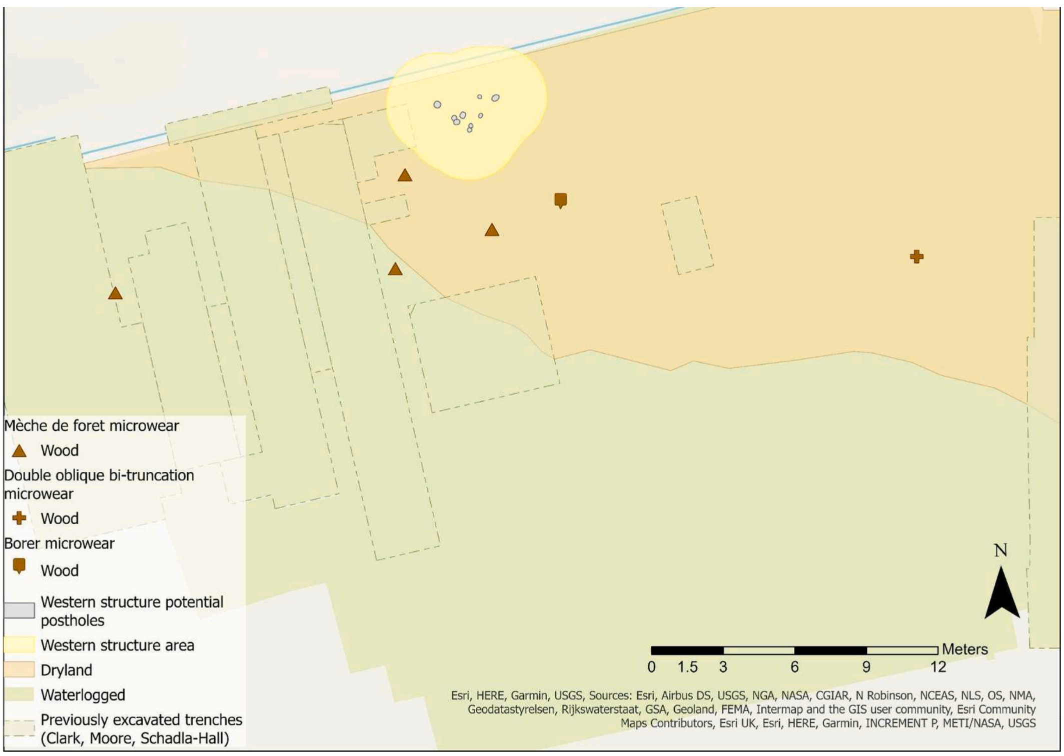

Fig. 12. Distribution of awls interpreted as used on wood.

5. Discussion

5.1. Overview

The results encourage three areas of discussion that will be considered in turn: (1) functional considerations of awls at Star Carr; (2) what activities the identified contact materials might reflect and how this activity is spatially distributed; (3) whether the tools utilised and results generated can usefully augment existing Mesolithic awl typologies.

5.2. Awl function at Star Carr

The results provided minimal evidence to suggest an exclusive relationship between contact material and specific tool types (i.e. mèche de foret, oblique bi-truncation or borer). Instead, both mèche de foret and oblique bi-truncations were employed across a range of contact materials. In the case of hide, wood, soft mineral and hard mineral, mèche de foret, oblique bi-truncations and borers were used. The working of bone is a possible exception; only mèche de foret were used. The mèche de foret was the most common tool utilised for working each contact material, while 11/13 tools displaying rotational removals can be classified as mèche de foret or double mèche de foret. The three awls with well-developed soft mineral traces, as well as 5 additional awls with less developed traces, provides an important insight into personal ornament production and use at Star Carr, suggesting significantly more shale beads were produced at the site than were excavated.

Neither mèche de foret nor oblique bi-truncations appear to have been used exclusively for a particular type of working motion at Star Carr. In both cases, mèche de foret and oblique bi-truncations were used on contact materials where drilling would be required, but were each also used to work hide, where a combination of piercing and rotational motions was likely employed to create and widen each perforation. The available data does not support a rigid distinction of discrete uses, but rather suggests that at Star Carr use was more nuanced and variable across different awl forms.

Previous technological studies (e.g. Nash, 2011) have suggested that length could be a diagnostic measure of function. However, the results do not support this at Star Carr. As Fig. 4 demonstrated, there is no archaeological patterning in use based on the size of the awl and similarly this did not prove to be a significant factor during experimentation. Further, tip modifications on the Star Carr Project awls, as well as comments by Clark (1954, 106) of 14 awls missing a tip, highlight that severe tip snapping is significant at Star Carr. The reason for this pattern remains unclear at this stage and requires further work.

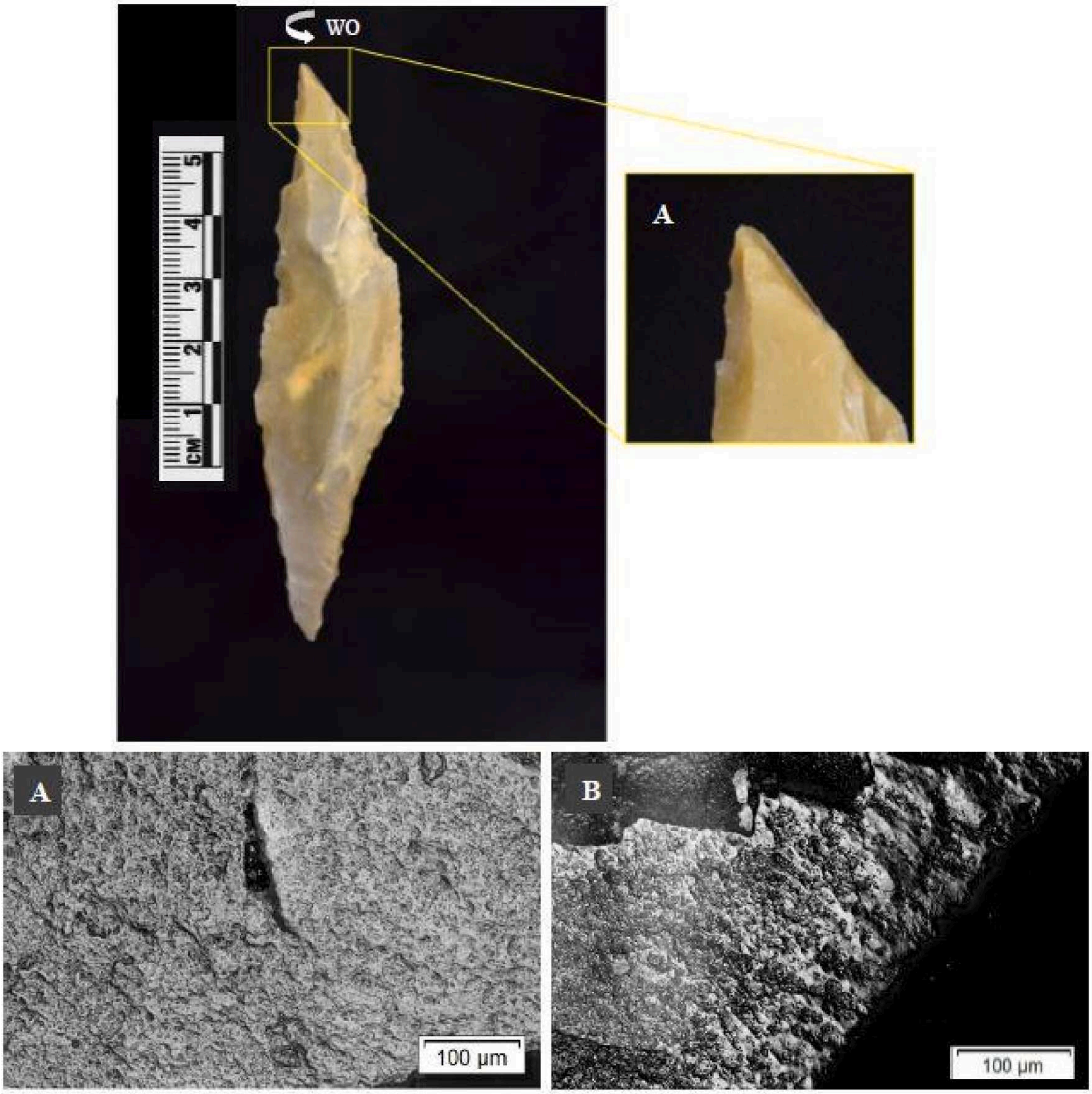

Fig. 13. A - SC95321 a double oblique bi-truncation interpreted as used to drill wood, magnification 200×. No wear was observed on the ventral aspect; B - experimental mèche de foret used to drill seasoned wood for 40 mins, magnification 200×. The polish on A, the archaeological tool, is clearly less developed than the experimental tool.

The extent of tip wear provides important insights regarding raw material sourcing and tool use at Star Carr. As shown through the tip modification groups, not all awls were used to exhaustion. From macro-observations, 40 awls still had a functional tip, based on experimental observations from using mèche de foret extensively on different materials. This is interesting given that much of the flint used, around 90%, favours good quality till flint sourced from the coast, some 10 km away (Conneller et al., 2018b, 499). Further work is required to understand why tools that are made from a material that requires transport might be deposited before being exhausted. Experimental data suggests that tool efficacy diminishes once the tip begins to significantly wear. In a context where raw material is plentiful, it may be preferable to discard and make a new tool rather than extend the life of a worn tool.

Mèche de foret at Star Carr have previously been interpreted as multi-functional craft working tools (Conneller et al., 2018b; Needham et al., 2018) and this can now be extended to all recently excavated awls. The primary role of this broad tool type appears to be drilling with some evidence for piercing. While microwear results have advanced understanding of use through the range of contact materials identified, translating these traces into particular activities remains challenging and, in some cases, necessarily speculative. The evidence for soft mineral translating to shale bead/pendant production is strong, with some possibility of mineral traces relating to amber pendant production. Relative to other materials, mineral can be expected to preserve well and there are only limited alternatives to shale or amber from the materials found at the site. Ochre would be the primary candidate, but this is discernible from shale and has been identified as used in combination with hide.

While animal hides have not been preserved at Star Carr, their use as part of clothing - sometimes decorated with beads - is widely attested in the Mesolithic (Cristiani and Borić, 2012; Cristiani et al., 2014; Mărgărit et al., 2018), and seems a likely possibility at Star Carr. Equally, the sewing together of hides to cover structure is also a possibility (Bamforth et al., 2018). Wood and bone are perhaps more difficult to interpret. In both cases, the range of preserved examples of perforated objects is minimal. In the case of bone, it is possible that perforated teeth used as pendants could account for some of the wear. Additionally, Clark recovered an antler barbed point (P86) that appears to have been

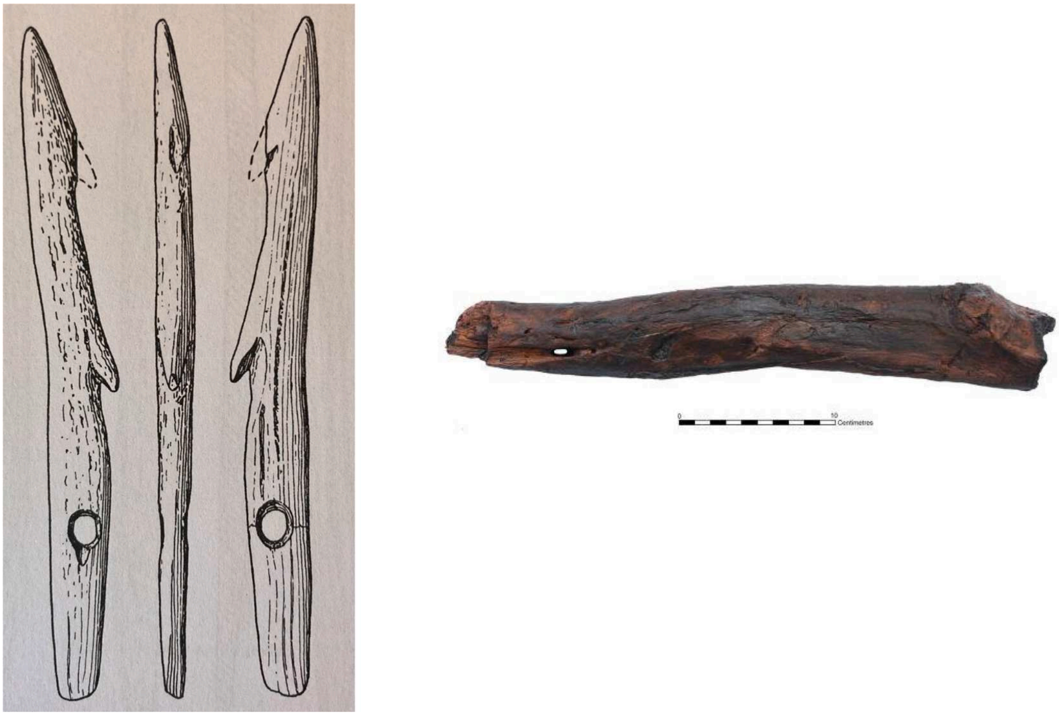

Fig. 14. Left - P86, perforated barbed point recovered by Clark (Clark 1954, 140). Right - roundwood identified with hole < 115952> (Copyright Michael Bamforth, CC BY-NC 4.0).

perforated; as bone and antler microwear polish can be difficult to differentiate when undeveloped, it is also possible that some awls may have been used to drill barbed points (Clark, 1954, 140). Despite the recovery of wooden artefacts being plentiful (Taylor et al., 2018c), only two pieces of roundwood exhibited signs of a perforation, though they are morphologically very different to perforations observed from experimental drilling of wood (see Fig. 14); this leaves the role of drilling wooden artefacts an open question. It is likely that broken wooden objects would have been burned as fuel for fires, which could go some way to explain the lack of perforated wooden objects.

5.3. Spatial distribution of activities at Star Carr

Generally, the microwear identifications of different contact materials show no obvious spatial clustering across the site. However, there are several exceptions to this: bone working was focused in and around a large deposit of bone material; soft mineral traces were primarily observed to the west of the site but across a large area along with soft/medium and soft indeterminate materials. Although awls used to work hide and hide and mineral were spread across the site, they were the only contact materials found closely associated with the western structure, from those identified. Only two mèche de foret were found next to the western structure features: both were interpreted as used to work hide and hide and mineral. While the western structure area may be associated with secondary deposition of flint waste (Conneller et al., 2018a), the microwear results suggest that patterns of awl activity in the western structure area were more clearly defined. Considering the hide and hide and mineral traces alongside the indeterminate results (soft/medium indeterminate (1), hard indeterminate (2)) from this area, the western structure maintains a smaller range of worked materials compared to the surrounding areas. This pattern is of interest as areas of secondary deposition are probably more likely to reflect a heterogenous range of materials and activities from across the site, rather than a limited selection. Alternatively, it is possible that material has been deposited here from specific working areas, supporting the hypothesis of a middening area.

The spatial results further highlight the importance of caution in assigning function based on spatial proximity of tools and artefacts. For example, awls found close to the shale beads were not more likely to show extensive microwear traces of shale. Studies which rely on spatial analysis and typology in isolation are therefore potentially limited as the true range of uses can be more complex than the spatial patterning might imply.

Given awls were used on a wide range of contact materials it is interesting to consider potential spatial relationships between different materials involved in specific tasks. Thinking about the relationships between contact materials and how they translate into separate or related functions in this way may prove fruitful in trying to understand Mesolithic craft practices; how different aspects of craft were related, and how this might manifest spatially. The theme of drilling shale beads can be extended to consider their relationship to piercing/drilling animal hides. Given the relative spatial proximity of shale and hide working, it is possible these activities could be part of a more complex chaîne opératoire of production of composite objects: in this case animal hide garments with shale bead appliqué (Needham et al., 2018; Figs. 6 and 8).

Interestingly, two awls - one mèche de foret and one double mèche de foret - were recovered from the wetland periphery to the south-east of the site; the former used on soft mineral and the latter on hide and mineral. Similar to the organic material found in this area, such as dehafted barbed points, antler headdresses, complete animal carcasses and articulated faunal remains, the awls can be interpreted as intentionally deposited. The use of these two awls and their deposition alongside material interpreted as part of a ritual deposition might further suggest that awls were seen as important tools, used to produce objects of possible ritual significance (Milner et al. 2018b). While caution is needed when inferring spatial relationships based on proximity of tools and other artefacts, microwear can allow patterns to emerge, both within and across contact material classes, providing insight into spatial patterning of activity.

5.4. Moving beyond form as function: Augmenting typologies

Drawing from discussions pertaining to awl use and spatial relationships at Star Carr, suggestions can be made that are pertinent to debates surrounding Mesolithic awl typologies more widely. Although only 54 tools from one site were analysed, this is a significant sample for a single tool category when using microwear analysis and where spatial data is also available. Size does not appear to be a robust indicator of function, neither is a typological designation as a mèche de foret, oblique bi-truncation or borer. Typology remains essential in organising collections and attempting to create a common language to consistently describe artefacts. However, typologies could be usefully augmented by the addition of increasing datasets that make use of macroscopic observations and spatial analysis, providing an increasingly robust and independent means of assessing use. In turn, this could facilitate increasingly unified typologies and common languages, tackling some of the key challenges identified in lithics analysis in recent decades (Ballin, 2000, 2021).

6. Conclusion

The results of macroscopic observations, microwear and GIS suggest awls were used to work a range of materials: soft mineral (shale), hard mineral (amber), bone, wood, hide, hide with mineral, mostly in a drilling action and more rarely a combined piercing and drilling action. Despite the typological distinction of mèche de foret, oblique bi-truncation and borer, morphological variables prove to be inaccurate when compared against results generated using microwear and macroscopic tip analysis. Plotting microwear results using GIS provides spatial insights about awl use which can be used to identify activity areas or perhaps even how different activities may connect into more complex sequences of production. In the case of Star Carr, there appears to be a connection between drilling shale and piercing/drilling hide, with the former possibly being applied to the latter via appliqué. Awls are rarely studied in this level of analytical detail and the analysis of a large sample has demonstrated their important role as multifunctional craft tools. It seems likely that they played an essential role in the Mesolithic hunter-gatherer toolkit at Star Carr and beyond. Future work on this tool type from other Mesolithic sites needs to be undertaken to advance understanding of awls within European Mesolithic toolkits more generally.

At a broader level, the integrated methodological toolset adopted here provides a useful means of augmenting typology. Typology provides an important way of communicating precise forms in a common language, facilitating inter- and intra-site comparison, and aiding in cataloguing and curation. Microwear, GIS and macroscopic modifications furthers understanding of use where preservation of microwear traces allows these methods to be employed. With greater application of this integrated methodological approach to the study of prehistoric lithic scatters, the data generated may allow for more rigorous inference of tool functions, specifically at sites where detailed microwear analysis cannot be undertaken.

CRediT authorship contribution statement

Jessica Bates: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization, Writing – review & editing. **Andy Needham:** Methodology, Investigation, Writing – original draft, Visualization, Writing – review & editing. **Chantal Conneller:** Formal analysis, Investigation, Validation, Writing – original draft. **Nicky Milner:** Writing – review & editing, Supervision, Funding acquisition, Project administration. **Diederik Pomstra:** Resources, Investigation. **Aimée Little:** Validation, Writing – review & editing, Supervision.

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Declarations of Interest

None.

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