STAR CARR

Volume 2: studies in technology, subsistence and environment

NICKY MILNER, CHANTAL CONNELLER AND BARRY TAYLOR

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Contents

Preface to Volume 2

Nicky Milner, Barry Taylor and Chantal Conneller

Volume 2 provides detail on the specific areas of research carried out as part of the recent programme of work at Star Carr. Much of this research has been brought together to provide the interpretations presented in Volume 1.

The volume has been divided into six sections, reflecting (broadly) the nature of the material under discussion. The first three describe the work on which our understanding of both the context and chronology of the archaeology is based. These begin with Part 7, which outlines the aims, objectives and methods for the project and the geophysical survey carried out on the site. Part 8 provides a detailed discussion of the dating of the site, the climate reconstruction and the palaeoenvironmental analysis. Part 9 deals with the research undertaken on sediments, starting with an overview of the site stratigraphy, the soil geochemistry and the research on the deterioration on the site and conservation of the artefacts.

The final three sections describe the analyses of the main archaeological material from the site, divided into animal, vegetable and mineral (following Clark 1954). Part 10 focuses on the animal remains and the ways in which they were utilised, starting with the faunal analysis and the osseous technology, followed by the analysis of the barbed points and antler frontlets, and concluding with a discussion of animals within the broader context of the European Mesolithic. Part 11 deals with the use of plant material, beginning with woodworking technology and evidence for possible plant management, the wooden artefacts, birch bark, fungi and the palaeoethnobotanical evidence in the form of charcoal and phytoliths. Part 12 covers the mineral finds: beads including an engraved shale pendant, utilised stones and flint. Much of the data from these chapters can be found in the site archive in ADS (https://doi.org/10.5284/1041580).

Throughout the volume we refer to the trenches excavated during earlier programmes of work at the site (Figures A and B) and as part of the recent project (Figures C and D), and the principal archaeological features such as the wooden platforms, dryland structures and the dense concentration of material in the area investigated by Clark (Figure E).

Information on the presentation of dates in this volume

Calendar date estimates given in the text have been derived by a variety of methods. Date ranges given in italics are Highest Posterior Density intervals derived from formal Bayesian statistical models. The parameter and the figure on which it is illustrated identify the distribution exactly. For example, Mesolithic occupation at Star Carr began in *9385–9260 cal BC (95% probability; start Star Carr*; Fig. 17.2*), probably in 9335–9275 cal BC (68% probability).*
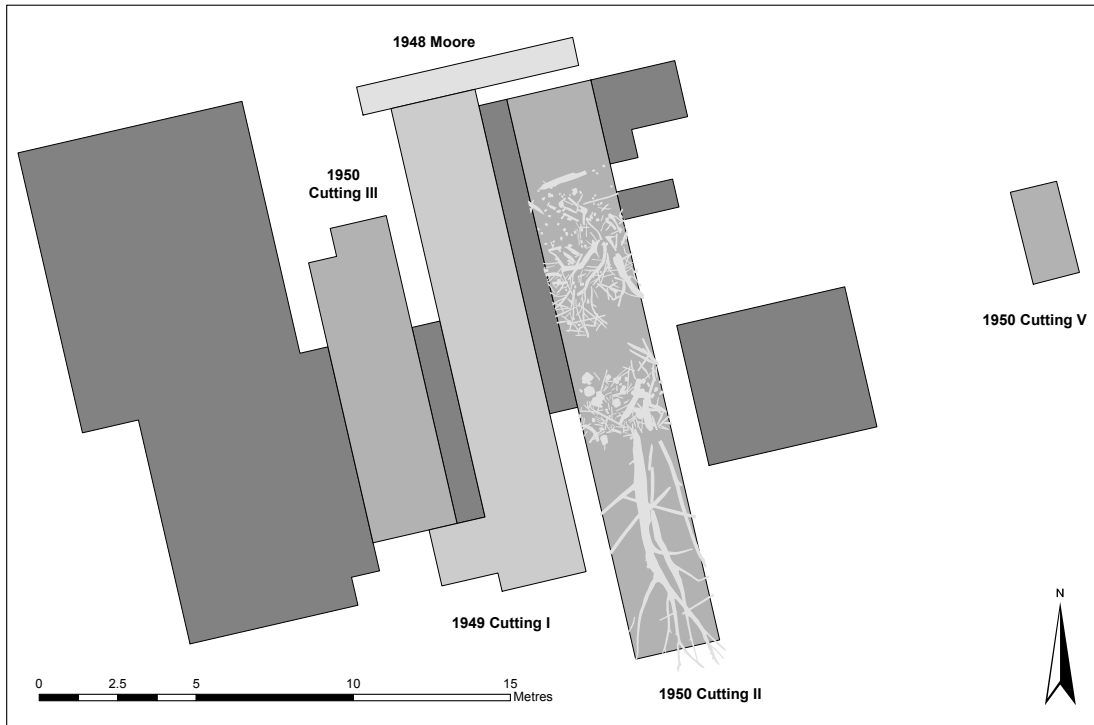
Figure A: Plan of the trenches (see Chapter 2 for further information). Moore's trench was excavated in 1948 followed by three seasons of excavation by Clark. Trenches excavated in 1949 and 1950 have cutting numbers assigned; trenches excavated in 1951 do not and are here marked in darker grey. The 'brushwood' and two trees from cutting II are digitised from Clark's plan in the 1954 monograph and superimposed on the trench plan here (Copyright Star Carr Project, CC BY-NC 4.0).
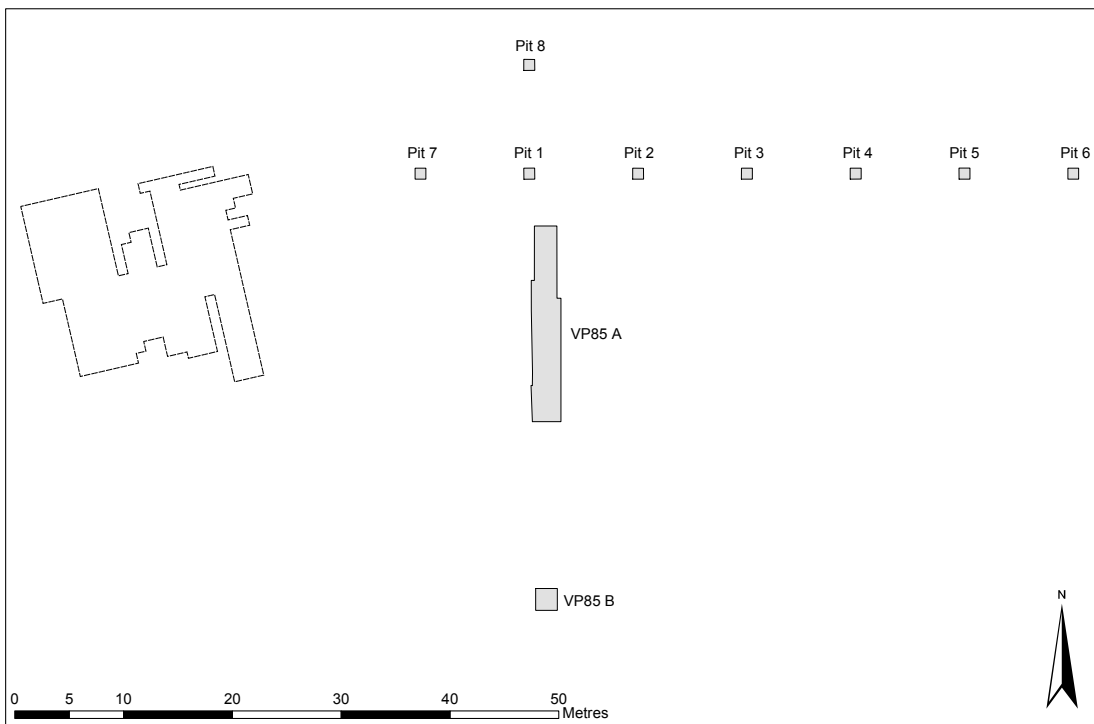
Figure B: Plan of the trenches excavated in 1985 and 1989 in relation to Clark's excavation (on left) (Copyright Star Carr Project, CC BY-NC 4.0).

Figure C: Excavated areas on the Star Carr peninsula, with the extent of the Early Mesolithic lake/wetland coloured light blue (see Chapter 3 for further information). Trenches excavated during Phase 1 of the project are coloured in red, with Moore/Clark's trenches and VP85A and B trenches in grey. The modern line of the River Hertford cuts across the peninsula, roughly southwest to northeast, and a drainage ditch lies to the north (both coloured dark blue) (Copyright Star Carr Project, CC BY-NC 4.0).
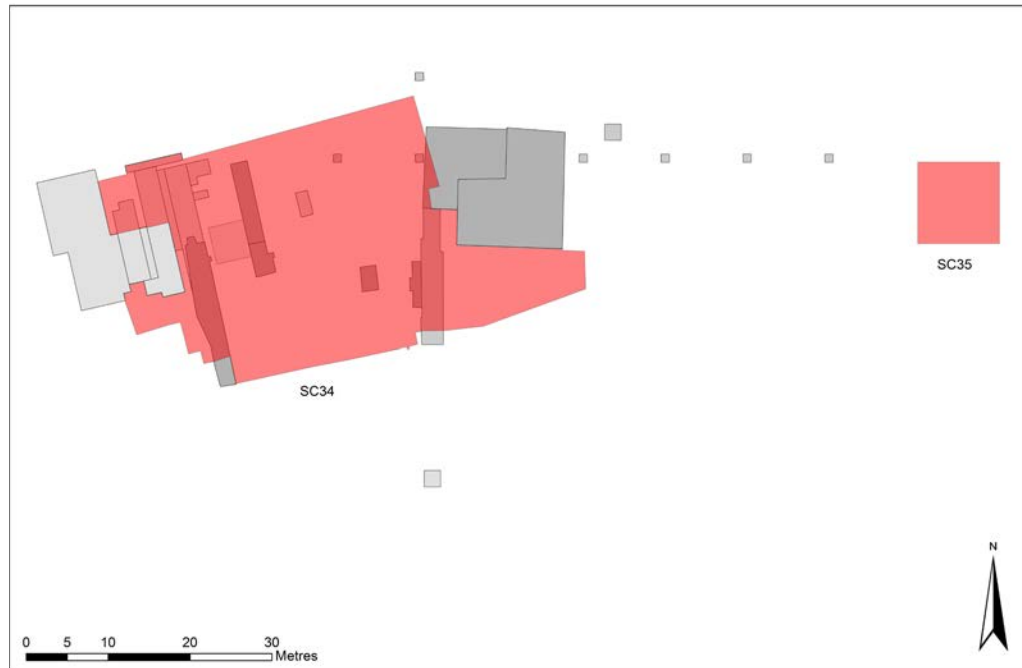
Figure D: The full extent of trenches SC34 and SC35 (in red), in relation to previous excavations (shown in grey) (Copyright Star Carr Project, CC BY-NC 4.0).
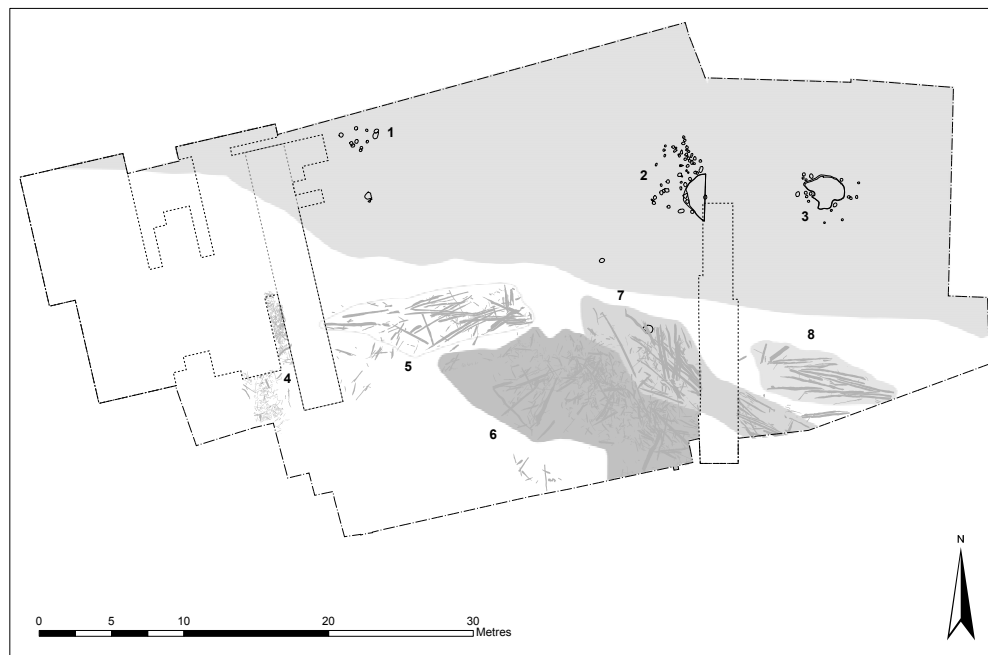
Figure E: The principal archaeological features that will be referred to in this volume (see volume 1 for further discussion): 1: western dryland structure; 2: central dryland structure; 3: eastern dryland structure; 4: Clark's baulk (this and the area to the south of this are referred to as Clark's area); 5: western platform (and the brushwood is also in this area); 6: detrital wood scatter; 7: central platform; 8: eastern platform. The extent of the Early Mesolithic lake and wetland environments are in white and the adjacent dryland is shaded light grey (Copyright Star Carr Project, CC BY-NC 4.0).

Unmodelled radiocarbon dates have been calibrated using the probability method (Stuiver and Reimer 1993), rounded outwards to 10 years (or 5 years if the error term on the radiocarbon age is less than ±25 BP), and are given in normal type. These dates are identified by the internationally agreed laboratory code for the measurement (the uncalibrated radiocarbon determination is given either in the text or in the table referenced). For example, burning at Eton Rowing Lake is attested in 9180–8750 cal BC (95% probability; OxA-9411, 9560±55 BP), probably in 9130–8990 cal BC (36% probability) or 8930–8800 cal BC (32% probability).

All radiocarbon dates have been calibrated using IntCal13 (Reimer et al. 2013). Date ranges are given at 95% probability unless noted otherwise. Dates quoted by century or prefixed by 'c.' are informal date estimates derived from either Bayesian modelling or calibrated radiocarbon dates. For example, Mesolithic occupation at Star Carr began c. 9300 cal BC and the western platform was constructed in the middle of the 88th century cal BC (Figure 9.1).

PART 7
Fieldwork

'The physical remoteness of the site and its extreme unattractiveness, compounded by mud, ooze, rising water, and all too attentive clegs (small horseflies), only served to enhance the morale of the party. Under such conditions concentration on the job was the only way out.'

(Clark 1972, 10–18)

Methods, Aims and Objectives

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Becky Knight, Aimée Little, Ian Panter, James Rackham, Anita Radini,
Charlotte Rowley, Maisie Taylor and Emma Tong

Introduction

The fieldwork methods were, by necessity, reflexive, evolving over time, as the results from one season went on to inform the strategy that was adopted in the following year. The fieldwork strategy and methodology were enhanced further by the close working relationship that was established with the specialists who worked on the project, many of whom had become an integral part of the excavation team by 2013, and some considerably earlier. From 2013–2015, drawing on the experiences of the previous phase of work, many of the specialists that would be involved in the post-excavation analysis were on site throughout each season and worked in an on-site laboratory (Figure 15.1). They also took a lead role in the excavations: this included the project zooarchaeologist, and the antler, wood and flint specialists. Detailed methodologies for the collection of samples and materials were provided by the other relevant specialists who provided training for members of the excavation team and regularly visited the site.

   This approach has had several important benefits for the project. First, it meant that material was excavated and recorded either by the relevant specialist or under their direct supervision, which ensured that all necessary data was collected on site and that the specialist was already familiar with the material prior to post-excavation analysis. Second, material that might be damaged through the process of excavating it could be recorded in situ and then lifted by specialists. Third, it meant that recording and sampling strategies for specific deposits or assemblages, grounded in both specialist knowledge and prior experience, could be quickly and effectively established on site. Finally, the integration of specialists within the excavation team allowed them to share knowledge and experience with other site staff. This helped to create a confident, well-informed and highly motivated excavation team, who could provide considerable assistance to the specialists. Altogether, this reflexive approach was to prove invaluable during the excavations given the large quantities of worked wood and faunal material encountered in the wetland areas.

Figure 15 (page 1): Maisie Taylor and Michael Bamforth recording wood on site (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 15.1: Analysis being conducted in one of the on-site laboratories by Charlotte Rowley (Copyright Star Carr Project, CC BY-NC 4.0).

The project design for the second phase of excavation, written in 2011 for the European Research Council grant, and for English Heritage, aimed at going beyond 'state-of-the-art' and implementing a range of methods that could aid in mapping activity areas across the site of Star Carr through time. This involved the integrated analyses of, for example, 3D plotting of all finds and examination of artefacts and ecofacts using 'forensic approaches' such as geochemistry, microwear and residue analysis.

This chapter first sets out the aims and objectives for the work at Star Carr. It then presents the main methods used on site for collecting data and the approach taken for sampling sediments. In most cases, post-excavation methods are provided in individual chapters; however, some methods have been applied in several chapters and so are reported here to avoid repetition. Project designs, assessment reports and specialist reports are archived in the Archaeological Data Service (https://doi.org/10.5284/1041580).

Aims and objectives

The principal aim of the phase 2 investigations, as part of the Historic England and European Research Council funded POSTGLACIAL project, has been to implement an interdisciplinary, high-resolution approach to understanding hunter-gatherer lifeways within the context of climate and environment change during the early part of the postglacial period (c. 9600–8000 cal BC), with five major objectives:

1. To push forward the frontiers of knowledge of postglacial archaeology;
2. To conduct high-resolution, multi-proxy analyses of climatic and environmental change;

3. To set a new benchmark for the analysis of archaeological deposits by developing an integrated 'forensic' approach to the analysis of the artefactual and molecular debris left by human activity;
4. To integrate climate signals with environmental change and human activity;
5. To identify and implement best practice for improving public understanding of the Mesolithic period and Star Carr and to ensure long term public benefit.

Climate and environmental change

Key questions:

- What is the climatic and environmental sequence from the Younger Dryas to the mid Holocene in this region?
- Can we detect and define a chronologically high-resolution temperature signal for abrupt environmental signals seen in ice core records within the palaeo-lake records?
- Can we link this to local environmental responses such as open grassland and birch woodland, and if so, how does this link with human occupation at Star Carr?

Objectives:

- To produce two deep master records for the lake covering the Holocene and Lateglacial;
- To examine palaeoenvironmental change through the analysis of pollen, plant macrofossils and geolithology;
- To determine lake hydrology and palaeoclimate through lake analysis of carbonates, carbonate-clays and oxygen isotopes;
- To estimate palaeotemperature through the examination of chironomid fossils;
- To determine chronology from microtephra analyses, radiocarbon dating and Bayesian age modelling;
- To link results with the archaeological record.

Spatial and temporal mapping of occupation activities at Star Carr

Key questions:

- What is the spatial patterning of activities and occupation on the dryland?
- What types of structures can be found on the dryland and what was their function?
- How are the flint tools and debris distributed?
- What were the tools used for and what is the relationship between tool form and function?
- What other 'invisible' activity areas can be detected?
- How was the timber platform/trackway constructed and what was its function?
- How do temporal changes in activity relate to changing climate and local environmental conditions?
- What is the nature of the relationship between the dryland and the lake shore activities?

Objectives:

- To ground-truth geophysical anomalies on the dryland and to determine whether other structures exist;
- To use forensic approaches for reconstructing the cultural biography of the stone and organic tools through the microwear and residue analysis;
- To examine the patterning of micro-debris (bone chips, flint flakes, burnt flint, etc);
- To distinguish discrete episodes of human activity through geochemical survey and micromorphology of the sediments;
- To conduct fine-resolution palaeoenvironment analysis;
- To sample for microtephra in order to link with climatic records from the lake sequence;
- To excavate the extent of the timber platform;

- To create a 3D model of activities across the excavated area;
- To continue to interrogate the degradation processes.

Public benefit

Key questions:

- In what ways is the Mesolithic presented to the public in Britain?
- In what ways is the Mesolithic presented to the public in other European countries, particularly Denmark?
- Which methods of presenting the past are best applicable to the Mesolithic?
- Which aspects of Mesolithic lifeways are more likely to engage a public audience?
- How effective are different types of outreach activities?

Objectives:

- To investigate the ways in which Mesolithic research is best communicated in Europe;
- To devise and put in place a comprehensive outreach strategy for the entire course of the archaeological excavation;
- To engage a wide range of groups including local school children, local societies and national and international audiences through the media;
- To measure the impact of activities on public value;
- To raise the profile of the Mesolithic period, both locally in the Vale of Pickering and nationally.

Field methods

Survey

Throughout the project all surveying was undertaken using Leica TC407 and Leica TS02 total stations set up on a network of fixed points that had been tied into the British Ordnance Survey grid using a Leica System 500 GPS using realtime kinematic correction (10–20 mm precision). This allowed all spatial data (including the locations of finds, planning points, section nails, spot heights, trench edges, samples etc) to be collected using a common coordinate system. Each survey point was coded with a unique numeric identifier, a brief description (e.g. Find, Spot Height, Sample etc) and the relevant identifier for the point being taken (e.g. Find or Sample Number). The survey records were then linked to the various specialist databases and the combined data managed using ArcGIS. All final registers are archived in the Archaeological Data Service (https://doi.org/10.5284/1041580).

   The basal topography of the area around the site, and the sequence of deposits that had formed over it, was recorded by augering, using a 25 mm diameter gouge auger. The dryland areas and lake margins were mapped at 10 m intervals, and two long transects were recorded into the deeper parts of the Star Carr embayment. The character of each deposit and its depths from the modern ground surface was recorded by hand, and the three-dimensional location of the auger point was recorded using the total station. The data for the heights of the basal topography were added to the results of auger surveys carried out by the Seamer Carr Project and the Vale of Pickering Research Trust at sites in the surrounding area (Lane & Schadla-Hall forthcoming) and more surveys of Flixton School House Farm and the eastern end of the lake basin (Taylor 2012). This was then processed in ArcGIS to produce a Digital Terrain Model and contour maps for the site and the surrounding area. Geomagnetic and resistance surveys were conducted in 2009 and 2010 (as reported in Chapter 16).

Excavation

All trenches on the dryland were de-turfed by hand, and then excavated by trowel, due to the presence of worked flint within the topsoil and peat. This was carried out in controlled, single-surface excavation of c. 20 mm

spits; however, where sedimentological boundaries were evident these were followed. The only exceptions were the parts of the site where redeposited sand and gravel, dredged from the River Hertford, had been dumped onto the old topsoil. This deposit was removed by a mechanical excavator under archaeological supervision, down to the level of the buried topsoil, which was then hand excavated as with other trenches on the dryland. Excavation continued into the basal, mineral substrate until no finds were recorded in five successive spits.

Between 2004–2007, the wetland trenches were de-turfed and excavated entirely by hand; the topsoil and upper humified peats removed by careful shovelling, the lower peats excavated by trowel. By 2008 it was clear that there were no finds within the upper peats, and after this date these deposits were removed by mechanical excavator under archaeological supervision. As with the dryland areas, the lower peats were excavated over a single, flat surface until a new context boundary was encountered. The context was then exposed in full before excavation continued.

Each context was given a unique number. Detailed sediment descriptions were undertaken of all contexts encountered, and context descriptions were written on a pro forma context record sheet. Mineral sediments were described on the basis of their principal grain size (gravel, coarse sand, fine sand, silt and clay, or combinations thereof), sorting (well sorted to poorly sorted) and inclusions (material forming less than 10% of the deposit), following the procedures outlined in the MoLAS handbook (Museum of London Archaeology Service 1994). From 2010 the recording of the wetland deposits followed a simplified, longhand version of the Troels-Smith method (1953). All cut features were recorded in plan, half sectioned, and the section was hand drawn at an appropriate scale. Plans were drawn in relation to planning points that were recorded three dimensionally using the total station. Likewise, all section datum points were recorded using the total station. Registers for contexts, drawings, samples, photographs, levels and recorded finds were kept on recording sheets. All records were entered into Excel spreadsheets during each season and checked in post-excavation.

Finds recording on site

Protocol

All wood, bone and antler was excavated using wooden tools to avoid damage. All finds from stratified contexts were bagged as an individual find with a unique number (using pre-printed labels and pre-written bags) and tagged in the ground for recording using the total station (Figure 15.2).

Lithics

Lithics found whilst removing or sieving topsoil were bagged by grid square, as was flint spall (small flint chips smaller than 10 mm). For all lithic material, excavators were asked to minimise the amount of handling the object encountered as this can potentially be damaging to the surface of the object, which can cause problems for microwear analysis. Lithics were washed as soon as possible to ensure that the sediment did not adhere, and as carefully as possible using clean water and fingertips rather than brushes, again to avoid damage. Hundreds of lithics were collected on site for residue analysis. Each lithic for residue analysis was not touched but lifted out of the ground by inserting the trowel into the deposit below the flint and levering the flint and adhering soil into a finds bag. In a separate bag, c. 5 g of the surrounding matrix was sampled. The lithics and soils were kept in cold storage prior to analysis. A sample of the lithics was selected for microscopic and chemical residue analyses, choosing artefacts with a high likelihood of containing anthropogenic residues, but also representing all major typological categories.

Wood

Assemblages of worked wood were excavated under the supervision of the wood specialists, MT and MB. All wood encountered was hand excavated using fingertip techniques and non-metal implements; usually wooden clay modelling tools. The excavation and analysis was carried out in accordance with Historic England

Figure 15.2: Tagging flint and recording it using a total station (Copyright Star Carr Project, CC BY-NC 4.0).

guidelines for the treatment of waterlogged wood (Brunning and Watson 2010) and recommendations made by the Society of Museum Archaeologists (1993) for the retention of waterlogged wood. Each discrete item was recorded individually using a pro forma wood recording sheet, based on the sheet developed by Fenland Archaeological Trust for the post-excavation recording of waterlogged wood. Every effort was made to refit broken or fragmented items. However, due to the nature of the material, the possibility remains that some discrete yet broken items may have been processed as their constituent parts as opposed to as a whole. The system of categorisation and interrogation developed by Taylor (1998a; 2001) has been adopted for the work reported in this volume.

Where possible, discrete structures and accumulations of wood were revealed fully in plan. Extensive root scatters were present along much of the lake edge, particularly in the base of the wood peat. Where present these were roughly revealed, sub-sampled and removed. Where in situ tree boles were encountered, these were individually recorded and located. All excavated wood was assigned a unique finds number and 3D located.

All extensive spreads and discrete structures were photographed and 3D models were produced using Agisoft Photoscan Pro. This was generally undertaken using DSLR cameras mounted on a tripod or an extendable pole, the exception to this being the eastern platform which was modelled by Dominic Powlesland using a drone-mounted compact digital camera. In addition, all spreads and structures were hand planned at 1:10. Prior to the 2014 season this was undertaken using planning points, hand tapes and planning frames. During the 2014 and 2015 seasons orthophotos were printed out at 1:10 and used as an underlay to produce a hand-drawn plan on site.

The wood was recorded by MT and MB, using a three-stage 'triage' system of data selection (Table 15.1). This concentrated the recording, sub-sampling and retention/discard process at the point of excavation. The metric

Type	Method	Location	Retained?	Information	Criteria	Aims	Typical Item
Basic	wood sheet	on site	sub-sample and discard	metric and conversion data	poor condition and/or no toolmarks or evidence for nature of woodworking	to provide data for statistical analysis of woodworking assemblage	roundwood
Full	wood sheet	on site	may be retained	metric, conversion and surface data	moderate condition and/or evidence for nature of woodworking	as above and to inform in terms of woodworking techniques	worked timber
Enhanced	wood sheet and illustration	on site and lab	retained for cleaning and further analysis	metric, conversion and surface data	good condition and/or toolmarks or evidence for nature of woodworking	as above and to inform in terms of woodworking techniques	heavily worked timber or artefact

Table 15.1: Details of three-stage 'triage' recording system.

data were measured with hand tools including rulers and tapes. The tool marks were measured using a profile gauge. All recorded items were sub-sampled to allow later identification to taxa via microscopic identification as necessary.

The rapid degradation of waterlogged wood of this antiquity when removed from the burial environment necessitated a rapid workflow. Several exceptions were made to the standard recording process. Where extensive spreads of natural roundwood were present, these were characterised and recorded via a c. 10% subsample. Where diffuse scatters of natural roundwood were encountered throughout deposits these were also subjected to characterisation and a c. 10% sub-sample was recorded in detail. Finally, the extensive layer of brushwood located around the western end of the western timber platform was subjected to rapid recording whereby each item was recorded only in terms of diameter, condition and presence/absence of bark.

Faunal remains

During the 2007 and 2008 seasons on the dryland some of the particularly friable faunal remains were lifted within small blocks of sediment for further cleaning in the laboratory. However, the sediment tended to turn to a concrete-like consistency which became virtually impossible to remove at a later date, even in conservation. Therefore, from 2013, where faunal remains were encountered on the dryland, the surrounding sediments were cleaned down to the base of the specimen to reveal the full extent of the remains. They were then assessed and recorded, i.e. identifications made where possible, by a zooarchaeologist or antler specialist and photographed. The specimen was then plinthed before lifting. Very poorly preserved specimens were covered in cling film and then several layers of wetted, plaster impregnated bandages, before being left to dry, and then lifted (Figure 15.3). In some cases wooden skewers were used within the bandages to strengthen them. In order to lift the specimens, they were undercut with a thin sheet of steel or a stiff plastic sheet and inverted onto its supportive mould. It was then left to completely harden in the on-site finds laboratory before removing the soil from the newly exposed underside and placing the whole mould into a storage bag, or a box with a bag round it. The bag was pierced several times to allow the specimen to breathe to avoid condensation and the build-up of mould.

Figure 15.3: Dryland bone being covered in plaster impregnated bandages by Becky Knight (Copyright Star Carr Project, CC BY-NC 4.0).

Faunal remains from the wetland were cleaned and recorded in situ before lifting, but generally did not need the plaster bandages because they were more robust. Because they were waterlogged they were bagged with some water from the trench and then stored in a refrigerator or cold store room.

In the laboratory, specimens were carefully washed using water, and specimens that had been excavated from the dryland were dry brushed using a very soft silicon brush. The waterlogged specimens were retained in bags of water and kept in the refrigerator or cold store. At various intervals, the water within the bags was discarded and exchanged with clean tap water so that the high levels of acid encountered within the specimens could be flushed away in an attempt to minimise further demineralisation.

Sieving and flotation strategy

Artefact retrieval

The sieving strategy on the dryland evolved through phase 1 as different types of context were encountered. Excavation spoil was sieved through a 4 mm mesh by grid square, employing a sampling strategy of one bucket in two, or sometimes one in three or four depending on the nature of the sediment and the density of finds. The backfill from Clark's trench was dry sieved in 2007 and 2010 in order to look for discarded artefacts or ecofacts but with very little success, and the artefacts which were found were fairly large bones or flint which had generally been dumped in a discrete area (Chapters 7 and 8). In addition, features and areas of interest (e.g. around artefact spreads such as flint or antler and in Clark's baulk) were 100% bulk sampled where possible for

flotation. Random samples for flotation were also taken across the site on several occasions, particularly when the dryland Mesolithic land surface began to emerge (see Chapter 32). In all cases the residues as well as the flot were sorted for the retrieval of, for example, microdebitage and microfauna as well as charred palaeobotanical remains (results in Chapters 7, 8 and 32).

During the first phase of fieldwork there was some controversy as to whether the methods of excavation employed on the site, and particularly in the wetland, would pick up small and delicate finds e.g. small or broken beads, microfaunal remains especially teeth, amber, fish bones, leather clothing, containers, fragments of string, thong or twine, traces of mastic for hafting tools or remnants of woven textiles. In response, two methods were tested: block lifting of sediment and wet sieving.

In 2007 a block of sediment was lifted from SC24, measuring approximately 0.6 m square and 0.5 m in height. The excavation was carried out at the University of York by PH under the supervision of NM. The sediment was removed in spits of c. 10 mm thickness and 53 layers were excavated in total. Overall the excavation took over 20 working weeks to complete and no data was recovered that had not been recovered by other means within the trench (Hadley et al. 2010). One of the key arguments against using this method again was that the sediments had become so susceptible to oxidation that excavating them slowly in a laboratory was creating further extensive damage. In addition, the kinds of materials that were found in the block could have been found through other methods, including excavation in the field and flotation. There was also clear evidence that the damage from cutting the block distorted the metrical data for wood needed for statistical analysis. Finally, the reduction of the site to small blocks obscures the more extensive pattern of deposition, which has since proved crucial in the interpretation of how and why the material was originally deposited.

In 2010, wet sieving was carried out for trowelled sediment from all trenches by collecting buckets of spoil (Figure 15.4). Column samples were also taken in blocks from SC24, VP85A and SC33. Here blocks of sediments were removed and carefully disaggregated at the sieves. Peat is a very difficult material to pass through sieves; it has variable buoyancy, individual clasts absorb and release water very slowly and the clasts are often fairly durable and do not break down in water in the way a concretion of mineral soil will. Sample processing, therefore, requires a great deal of manual disaggregation. This took place in tank 1. The division of the samples into >20 mm, 20–10 mm and 10–4 mm fractions took place in tank 2. The careful manual disaggregation of the sediment provided the opportunity to look for any unusual and fragile material. The speed of the manual disaggregation of a sample was very variable, depending on the nature of the sediment, the excavator, the sievers and conditions (e.g. weather and light levels). The tank fitted with a 1 mm mesh was also significantly slower than the one with a 2 mm mesh. The less-experienced sievers tended to be over-cautious and thus much material was retained that the specialists subsequently deemed natural or undiagnostic.

The initial plan to sieve 50% of the excavated sediment was reduced to 33% after the first day of processing and 25% halfway through the second day because of the time-intensive nature of the activity. An exception to this was made for the flint scatter encountered in SC33 from which 100% of the excavated material was sieved.

Chemical disaggregators are used by many environmental archaeologists, particularly in the processing of heavy clay soils. Tests were run to see whether the addition of sodium phosphate affected the processing or results from one of the column samples. Half the divided sample was soaked for approximately 72 hours in water and the other half in a 4% sodium phosphate solution. No significant differences were noted in the ease or speed of processing.

Of the 12 column samples the sieve teams examined, possible finds from 11 of the samples were retained for specialist analysis; however, on examination none of them turned out to be of archaeological value (e.g. natural pieces of wood as opposed to wood chips). From the 141 spoil samples processed there were three types of finds: flint, worked wood and charcoal. The sievers produced 99 possible finds but the specialists reduced the overall number of finds to 30, most of which was flint which came from a scatter in trench SC33 and could have been sieved using conventional methods much more quickly and efficiently. The five pieces of charcoal found in the sieve are not particularly useful out of context and it was deemed more sensible to hand-pick these on site and 3D locate them. Importantly, fragments of potentially worked wood in the samples were far less informative than those recovered in the trenches; this is due to the loss of spatial information but also because even the gentlest sieving abraded key surfaces. It was agreed with English Heritage/Historic England that wet-sieving (using a 4 mm mesh) would be limited to areas where flint scatters are present or where the deposits were observed as being different to those previously excavated.

Figure 15.4: Wet sieving. From left to right: Keith Emerick (English Heritage/Historic England), James Rackham and Pat Hadley (Copyright Star Carr Project, CC BY-NC 4.0).

Palaeoenvironmental sampling

Contiguous sequences of samples were taken for insect and plant macrofossils through the entire sequence of wetland deposits at three locations in order to establish the character of the local environment throughout the period the site was occupied. Shorter and less complete sets of samples were taken from deposits containing significant assemblages of archaeological material to provide more information on the local environmental context (see Chapter 19). In addition, 75 centimetres of sediment were recovered in aluminium alloy monolith tins from the exposed section from SC24 in 2010 for pollen analysis which further demonstrated degradation of the deposits and which has been published elsewhere (Albert et al. 2016).

Carbonised plant material

In order to sample all archaeological features with strong potential for the recovery of charred remains, a sampling strategy and flotation programme was adopted following English Heritage/Historic England guidelines (Campbell et al. 2011), supervised by BT and AR. In total 411 bulk samples were taken and 172 charcoal fragments were handpicked (Chapter 32). Sampling was undertaken on the deposits from archaeological features (fills of pits and postholes), sediments containing dense scatters of lithic material and spot-checks across the dryland part of the site (Peterson 2009). In each case, bulk samples were taken during the excavations of the archaeological feature or finds scatters and stored in sample bags or sealed tubs.

Soil samples that were below four litres in volume were sieved using the bucket flot method, to maximise the recovery of remains: 1) the entire sample is placed in a small bucket, 2) warm water is then added to the sample, 3) it is allowed to sink into the soil, and a gentle swirling movement is then applied and in this way the sample is gently washed over a 0.3 mm sieve, allowing charred remains to be collected and the fraction in the bucket

washed, 4) the operation is repeated until nothing floats anymore, 5) the two fractions, the one in the 0.3 mm sieve and the one at the bottom of the bucket, are then dried and sorted.

Larger samples were sieved in a tank using 0.5 mm mesh and flotation into a 0.3 mm mesh sieve. Initially a slightly larger mesh was tried; however, this was found to be inadequate for capturing the very small charcoal fragments. Residues were all air dried and separated on a 4 mm mesh riddle. The flotation fractions were transferred from the sieve into plastic boxes and air dried. All fractions were scanned and sorted for analysis by ET. An acupuncture needle was used to fracture charcoal fractions in the correct sections needed to view anatomical features and IDs were made using the criteria presented in the wood section below.

Soils analysis

A number of micromorphological studies have been carried out: by Richard MacPhail in 2006 and 2007 and Charles French in 2008, 2010, 2014 and 2015 (reports archived in ADS). Judgemental samples were taken where the excavations exposed suitable but thin buried soil contexts, especially associated with the possible structures on the dryland. These samples were prepared for thin section analysis (after Murphy 1986) and described using the accepted terminology of Bullock et al. (1985) and Stoops (2003).

Soil geochemistry was carried out in 2008 and 2010 by Steve Boreham and colleagues (2011a; 2011b), which involved analysing sediments which had been augered prior to excavation and the investigation of possible 'halo' effects caused by excavation trenches (see Chapter 22). Geochemical analysis was also undertaken around the central structure and western structure as described in Chapter 21.

Post-excavation methods

Microwear

Microwear is used here instead of use-wear as the former places emphasis on the full range of wear traces visible on a tool, inclusive of manufacture, hafting, post-depositional modification and so forth. Microwear traces were first analysed at low power (×10–×100) followed by high-power magnification at ×100–×500, with eye-piece magnifications at ×16. This combined approach (low and high power) has long been recommended as best practice by most microwear specialists (e.g. Keeley 1980; Tringham et al. 1974; van Gijn 1990). High-power analysis was undertaken on a Leica DM1750M reflected light microscope for the smaller pieces and a Leica DM2500 MH long working distance microscope for larger pieces. Micrographs were taken, when relevant, using Leica LAS Z-stack software. The Leiden University Laboratory for Artefact Studies co-ordinate system was used to record the location of wear traces. An extensive experimental programme was undertaken at the York Experimental Archaeology Research (YEAR) Centre in conjunction with the microscopic analysis.

Flint was washed as part of the post-excavation procedure; however, to remove any remaining surface grime, some pieces were placed into plastic bags with detergent and water before being placed into an ultrasonic tank to agitate for 15 minutes. Cotton wool dipped in acetone was also used to clean the surface when necessary. Regular cross-reference was made with replica flint tools used in actualistic tasks involving contact materials which we know existed at Star Carr, either directly (e.g. birch wood) or indirectly (e.g. hide from deer), which helped confirm the identification of specific wear traces.

A number of osseous artefacts and wooden artefacts were analysed for wear traces. These artefacts are stored in cool, wet conditions, mimicking their burial environment. Therefore, before an organic artefact could be analysed for microwear, it was first necessary to let it dry out to a state in which micropolish, if present, could be detected. However, if left to dry for too long the condition of the artefact is compromised. This presented a very narrow window of opportunity between when the artefact was dry enough to view surface detail and the point at which it over-dried, potentially causing irreparable damage. This required careful management, involving limited air drying and rewetting, seeking an optimum working window whilst limiting physical damage due to drying.

Figure 15.5: Burial of experimentally produced residues on replica flint flakes by Shannon Croft to test their survival at Star Carr (Sourced from Milner et al. 2016, *Internet Archaeology* licenced under CC-BY 2.0).

Residue analysis

Before archaeological lithics were analysed for in situ microscopic residues, there was a question as to which residue types could be expected to preserve on artefacts, particularly in acidic conditions. Thus, an experimental programme was carried out by Croft et al. (2016) which showed that conifer resin, red ochre, softwood tissue, bird feathers and squirrel hair residues on lithics survived after nearly a year of being buried in both the dry and wetland contexts at Star Carr, as well as within an off-site control context (Figure 15.5). The extent to which microscopic residues could be diagnostically identified was also investigated in this study.

The methods used for the archaeological tools consisted of microscopic analysis followed by several chemical analyses to determine the origin of specific residue types. A sample of 139 flint tools was first scanned with a reflected visible light microscope (VLM, Leica DM1750 M). All edges as well as the dorsal and ventral surfaces of the tools were scanned for residues using objectives ranging from ×10 to ×100. Microscopic visual characteristics recorded for each residue included colour, shape, texture, brightness, reflectivity, transparency, structural patterns, presence of identifiable cell margins (where possible), presence of microcrystals and their colour and habit, and shape of residue deposit edges (circular, ragged, angular etc). Residue locations were documented and z-stacked images taken using the Leica Application Suite program Montage. Anti-contamination protocols were followed during all phases of residue analyses.

After potential residues were found microscopically, several chemical characterisation techniques were trialled to test the identification of microscopic residues that lack diagnostic structure: gas chromatography mass spectrometry (GC-MS), confocal Micro-Raman, scanning electron microscopy in backscattered electron mode (SEM-BSE) and with elemental microanalysis (SEM-EDS), and Fourier transform infrared microspectroscopy (FTIRM). The results of this research calls into question the reliability of residue identification by visual means

only, since most hypotheses of residue identity based on microscopic observations were unsupported by the chemical data (Croft 2017).

Wood identification

Sub-samples of wood for identification were analysed in the laboratory. In the first phase of excavation a small sample of the wood was identified by Allan Hall. The rest of the wood and charcoal has been identified by AR, with the exception of SA, who identified the wooden artefacts (Chapter 29), and Dana Challinor, who identified some of the wood prior to dating (Chapter 17). Preservation of waterlogged wood varied, but overall the identification procedures were challenging due to the presence of pyrite growing in the wood. Fungal spores and hyphae had also produced damage and iron and manganese deposits had made the wood very dark. The extensive damage of the wood made sectioning, necessary for the identification, very difficult if not impossible.

In order to maximise the identifications, the following protocol was developed. Waterlogged wood samples were inspected at magnification up to ×20, to first assess ring curvature and counts, and second to identify areas of the wood where damage was minimal. Less damaged areas of wood were sub-sampled in the form of small blocks. The blocks were kept overnight in a solution of 20% HCl, in order to remove the deposit of pyrite (soluble in this solution) and to 'bleach' the wood. The block was then removed and put into a warm solution of 80% glycerol and ultrapure water, to penetrate the wood. The block was then placed in a petri dish, covered with aluminium foil and placed in a refrigerator at 2°C. This allowed the glycerol to become almost solid, while still tender, and it made it possible to take radial, tangential and transversal sections of the wood necessary to observe the structural organisation of wood elements, and to allow identification.

Wood as well as charcoal identifications were made following the anatomical keys by Schweingruber (1982; 1990), and these were complemented by online resources: http://www.woodanatomy.ch/ (accessed 1st March 2017). Identifications were also confirmed with a specially built reference collection of modern material of British wood species available at the Archaeobotany Lab at the University of York. This reference collection consists of both mounted slides (for waterlogged wood identification) and artificially charred fragments of wood necessary for comparison when identification is conducted on charcoal fragments. The age of the wood is based on absolute ring count wherever possible, or for charcoal on ring curvature when the pith was missing. Samples were viewed using a Zeiss AX10 compound microscope fitted with both incident and transmitted light, and at magnification up to ×500 as well as a Leica SM-LUX transmitted light microscope with ×20, ×40, ×200 and ×400 magnification. Botanical names follow Stace (2010).

Many species of wood do not have anatomical features that allow precise identification; for example, oaks (*Quercus* spp.), willows (*Salix* spp.), poplars (*Populus* spp.) and birches (*Betula* spp.). Likewise, it is not always possible to distinguish between willow and poplar, as both belong to the same botanical family (Salicaceae, here described as *Salix/Populus*) and have similar anatomical characteristics. Indeed, willow and poplar are often considered impossible to separate in the archaeological record; however, in willows, the presence of both procumbent and upright ray cells gives it heterocellular rays, and where these cells are missing or not clearly visible identification is not possible. Aspen catkin scales were found on site, pointing to the presence of aspen. Wood with securely heterogeneous ray cells is *Salix* spp. Wood with securely homogenous ray cells is *Populus* spp., which has been interpreted as aspen (*Populus tremula*) based on the presence of its distinctive catkin scales in the macrofossil samples taken from the lake edge peats. Where wood or charcoal were badly preserved and secure identification was not possible, we assigned the remains to *Salix/Populus*. Finally, while it was often possible to distinguish birch wood and charcoal (*Betula* sp.), where this was not achieved due to preservation, the identification is presented as birch/alder/hazel (*Betula/Alnus/Corylus)*.

Conclusions

The methods used in this project have developed over time, using a reflexive method as encouraged by English Heritage/Historic England. The fact that specialists have been actively involved from the project design stage, and have worked alongside the excavation team on site, has made a very positive contribution to the project and all parties have substantially benefited. Hopefully, in future Mesolithic excavations this approach will be used again.

Geophysical Survey

Edward Blinkhorn and Dominic Powlesland

Introduction

The traditional application of shallow geophysical survey techniques has been largely restricted to identifying feature-dominated archaeology from the Neolithic onwards, although extinct landforms are frequently identified and there is no reason to exclude the Early Holocene from the scope of application. Due to the suspected extensive nature of occupation at Star Carr, the identification of a Mesolithic structure in 2008 and the (increasingly) shallow depths of peat and plough soil overlying archaeological deposits, the opportunity was taken to investigate the viability of geophysical survey at the site. This chapter reports on the geomagnetic and resistance surveys conducted in 2009 and 2010 (Figure 16.1).

The survey areas are mapped by the British Geological Survey (2016) as mudstones of the Speeton Clay Formation, overlain by either sands and gravels (uncertain age and origin) in 'dryland' areas or lacustrine deposits (clay, silt and sand) in the lake proper. However, archaeological investigations have better refined local mapping of the superficial deposits in the immediate area of the former Lake Flixton (Chapters 3 and 4) and the complex variations in these can significantly influence geophysical readings.

Historic mapping shows minimal changes in the local area. A field boundary dividing the southern field at Star Carr intermittently disappears and is reinstated between the 1850s and 1990s. 'Star Carr Bridge' is mapped c. 110 m to the west of the modern metal bridge until the 1970s, from which a bridleway leads southwest in the southern field in the 1950s, and north to Ling Lane until the 1910s. The northern field remains otherwise unchanged.

Background to Mesolithic Geophysics and work in the Vale of Pickering

The Mesolithic is situated at a crossroads in archaeological prospection methods. Although the dynamic reworking of deposits common in the Pleistocene is far more prevalent than in Holocene contexts, landscape processes in the Early Holocene have led to sites becoming deeply buried or truncated. For these reasons, a geomorphological approach to geophysical survey might be deemed most appropriate. Nevertheless, detection of archaeological features at an early stage of investigation at Mesolithic sites, conventionally considered to be
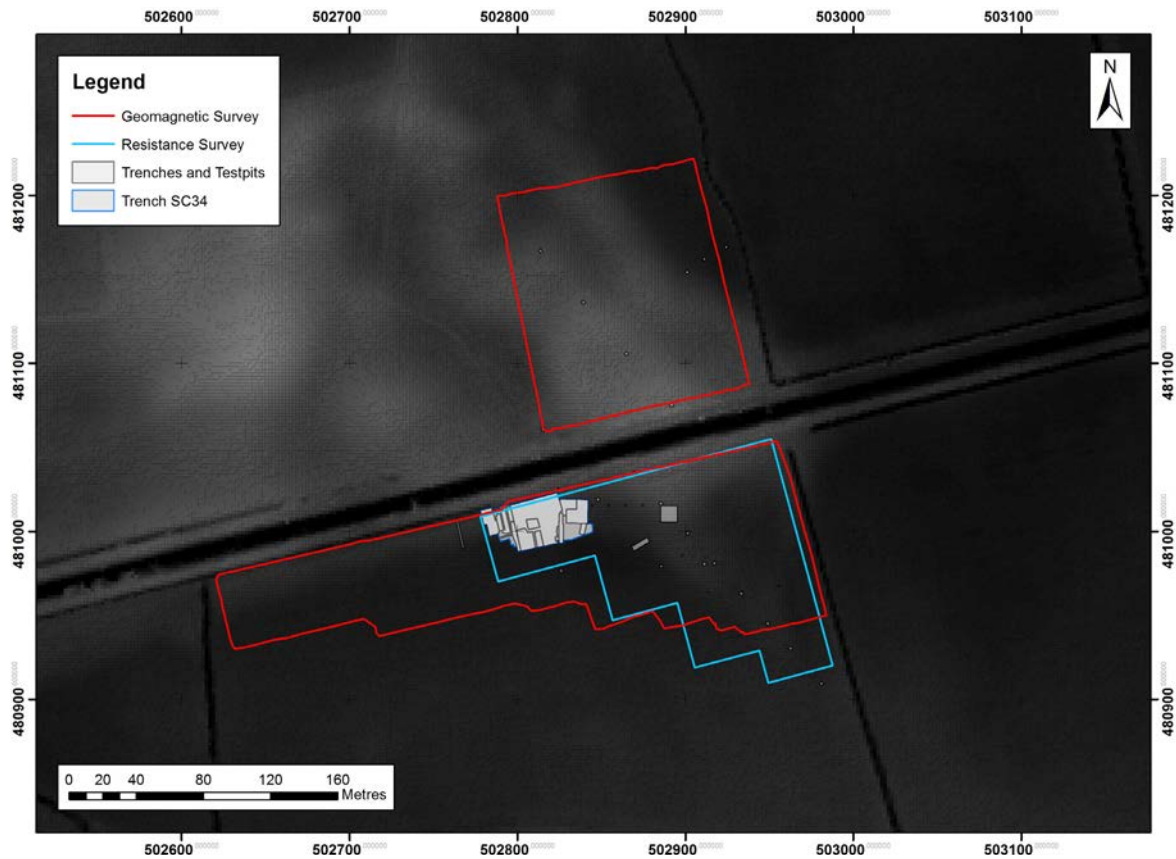
Figure 16.1: Plot of the survey locations and LiDAR topography (Copyright Edward Blinkhorn, CC BY-NC 4.0).

impoverished of such elements, is of equivalent importance in discerning foci of activity and scientific opportunities. However, identifying Mesolithic sites is difficult where excavation is not already underway, sediments are not exposed through erosion or the landscape context is locally unmatched. Indeed, a great majority of the best-known sites are discovered serendipitously rather than through concerted prospection.

Therefore, there is little comparative evidence for how Mesolithic archaeology might be manifested in geophysical survey output. The nature of Mesolithic features is poorly understood and it is the contrast deriving from archaeological features which make surveys such as those in the western Vale of Pickering (e.g. Powlesland et al. 2006) so rich. Additionally, the feature-based archaeology of later prehistory and the historic periods, its durability and detectability through remote prospection techniques such as aerial photography and topographic survey, amongst others, has facilitated the creation of large corpuses of data on form. Ground-truthing of these forms means that some degree of confidence can be ascribed to the interpretation of (Iron Age) square barrows, for instance, and thus a sense of antiquity can be discerned. However, hunter-gatherer archaeology tends to be more ephemeral. Moreover, Mesolithic archaeology is frequently found within multi-period landscapes yet has been buried for considerably longer, therefore increasing the potential for deformation of the target deposits.

Attempts have been made at a number of sites to incorporate more widely used geophysical survey techniques to detect Mesolithic archaeology. In the British Isles, structures discovered at Howick (Biggins 2007) and East Barns (Gooder 2007), and the pit identified on the Kingsdale Head project (Melton et al. 2014), all yielded strong, if diagnostically unremarkable, subround positive magnetic signals which are inherently undateable without further evidence.

Results from the Scottish Mesolithic Geophysical Survey Project (Finlay 2007) have yet to be widely published excepting Sand (Finlay and McAllen 2008), which unfortunately yielded negative results. Short reports reveal that at Port Lobh 1 on Colonsay a shell midden was identified and ground-truthed and at Newtown on

Islay (Finlay 2004) significant anomalies were identified close to a known Mesolithic site. In the Iberian Peninsula, magnetometry has successfully located both shell middens (Arias et al. 2017) and structures (Arias et al. 2015). At the Mesolithic hazelnut-roasting site at Duvensee, Germany (Hausmann et al. 2012), several survey techniques were trialled and while geomorphological modelling seems to have been the intention, significant geomagnetic anomalies were identified.

Unpublished work at Flixton School House to the east of Star Carr is probably the best analogue for the surveys presented below. Aside from modern ferrous anomalies, magnetometry responded most strongly to the probable plough disturbance on sub-surface topographical slopes, and magnetic enhancement was identified along the northern periphery of the island/dryland. Scattered discrete positive anomalies elsewhere across dryland areas may represent buried features—potential counterparts to those already excavated (Taylor and Gray Jones 2009).

Successes across Europe prove that magnetometry and resistance survey can be considered a valuable tool in Mesolithic prospection. However, in all of the above cases, the results are difficult to interpret, require close reading of the local geology, and beyond elevated magnetic responses in sizeable or strongly heat-affected features, Mesolithic features are near impossible to categorise through geophysical survey where similar features have not been identified locally.

Technique selection

Resistance and geomagnetic survey were selected to rapidly assess the Star Carr landscape prior to excavation, in the case of the former prioritising coverage over resolution. In addition to contributing to the growing number of surveys targeting Mesolithic deposits, these techniques are used widely in developer-funded contexts where a large proportion of Mesolithic archaeology is now identified (Blinkhorn 2012). Their selection addresses Strategic Theme S2.1 of the Mesolithic Research and Conservation Framework (Blinkhorn and Milner 2013): to explore the extent and ways in which geophysical survey and aerial remote sensing techniques can be used to understand the presence and nature of Mesolithic archaeology.

As electrical and magnetic techniques are reliant on different phenomena, it is often the case that one technique will respond to subsurface remains where the other does not, though differences can be changeable dependent on depth of target archaeology, their make-up (differentially porous or magnetic sediments), ground conditions, weather conditions, proximity of highly magnetic materials, and local bedrock and superficial geology.

Aims and objectives

Both archaeological features and a detailed reading of the local superficial geology and soils were considered the main targets of the surveys. The aims of the surveys were to determine the presence or absence, nature and extent of potential archaeological features within the survey area to inform both fieldwork and site management.

Methods

Resistance

The 1.56 ha resistance survey was undertaken in 2010 by one of the authors (EB) assisted by students from the Universities of York and Manchester. Land use had recently changed from crop to improved pasture and at the time of the survey was used for cattle grazing. Whilst the survey was underway an electrified fence was erected to restrict livestock access to the area marked for excavation. The survey area was situated over gently undulating ground at a mean O.D. of 26 m. Whilst the summer was generally dry, a day of rain had fallen in the area a week prior to the onset of the survey.

A 20 m grid was established across the survey area using a Leica total station theodolite (TST) along the baselines and corners, supplemented by tape-measured triangulated points, and were arranged to cover as much

of the dryland peninsula as possible in the north-eastern portion of the Star Carr field. Measurements of earth resistance were determined using a Geoscan RM15 resistance meter with a mobile twin probe separation of 0.5 m, giving a maximum depth of readings of 0.75 m (Gaffney and Gater 2003, 32). A zig-zag traverse scheme was employed and data were logged in 20 m grid units. The instrument sensitivity was set to 0.1 ohm, the sample interval to 1 m and the traverse interval to 1.0 m, thus providing 400 sample measurements per 20 m grid unit.

Data were downloaded on site and Geoplot v.3.00t software was used to process the geophysical data as greyscale images. *EdgeMatch* was the sole processing function used. This function is used to remove grid edge discontinuities which may be present in twin electrode resistance surveys as a result of improper placement of the remote probes, here used to eliminate discontinuities in data acquisition. Although position of both remote and mobile probes was kept consistent when moving the former, exact placement cannot be guaranteed. However, it is possible that the discontinuities are instead a result of moisture loss from the peat.

Magnetometry

The Landscape Research Centre (LRC) assisted the POSTGLACIAL project by loaning equipment and processing the data from two surveys; that over the Star Carr site itself (LRC Site 498) and part of the field to the north of the Hertford Cut (LRC Site 497). The surveys at sites 497 (c. 1.68 ha) and 498 (c. 2.45 ha) were carried out by Hayley Saul (University of York) in February 2009 in cool overcast conditions, following heavy snowfall at the beginning of the month.

The north field was put down to grass though coverage was patchy across the area surveyed, and the ground surface was locally undulating with <150 mm sods and molehills. The survey area was bounded to the east by a drainage channel banked by reeds and incorporating some ferrous litter, to the southwest by a track, and to the south by the Hertford Cut banked by trees and hedges incorporating a barbed wire fence between 1.2 m and 2.1 m high. A drop in topography along a SE-NW axis in the northeast of the survey was noted, the land surface differing by c. 1.0 m.

The south field was laid to pasture with extensive disturbance at the site of trench SC23 and to the southeast, where a large puddle had survived since the 2008 excavation season. The ground surface was wet, locally muddy and undulating with molehills. The survey area was bounded to the north by a hedge c. 1.8 m high and, beyond, the Hertford Cut. A large metal trough was positioned at the northern limit of the survey, to the northwest of SC24. Significant variations in topography were noted across the survey area.

The LRC primarily uses a *Foerster Ferex 4.032 DLG* 4-probe fluxgate gradiometer array, mounted upon a wheeled cart for geomagnetic surveys. The cart is designed to support survey covering large areas, and rather than rely upon hand surveyed and laid out survey grids collecting data on an estimated grid, relying upon the walking speed of the surveyor, the Foerster instrument employs a real time Kinematic GPS to record spatial data, which allows precise positioning of each data point with a nominal 20 mm precision. The instrument, which collects data within a 0.2 nT (nanoTesla) sensitivity range, is set to log data at 0.10 m intervals along the survey traverse axis, recording the magnetic values of each of the four probes spaced at 0.50 m intervals covering a 2 m span, and provides a maximum depth of readings of 1–2 m. The data density at 20 readings per square gives better definition to any magnetic anomalies recorded than we see in conventional surveys based on data collected at 0.25 × 1 m intervals. The resulting data, whilst spatially very precisely located, requires more extensive processing than conventional gridded data. The processing generates a triangulated surface model of the magnetic response which is then intersected at regular intervals to create the resulting geo-referenced magnetic survey image. The processing, generation and spatial integration of the survey images is undertaken using G-Sys (a proprietary Geographic Database Management program used by the LRC which can also display, process and present digitised plans and images). The fully processed files are archived in TIFF and PNG formats with supporting location information held in linked text files. The resulting data files are also saved in kml or kmz files for use within Google Earth.

During the processing, the geomagnetic data is re-scaled through simple multiplication by a factor of 10 to minimise any potential problems resulting from mapping the nanoTesla values to 8-bit greyscale images. The surveys covered in this report are based upon magnetic values of +12.8 nT and -12.8 nT whilst out of range values are clipped prior to full processing. The use of the Kinematic GPS, employing real-time corrections, generates spatial referencing data on the ordnance survey OSGB36 national grid.

Survey results

Interpretations made below should be read in combination with Figures 16.2–16.5. Not all anomalies are referred to in the text, nor are all anomalies marked in the Figures. Dipolar anomalies are presumed to come from recent agricultural land-use.

North field

Data in the field to the north of the Hertford Cut is dominated by a series of E-W (Figure 16.3, M1) and NE-SW (Figure 16.3, M2) linear anomalies, almost certainly with modern agricultural origins. Aerial imagery (Google Earth imagery date 29th October 2008) shows a close spaced but intermittent NE-SW linear scheme of linear features and a wider spaced E-W series of crop marks. The former regime dominates across the survey although the E-W trends become more prominent to the south. Considering the recent potato crop in this field it is highly likely that both subsoiling and potato harvesting are responsible for the anomalies discussed.

To the northeast the linear trends are lost and an enhanced NW-SE signal coincides with a drop in topography. Agricultural activity can therefore be thought to create disturbed linear signals on dryland areas and become almost invisible in the peat of the lake. The discontinuity of these may be a result of deeper geomorphological features on the dryland where agricultural machinery does not disturb the solid substrate. One such feature is highlighted by an irregular trend of enhanced readings (Figure 16.3, M3), partnered by a NNE-SSW example to the west (Figure 16.3, M4).

Whilst noise created by modern activity precludes a closer reading of the survey, a small group of weak positive magnetic anomalies may relate to archaeological features. A faint semi-circular anomaly to the south (Figure 16.3, M5), measuring a maximum of 10 m across may be associated with other magnetically enhanced features. To the north of these, two rough circular anomalies (Figure 16.3, M6) each measuring approximately 3 m across may equally represent archaeological soil-filled features.

South field

Agricultural action is far less apparent in the southern field, although some presumed plough damage is evident in the magnetic survey (Figure 16.3, M7), perhaps corroborated by linear anomalies in the resistance data (Figure 16.5, R1) and concentrations of high resistance spikes close to the peninsula. The signal returned by the edge of the dryland peninsula is strong in both surveys. To the east a linear high-resistance anomaly (Figure 16.5, R2) matches a magnetic trend (Figure 16.3, M8), and to the west a sharp contrast between high and low resistance and magnetic disturbance denotes the edge of the dryland (Figure 16.3, M9).

Along the north of the field significant magnetic disturbance is evident (Figure 16.3, M10), contributed to by a number of possible factors, including ferrous material in the field boundary, material dumped from the Hertford Cut, desiccating peat, or agricultural land-use. To the northeast (Figure 16.3, M11) more discrete magnetic enhancements could relate to palaeoenvironmental sample processing conducted in this area. In places, arrangements of dipoles or weak positive anomalies (Figure 16.3, M12), one group associated with Clark's cutting IV, may indicate former fence lines. Crescentic low-resistance anomalies (Figure 16.5, R3), each c. 10 m in diameter, found on the peninsula have no corresponding magnetic signal; their nature is uncertain and was unresolved by excavations in Trench SC35.

A large zone of magnetic disturbance (Figure 16.3, M13) correlates with both a zone of very low resistance readings (Figure 16.5, R4) and the location of standing water. The resistance signal is simply explained though the magnetic response is more obscure, perhaps deriving from modern dumped material used to fill the puddle. A more complex explanation invokes bacterial action on the iron and sulphur compounds in the waterlogged zone leading to magnetically enhanced, though disturbed, signals.

Subtle variations in the magnetic signal across the plot may be an indication of the condition of the peat, its depth or the degree to which it is affected by geomorphological change; for instance, the marbling evident at the east of the magnetic plot in an area interpreted here as wetter (on the basis of the resistance results) yet still on the dryland of the peninsula. However, to the west, greater depth of peat has yielded a more consistent quiet signal. Equally, the highest resistance results along the peninsula correlate with a fairly quiet magnetic signal.

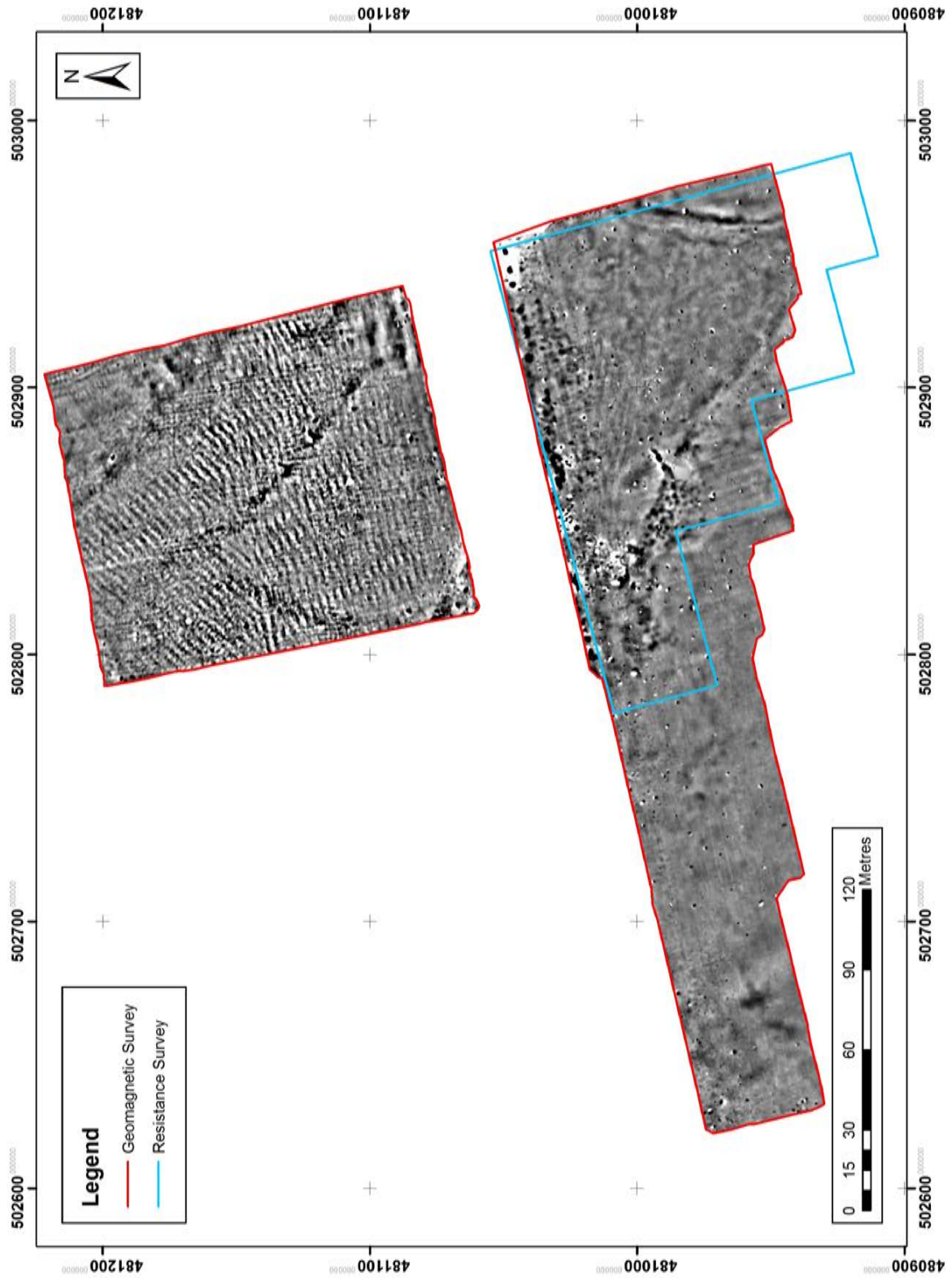**Figure 16.2:** Magnetometry survey: data clipped to between +12.8 nT and -12.8 nT (Copyright Edward Blinkhorn, CC BY-NC 4.0).
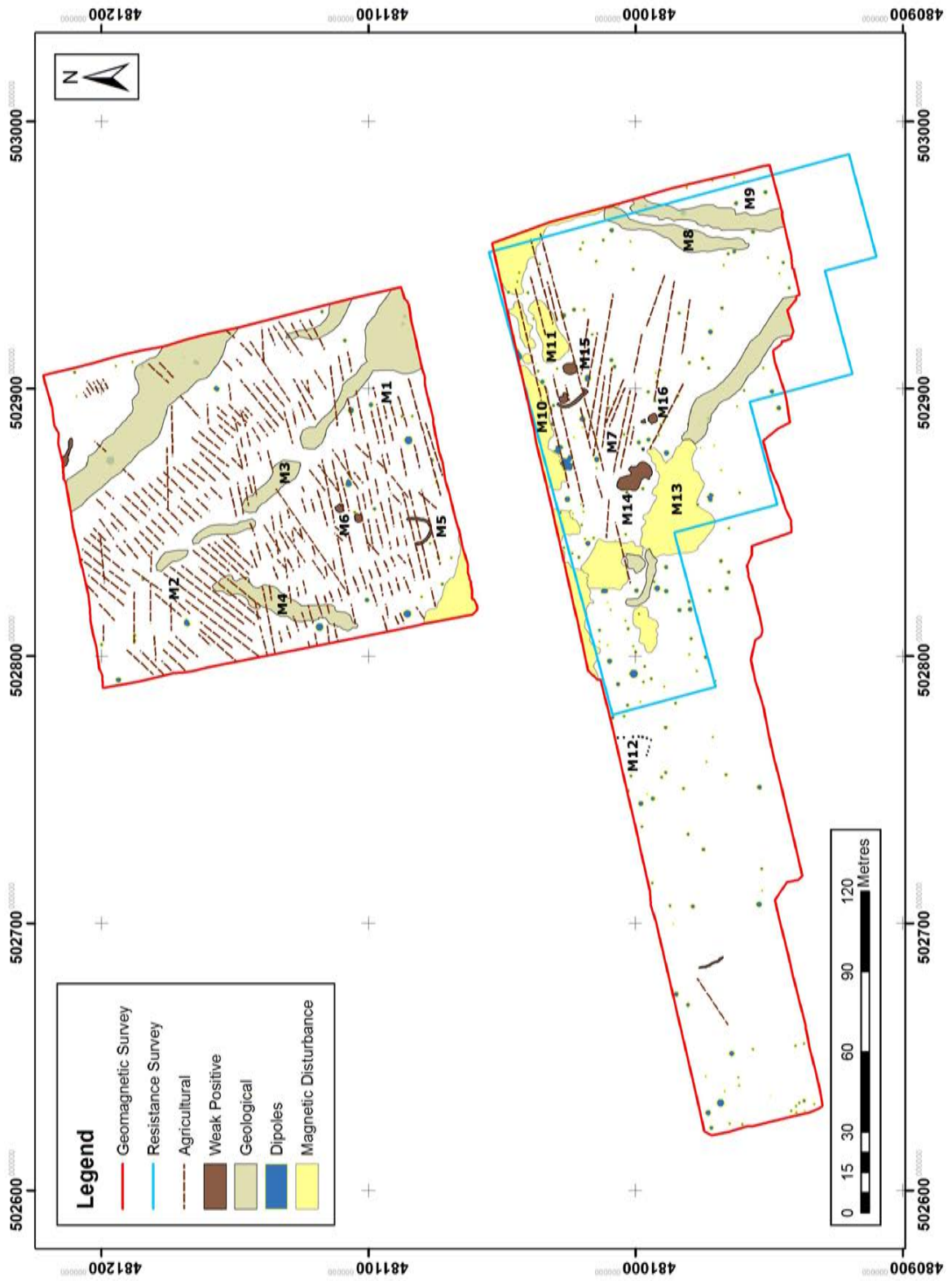
Figure 16.3: Magnetometry survey: interpretation (Copyright Edward Blinkhorn, CC BY-NC 4.0).
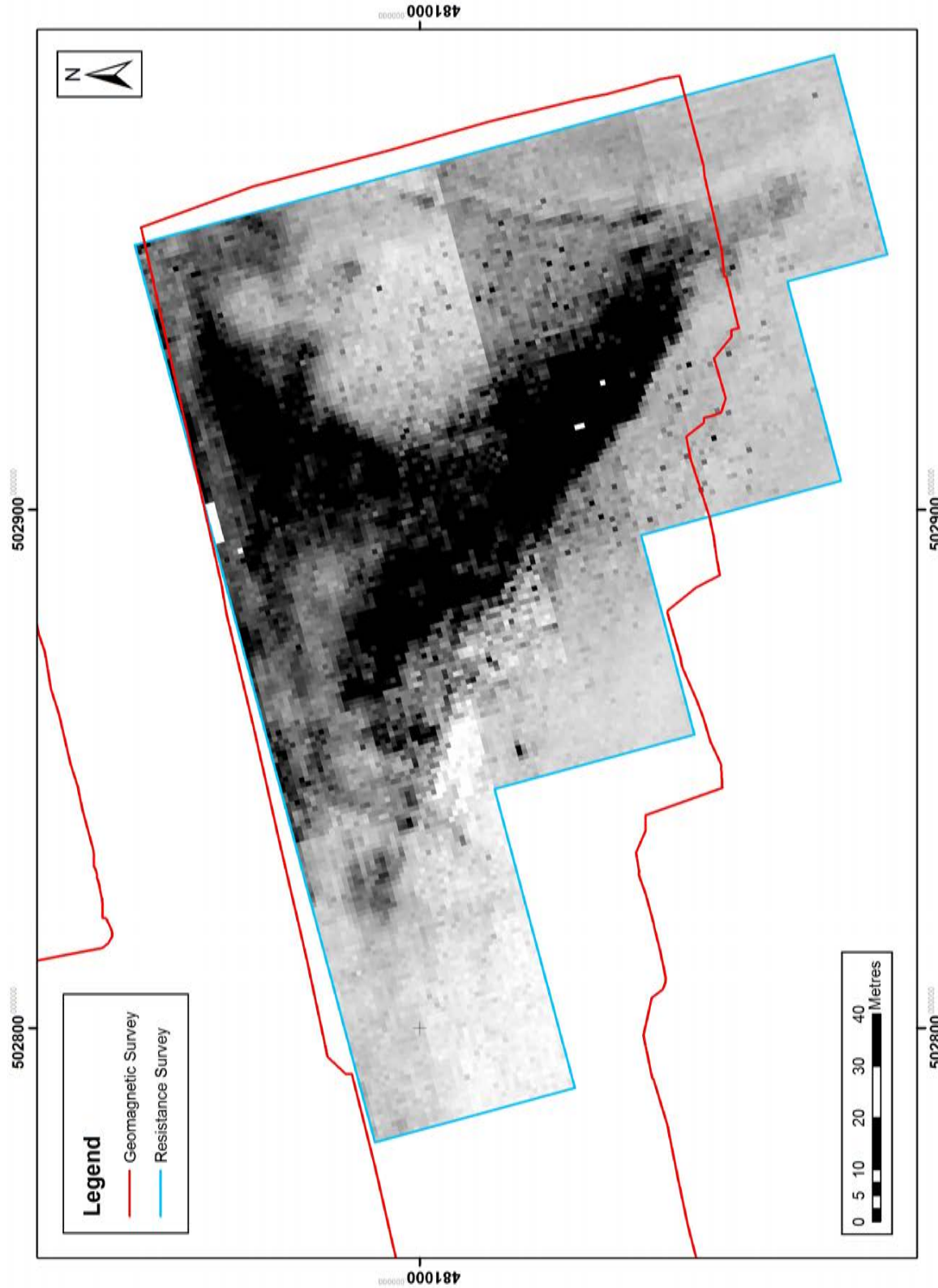
Figure 16.4: Resistance survey: data clipped to 25–85 Ohms (Copyright Edward Blinkhorn, CC BY-NC 4.0).
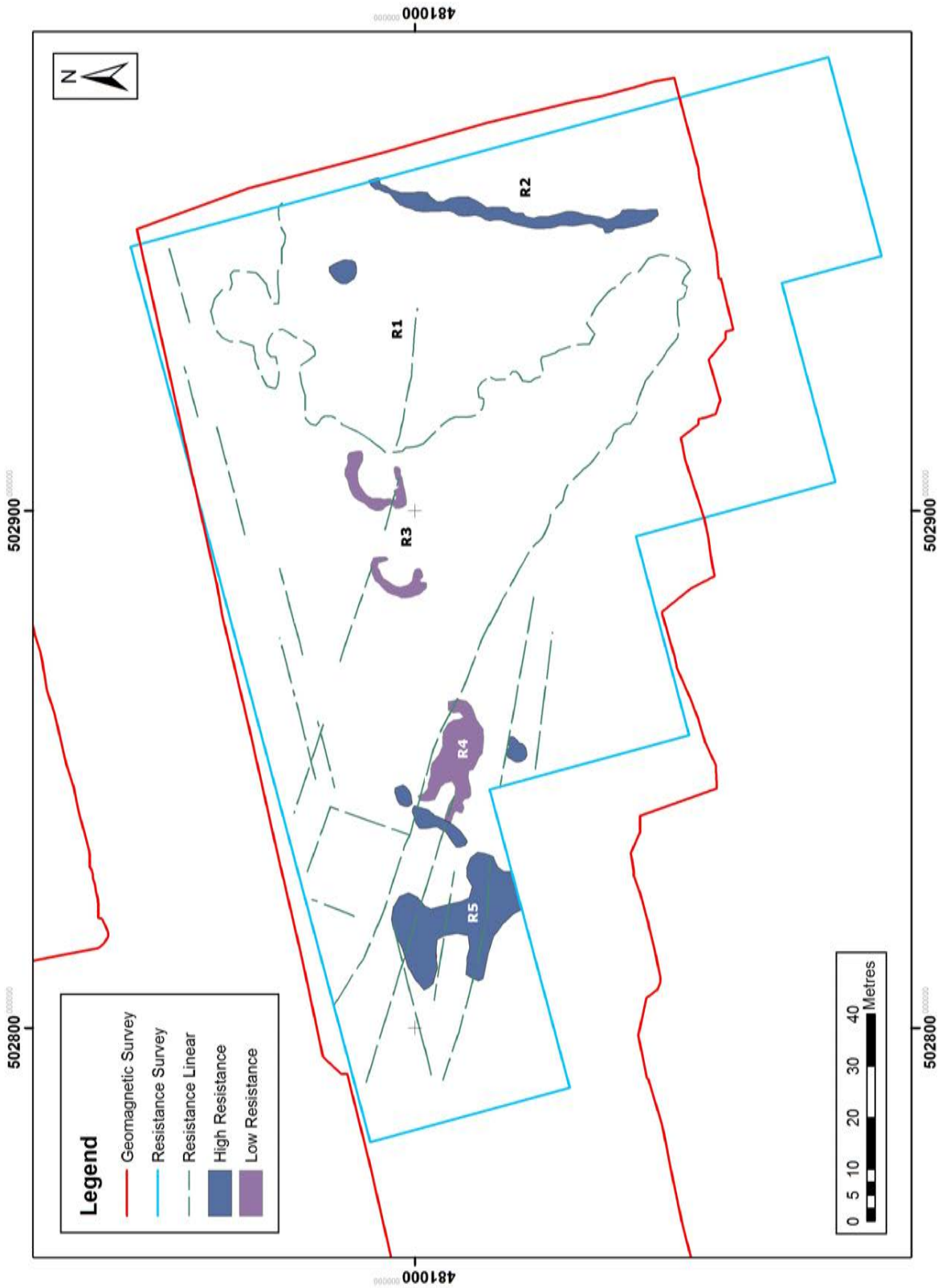
Figure 16.5: Resistance survey: interpretation (Copyright Edward Blinkhorn, CC BY-NC 4.0).

Patches of magnetic enhancement nearby (Figure 16.3, M14) broadly match variable resistance readings, perhaps showing the edge of significant localised peat development.

A small number of subround positive anomalies may be archaeological in origin (Figure 16.3, M15), although their distribution across the survey in areas of magnetic disturbance to the north urges a cautious interpretation. A single similar anomaly is located farther south (Figure 16.3, M16).

Little in the geophysical survey results correlates well with the archaeological discoveries, although trenches SC21 and SC24 are clearly visible. The western and central dryland structures have no discernible signal in either survey, despite associations with burnt flint, and the surveys were commissioned following the excavation of the SC08 structure in Trench SC24, leading to specious results. However, concentrations of wood are located in an area of subtle variations in the resistance results (Figure 16.5, R5), west of the waterlogging, which are most likely related to the complex hydrology and geology at the site which influences much of the resistance data.

Discussion

The greatest value in the plots presented here is the wider landscape approach whereby detail of the geomorphology can be extrapolated across the area surveyed and complement geochemical analyses and subsurface topographical modelling to understand the detailed geological architecture of Lake Flixton. Geomorphological responses dominate in the surveys, unsurprising considering the glacial derivation of landforms in the region. At the broader scale, significant anomalies can be correlated with ancient lake-edge topography, visible today due to peat shrinkage and demonstrated by auger survey (Chapters 3 and 4).

Perhaps more interestingly, subtler elements of geomorphology appear to be represented in the data. The resistance survey highlights the difficulty in making a clear distinction between 'dryland' and 'lake': the eastern portion of the peninsula yields readings similar to the lake peats, and significant areas of locally low resistance immediately to the east of trench SC34 suggest moisture retention, as does mottling south of trench SC35, associated with two semi-circular anomalies. The high resistance of the dryland is broken up to the north by a number of lower resistance readings, and discrete anomalies at both ends of the scale across the resistance survey illustrate the complexity of the subsurface ground structure.

The area southeast of trench SC34 is difficult to interpret and comprises complex variations in both resistance and magnetic data (Figure 16.6). Evidence from excavation implicates the influence of artesian springs in the Lake Flixton landscape and the possibility remains that such a spring is located nearby yielding modern waterlogging and expected low resistance, and minor variations in resistance readings in this area might represent a more complex depositional sequence than the contrast suggests. The effects of intrusive geology on the geomagnetic and resistance surveys are unknown, although they are likely to affect both, and differently. Magnetically enhanced deposits may be brought to the near surface in instances where there is significant vertical transport of deposits, though equally, target deposits might be eroded and replaced with magnetically unenhanced sediment. Dependent on the antiquity of springs, the resultant channels and modern soil moisture levels, resistance results may or may not accurately reflect ancient geomorphology. Peat cover may be reflected in both the survey results with magnetically quiet and widespread low resistance areas appearing to correlate with greater depths of peat, whereas shallow coverage leads to the inverse.

The geophysical surveys are ambiguous in the sense that clear-cut features are not easily interpreted. Nevertheless a small number of features are discernible which may relate to archaeological activity, although these have not been excavated and are difficult to truly justify without ground-truthing. These comprise equivocal anomalies all between c. 3–5 m in diameter in areas of relative magnetic enhancement or disturbance, and are the only examples suggestive of any excavated, albeit rather weakly. Needless to say the subround forms yield no information on date. Archaeological features revealed during excavations are not clearly represented in the data due to their proximity to magnetically noisy zones and presumed lack of local contrast in either magnetic or moisture. Considering the extent of plough damage in some areas, features cut into hard substrate may be the only evidence to survive.

Consideration must be given to the duration of deposition in the Lake Flixton landscape. The influence of many thousands of years of change is represented in the surveys: in the geological make-up of the landscape, regimes of hydrology, modern agricultural practice, recent archaeological interventions and possible archaeo-

Legend

	Geomagnetic Survey
	Resistance Survey
	Resistance Linear
	High Resistance
	Low Resistance
	Agricultural
	Weak Positive
	Geological
	Dipoles
	Magnetic Disturbance

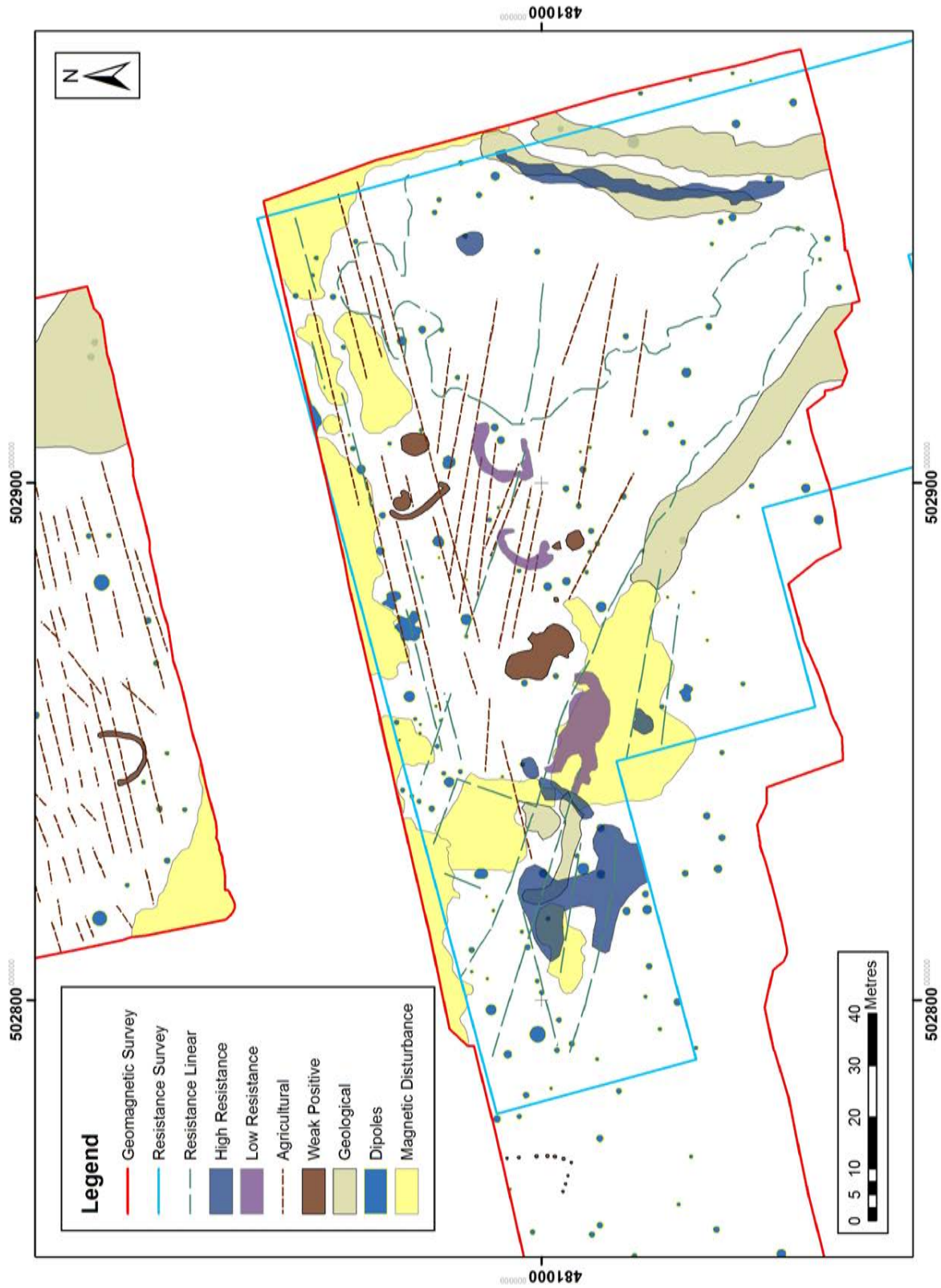0 5 10   20   30   40   Metres

Figure 16.6: Detail of the south field, superimposed magnetometry and resistance interpretations (Copyright Edward Blinkhorn, CC BY-NC 4.0).
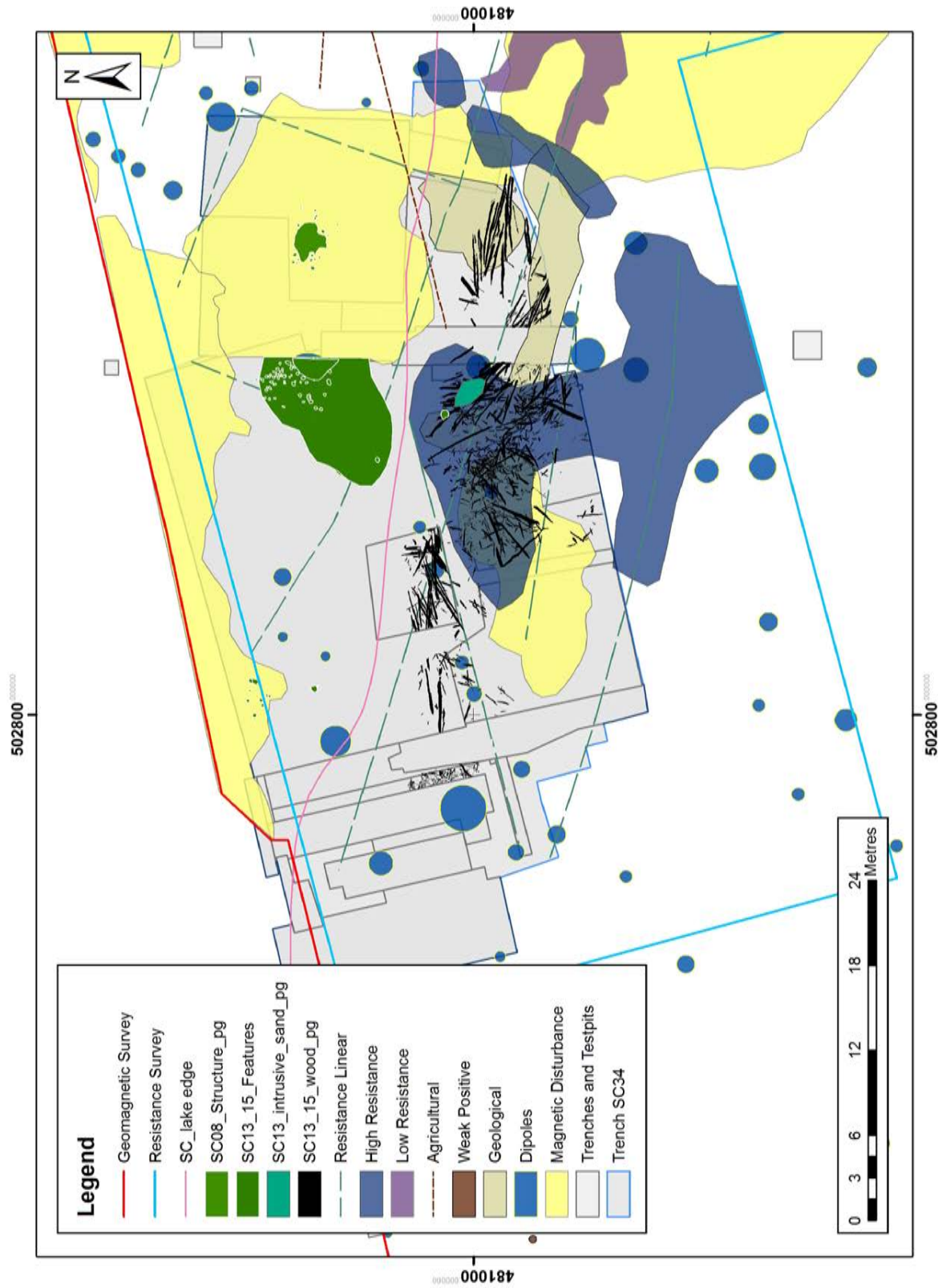
Figure 16.7: Correlation of geophysical survey interpretations with excavated findings (Copyright Edward Blinkhorn, CC BY-NC 4.0).

logical anomalies. Few indicators of date are inherent in the data beyond dipole responses and that which can be garnered from mapping. The data seems to support an argument that a more detailed geomorphological picture can gleaned from the techniques used here, though the antiquity of the deposits surveyed is in question. Natural electrical and geomagnetic phenomena measured in the surveys is a statement of modern condition rather than ancient configuration, and studies such as that on deterioration at the site (Chapter 22) highlight the influence of modern interference. Further interferences may derive from the Neolithic to post-Medieval periods.

Conclusions

This study has highlighted how traditional geophysical techniques can be of value in well-trodden parts of an archaeological landscape. However, it is not a final statement on the nature of deposits at Star Carr. Rather, the data should serve as the basis for an iterative model whereby schemes of interpretation could be extrapolated across horizontal space, drawing on other datasets which detail point-specific information, such as auger surveys and geochemical analyses, and alongside other remote datasets such as LiDAR or aerial photography. Considering the close spacing of the geophysical readings, appropriately sampled datasets would be of most value. In this way the geophysical surveys may function as a valuable proxy for the depth of Holocene deposits or even their condition.

Despite the absence of conventionally interpretable anomalies, and the uncertainty in those which have been identified as archaeological, geomagnetic and horizontal resistance survey may not be considered the most appropriate approaches with which to target the Mesolithic. At the time of the survey, other methods such as electrical resistance tomography or ground penetrating radar, whilst defining stratification would not have enabled such widespread coverage, nor were these widely deployed techniques. Considering the landscape processes at work and resolution of the data when interpreted geomorphologically, the results can be considered a useful resource in refining knowledge of the complex history of deposition at Star Carr.

Climate, Environment and Dating

'Star Carr lies in the Danelaw, the area of eastern England historically settled by the Vikings.
"Star Carr" apparently derives from the Danish star kjær, "Sedge Fen", as Godwin also noted.'

(Rowley-Conwy 2010, 77)

Dating the Archaeology and Environment of the Star Carr Embayment

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Introduction

Chronology has always been a key issue in the interpretation of Star Carr, both in terms of the age of the site and the period of time over which it was occupied. The ways in which this issue has been addressed have varied in the years since Clark's initial excavations, as subsequent researchers have taken advantage of methodological and interpretive advances in radiocarbon dating. However, all researchers have been faced with a similar set of problems. Firstly, that the bulk of the material record from the site was rendered un-datable by the conservation treatment used by Clark, and secondly, that the relationship between this material and the stratigraphy of the site could never be properly demonstrated.

The new excavations at Star Carr have provided an opportunity to address both of these issues by collecting a large number of new dating samples of known stratigraphic provenance. This enables us to date newly excavated material (thus avoiding the issue of past conservation treatments) and to combine the calibrated radiocarbon dates with the stratigraphic sequence in a formal Bayesian statistical model. The analysis of this new data has enabled us to construct a more precise chronology for human activity and the local environment at Star Carr.

This chapter focuses on the construction of the chronicle of what happened when around the Star Carr embayment during the early centuries of the Mesolithic. It does not attempt to untangle the web of causality, connections and consequence that creates narrative from the mere sequence and tempo of beads on the string (Ingold 1993, 187). This is undertaken in Chapter 9.

Previous dating

The first attempts to establish a chronology for Star Carr drew upon a broad range of methods to determine both the age of the site and the duration of occupation. With radiocarbon dating still in its infancy, Clark relied largely on

Figure 17 (page 31): Bulrush and willow, Christleton, Cheshire (Copyright Barry Taylor, CC BY-NC 4.0).

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the more-established method of pollen zonation to date the site in relation to the known sequence of vegetation succession across Northern Europe after the end of the Last Glacial Maximum. Based on Walker and Godwin's pollen analysis, this placed the occupation of Star Carr at the end of the Preboreal (Godwin's pollen Zone IV), making it earlier than typologically similar sites in Northern Europe (Clark 1954, 179). This was supported by two of the first radiocarbon measurements ever undertaken on British archaeological materials, on pieces of the brushwood platform recorded during the excavations, which fell within the known ages of the European Preboreal (Clark 1954, 12).

Different approaches were taken to establish the duration of activity at the site. Here, Clark drew upon the vertical distribution of artefacts and charcoal layers in the peat, and typological differences in the form of the barbed points to argue that the site had been occupied at least twice (Clark 1954, 9), whilst the estimated calorific value of the animal remains suggested a total duration of no more than six and a half years.

Although the application of radiocarbon dating become more widespread in succeeding decades, attempts to use it to establish a more precise chronology for Star Carr were hampered by the conservation methods used by Clark, which had contaminated the artefact and faunal assemblages to such an extent that they could not be dated (Dark et al. 2006, 186). However, new excavations and associated palaeoenvironmental investigations carried out by the Vale of Pickering Research Trust provided an opportunity to establish an absolute chronology, both for the human occupation of the site and its environmental history. In 1985, the Trust carried out excavations to the east of Clark's trenches in order to investigate the environmental setting of the site, during the course of which they recorded a small assemblage of faunal material and part of a wooden platform (Cloutman and Smith 1988). As this material had never been conserved, it provided the first opportunity to date directly material culture from Star Carr. To this end, AMS dates were also obtained on two pieces of bone and antler, a fragment of charcoal, and a sample from the timber platform, along with conventional dates on the sediments from around these and several other artefacts (Cloutman and Smith 1988, 42). Bulk samples of peat and a piece of charcoal from a series of four pollen profiles were also dated, and the results brought together to establish the chronology for the changing environments at the site and the episodes of human occupation (Cloutman and Smith 1988).

Unfortunately, as Cloutman and Smith noted, the results of their dating programme were problematic (Cloutman and Smith 1988, 54). To begin with, the samples taken from the base of the pollen profiles appeared to be erroneously old, which Cloutman suggested resulted from the reworking of older material into the basal sediments (Cloutman and Smith 1988, 45). What is more, the timber platform was several centuries younger than the other artefacts, even though they had been recorded from a similar level, and some of the artefacts were older than the sediment surrounding them (Cloutman and Smith 1988). Whilst Cloutman and Smith argued that may have been caused by the artefacts moving in the peat or that they were already old when they were deposited, the net result was that they were unable to provide a convincing date for occupation at the site or its duration (Cloutman and Smith 1988, 54–55).

In the following years it became clear that a number of methodological issues lay behind these problems. Principal among these was the dating of bulk samples of sediment, which could be contaminated through the inclusion of intrusive, younger material particularly in the form of rootlets (Mellars 1990, 839), or older reworked material (Cloutman and Smith 1988, 45), or the presence of aquatic plant material containing 'old' carbon derived from lake water rather than the atmosphere (Day 1996a, 10–11).

In the absence of a radiocarbon calibration curve covering the Early Holocene, Cloutman and Smith (1988) perforce worked in a 'timescale' of uncalibrated radiocarbon measurements. However, from the late 1980s, it was increasingly apparent that Star Carr dated to a time when measured radiocarbon ages showed no detectable change over a period of several centuries, making it difficult to distinguish different episodes of activity within this 'plateau' (Mellars 1990). High-precision tree-ring calibration was first proposed for this period in 1993 (Kromer and Becker 1993).

In the early 1990s a new programme of palaeoenvironmental investigations provided an opportunity to address these issues (Dark 1998a; Mellars and Dark 1998). Again, dating was undertaken on a vertical sequence of samples from one of the environmental profiles from VP85A (Profile M1), as well as at a lower resolution on a profile taken close to Clark's cutting II (referred to as the Clark Site profile) (Dark 1998a, 142). But this time AMS dates were obtained on terrestrial macrofossils to avoid potential contamination, and 'wiggle matching' was used to overcome the difficulties caused by the plateau in the calibration curve (Dark 1998a). As well as supporting the palaeoenvironmental analysis, these dates provided the backbone for the first reliable calendar chronology for the site.

To begin with, Mellars compared the vertical distribution of the artefacts in VP85A with the dated peat stratigraphy from the environmental sequence and suggested that the assemblage in that trench had been

deposited between c. 8700 and c. 8400 cal BC (Mellars and Dark 1998, 210). This was refined further by the work of Dark, who used evidence for episodes of burning, represented by inputs of micro- and macro-charcoal in the environmental profiles, as a proxy for human activity at the site. As these profiles had been dated, it was possible to estimate the chronological range of these episodes, both by dating the levels in the monolith where they started and ended and by estimating their duration by calculating the sedimentation rate of the deposits from which the charcoal had been recorded (Day and Mellars 1994; Dark 1998a; Dark 2000).

This programme of radiocarbon dating was pioneering, clearly recognising the need to utilise the archaeological or sedimentary sequence of deposits to overcome the emerging issues of radiocarbon calibration in the Early Holocene and addressing complex technical issues in dating the sediments from the Vale of Pickering accurately. However, the initial results were swiftly overtaken by developments in the methods employed. Firstly, the initial calibration data proposed for this period were swiftly revised (Spurk et al. 1998; Kromer and Spurk 1998; Stuiver et al. 1998), which led to substantial revisions to the chronology for Star Carr than had been originally proposed (Dark 2000). Secondly, the statistical methods for age-depth modelling available in the mid-1990s were primitive, either visual fitting of the uncalibrated sequence of radiocarbon measurements to the calibration curve (Day and Mellars 1994, 420–1; Dark 1998b, 119) or a simple Bayesian model incorporating only the relative sequence of dated samples (Dark 1998b, figure 10.3). Although the first formal mathematical approaches for modelling age-depth sequences through sediments were appearing at this time (Christen et al. 1995; Kilian et al. 2000), freely available software allowing the application of these approaches was in the future (Blaauw and Christen 2005; Bronk Ramsey 2008; Haslett and Parnell 2008).

The chronology proposed in the 1990s was refined further by the integration of archaeological material from Clark's excavations. During the 1990s direct dates had been obtained on a number of artefacts that had not been contaminated by the conservation techniques employed by Clark. The most significant of these was the Tot Lord collection, a small assemblage of material that had been collected from the baulks of two of Clark's trenches after the 1950 excavation season (Dark et al. 2006, 192). Four of these artefacts were dated by the Oxford Radiocarbon Accelerator Unit, two of which were subsequently re-dated using a different pre-treatment method (Dark et al. 2006, 193–4). In addition to these, a date was obtained on a 'resin cake', a piece of birch resin that had been recorded by Clark but not conserved (Roberts et al. 1998). Dark et al. (2006, 190) also attempted to correlate the deposition of artefacts in Clark's trenches with the phases of burning, by comparing the heights of the barbed points with the vertical distribution of the macro charcoal in the adjacent environmental profile.

Bringing this material together with the two AMS dates on artefacts from VP85A, Dark et al. (2006, figure 2) proposed the first detailed chronology for human activity at Star Carr, estimating both the initial date of occupation and its duration. Dark's (2000) analysis of the dating of the charcoal record suggested that the first phase of burning recorded in VP85A began at 8970 cal BC and lasted c. 80 years, with a contemporary though slightly longer episode in Clark's Site profile. This seemed to correspond with the majority of the artefacts recorded by Clark and in trench VP85A, and with the direct dates on artefacts made by AMS (Dark 2000, 197–8). Following a brief hiatus, a second phase of activity was represented by burning recorded in VP85A, which started at 8790 cal BC and lasted c. 130 years, and a later episode in the Clark Site profile. This seemed to correspond with a lower quantity of material culture and was thought to reflect a change in either the character or location of activity (Dark 2000, 198).

Subsequent work has challenged aspects of this interpretation, particularly the suggestion that the different episodes of burning may have reflected differences in forms of activity at the site. Excavations in trench SC22 in 2006 recorded two pieces of worked antler in a trench to the east of the area investigated by Clark. Dating of this material (OxA-16809–10) suggested that it was contemporary with the second phase of burning recorded in Dark's Clark Site profile, indicating that comparable forms of activity and deposition may have occurred in both phases at the site (Conneller et al. 2009, 89). Despite this, the chronology proposed by Dark et al. (2006), and in particular the two dated phases of occupation, have continued to structure the way the site has been discussed (e.g. Mellars 2009).

The aims of current dating programme

Whilst Dark et al.'s (2006) chronology for Star Carr was well established by the time the current fieldwork began, the new excavations quickly showed that occupation at the site was far more complex than had previously been thought. Structures were recorded on both the wetland and dryland areas as well as numerous

episodes of artefact deposition representing a range of different activities (e.g. Taylor 2007; Conneller et al. 2009; Conneller et al. 2012). What is more, this material occurred at different levels within the peat stratigraphy suggesting numerous phases of occupation. As the existing chronology only dated two phases of activity, a new programme of dating was required in order to establish the timing and duration of different episodes of human occupation at the site more precisely.

Initially the dating programme focused on providing sufficient information on the scale, condition and importance of the surviving archaeological remains on the site to inform the designation of Star Carr as a Scheduled Monument (which occurred in November 2011). Following the agreement of the management strategy (Milner 2011), the radiocarbon and chronological modelling programme was extended to include material from the European Research Council (ERC) and English Heritage/Historic England funded excavations (2013–2015) and to address the wider research objectives of that project. A partnership approach was adopted, with English Heritage/Historic England supporting the dating of the archaeological remains and environmental sequence around the Star Carr embayment reported in this chapter, and the ERC supporting the more extensive environmental and climatic research programme around Lake Flixton (Chapter 18).

This new dating programme had three aims.

First, to construct a human-scale narrative for Star Carr by:

- untangling the order of episodes of activity that cannot be related by direct stratigraphy,
- determining the duration and intensity of different episodes of activity,
- understanding the temporal relationships between different episodes of human activity and identifying any hiatus in occupation.

Second, to establish the chronological relationships between different forms of human activity at Star Carr and the contemporary environment and climate by:

- relating different types of human activity to the changing character of the wetland environments at the lake edge,
- relating the human occupation at Star Carr with changes in climate over time,
- relating the occupation at Star Carr with changes occurring to the landscape and environment at other points around the lake and the wider Vale.

Third, to compare human activity at Star Carr with contemporary activity at other sites in Britain (Conneller et al. 2016).

Bayesian chronological modelling

The application of Bayesian statistics for the interpretation of radiocarbon dates allows chronologies that are precise within a scale of human lifetimes and generations to be constructed routinely (Bayliss 2009). This makes fuzzy prehistory, a space where past agents and individuals float timelessly in a kind of pseudo-ethnographic present, a choice rather than a necessity and opens up new avenues of interpretation for archaeologists (Bayliss and Whittle 2007; Whittle et al. 2011; Bayliss and Whittle 2015).

The basic idea behind the Bayesian approach to the interpretation of data is encapsulated by Bayes' theorem (Bayes 1763; Figure 17.1). This simply means that we analyse the new data we have collected about a problem ('the standardised likelihoods') in the context of our existing experience and knowledge about that problem (our 'prior beliefs'). This enables us to arrive at a new understanding of the problem which incorporates both our previously existing knowledge and our new data (our 'posterior belief'). We do this by the use of formal probability theory, where all three elements of our model (that is, existing beliefs, new information, and revised interpretations) are expressed as probability density functions. These give us a quantitative measure of our state of knowledge of each component of the model. Bayesian models are thus interpretative constructions which rely on multiple lines of evidence (Buck et al. 1996). An accessible general introduction to the principles of Bayesian statistics is provided by Lindley (1985), and to its history by Bertsch McGrayne (2011).

$$\frac{P(data|parameters) \times P(parameters)}{P(data)} = P(parameters|data)$$

Standardised likelihoods x Prior beliefs = Posterior beliefs

"the dates"   "the archaeology"   "an answer"

Figure 17.1: Bayes' theorem (Copyright Historic England, CC BY-NC 4.0).

Alison Wylie (2002, 162–3) has suggested that 'scientific arguments are more like cables than chains'. In this view, individual lines of argument that are insufficient on their own can make a cumulatively persuasive case when woven together, although the strands that make up a cable of comparative, evaluative argument may conflict with one another and thus may require dynamic judgements and revisions. In the construction of archaeological chronologies, Bayesian statistics provide a formal and explicit methodology for weaving together different strands of evidence to form the cable. The approach combines calibrated radiocarbon dates with knowledge of the character and sequence of deposits from which they are derived to produce a series of formal, probabilistic date estimates. Stringent demands are made of both the radiocarbon dates and our archaeological understanding of stratigraphy, associations, sample taphonomy and context in general, but the combined chronology should be more reliable than its individual components, since it is reliant on multiple strands of reinforcing evidence. To return to Wylie's metaphor, the resultant cable should be both stronger (more robust) and tighter (more precise).

Our models incorporate archaeological prior beliefs of various kinds. We need to be clear about the basis of these beliefs. Some may be comparatively unequivocal—the stratigraphic succession of a sequence of plant macrofossils in a monolith, for example. In other cases the stratigraphic sequence may be open to alternative interpretations, or there may be doubt about the taphonomy of the dated material. The fundamental point is that Bayesian statistics, being a formal methodology, force archaeologists to be explicit about their strands of reasoning.

In theory, once the model has been defined, the posterior beliefs can be calculated using Bayes' theorem. However, in practice almost all chronological models have so many independent parameters that the number of possible outcomes to consider at a useful resolution makes such a calculation impractical. For this reason, Markov Chain Monte Carlo (MCMC) methods are used to provide a possible solution set of all of the parameters of the model. The algorithm 'samples' the prior probability distributions (i.e. usually calibrated radiocarbon dates), and then attempts to reconcile these distributions with the prior beliefs included in the model (such as relative dating from stratigraphy), by repeatedly sampling each distribution to build up a set of solutions consistent with the model structure. The probability of a particular solution appearing in the MCMC analysis should be directly proportional to its probability as defined by the posterior probability density.

In most cases a reasonably representative solution can be generated by this method. If there are too few iterations in the analysis, the resulting probability distributions will usually be noisy and will vary from run to run. The degree to which a truly representative solution set has been generated is called 'convergence'. The verification of convergence in models which employ MCMC sampling is not straightforward and a number of diagnostic tools have been proposed: that employed in OxCal is described by Bronk Ramsey (1995, 429). This convergence integral has a critical value of 95%, and models which fail to pass this threshold may be unstable and their outputs should be regarded with the utmost caution (Bronk Ramsey 1998, 469). The program attempts to produce stable models by increasing the number of passes the MCMC sampler calculates each time

the convergence value falls below 95%. In an attempt to ensure stable outcomes all models reported in this volume have been calculated using a minimum of 20 million passes.

Stability of the model outputs is not the only criterion by which models can be validated. We also need to consider whether the two components input into the model, the 'prior beliefs' and the 'standardized likelihoods', are compatible. There are four main reasons why radiocarbon dates may conflict with the archaeological information included in a model:

1. Erroneous prior beliefs—situations where the overall form of the model is incorrect (for example, unidentified episodes of truncation interrupting continuous sedimentation). These must be identified and more plausible alternative prior beliefs implemented.
2. Statistical outliers—the 1 in 20 radiocarbon results whose true age lies outside the 95% range. These must be retained in the model as their exclusion would statistically bias the model outputs.
3. Misfits—dates which do not fit in the expected stratigraphic position, or which are inaccurate for some technical reason. Generally, samples which prove to be residual can be used as *termini post quos* for their contexts, but intrusive samples or inaccurate dates need to be excluded from the analysis. Sometimes it may be possible to reinterpret the stratigraphy.
4. Offsets—measurements that are systematically offset from the calibration data (most commonly, reservoir effects). Confusingly, categories 3 and 4 are both known in the statistical literature as 'systematic offsets' although archaeologically they are very different.

We clearly have the potential for all four situations in our assemblage of radiocarbon dates and chronological models from Star Carr.

There are two possible approaches to this issue.

The first approach is to identify problems manually using our archaeological judgement about the character of particular samples and deposits and the agreement indices provided by OxCal (Bronk Ramsey 1995, 429; Bronk Ramsey 2009a, 356–7), and then to decide how to include each date in the model depending on its specific characteristics. The major advantage of this approach is that it allows us to account for all the information we have about the character of particular samples or deposits; the disadvantage is that the indices of agreement provided by OxCal are not derived from a formal statistical approach (although they have proven robust in a wide range of applications).

The second approach is formal, statistical outlier detection. This assumes that we can never really be sure whether any particular measurement is an outlier, and so weights each sample according to how likely it is to be correct using a model averaging approach. The advantage of this method is that it is an explicit statistical process; the disadvantage is that it may not take account of the archaeological information we may have about the relative strengths and weaknesses of particular samples or deposits. Since we are hoping to identify misfits that are outliers on the calendar scale (samples that are residual or intrusive at the depth at which they were found), the general outlier model proposed by Bronk Ramsey (2009b, 1028) would be appropriate for this application.

These diagnostic statistical tools aid us in ensuring internal consistency within our cable (see also Wylie 2002, 176–7).

The chronological model presented in this chapter has been constructed using the program OxCal v4.2 (Bronk Ramsey 2009a; Bronk Ramsey 2009b; Bronk Ramsey and Lee 2013) and the atmospheric calibration curve for the northern hemisphere published by Reimer et al. (2013). The model is defined exactly by the OxCal CQL2 code provided in Appendix 17.1 (with additional parameters calculated using the code provided in Appendix 17.2). In the Figures, the posterior density estimates output by the model are shown in black, with the unconstrained calibrated radiocarbon dates shown in outline. The other distributions correspond to aspects of the model. For example, '*start Star Carr*' is the estimated date when Mesolithic activity at Star Carr began (Figure 17.2). In the text and Tables, the Highest Posterior Density intervals of the posterior density estimates are given in *italics*. So, for example, the model presented in this chapter estimates that Mesolithic activity at Star Carr began in *9385–9260 cal BC* (*95% probability*; *start Star Carr*; Figure 17.2), probably in *9335–9275 cal BC* (*68% probability*). Where unmodelled radiocarbon dates are given, they have been calibrated using the probability method (Stuiver and Reimer 1993) and IntCal 13. All ranges have been rounded outwards to the nearest five years.
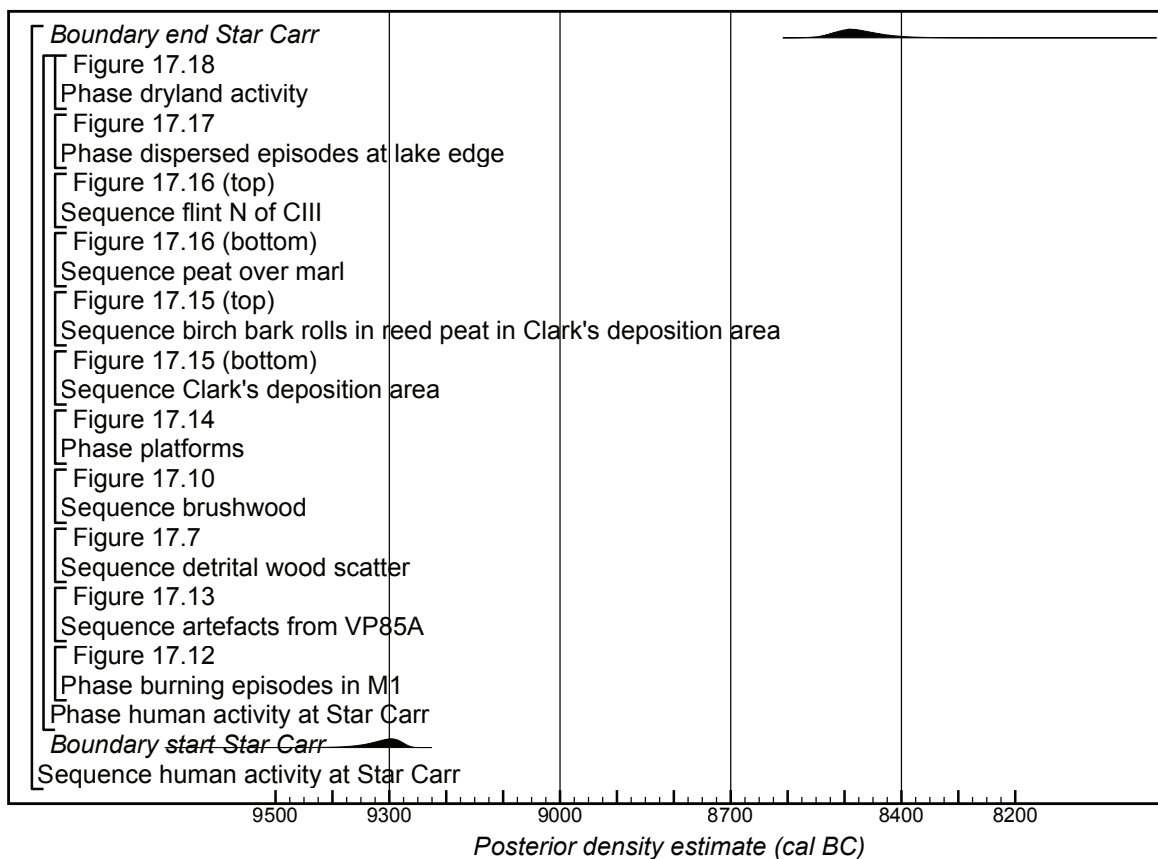
```
Boundary end Star Carr
  Figure 17.18
  Phase dryland activity
  Figure 17.17
  Phase dispersed episodes at lake edge
  Figure 17.16 (top)
  Sequence flint N of CIII
  Figure 17.16 (bottom)
  Sequence peat over marl
  Figure 17.15 (top)
  Sequence birch bark rolls in reed peat in Clark's deposition area
  Figure 17.15 (bottom)
  Sequence Clark's deposition area
  Figure 17.14
  Phase platforms
  Figure 17.10
  Sequence brushwood
  Figure 17.7
  Sequence detrital wood scatter
  Figure 17.13
  Sequence artefacts from VP85A
  Figure 17.12
  Phase burning episodes in M1
Phase human activity at Star Carr
  Boundary start Star Carr
Sequence human activity at Star Carr
```

| 9500 | 9300 | 9000 | 8700 | 8400 | 8200 |

Posterior density estimate (cal BC)

Figure 17.2: Diagram showing the overall form of the model for human activity along the lake edge at Star Carr, components are illustrated in the Figures indicated (but the model is only exactly defined by the CQL2 code in Appendix 17.I) (Copyright Historic England, CC BY-NC 4.0).

Sampling strategy

The dating programme followed the reflexive approach to implementing Bayesian chronological modelling in archaeology that has been developed by English Heritage/Historic England over the past twenty years (Bayliss 2009, figure 9). A sequential sampling strategy was thus devised using a series of simulation models which combined the available archaeological and environmental information with simulated radiocarbon dates from the available pool of potential suitable datable samples and the large suite of existing radiocarbon dates (Tables 17.1 and 17.2).

Sampling was also informed by a series of pragmatic considerations:

First, the objectives of the dating programme developed during the course of the project. Initially sampling focused on the trenches along the lake edge excavated between 2004 and 2010 as part of a programme of research to assess the extent of the site and the quality of its preservation (Milner 2011). Once the excavation of the site had been agreed, the dating programme was extended to cover material from the dryland and newly excavated areas and the range of academic objectives described above.

Second, sampling was informed by technical difficulties in dating some sample types. Bone and antler artefacts recovered by Grahame Clark in the 1950s were vacuum impregnated with a chemical consolidant (Clark 1954, plate IIIA), and we were not confident that this could be completely removed and accurate radiocarbon measurements obtained. In 2007, two severely degraded antler samples were dated from trench SC22 (OxA-16809–10; Table 17.1). These produced radiocarbon ages which are clearly anomalously recent in relation

Laboratory number	Sample and context description	Radiocarbon age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N$ (‰)	C:N	References
Clark's Site Legacy						
KIA-307034	*Canis familiaris* subadult cranium (no. 58.11.15.3) from unknown location in Clark's excavation	9342±41	−21.1±0.1	9.0±0.2	3.5	Schulting and Richards 2009
OxA-V-994-33	*Canis familiaris* adult left femur (no.58.11.15.4) from unknown location in Clark's excavation	9680±55	−19.0±0.2	11.2±0.3	3.5	Schulting and Richards 2009
OxA-2343	Unconserved inner fragment of resin 'cake' from unknown location in Clark's excavation	9350±90	−29.1			Hedges *et al* 1994; Roberts *et al* 1998
Q-14	Waterlogged wood, *Betula* sp., from 'brush platform' in Clark's excavation	9557±210	nm			Godwin and Willis 1959; Clark 1954
C-353	Replicate of Q-14	9488±350	nm			Arnold and Libby 1951; Clark 1954
Mean	T'=0.0; T'(5%)=3.8; ν=1	9539±181				
Clark Site Legacy (Lord Collection)						
OxA-4451	The lower (proximal) portion of an anciently broken *Cervus elaphus* antler barbed point (no. 463) from unknown location in Clark's excavation	9120±150	−22.9±0.2			Dark *et al* 2006; Mellars and Dark 1998
OxA-21236	Replicate of OxA-4451	9561±38	−21.3±0.2			Jacobi pers comm
OxA-10808	Replicate of OxA-4451	9505±60	−22.3±0.2	1.9±0.3	3.2	Dark *et al* 2006
Mean	T'=**7.9**; T'(5%)=6.0; ν=2					
OxA-4450	Anciently broken *Cervus elaphus* antler splinter (no. 460) from unknown location in Clark's excavation	9060±220	−23.1±0.2			Dark *et al* 2006; Mellars and Dark 1998
OxA-10809	Replicate of OxA-4450	9530±55	−21.4±0.2	+2.2±0.3	3.2	Dark *et al* 2006
OxA-21237	Replicate of OxA-4450	9585±39	−22.2±0.2			Jacobi pers comm
Mean	T'=5.6; T'(5%)=6.0; ν=2	9567±32				
OxA-4577	*Cervus elaphus* antler crown splinter (no. 461) from unknown location in Clark's excavation	9670±100	−20.8±0.2			Dark *et al* 2006; Mellars and Dark 1998
OxA-21238	Replicate of OxA-4577	9485±38	−22.7±0.2			Jacobi pers comm
Mean	T'=3.0; T'(5%)=3.8; ν=1	9509±36				
OxA-4578	Fragment of *Cervus elaphus* antler tine (no. 465) from unknown location in Clark's excavation. This fragment may originate from the crown dated by OxA-4577	9590 ±90	−20.2±0.2			Dark *et al* 2006; Mellars and Dark 1998

OxA-21239	Replicate of OxA-4578	9468±38	−22.6		Jacobi pers comm
Mean	T'=1.6; T'(5%)=3.8; v=1	9487±36			
VP85A Legacy					
CAR-921	Bulk sample of coarse detritus mud from around antler tine (no. 130) dated by OxA-1154, context 223, Trench VP85A	9360±110	nm		Cloutman and Smith 1988, figure 3
CAR-922	Bulk sample of coarse wood peat from around antler (no.216), context 223, Trench VP85A	9250±80	nm		Cloutman and Smith 1988, figure 3
CAR-925	Bulk sample of medium detritus mud from around barbed point (no.245), context 223, Trench VP85A	9260±100	nm		Cloutman and Smith 1988, figure 3
OxA-1154	*Cervus elaphus* antler tine (no. 130) (wrongly described as an antler frontlet in Cloutman & Smith 1988) from context 223, Trench VP85A (See CAR-921)	9500±120	nm		Hedges *et al* 1989; Cloutman and Smith 1988; Mellars 1990
CAR-923	Bulk sample of coarse reed peat from around *Bos primigenius* metatarsal (no. 56) dated by OxA-1176, context 225, Trench VP85A	9030±100	nm		Hedges *et al* 1989; Cloutman and Smith 1988; Mellars 1990
OxA-1176	*Bos primigenius* metatarsal (no. 56), context 225, Trench VP85A (See CAR-923)	9700±160	nm		Hedges *et al* 1989; Cloutman and Smith 1988; Mellars 1990
CAR-920	Bulk sample of coarse detritus mud around worked antler (no.141), base of context 225, Trench VP85A	9400±110	nm		Cloutman and Smith 1988, figure 3
CAR-924	Bulk sample of coarse reed peat from around *Bos primigenius* skull (no.150), context 225, Trench VP85A	9320±80	nm		Cloutman and Smith 1988, figure 3
CAR-930	Bulk sample of coarse reed peat from around charcoal (no.153), base of context 225, Trench VP85A	9660±110	nm		Cloutman and Smith 1988, figure 3; Mellars 1990
CAR-928	Unidentified charcoal from beneath the central platform dated by CAR-926, probably context 226, Trench VP85A	9670±120	nm		Cloutman and Smith 1988, figure 3; Mellars 1990
CAR-919	Bulk sample of fine detritus mud from around antler point blank (no.222) from top of context 228, Trench VP85A	9510±80	nm		Cloutman and Smith 1988, figure 3
CAR-926	Unidentified waterlogged wood from central platform, probably from the base of context 225, Trench VP85A	9240±90	nm		Cloutman and Smith 1988, figure 3
CAR-927	Bulk sample of coarse reed from around central platform (See CAR-926)	9800±80	nm		Cloutman and Smith 1988, figure 3

Table 17.1: Radiocarbon and stable isotopic measurements on archaeological samples made before 2006 (* indicates stable isotopic ratio measured by AMS; nm indicates stable isotopic ratio not determined).

to stratigraphically associated samples of waterlogged wood and plant macrofossils, and so dating bone was generally avoided until better preserved material was recovered from deeper deposits in 2013.

Third, our attempts to date artefacts recovered from the 1980s excavation of VP85A were frustrated. The waterlogged timbers, which had remained in cold storage at the English Heritage/Historic England laboratory facility at Fort Cumberland, Portsmouth, had degraded to the point where neither species identification nor ring counting was possible. Furthermore, all but two of the bone artefacts, which had been considered too precious for sampling in the 1980s (Cloutman and Smith 1988, 42), could not be located.

In 2011–12, samples of waterlogged wood and plant macrofossils were dated from sequences of deposits in trenches SC22, SC24 and the 2010 extensions of cutting II and VP85A extension. These were selected to bracket stratigraphically key archaeological events, such as the construction of the central platform in VP85A, thus providing dating for the archaeological deposits within the sediments. Preliminary modelling of these results indicated that it was possible to obtain coherent sequences of radiocarbon dates from the available material, although some inaccurate results on waterlogged wood could be identified using the sequence of stratigraphic relationships between the dated samples and the programme of inter-laboratory replication. It also indicated that key horizons in the hydroseral succession at Star Carr—the onset of organic sedimentation, the onset of seasonal flooding, and possibly the onset of fen/carr—might be sufficiently close in date along the lake edge to enable them to be used as marker horizons to tie the stratigraphic sequences in separate trenches together.

Early in 2015, once excavations had been extended into deeper deposits farther away from the lake shore, a series of bone and antler samples were submitted for dating from within the detrital wood scatter (see Chapters 6 and 7). Each bone or antler was dated by two laboratories and was inter-stratified between waterlogged timbers that were also dated. Other samples submitted at this time were on humanly modified waterlogged wood, to assess the span of human activity on the site. All three pairs of replicate measurements on the bone and antler samples were statistically consistent (OxA-32061−3 and SUERC-59180, -59184−5; Table 17.3) and, with one exception, the dates on the bones were compatible with those on the stratigraphically related samples of waterlogged wood. For this reason, in 2015–16, a larger series of samples from archaeological activity around the lake edge at Star Carr were dated, including worked waterlogged wood, worked bone and antler (including a selection of artefacts), and charred birch bark rolls. Different areas of activity were dated, including materials from Clark's area, the brushwood area, the eastern and western timber platforms, an area where stone beads were manufactured (north of Clark's area) and further material from within the detrital wood scatter. Particular efforts were made to locate datable material from areas of human activity within the wood peat, to ensure that a representative sample was obtained of later episodes of occupation.

Further preliminary chronological models were constructed during this sampling programme, as each set of results was reported. This raised the question of how far the key horizons in the environmental profiles, which had been highlighted as potentially marker horizons in 2012, could be considered contemporaneous away from the shoreline. To investigate this question, a further series of samples were dated from an environmental profile at the southern end of the site in 2015 (Profile 3178; see Chapter 19), although in the event half the samples that were submitted for dating from this sequence failed during laboratory processing.

Finally, early in 2016 a series of samples was submitted from the three dryland structures (Chapter 5). All were single fragments of short-lived charcoal, recovered either from postholes of the structure or from the central hollow. In all cases, there was very little datable material of sufficient size even for dating by Accelerator Mass Spectrometry and so there are fewer radiocarbon dates than the simulation models suggested would be ideal.

Overall, the sampling strategy for Star Carr was constructed on the basis of a pragmatic mix of archaeological, scientific and statistical criteria.

Radiocarbon dating

A total of 223 radiocarbon measurements are now available from archaeological and palaeoenvironmental deposits around the Star Carr embayment, of which 76 were obtained by previous researchers (Tables 17.1 and 17.2) and 147 have been obtained as part of the current project (Table 17.3). All but the two measurements

made in the early 1950s (C-353 and Q-14), which were not corrected for fractionation, are conventional radio-carbon ages (Stuiver and Polach 1977).

A pair of statistically consistent measurements was obtained in the early years of radiocarbon dating on a waterlogged birch timber from the 'platform' in Clark's trench (C-353 and Q-14; see Table 17.1). The measurement made in Chicago (C-) was undertaken using screen-wall counting of elemental carbon as described by Libby (1952), that made at Cambridge (Q-) was dated by gas proportional counting of carbon dioxide as described by Godwin and Willis (1959).

A total of 42 measurements were undertaken at Cardiff University (CAR-) in the mid 1980s using gas pro-portional counting of methane (Dresser 1985). All but two of these samples were of bulk organic sediment, the acid- and alkali-insoluble fraction being selected for dating. Ten samples of waterlogged wood were dated by gas proportional counting of carbon dioxide at the Universität Heidelberg (Hd-) in 2011–12 using methods outlined by Münnich (1957), Dörr et al. (1989) and Schoch et al. (1980).

The 98 radiocarbon results reported by the Oxford Radiocarbon Accelerator Unit have been produced using a variety of methods over the past 30 years. Two samples of bone and antler submitted in 1986 (OxA-1154, -1176; Table 17.1) were pre-treated using the ion-exchange protocol, graphitised and dated by accelerator mass spectrometry (AMS) as described by Hedges et al. (1989). Four samples of bone and antler from artefacts recovered by Tot Lord from Clark's section in 1950 (and thus not consolidated; OxA-4450–1 and OxA-4577–8; Table 17.1) submitted in 1995 were similarly processed using the ion-exchange protocol, but combusted to car-bon dioxide and dated by AMS (Hedges 1981; Gillespie *et al.* 1983; Hedges et al. 1992). A sample of resin 'cake' recovered in Clark's excavations and submitted for dating in 1990 (OxA-2343; Table 17.1) was not pretreated, but simply combusted and dated using the same methods. In 1991–4, a series of waterlogged plant macro-fossil and charcoal samples were dated from two environmental profiles (OxA-3342–51, OxA-4376–7, and OxA-4797–8; Table 17.2). The samples from VP85A M1 were pretreated using variations of the acid-base-acid protocol (Brock et al. 2010, Table 17.1) and those from Dark's Clark Site Core were pretreated using acid washes only (Brock et al. 2010, 108). Both series of samples were then combusted and dated by AMS (Hedges 1981; Gillespie et al. 1983; Hedges et al. 1992).

Two of the antler samples were re-dated in 2001 using the original ultrafiltration protocol at Oxford (Bronk Ramsey *et al.* 2000; OxA-10808–9; Table 17.1), graphitised (Dee and Bronk Ramsey 2000) and dated by AMS using the hybrid ion source (Bronk Ramsey and Hedges 1997). This pretreatment protocol was subsequently found on occasion to produce measurements that were slightly too old (Bronk Ramsey et al. 2004a), and in 2009 new samples from all four previously dated artefacts recovered by Tot Lord were processed using the revised ultrafiltration protocol (Bronk Ramsey et al. 2004a), graphitised and dated by AMS as described by Bronk Ramsey et al. (2004b). At this time two further radiocarbon measurements were obtained on dog remains recovered in Clark's excavations. OxA-V-994-33 had been treated by PVA and was subject to an acetone pre-treatment (Moore et al. 1989) followed by collagen extraction and ultrafiltration (Brown et al. 1988) at the Max Planck Institute in Leipzig. This sample was then combusted, graphitised and dated at Oxford (Dee and Bronk Ramsey 2000; Bronk Ramsey et al. 2004b). A further unconsolidated sample from a different, sub-adult dog was similarly gelatinised and ultrafiltered in Leipzig (Brown et al. 1988) but combusted, graphitised and dated by AMS at the Christian-Albrechts Universität, Kiel (KIA-) as described by Nadeau et al. (1997; 1998).

In 2006, two samples of antler were dated from excavations undertaken earlier that year (OxA-16809–10; Table 17.3). These samples were gelatinised, ultrafiltered, combusted, graphitised and dated by AMS as described by Bronk Ramsey et al. (2004a; 2004b). In 2011–16, a further 67 samples were dated at Oxford, using methods described by Brock et al. (2010) and Bronk Ramsey et al. (2004b). At this time a total of 68 samples were also dated by AMS at the Scottish Universities Environmental Research Centre (SUERC-) using methods described in Dunbar et al. (2016). In 2011, two samples which had been submitted for gas proportional counting at the Universität Heidelberg failed to produce sufficient carbon dioxide for conventional measurement. Conse-quently, the carbon dioxide was sub-sampled, graphitised, and dated by AMS at the Curt-Engelhorn-Zentrum Archäometrie, Mannheim (MAMS-) as described by Kromer et al. (2013).

All the radiocarbon laboratories that have produced measurements for Star Carr maintain continual programmes of quality assurance procedures, in addition to participation in international inter-comparison exercises. Even in the 1950s groups of radiocarbon laboratories were exchanging and dating known-age mate-rials (Willis et al. 1960), and inter-comparisons are available that are relevant to all the measurements that

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ¹³C(‰)	References
Dark's Clark Site Core				
OxA-4799	*Phragmites australis* charcoal picked from a slice of sediment 2cm thick at 23.52–23.54m OD in Dark's Clark Site Core. Probably equivalent to the base of context 242 in Trench CII	9500±75	–26.1	Mellars and Dark 1998, 142; Dark et al 2006
OxA-4797	*Phragmites australis* charcoal picked from a slice of sediment 2cm thick at 23.75–23.77m OD in Dark's Clark Site Core. Probably equivalent to the middle of context 242 in Trench CII	9385±80	–27.7	Mellars and Dark 1998, 142; Dark et al 2006
OxA-4798	*Phragmites australis* charcoal picked from a slice of sediment 2cm thick at 23.59–23.61m OD in Dark's Clark Site Core. Probably equivalent to context 241 in Trench CII	9260±100	–27.6	Mellars and Dark 1998, 142; Dark et al 2006
Legacy Sequences Star Carr Environs				
CAR-884	A 2cm slice from bulk of oxidised coarse detritus mud at 25.00m OD from Transect NC-Sample 25	8430±100	nm	Cloutman 1988, Table 1
CAR-885	A 2cm slice from bulk of coarse reed rich detritus mud at 24.00m OD from Transect NC-Sample 24	9510±100	nm	Cloutman 1988, Table 1
CAR-886	A 2cm slice from bulk *Phragmites* peat at 23.00m OD from Transect NC-Sample 23	10100±80	nm	Cloutman 1988, Table 1
CAR-864	A 2cm slice from bulk oxidised peat over calcareous sand at 25.00m OD from Transect SCP-Sample 25	8830±100	nm	Cloutman 1988, Table 1
CAR-866	A 2cm slice from bulk oxidised peat over sand with chalk pebbles at 24.00m OD from Transect SCP-Sample 24	8950±90	nm	Cloutman 1988, Table 1
CAR-867	A 2cm slice from bulk *Phragmites* peat over coarse grey sand at 23.00m OD from Transect SCP-Sample 23	10150±110	nm	Cloutman 1988, Table 1
CAR-868	A 2cm slice from bulk oxidised peat (possible plough damage) at 25.00m OD from Transect SCS-Sample 25	6200±90	nm	Cloutman 1988, Table 1
CAR-869	A 2cm slice from bulk oxidised reed peat at 24.00m OD from Transect SCS-Sample 24	9280±80	nm	Cloutman 1988, Table 1
CAR-870	A 2cm slice from bulk *Phragmites* peat at 23.00m OD from Transect SCS-Sample 23	9710±110	nm	Cloutman 1988, Table 1
VP85A Monolith M1				
OxA-3342	Miscellaneous waterlogged terrestrial plant detritus from a 0.5cm thick sample at 23.755–23.76m OD, the lower part of context 223 from Monolith M1 from the east-facing section of VP85A	9390±70	–29.2	Day 1993; Day and Mellars 1994; Mellars and Dark 1998
OxA-3343	Miscellaneous waterlogged terrestrial plant detritus from a 0.5cm thick sample at 23.705–23.71m OD, the base of context 223 from Monolith M1 from the east-facing section of VP85A	9420±70	–28.4	Day and Mellars 1994; Mellars and Dark 1998
OxA-4376	Unidentified waterlogged wood from a 2cm thick sample of coarse wood peat at 23.81–23.83m OD, from the middle of context 223 from Monolith M1 from the east-facing section of VP85A	9385±115	–28.5	Day and Mellars 1994; Mellars and Dark 1998
OxA-4377	Unidentified waterlogged wood from a 2cm thick sample of coarse wood peat at 23.93–23.95m OD, from the top of context 223 from Monolith M1 from the east-facing section of VP85A	8940±90	–28.5	Day and Mellars 1994; Mellars and Dark 1998

OxA-3344	Miscellaneous waterlogged terrestrial plant detritus from a 0.5cm thick sample of peat at 23.65–23.655m OD, from the middle of context 224 from Monolith M1 from the east-facing section of VP85A	9360±70	−28.1	Day and Mellars 1994; Mellars and Dark 1998
OxA-3345	Carbonised reed fragment from a 0.5cm thick sample of peat at 23.595–23.60m OD, from the top of context 225 from Monolith M1 from the east-facing section of VP85A	9580±70	−26.3	Day 1993; Day and Mellars 1994; Mellars and Dark 1998
OxA-3346	Unidentified waterlogged wood from a 1cm thick sample of coarse reed peat at 23.55–23.56m OD, from the middle of context 225 from Monolith M1 from the east-facing section of VP85A	9560±70	−27.3	Day and Mellars 1994; Mellars and Dark 1998
OxA-3347	Unidentified waterlogged wood from a 0.5cm thick sample of coarse reed peat at 23.505–23.51m OD, from the lower part of context 225 from Monolith M1from the east-facing section of VP85A	9680±70	−28.7	Day and Mellars 1994; Mellars and Dark 1998
OxA-3348	Carbonised reed from a coarse reed peat from a 0.5cm thick sample at 23.45–23.455m OD, from the top of context 226 from Monolith M1 from the east-facing section of VP85A	9700±70	−25.7	Day and Mellars 1994; Mellars and Dark 1998
OxA-3349	Unidentified waterlogged wood from a 0.5cm thick sample of coarse reed peat at 23.415–23.42m OD, from the middle of context 226 from Monolith M1 from the east-facing section of VP85A	9640±70	−26.6	Day 1993; Day and Mellars 1994; Mellars and Dark 1998
OxA-3350	Waterlogged *Populus tremula* and *Betula* sp. fruits, bud- and catkin-scales from a 1cm thick sample of coarse reed peat at 23.36–23.37m OD, from the base of context 226 from Monolith M1 from the east-facing section of VP85A	9500±70	−27.4	Day and Mellars 1994; Mellars and Dark 1998
OxA-3351	Waterlogged *Populus tremula* and *Betula* sp. fruits, bud- and catkin-scales from a 1cm thick sample of fine detrital mud at 23.30–23.31m OD, from the base of context 228 from the east-facing section Monolith M1 of VP85A	9630±100	−27.2	Day 1993; Day and Mellars 1994; Mellars and Dark 1998
VP85A/1 Cloutman pollen sequence				
CAR-1047	A 2cm slice of coarse wood peat at 23.87–23.89m OD, probably from the bottom of context 223 from Column 1 from the west-facing section of VP85A	9690±110	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1048	A 2cm slice of coarse wood peat at 24.19–24.21m OD, probably from the upper part of context 223 from Column 1 from the west-facing section of VP85A	8810±100	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1049	A 2cm slice of coarse wood peat at 24.13–24.15m OD, probably from the upper part of context 223 from Column 1 from the west-facing section of VP85A	9240±110	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1050	A 2cm slice of coarse wood peat at 23.97–23.99m OD, probably from the lower part of context 223 from Column 1 from the west-facing section of VP85A	9310±80	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1051	A 2cm slice of coarse wood peat at 23.83–23.85m OD, probably from the base of context 223 from Column 1 from the west-facing section of VP85A	10010±80	nm	Mellars 1990; Cloutman & Smith 1988
VP85A/2 Cloutman pollen sequence				
CAR-1017	A 1cm slice of coarse reed peat at 23.76–23.77m OD, probably from the top of context 224 from Column 2 from the west-facing section of VP85A	8580±90	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1018	A 1cm slice of coarse reed peat at 23.52–23.53m OD, probably from the base of context 225 (above timber platform) from Column 2 from the west-facing section of VP85A	9410±110	nm	Mellars 1990; Cloutman & Smith 1988

Table 17.2: *Continued*

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ^{13}C(‰)	References
CAR-1020	A 1cm slice of fine detrital mud at 23.36–23.37m OD, probably from the top of context 228 from Column 2 from the west-facing section of VP85A	9720±80	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1021	A 1cm slice of coarse sand with fine detrital mud at 23.33–23.34m OD, probably from the coarse sand (229) from Column 2 from the west-facing section of VP85A	11010±120	nm	Mellars 1990; Cloutman & Smith 1988
CAR-1019	A 1cm slice of coarse reed peat at 23.39–23.40m OD, probably from the base of context 226 from Column 2 from the west-facing section of VP85A	9410±110	nm	Mellars 1990; Cloutman & Smith 1988
VP85A/3 Cloutman pollen sequence				
CAR-1022	A 1cm slice of wood peat at 221. 23.94–23.95 m OD, probably from the base of context 221 from Column 3 from the west-facing section of VP85A	8670±90	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
CAR-1023	A 1cm slice of coarse reed peat at 23.65–23.66m OD, probably from the upper part of context 225 from Column 3 from the west-facing section of VP85A	9290±60	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
CAR-1024	A 1cm slice of coarse reed peat at 23.41–23.42m OD, probably from the upper part of context 226 from Column 3 from the west-facing section of VP85A	9540±110	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
CAR-1025	A 1cm slice of coarse reed peat at 23.35–23.36m OD, probably from the middle of context 226 from Column 3 from the west-facing section of VP85A	9480±100	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
CAR-1026	A 1cm slice of fine detrital mud at 23.25–23.26m OD, probably from the middle of con-text 288 from Column 3 from the west-facing section of VP85A	9680±110	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
CAR-1027	A 1cm slice of coarse sand with fine detrital mud at 23.14–23.15m OD, probably from the base of context 229 from Column 3 from the west-facing section of VP85A	10950±90	nm	Mellars 1990; Cloutman & Smith 1988; Mellars & Dark 1998
VP85B Cloutman Pollen Sequence				
CAR-1028	A 1cm slice of coarse detritus mud containing many reeds including *Phragmites* at 23.74–23.75m OD, at the top of the monolith from the north-facing section of VP85B	8620±100	nm	Cloutman & Smith 1988
CAR-1030	A 1cm slice of coarse *Cladium* peat at 23.26–23.27m OD, from the monolith from the north-facing section of VP85B	9160±100	nm	Cloutman & Smith 1988
CAR-1031	A 1cm slice of fine detrital mud at 23.10–23.11m OD, from the monolith from the north-facing section of VP85B	9760±100	nm	Cloutman & Smith 1988
CAR-1032	A 1cm slice of marl at 22.96–22.97m OD, from the top of the marl in the monolith from the north-facing section of VP85B	10710±90	nm	Cloutman & Smith 1988
CAR-1033	A 2cm slice of marl at 22.82–22.84m OD, from the base of the marl in the monolith from the north-facing section of VP85B	10520±90	nm	Cloutman & Smith 1988
CAR-1029	A 1cm slice of coarse *Cladium* peat at 23.50–23.51m OD, from the monolith from the north-facing section of VP85B	8830±100	nm	Cloutman & Smith 1988

Table 17.2: Radiocarbon and stable isotopic measurements on environmental samples made before 2006 (* indicates stable isotopic ratio measured by AMS).

have subsequently been made on materials from the site (Otlet et al. 1980; Scott et al. 1990; Rozanski 1991; Rozanski et al. 1992; Bronk Ramsey et al. 2002, Table 17.1; Scott 2003; Scott et al. 2007; Scott et al. 2010a; Scott et al. 2010b).

Replicate radiocarbon measurements are available on 27 samples: 19 samples have two measurements, seven samples have three measurements, and one has four (Tables 17.1 and 17.3). Nineteen of the 27 replicate groups are statistically consistent at 95% confidence (Ward and Wilson 1978), with three more consistent at the 99% level but not the 95% level. This scatter is more than would be expected simply from the statistical spread of replicate radiocarbon measurements. It is clear that samples of waterlogged wood have proven particularly problematic, as seven of the thirteen replicate groups are inconsistent. In contrast, only one of the nine replicate groups on animal bone or antler is statistically inconsistent (Table 17.1), probably reflecting our caution in only attempting to date bone from the deeper parts of the site where preservation was better.

Examination of the statistically inconsistent groups of measurements reveals that, in almost all cases, one measurement in the group is a clear misfit (e.g. OxA-4451 is clearly much more recent than the other two measurements on barbed point no.463; Table 17.1). This suggests that the issue is with the chemical pretreatment of certain samples, which did not adequately remove all exogenous carbon. Since all the participating laboratories produced some misfits, it is unlikely that the observed replication arises from laboratory error, rather some samples seem to have been degraded to the point where accurate dating was difficult (if not impossible). Overall, perhaps 9 or 10 of the 63 measurements in the replicate groups are incorrect (*c.* 15%). However, this is probably not a true reflection of the overall accuracy of the dataset as replicate measurements were not always selected randomly; rather, they were obtained on a number of samples when the initial result seemed problematic.

Five pairs of replicate $\delta^{13}C$ and $\delta^{15}N$ values are available, all of which are statistically consistent at 95% confidence (Ward and Wilson 1978; Table 17.3).

Statistically consistent replicate groups on radiocarbon measurements have been combined by taking a weighted mean before calibration and inclusion in the chronological model (Tables 17.1 and 17.3). The accuracy of each measurement in the statistically inconsistent groups has been assessed from the replicate group itself, from any notes made during its laboratory processing and from the agreement between the date and related dates within the model. The accuracy of measurements that have not been replicated has also been judged on this basis. Results that we consider inaccurate for technical reasons have been excluded from the model described below.

Modelling Star Carr

This is a complex model defined by the OxCal CQL2 code provided in Appendix 17.1 (with additional parameters calculated using the code provided in Appendix 17.2). The basic principle behind it is that stratigraphic relationships between radiocarbon dates associated with human activity and dates associated with environmental sequences and events are implemented together, and then cross reference is made to these constrained distributions in considering the chronologies of the human activity and lake edge environment respectively. For example, the dates on artefacts from the detrital wood scatter from trench SC34 were recovered from fine detrital mud that must post-date the start of organic sedimentation in the adjacent environmental profile 3178. However, this date estimate also provides information on when environmental Zone 1 began in a specific part of the lake edge. The parameter *onset organics 3178,* which is shown in the age-depth model in Figure 17.6, therefore cross-refers to both the archaeological and environmental parts of the model and is constrained by relationships of both types.

Human activity

The overall form of the model for human activity around the lake at Star Carr is illustrated in Figure 17.2. Human activity at Star Carr during the Mesolithic is assumed to comprise a relatively continuous period of possibly episodic but regular activity. Within this overall phase of use we have modelled separate phases for episodes of human occupation where we have four or more effective likelihoods (i.e. radiocarbon dates or calculated parameters) relating to that activity. This ensures that episodes of potentially short duration that have a

Laboratory number	Sample and context description	Radiocarbon age (BP)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C:N
110553					
OxA-32056	Waterlogged *Salix/Populus* sp. radially 1/3 split timber (Find no 110553), context 320	10010±40	−28.1±0.2		
SUERC-65242	Replicate of OxA-32056	9977±30	−28.3±0.2		
Mean	T′=0.4; T′(5%)=3.8; ν=1	9989±25			
Bead manufacturing area north of CIII					
OxA-33664	Carbonised *Betula* sp. bark roll (Find no 114968), context 310 to the north of Clark's trenches	9660±45	−30.0±0.2		
SUERC-66043	Carbonised *Betula* sp. bark roll (Find no 113409), context 310 to the north of Clark's trenches	9448±27	−27.3±0.2		
OxA-33663	Carbonised *Betula* sp. bark roll (Find no 115499), context 312 to the north of Clark's trenches	9550±40	−28.7±0.2		
SUERC-66039	Carbonised *Betula* sp. bark roll (Find no 115037), context 312 to the north of Clark's trenches	9552±30	−27.5±0.2		
Birch Bark Rolls in Clark's deposition area					
OxA-33667	Carbonised *Betula* sp. bark roll (Find no 116553), context 312 to the south of Clark's trenches	9580±45	−29.2±0.2		
OxA-33669	Carbonised *Betula* sp. bark roll (Find no 115195), context 312 to the south of Clark's trenches	9465±45	−29.8±0.2		
OxA-33670	Replicate of OxA-33669	9490±45	−29.1±0.2		
Mean	T′=0.2; T′(5%)=3.8; ν=1	9478±32			
SUERC-66048	Carbonised *Betula* sp. bark roll (Find no 115014), context 312 to the south of Clark's trenches	9600±28	−28.1±0.2		
SUERC-66049	Carbonised *Betula* sp. bark roll (Find no 115185), context 312 to the south of Clark's trenches	9389±29	−28.0±0.2		
Birch Bark Rolls to North of CII					
OxA-33665	Carbonised *Betula* sp. bark roll (Find no 94084), context 310 at the north end of Trench 34	9500±45	−30.8±0.2		
SUERC-66045	Carbonised *Betula* sp. bark roll (Find no 95934), context 310 at the north end of Trench 34	9519±29	−28.3±0.2		

Clark's deposition area

Lab code	Description	Age BP	δ13C	δ15N	C:N
OxA-33674	Groove and splintered *Cervus elaphus* antler beam from a frontlet/headdress (Find no 115876), the middle of context 312 from the baulk between cuttings I and II	9345±50	−21.0±0.2	+2.4±0.3	3.2
SUERC-66177	Replicate of OxA-33674	9431±32	−20.9±0.2	+3.0±0.3	3.3
Mean	T'=2.1; T'(5%)=3.8; ν=1	9406±27			
OxA-33676	Worked piece of *Bos primigenius* (Find no 117546), context 312 from the baulk between cuttings I and II	9560±45	−22.6±0.2	+3.7±0.3	3.1
OxA-33677	Worked piece of *Cervus elaphus* tibia (Find no 115872), context 312 from the baulk between cuttings I and II	9490±45	−20.3±0.2	+7.0±0.3	3.1
SUERC-66178	*Cervus elaphus* pedicle fragment from a frontlet/headdress (find no 114937), context 312 to the south of Clark's cutting I	9529±35	−22.5±0.2	+2.4±0.3	3.3
SUERC-66187	Worked piece of *Cervus elaphus* right ulna (Find no 117267), context 312 to the south of Clark's cutting I	9479±35	−21.6±0.2	+3.4±0.3	3.3
OxA-33675	Worked piece of *Cervus elaphus* radius (Find no 116803), context 317 from the baulk between cuttings I and II	9465±45	−22.4±0.2	+3.6±0.3	3.2
SUERC-66182	Worked piece of *Cervus elaphus* humerus (Find no 117900), context 317 to the south of Clark's cutting III.	9531±35	−22.4±0.2	+4.5±0.3	3.3
SUERC-66186	Worked piece of *Cervus elaphus* 3rd phalanx (Find no 116896), context 317 from the baulk between cuttings I and II	9518±35	−22.7±0.2	+3.1±0.3	3.3
Southern end of Clark's excavation area					
OxA-25240	Waterlogged *Salix* sp. bow with 5 rings (Find no 92684), context 234, cutting II extension. Rest of the artefact was excavated in 2015 (Find no 113300), Trench 34	9470 ±45	−26.1±0.2		
SUERC-66047	Carbonised *Betula* sp. bark roll (Find no 114814), context 312 south of Clark's excavation area, Trench 34	9518±29	−28.4±0.2		
Brushwood					
OxA-32059	Waterlogged *Salix/Populus* sp. tangentially split possible wood working debris (Find no 98016), context 312, brushwood spit 2	9580±40	−24.7±0.2		
OxA-32060	Waterlogged *Populus* sp. radial 1/3 split roundwood debris (Find no 94032), context 312, brushwood spit 1	9696±40	−27.9±0.2		
OxA-32320	Waterlogged cf *Salix/Populus* sp. radially half split roundwood debris (Find no 98031), context 312, brushwood spit 2	9615±45	−27.5±0.2		
SUERC-59170	Waterlogged *Salix* sp, tangentially split and possibly hewn timber (Find no 98009), context 312, brushwood spit 2	9465±31	−27.7±0.2		

Table 17.3: *Continued*

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ¹³C (‰)	δ¹⁵N (‰)	C:N
OxA-32055	Waterlogged cf *Salix/Populus* sp. or *Betula*, *Alnus/Corylus* sp., radially half split roundwood debris (Find no 98862), context 317, brushwood spit 7	9766±39	−26.1±0.2		
SUERC-59174	Waterlogged worked cf *Salix/Populus* sp., tangentially split roundwood debris (Find no 98792), context 317, brushwood spit 3	9471±31	−27.8±0.2		
SUERC-59175	Waterlogged worked *Betula/Alnus* sp, radially half split round wood (Find no 98865), context 317, brushwood spit 6	9547±31	−28.9±0.2		
SUERC-59176	Waterlogged worked cf *Salix/Populus* sp., radially half split roundwood debris (Find no 99210), context 317, brushwood spit 7	9670±31	−28.4±0.2		
OxA-32319	Waterlogged worked cf *Salix/Populus* sp., tangentially aligned outer split timber (Find no 103196), context 320, base of brushwood spit 9	9540±50	−29.1±0.2		
Central Platform					
OxA-25247	Waterlogged *Betula* sp. twig (Sample no 381A.3), picked from a bulk sample 4cm thick at 23.86–23.90m OD, context 223, Trench VP85A	8865±40	−29.9±0.2		
OxA-26561	Waterlogged *Salix* sp. twig (Sample no 246B), context 224, Trench VP85A	9305 ±45	−28.3±0.2		
SUERC-40160	Replicate of OxA-26561	9415 ±30	−29.8±0.2		
Mean	T′=4.1; T′(5%)=3.8; ν=1	9382±25			
OxA-25246	Waterlogged cf *Betula* sp. bark (Sample 300), context 225, Trench VP85A	9515±40	−27.4±0.2		
SUERC-36338	Waterlogged *Populus* sp. roundwood (Sample 244), context 225, Trench VP85A	9555 ±35	−28.9±0.2		
SUERC-36339	Waterlogged *Salix* sp. twig (Sample no 381M.2) picked from a bulk sample 2.5cm thick at 23.435–23.46m OD from macrofossil profile VP85a/2010, context 226, Trench VP85A	9600 ±35	−27.2±0.2		
OxA-33570	Carbonised *Salix/Populus* sp. roundwood fragment with 3 years growth and pith but no bark (Sample 1909A), context 318, Trench 34	9580 ±50	−29.5±0.2		
SUERC-65241	Carbonised *Salix/Populus* sp. roundwood fragment with 8 years growth, close to the pith (Sample no 1909B), context 318, Trench 34	9606 ±30	−24.2±0.2		
OxA-32146	Waterlogged sapwood from unconverted timber of diffuse/semi ring porous species (Find no 99738) from the upper layer of central platform, context 312, Trench 34	9660±45	−28.0±0.2		
SUERC-59169	Replicate of OxA-32146	9702±45	−29.0±0.2		
Mean	T′=0.4; T′(5%)=3.8; ν=1	9681±32			
OxA-32318	Waterlogged *salix/populus* or *betula/alnus/corylus* sapwood from unconverted timber (Find no 99726) from the upper layer of central platform, context 312, Trench 34	9460±65	−28.2±0.2		
SUERC-59168	Replicate of SUERC-59168	9650±31	−29.2±0.2		

Mean	T'=**6.9**; T'(5%)=3.8; v=1				
OxA-33574	Waterlogged *Salix Populus* sp. tangentially split timber (Find no 103111), from the middle layer of the central platform, context 312, Trench 34	9735±45	−29.5±0.2		
OxA-33731	Waterlogged *Salix Populus* sp. tangentially split timber (Find no 103288), from the central platform, context 312, Trench 34	9675±45	−27.2±0.2		
SUERC-65243	Waterlogged *Salix Populus* sp. tangentially outer split timber (Find no 103290) from the lower layer of the central platform, context 312, Trench 34	9663±31	−26.8±0.2		
SUERC-65247	Waterlogged *Salix Populus* sp. tangentially split timber (Find no 103254) from the middle layer of central platform, context 312, Trench 34	9629±30	−27.4±0.2		
Cutting II 2010					
OxA-25238	Waterlogged *Salix* sp. stem (Sample no 450L.1) picked from bulk sample 5cm thick at 23.47–23.52m OD from macrofossil profile CII/2010, context 235, cutting II	9735±40	−27.6±0.2		
SUERC-36348	Waterlogged *Salix* sp. stem, (Sample no 450L.2) picked from bulk sample 5cm at 23.47–23.52m OD, from macrofossil profile CII/2010, context 235, cutting II	9710±35	−25.9±0.2		
OxA-25242	Waterlogged *Betula* sp twig (Sample no 450A.4) picked from bulk sample 5cm thick at 24.03–24.08 m OD, from macrofossil profile CII/2010, context 243/231, cutting II	8810±40	−28.4±0.2		
SUERC-36354	Waterlogged *Betula* sp twig (Sample no 450A.1) picked from bulk sample 5cm thick at 24.03–24.08 m OD, from macrofossil profile CII/2010, context 243/231, cutting II	8845±35	−28.1±0.2		
OxA-25239	Waterlogged *Salix* sp twig (Sample no 450H.1) picked from bulk sample 5cm thick at 23.67–23.72m OD, from macrofossil profile CII/2010, context 244, cutting II	9400±40	−27.7±0.2		
Detrital Wood Scatter					
OxA-33668	Carbonised *Betula* sp. bark roll (Find no 107756) associated with a partial wooden stick (possible torch), from context 312, Trench 34	9570±45	−28.2±0.2		
OxA-33672	*Cervus elaphus* pedicile from a frontlet/headdress (Find no 99528), from context 312, Trench 34	9545±45	−22.1±0.2	+1.5±0.3	3.2
SUERC-66179	Replicate of OxA-33672	9538±35	−22.1±0.2	+1.8±0.3	3.3
Mean	T'=0.0; T'(5%)=3.8; v=1	9541±28			
SUERC-66180	*Bos primigenius* left femur head (Find no 99484), from context 312, Trench 34	9553±33	−22.8±0.2	+4.9±0.3	3.2
OxA-32061	*Alces alces* antler (Find no 108966), from context 317, Trench 34	9680±45	−20.9±0.2	+1.5±0.3	3.4

Table 17.3: *Continued*

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ¹³C (‰)	δ¹⁵N (‰)	C:N
SUERC-59180	Replicate of OxA-32061	9608±39	−21.1±0.2	+1.5±0.3	3.3
Mean	T'=1.5; T'(5%)=3.8; *v*=1	9639±30			
OxA-32062	Unshed *Curvus elephus* antler (Find no 108967), from context 317, Trench 34	9645±45	−20.5±0.2	+3.5±0.3	3.4
SUERC-59184	Replicate of OxA-32062	9611±37	−20.5±0.2	+3.2±0.3	3.2
Mean	T'=0.3; T'(5%)=3.8; *v*=1	9625±29			
OxA-32063	*Alces alces* cranium (Find no 108941), from context 317, Trench 34	9820±45	−21.4±0.2	+2.4±0.3	3.4
SUERC-59185	Replicate of OxA-32063	9779±40	−21.6±0.2	+2.3±0.3	3.3
Mean	T'=0.5; T'(5%)=3.8; *v*=1	9797±30			
SUERC-59178	Waterlogged cf. *Salix/Populus* sp. radial 1/3 split timber (Find no 109559), from context 317, Trench 34	9723±31	−28.6±0.2		
SUERC-59179	Waterlogged *Salix/Populus* sp. unworked timber (Find no 109030), from context 317, Trench 34	9743±31	−28.9±0.2		
OxA-33673	*Cervus elaphus* antler beam from a frontlet/headdress (Find no 103625), context 317, Trench 34	9585±45	−21.0±0.2	+1.9±0.3	3.2
SUERC-66181	*Cervus elaphus* left tibia (Finds no 103639), from context 317, Trench 34	9780±32	−22.0±0.2	+3.5±0.3	3.2
OxA-33671	*Cervus elaphus* worked right metatarsal (Find no 103650), from context 317, Trench 34	9520±45	−21.7±0.2	+2.8±0.3	3.2
Eastern Platform					
OxA-33662	Waterlogged *Salix/Populus* sp. timber of unknown conversion 10–12 years growth (Find no 113252), part of the eastern platform, context 312, Trench 34 (Outer rings sampled).	9525±45	−27.9±0.2		
OxA-33713	Waterlogged *Prunus padus* seed picked from a 5cm thick layer of reed peat (Sample S3404A&B), from above tree (113251), context 312, Trench 34	9320±50	−29.0±0.2		
SUERC-66037	Waterlogged *Betula* sp. fruits and catkin scales from a 5 cm thick slice of fine detrital mud (Sample S3404E) below timber 113252, context 317, Trench 34	9762±29	−28.2±0.2		
SUERC-66036	Waterlogged *Salix/Populus* sp. tree 5–7 years of growth (Find no 113251), context 312, Trench 34. (Outer rings sampled).	9512±29	−29.1±0.2		
Peat over marl in the area south of the western platform					
OxA-25241	Waterlogged *Betula* sp. twig (Sample 446B.1) picked from a bulk sample 5cm thick from the top of context 233, cutting II extension	8883±39	−29.7±0.2		
SUERC-36353	Waterlogged *Betula* sp. twig (Sample 446B.2) picked from a bulk sample 5cm thick, from the top of context 233, cutting II extension	8890±35	−28.7±0.2		
SUERC-36349	Carbonised *Phragmites* reed fragment (Sample 446J.1) picked from a bulk sample 3cm thick, from the base of context 234, cutting II extension	9510±35	−25.0±0.2		

OxA-33666	Carbonised *Betula* sp. bark roll (Find no 108565) from context 310 to the south of the western platform, Trench 34	9640±40	−28.6±0.2		
SUERC-66046	Carbonised *Betula* sp. bark roll (Find no 108554), from context 310 to the south of the western platform, Trench 34	9577±28	−27.7±0.2		
SUERC-66044	Carbonised *Betula* sp. bark roll (Find no 108454), from context 310 to the south of the western platform, trench 34	9562±29	−26.3±0.2		
OxA-33678	*Canis familiaris* complete left canine (Find no 108574), from the semi-articulated skeleton of a dog, context 310, Trench 34	9680±50	−18.5±0.2	+13.0±0.3	3.3
SC14 Macrofossil column 3178					
SUERC-65223	Waterlogged rhizome/culm base of indeterminate species (Sample D2) picked from a 5cm thick slice of reed peat at 23.635–23.685m OD, top of context 312. From macrofossil column 3178, taken from the north facing section of Trench 34	9290±30	−28.8±0.2		
OxA-33698	Waterlogged *Betula* sp. fruits and catkin scales, *Populus tremula* budscales and *Carex* nutlets (Sample Q1), picked from a 2.5cm thick slice of reed peat at 23.235–23.26m OD, context 312. From macrofossil column 3178, taken from the north facing section of Trench 34	9555±55	−26.3±0.2		
SUERC-65227	Carbonised *Poaceae* sp. culm node (Sample Q2), picked from a 2.5cm thick slice of reed peat at 23.235–23.26m OD, context 312. From macrofossil column 3178, taken from the north facing section of Trench 34	9583±30	−27.2±0.2		
Mean	T'=0.2; T'(5%)=3.8; ν=1	9577±27			
OxA-33699	Waterlogged *Betula* sp. fruits (Sample R1) picked from a 2.5cm thick slice of reed peat at 23.21–23.234m OD, interface between contexts 312 & 317. From macrofossil column 3178, taken from the north facing section of Trench 34	9740±65	−25.6±0.2		
SUERC-65228	Waterlogged *Carex* nutlets, *Betula* catkin scales and *Populus tremula* budscales (Sample R3) picked from a 2.5cm thick slice of reed peat at 23.21–23.235m OD, interface between contexts 312 & 317. From macrofossil column 3178, taken from the north facing section of Trench 34	9559±31	−26.7±0.2		
Mean	T'=**6.4**; T'(5%)=3.8; ν=1	9593±28			
SUERC-65229	Unidentified waterlogged twig (Sample X2) picked from a 2.5cm thick slice of fine detrital mud at 23.06–23.085, context 317. From macrofossil column 3178, taken from the north facing section of Trench 34	10095±30	−29.7±0.2		
Eastern Dryland Structure					
SUERC-65237	Carbonised *Betula* sp. fragment of 20–25 years growth (Sample S156B), from the lower fill of the hollow of the eastern structure	9556±30	−27.2±0.2		

Table 17.3: *Continued*

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ¹³C (‰)	δ¹⁵N (‰)	C:N
OxA-33700	Carbonised cf *Salix/Populus* sp. fragment (Sample no S161A), context 178, fill of posthole 177 of the eastern structure	9540±55	−23.5±0.2		
SUERC-65232	Carbonised *Salix/Populus* sp. fragment (Sample S161B), context 178 fill of posthole 177 of the eastern structure	9519±31	−25.1±0.2		
SUERC-65233	Carbonised *Salix/Populus* sp. fragment (Sample S163B), context 182, fill of posthole 181 of the eastern structure	9587±32	−25.0 (assumed)		
Central Dryland Structure					
OxA-33569	Carbonised *Salix/Populus* fragment of c.20 years growth (Sample 1955), context 330 upper fill of the central depression of the central structure	9710±50	−26.1±0.2		
OxA-33701	Replicate of OxA-33569	9765±55	−24.0±0.2		
Mean	T'=0.5; T'(5%)=3.8; ν=1	9735±37			
SUERC-65238	Carbonised *Salix/Populus* fragment of c.20 years growth (Sample 1955E), context 330 upper fill of the central depression of the central structure	9221±30	−26.6±0.2		
SUERC-65239	Carbonised *Salix/Populus* fragment of c.20 years growth (Sample 1955C), context 330 upper fill of the central depression of the central structure	9754±32	−26.3±0.2		
OxA-33702	Carbonised *Salix/Populus* fragment (Sample S1989B) from context 339 fill of posthole 338 of the central structure	9460±50	−25.2±0.2		
SUERC-65240	Carbonised *Salix/Populus* fragment (Sample S1989A), context 339 fill of posthole 338 of the central structure	9536±31	−26.4±0.2		
Western Dryland Structure					
SUERC-65231	Carbonised *Betula* sp. young twig (Sample 3491A), from context 405 fill of posthole 411 of the western structure	1.7648±0.0063	−25.6±0.2		
OxA-33598	Carbonised *Betula* sp. young twig (Sample 3491B), from context 405 fill of posthole 411 of the western structure	1.43572±0.00405	−25.6±0.2		
SUERC-65230	Carbonised *Salix/Populus* fragment of 10-15 years growth (Sample 3350A), from context 507 fill of posthole 507 of the western structure	9542±30	−26.4±0.2		
OxA-33703	Carbonised *Salix/Populus* fragment of 15-20 years growth (Sample 3350B), from context 507 fill of posthole 507 of the western structure	9585±55	−24.9±0.2		
SUERC-65222	Carbonised *Betula* sp. fragment of 15–20 years growth (Sample 3438A), from context 515 fill of posthole 515 of the western structure	9524±30	−27.3±0.2		
OxA-33571	Carbonised *Betula* sp. fragment of 25–30 years growth (Sample 3438B), from context 515 fill of posthole 515 of the western structure	9515±50	−27.3±0.2		

SC22 2006			
Hd-30192	Waterlogged *Salix* sp. roundwood (Sample 4.4), extracted from Monolith Tin 4, taken from the east-facing section of Trench SC22. Equivalent to context 34	9375±20	−29.4
OxA-26558	Waterlogged *Salix* sp. roundwood (Sample 4.2), extracted from Monolith Tin 4, taken from the east-facing section of Trench SC22. Equivalent to context 34	9515±45	−27.1±0.2
OxA-26559	Replicate of OxA-26558	9525±45	−27.4±0.2
Mean	T'=0.0; T'(5%)=3.8; ν=1	9520±32	
SUERC-36356	Waterlogged *Salix* sp. roundwood (Sample 4.3), extracted from Monolith Tin 4, taken from the east-facing section of Trench SC22. Equivalent to context 34	9560±35	−28.7±0.2
SUERC-40163	Waterlogged *Salix* sp. roundwood (Sample 4.1), extracted from Monolith Tin 4, taken from the east-facing section of Trench SC22. Equivalent to context 34	9455±30	−28.8±0.2
OxA-16809	*Cervus elaphus* worked antler (Find 82834), from the interface between context 35 and 39, Trench SC22	9355±40	−22.1±0.3
OxA-16810	*Cervus elaphus* antler (Find 82526) associated with a scatter of worked flint, from context 35, Trench SC22	9275±40	−22.2±0.3
OxA-25088	Waterlogged *Populus* sp. roundwood (Find 82660), from context 35, Trench SC22	9580±45	−26.4±0.2
SUERC-36355	Waterlogged *Salix* sp. roundwood (Find 82679), from context 35, Trench SC22	9450±35	−28.2±0.2
Hd-30168	Waterlogged *Salix* sp. roundwood (Find 82734) from the middle of context 39, Trench SC22	9481±20	−28.1
Hd-30190	Waterlogged *Salix* sp. roundwood (Find 82716), from the base of context 39, Trench SC22	9611±20	−28.0
SUERC-40161	Waterlogged *Betula* sp. roundwood stem (Find 827o5a), from context 39, Trench SC22	9525±30	−29.8±0.2
OxA-26560	Replicate of SUERC-40161	9540 ±45	−28.8±0.2
MAMS-18276	Replicate of SUERC-40161	9433±26	−28.2±0.3*
Mean	T'=7.3; T'(5%)=6.0; ν=2		
SUERC-40162	Waterlogged *Salix* sp. roundwood stem (82706B.1), from context 39, Trench SC22	9505±30	−28.2±0.2
OxA-26478	Replicate of SUERC-40162	9755 ±60	−27.3±0.2`

Table 17.3: *Continued*

Laboratory number	Sample and context description	Radiocarbon age (BP)	δ¹³C (‰)	δ¹⁵N (‰)	C:N
Mean	T'=**14.1**; T'(5%)=3.8; v=1				
Western Platform					
OxA-25236	Waterlogged *Corylus avellana* nutshell (Sample 201), from context 83, Trench SC24	9165±45	−26.3±0.2		
OxA-25237	Replicate of OxA-25236	9215±40	−26.1±0.2		
Mean	T'=0.7; T'5%=3.8; v=1	9193±30			
SUERC-36347	Waterlogged *Populus* sp. roundwood (Sample 4), from context 83, Trench SC24	9275±35	−27.8±0.2		
Hd-30166	Waterlogged *Populus* sp. roundwood (Sample 215), from context 84, Trench SC24	9420±21	−29.2		
OxA-25235	Waterlogged *Salix* sp. roundwood (Sample 216), from context 84, Trench SC24	9555±45	−27.7±0.2		
Hd-30193	Waterlogged *Populus* sp. worked timber (Sample 47/402) from the western platform, context 93, Trench SC24. (10 outer rings were sampled)	9463±18	−28.7		
SUERC-40168	Waterlogged *Populus* sp. worked timber (Sample 50), from the western platform, context 93, Trench SC24). (c. 10 outer rings were sampled)	9510±30	−29.7±0.2		
OxA-X-2475-22	Replicate of SUERC-40168	9570±90	−28.6±0.2		
Hd-30200	Replicate of SUERC-40168	9359±22	−29.4		
Hd-30439	Replicate of SUERC-40168	9302±23	−29.1		
Mean	T'=**35.9**; T'(5%)=7.8; v=3				
Hd-30440	Waterlogged *Populus* sp. worked timber (Sample 46/401) from the western platform, context 93, Trench SC24.	9606±22	−28.3		
OxA-26479	46b. Replicate of Hd-30440	9595±50	−27.2±0.2		
SUERC-40169	46a. Replicate of Hd-30440.	9585±30	−27.6±0.2		
Mean	T'=0.3; T'(5%)=6.0; v=2	9598±17			
SUERC-40170	Waterlogged *Populus* sp. worked timber (Sample 48) from the western platform, context 93, Trench SC24.	9515±45	−29.8±0.2		
MAMS-18277	Replicate of SUERC-40170	9441±26	−29.5±0.2		
Mean	T'=2.0; T'(5%)=3.8; v=1	9460±23			
OxA-25201	Waterlogged *Salix* sp. roundwood (Sample 453) recorded directly on top of the timbers of the western platform, context 93, Trench SC24	9550±45	−28.6±0.2		
SUERC-40164	453b. Replicate of OxA-25201	9445±30	−30.3±0.2		

Mean	T'=3.8; T'(5%)=3.8; ν=1	9478±25	
SUERC-36345	Waterlogged *Salix* sp. roundwood (Sample 455), recorded directly on top of the timbers of the western platform, context 93, Trench SC24	9485±35	−30.1±0.2
OxA-26562	455b. Replicate of SUERC-36345	9545±55	−28.9±0.2
Mean	T'=0.8; T'(5%)=3.8; ν=1	9502±30	
OxA-25202	Waterlogged *Populus* sp. roundwood (Sample BO344) from context 93, Trench SC24. Recovered during the micro-excavation of a sediment block (Hadley et al 2010)	9620±50	−28.1±0.2
SUERC-36346	Waterlogged *Salix* sp. roundwood (Sample BO343), from context 93, Trench SC24. Recovered during the micro-excavation of a sediment block (Hadley et al 2010)	9590±35	−27.8±0.2
Hd-30167	Waterlogged *Populus* sp. waterlogged plank (Find 418) of the western platform, from context 245, Trench CII. (approx. outermost 10 years sampled).	8951±18	−27.9
Hd-30201	Waterlogged *Populus* sp. worked timber (Find 420) from the western platform from context 245, Trench CII. (c. 10 outer rings sampled).	9451±34	−28.4
SUERC-59177	Waterlogged *Betula* sp. bark mat (Find no 99307b) from context 312/310.	9502±31	−27.2±0.2
OxA-32057	Replicate of SUERC-59177	9650±38	−25.3±0.2
OxA-32058	Replicate of SUERC-59177	9630±38	−25.3±0.2
Mean	T'=**11.4**; T'(5%)=6.0; ν=2		
OxA-25199	Waterlogged *Salix* sp. twig (Sample 460.3) from context 98, Trench SC24.	9765±50	−26.9±0.2
OxA-25200	Waterlogged *Salix* sp. twig (Sample 438.3), picked from a 50mm slice of bulk sediment immediately below timber 402 of the western platform, context 97, Trench SC24	9765±45	−28.5±0.2
OxA-26563	Waterlogged *Salix* sp. twig (Sample 438.5) picked from a 50mm slice of bulk sediment immediately below timber 402 of the western platform, context 97, Trench SC24.	9650±45	−27.5±0.2
SUERC-36343	Waterlogged *Salix* sp. twig (Sample 460.2) from context 98, Trench SC24.	9680±30	−28.5±0.2
SUERC-36344	Waterlogged Salix sp. twig (Sample 438.2), picked from a 50mm slice of bulk sediment immediately below timber 402 of the western platform, context 97, Trench SC24.	9590±35	−28.4±0.2

Table 17.3: Radiocarbon and stable isotopic measurements on samples analysed as part of this project (* indicates stable isotopic ratio measured by AMS).

number of dated samples, for example Clark's area, are proportionally weighted in our analysis as this event is represented in the overall model by only its two boundary parameters (i.e. *start Clark area* and *end Clark area*; Figure 17.15).

Within our model of human activity we have only included dates on samples with a clear anthropogenic association. These are: worked or butchered faunal material, worked wood, charcoal from cut features or forming discrete concentrations within the peat, the remains of domestic dogs, birch bark rolls, and the resin cake from Clark's excavations. As described above, because of concerns about the difficulty of accurately radiocarbon dating some materials (particularly the faunal remains), we have also dated many non-anthropogenic samples stratigraphically related to them. These have been used as constraints for dating the archaeology. We have also been able to estimate the dates of anthropogenic events that have not been directly dated by specific radiocarbon samples: for example, the dates of the three burning episodes identified by Dark (1998a) in her pollen profile M1. These have also been included as effective likelihoods in the overall model for human activity.

We have decided to use the agreement indices provided by OxCal (Bronk Ramsey 1995, 429; Bronk Ramsey 2009a, 356-7) for outlier detection in this analysis. This is because of the detailed information we have regarding, for example, sample chemistry, which means that in many cases we have information that allows us to choose an appropriate approach for modelling specific samples. However, we recognise that for the sediment profiles in particular, where we do not really have specific information that allows us to distinguish between reworked or intrusive material, an outlier approach might be more appropriate. It is not, however, possible to use a combination of these approaches in a single model and so we have judged that the advantages of using indices of agreement in this case outweigh the benefits of outlier modelling. The model presented has good overall agreement (Amodel: 65).

First, we begin by considering parts of the archaeological sequence which can be closely stratigraphically related to dated environmental profiles. This allows us to create age-depth models for the sediment sequences, which provide strong prior information for the anthropogenic and other dated samples that can be related to them. There are three such profiles, each of which has three or more radiocarbon measurements on samples that we know derive from the terrestrial biosphere. Each profile has been modelled using a Poisson-process age-depth model (Bronk Ramsey 2008, 43–7) with variable rigidity ((P_Sequence("",100,0U(-2,2))); Bronk Ramsey and Lee 2013, 723–6). This means that we assume that sedimentation was continuous but did not necessarily occur at an entirely uniform rate. The deviations from a constant accumulation rate are calculated by the model.

The first component is centred around a combined environmental profile from Dark's pollen and macrofossil profile M1 (Dark 1998a) and macrofossil profile VP85A/2010 (see Chapter 19), which can be related to the timbers of the central platform. The relative sequence of dated samples in this component is illustrated in Figure 17.3. The age-depth profile is shown in Figure 17.4. This profile includes measurements originally obtained by Dark (1998a, Table 17.1) with two additional dates from the sequence of macrofossil samples (Profile VP85-2010) taken immediately to the north (see Chapter 19). The boundaries of the Poisson-process model have been placed at the points on the environmental profile which reflect transitions to increasingly shallow and terrestrial conditions (i.e. *onset organics M1*, *start seasonal flooding M1*, and *onset fen carr M1*). This allows for the possibility that the sedimentation rate may have changed at these points. We have also estimated the dates of the burning episodes identified by Dark (1998a, 149) from the age-depth model. The start of burning episode 1 is dated by *OxA-3349*, but the other dates have been interpolated from their heights in the age-depth profile. A *terminus post quem* for the top of the profile is provided by CAR-1022, a measurement on a bulk sample of wood peat from a stratigraphically later context in pollen profile VP85A/3 recorded by Cloutman and Smith (1988, 46; Figure 6).

Parts of this environmental profile can be related to horizons in Cloutman's pollen profiles VP85A/2 and VP85A/3 (Cloutman and Smith 1988). The utility of his radiocarbon dates is limited by the fact that, perforce, he had to date bulk sediment samples, many of which came from deposits that contained aquatic material. These measurements may therefore include a component of hard-water error (Philippsen 2013), making the results anomalously old in comparison with fully terrestrial materials from the same deposits. For this reason, where it is probable that samples dated by Cloutman would contain aquatic material, these have been modelled as *termini post quos* for their deposits. *CAR-1027* and *CAR-1021* are earlier than *onset organics M1*, *CAR-1026* and *CAR-919* can be placed between *onset organics M1* and *start seasonal flooding*. Later than *start seasonal flooding M1* lie *CAR-1025* and *CAR-1024*. Above these are a date on an aurochs metatarsal 56 (OxA-1176) and
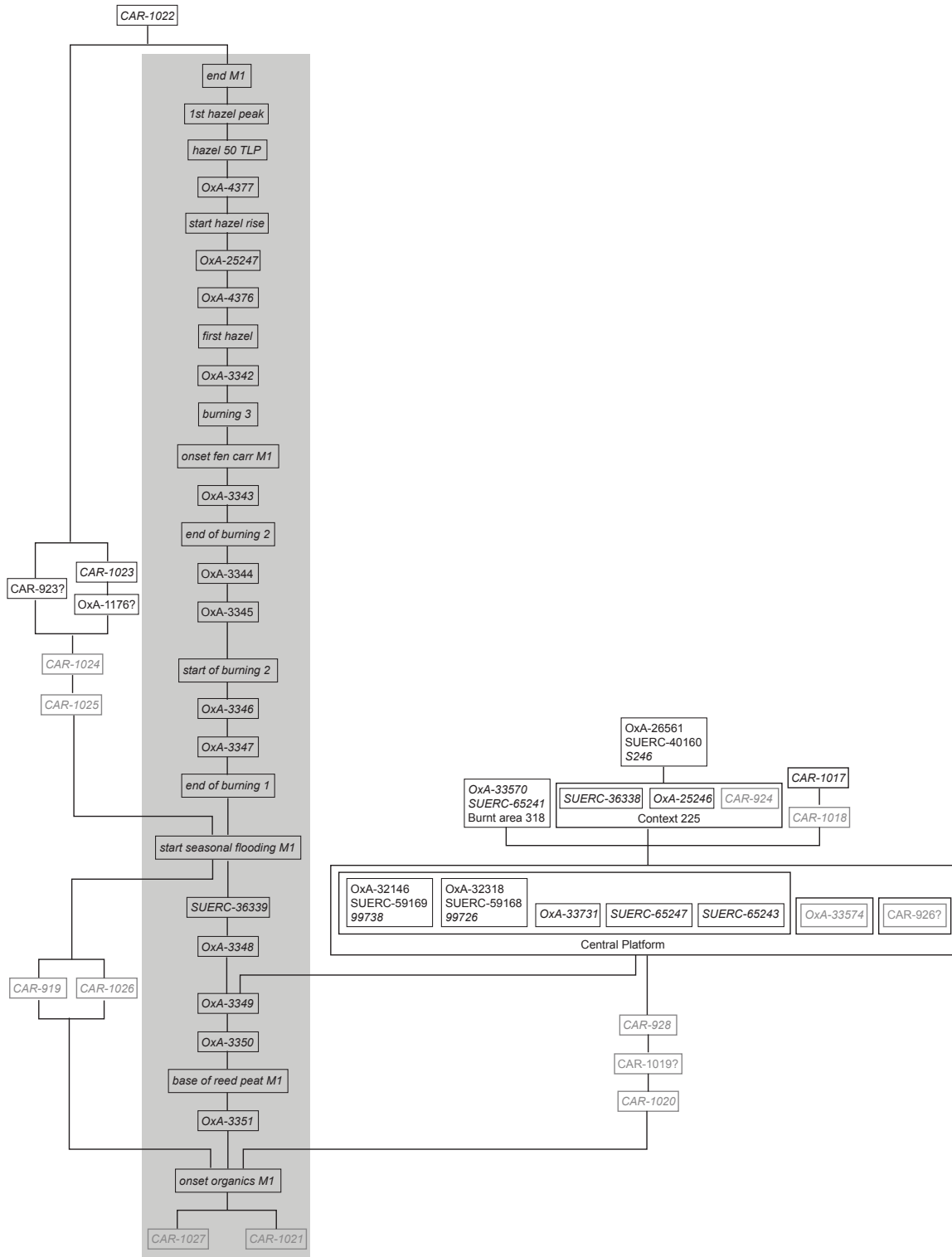
Figure 17.3: Harris matrix of dated samples from the component of the model including environmental profile M1 and VP85A 2010, the central platform, and stratigraphically related deposits (grey lettering, *termini post quos*; ?, excluded from model; grey shading, extent of age-depth model) (Copyright Historic England, CC BY-NC 4.0).

Boundary end M1

1st hazel peak
hazel 50 TLP

R_Date OxA-4377 [A:111]

start hazel rise

R_Date OxA-25247 [A:104]

R_Date OxA-4376 [A:46]

first hazel

R_Date OxA-3342 [A:70]

burning 3
Boundary onset fen carr M1
R_Date OxA-3343 [A:129]

end of burning 2

R_Date OxA-3344 [A:66]

R_Date OxA-3345 [A:90]

start of burning 2
R_Date OxA-3346 [A:115]

R_Date OxA-3347 [A:81]
end of burning 1
Boundary start seasonal flooding M1
R_Date SUERC-36339 [A:116]
R_Date OxA-3348 [A:75]

R_Date OxA-3349 [A:104]

R_Date OxA-3350 [A:98]
base of reed peat M1

R_Date OxA-3351 [A:106]
Boundary onset organics M1
P_Sequence VP85 2010 & M1 [A:100]

Position (m OD)

24.0
23.9
23.8
23.7
23.6
23.5
23.4
23.3

10000   9500   9000   8500   8000   7500

Posterior density estimate (cal BC)

the surrounding sediment (CAR-923), and a sample from an equivalent level in pollen profile VP85A/3 (*CAR-1023*). The measurements on OxA-1176 and CAR-923 diverge by more than 600 radiocarbon years. OxA-1176 is slightly too old for its stratigraphic position. It is possible that the aurochs metatarsal was reworked from an earlier deposit. However, we think that this is unlikely as contemporary assemblages of bone would have been sealed by substantial deposits of peat by this time. Given the demonstrable technical challenges of producing accurate radiocarbon dates on bone samples from Star Carr, we therefore think it is likely that this measurement is anomalously old. OxA-1176 was prepared using the gelatinisation and ion-exchange protocol (Hedges and Law 1989; Law and Hedges 1989), and it is possible that chemicals from the ion-exchange column may have contaminated the sample (Hedges and Pettitt 1998). CAR-923 seems to be anomalously recent for its position within the reed peat in comparison with SUERC-65223, which dates the top of this layer in the nearby environmental profile 3178 (see below). For this reason it has been excluded from the model. All three samples at this height are earlier than *CAR-1022*. A sequence of samples, *CAR-1020*, CAR-1019 and *CAR-928*, fall between *onset organics M1* and *central platform*. CAR-1019 is anomalously recent and has been excluded from the model. The central platform is also stratigraphically later than the level in the M1 profile dated by *OxA-3349*. This is a conservative reading that allows for uncertainties in the relationship between the platform and the dated samples in the environmental profiles.

Seven timbers have been dated from the three layers of the central platform (Chapter 6). Of these CAR-926 (a measurement obtained by Cloutman and Smith on an unidentified timber from the platform) seems to be anomalously recent and has been excluded from the model. *OxA-33574,* a measurement on timber <103111>, is slightly earlier than the other dated timbers and may have been salvaged from the surrounding swamp (and have been several hundred years old when incorporated in the platform; *reuse central*; Figure 17.19). The radiocarbon measurements on the other five timbers are statistically consistent (T'=3.4; T'(5%)=9.5; v=4; Ward and Wilson 1978). Though it was made up of three layers, the timbers lay directly on top of one another with no intervening sediment. As such, we believe the platform was constructed as a single event, and so we have combined the dates on its timbers. This suggests that the central platform was constructed in *8985–8925 cal BC (95% probability; central platform*; Figure 17.14), probably in *8970–8940 cal BC (68% probability)*.

Stratigraphically later than the platform was a discrete concentration of charcoal (318) which appears to be associated with a dense scatter of worked flint generated through the manufacture of a number of axes (Chapters 8 and 32). Several environmental samples are also later than the platform: *SUERC-36338*, and *OxA-25246*, which were collected from deposits overlying the timbers during the 2010 excavations, and *CAR-924* from comparable deposits excavated in 1985 (Cloutman and Smith 1988). These dates are, in turn, earlier than *S246*, a twig from the overlying sediment. Also later than the central platform are *CAR-1018* and *CAR-1017*, from Cloutman's VP85A/2 pollen profile (Cloutman and Smith 1988). *CAR-924 and CAR-1018* were bulk sediment samples that could have contained a component of aquatic plant material and so, conservatively, have been incorporated in the model as *termini post quos*.

The second sediment profile that can be related stratigraphically to archaeological activity is Profile 3178, a vertical sequence of macrofossil samples taken from the north-facing section of trench SC34 and adjacent to the southern edge of the debris scatter (Chapter 19). Six radiocarbon measurements are available from four levels in this sequence, although unfortunately a further six failed in laboratory processing. The relative sequence of dated samples in this component is illustrated in Figure 17.5. The age-depth model for profile 3178 is shown in Figure 17.6 and the phase of use of the detrital wood scatter is shown in Figure 17.7.

Five samples of bone and antler (*SUERC-66181, OxA-33671, OxA-33673, <108967> and <108966>*) and two samples of waterlogged wood (*SUERC-59178–9),* from the detrital wood scatter within the fine detrital

Figure 17.4 (page 60): Probability distributions of radiocarbon dates in the age-depth model for environmental profile M1 and VP85A 2010. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one, based on the chronological model used. Distributions other than those relating to particular samples correspond to aspects of the model. For example, the distribution '*onset organics M1*' is the estimated date when organic sedimentation began at this location. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).
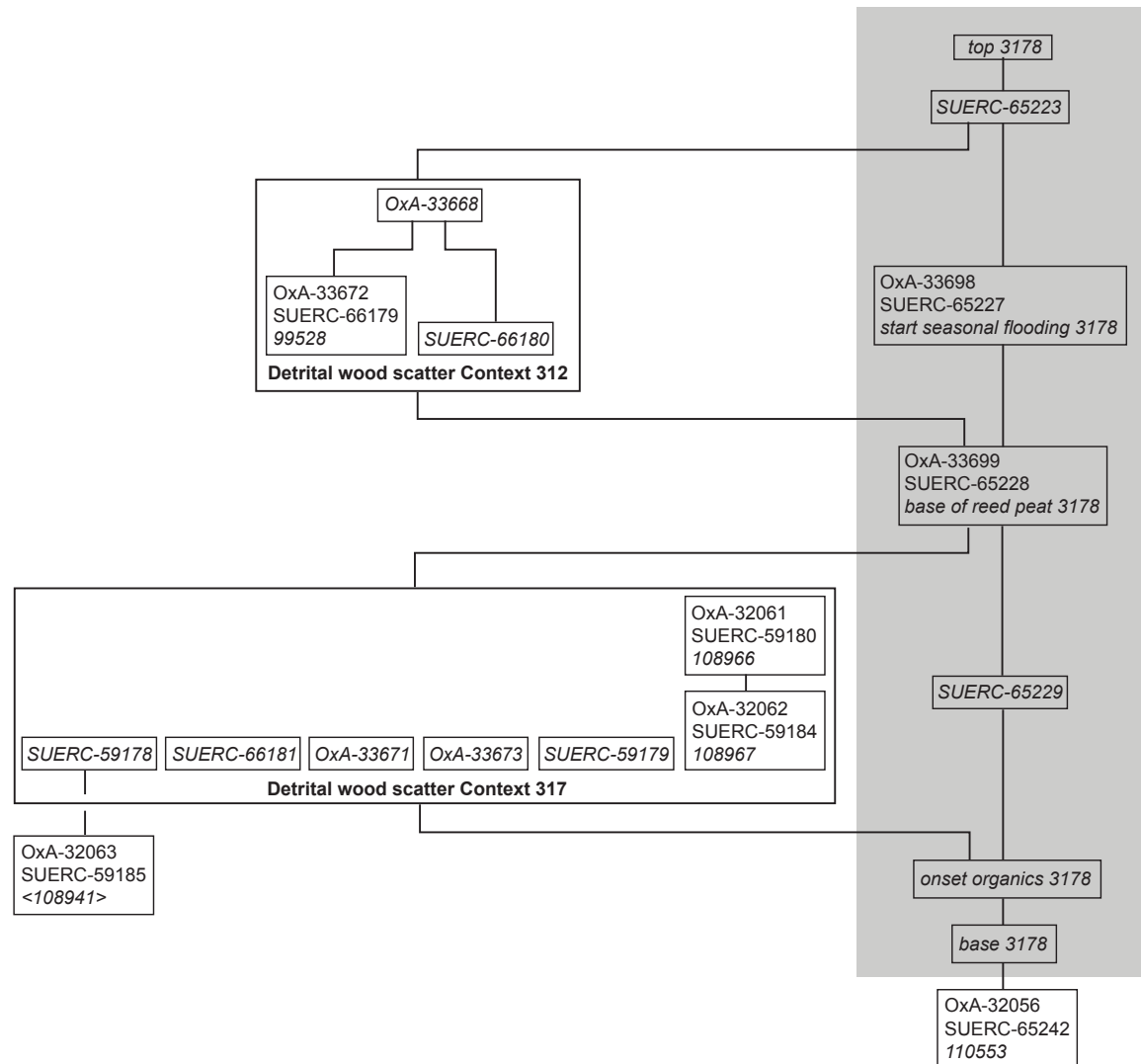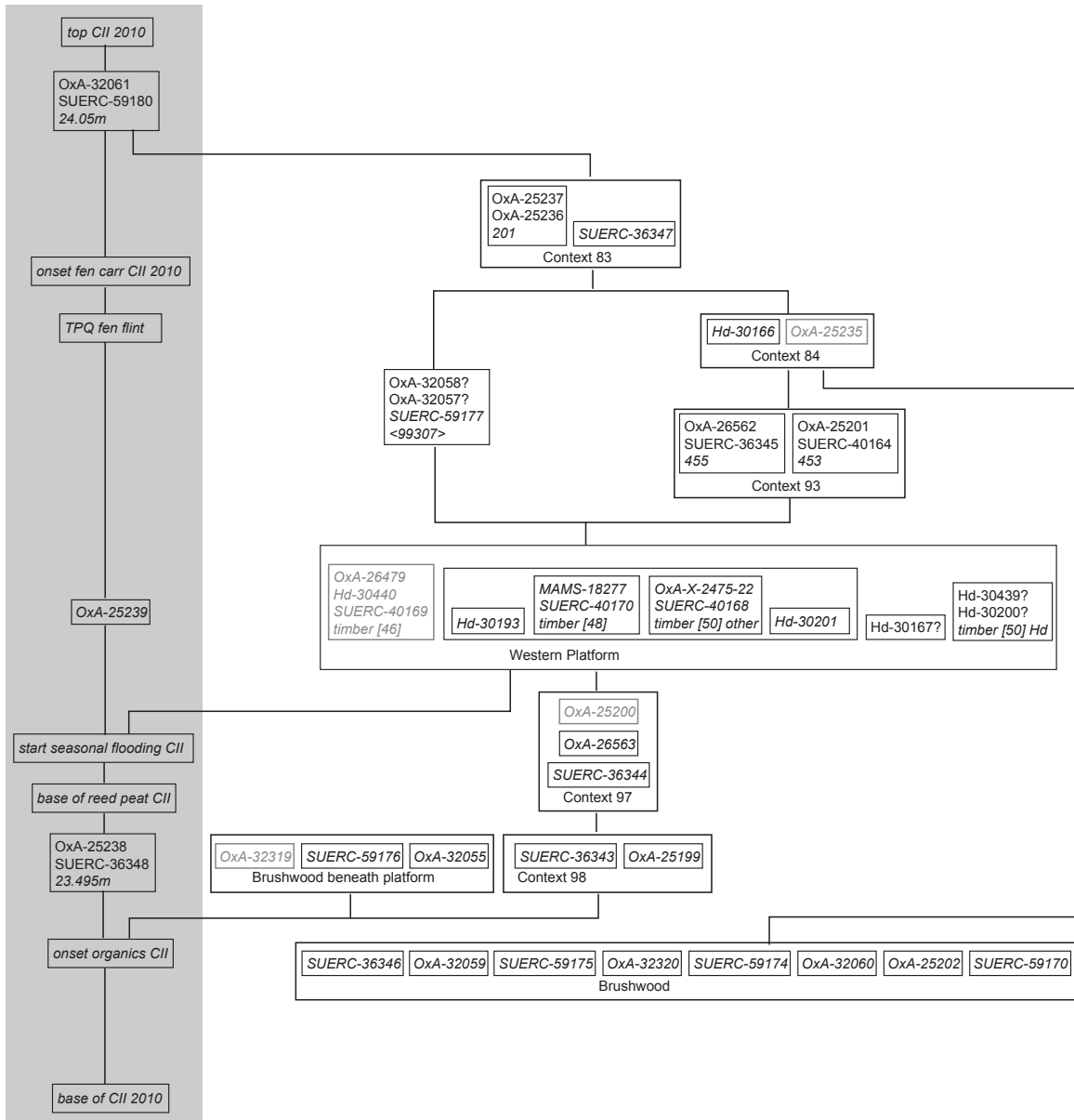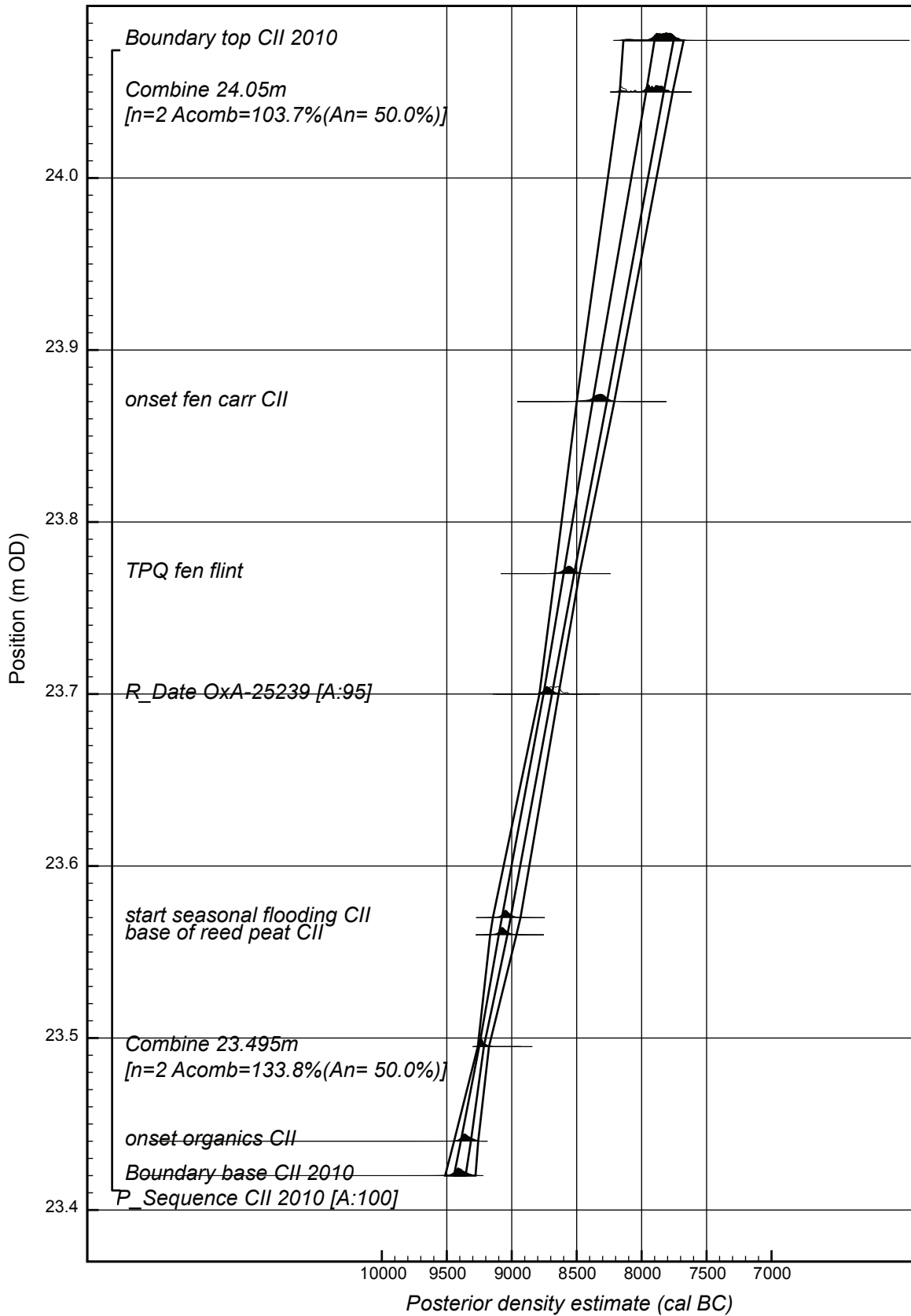
Figure 17.5: Harris matrix of dated samples from the component of the model including environmental profile 3178, the detrital wood scatter and stratigraphically related deposits (grey lettering, *termini post quos*; ?, excluded from model; grey shading, extent of age-depth model) (Copyright Historic England, CC BY-NC 4.0).
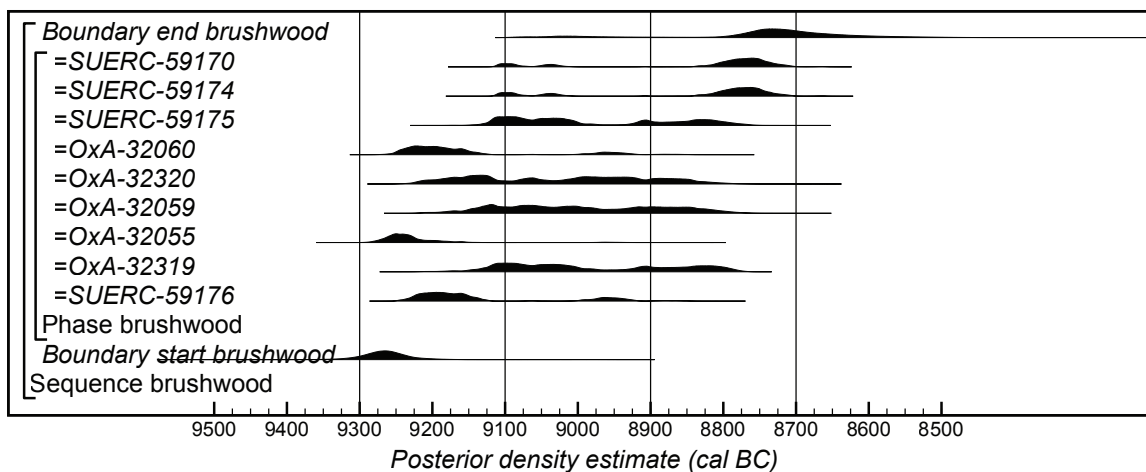
mud (317) have been dated (Chapters 6 and 7). These are stratigraphically later than *onset organics 3178* and earlier than *base of reed peat 3178*. Unshed red deer antler *<108967>* is physically below elk antler *<108966>*. Above this was recorded an unworked waterlogged timber (*SUERC-59179*), although the relevant radiocarbon measurements are incompatible with this sequence and this timber seems to have been displaced. *<108967>* is recorded as lying above a radially split timber *<110553>* from the underlying sand (320). There are two statistically consistent measurements on this timber (OxA-32056 and SUERC-65242; T'=0.4; T'(5%)=3.8; ν=1).

Figure 17.6 (page 63): Probability distributions of radiocarbon dates in the age-depth model for environmental profile 3178. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

Boundary top 3178

23.8

R_Date SUERC-65223 [A:107]

23.6

Position (m OD)

23.4

R_Combine start seasonal flooding 3178 [A:104]

R_Combine base of reed peat 3178 [A:93]

23.2

R_Date SUERC-65229 [A:26]

onset organics 3178
Boundary base 3178
P_Sequence Profile 3178 [A:100]

23.0

11000   10000   9000   8000   7000   6000

Posterior density estimate (cal BC)
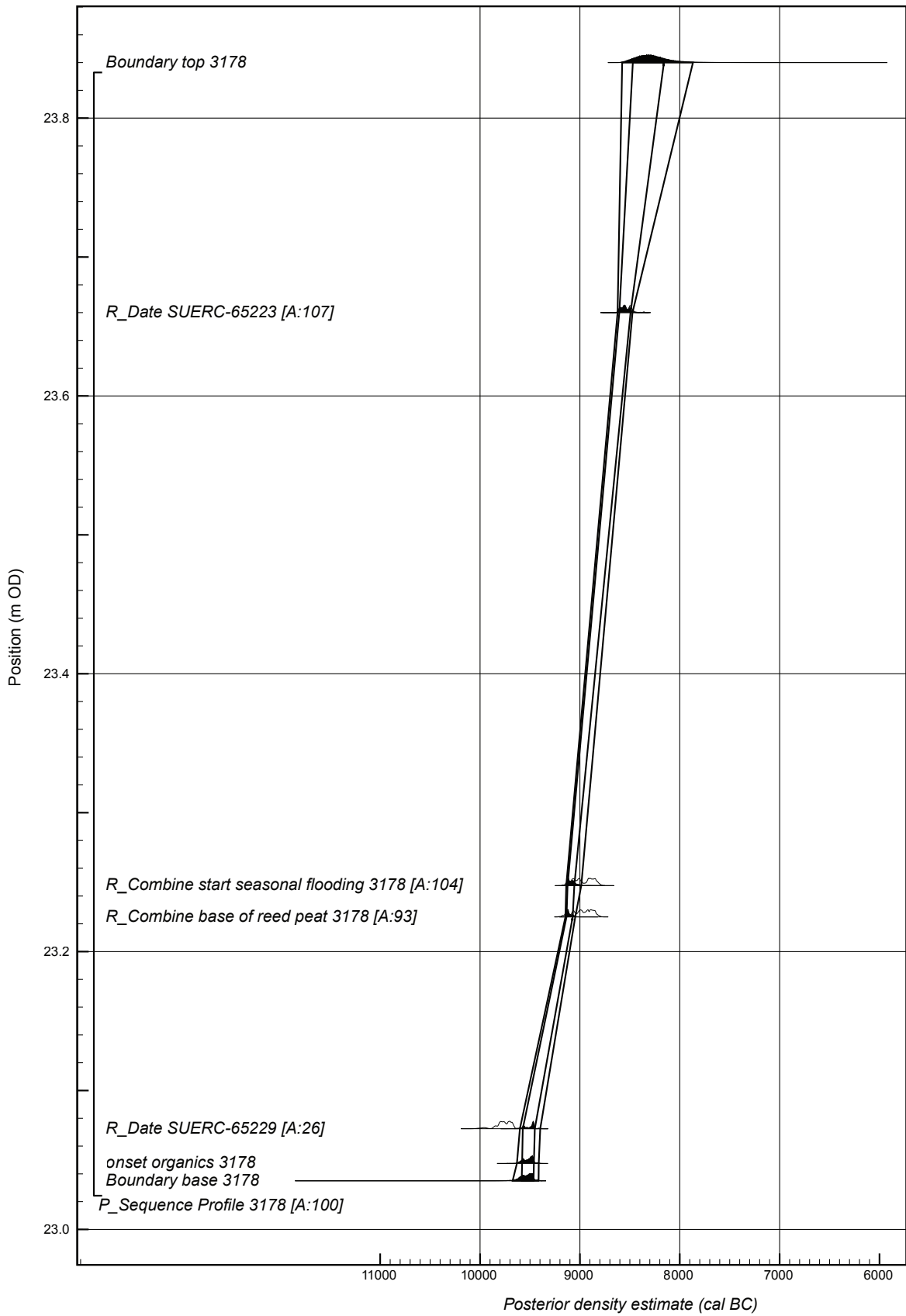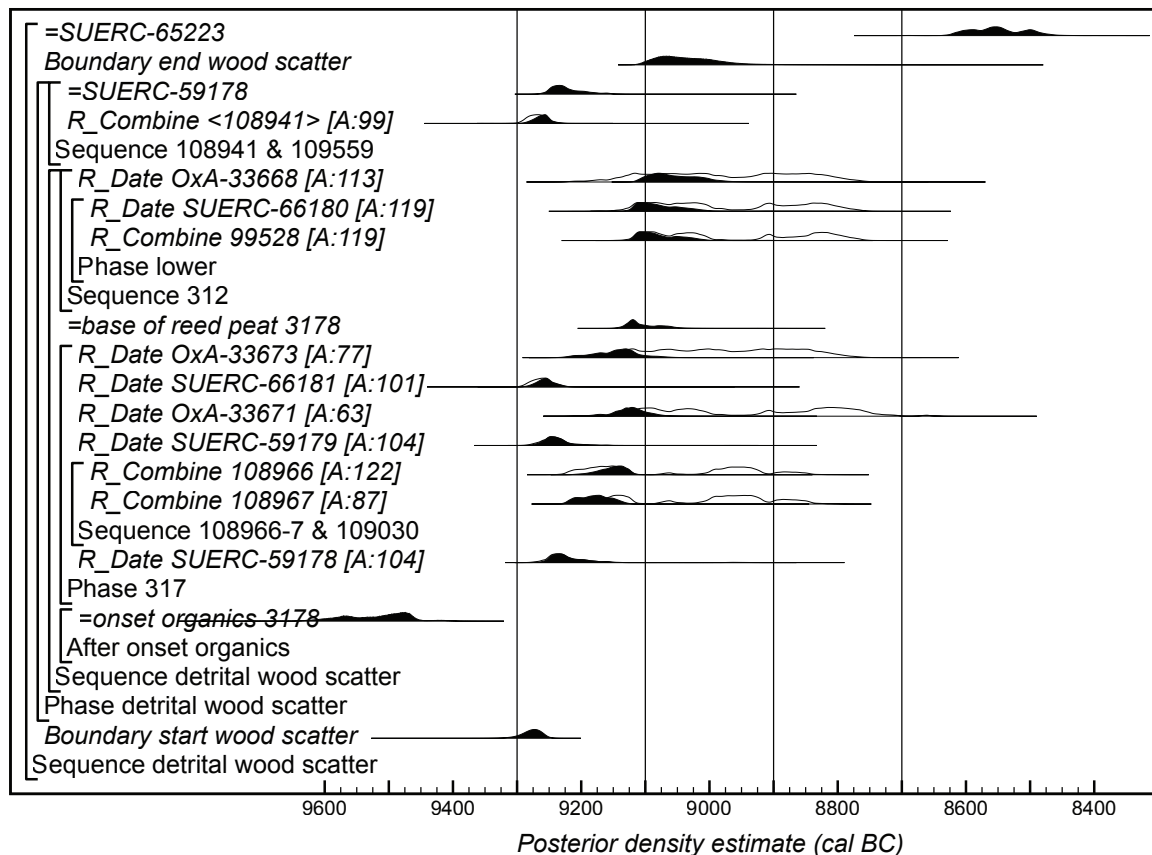
Figure 17.7: Probability distributions of radiocarbon dates from the detrital wood scatter. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

However, their weighted mean (9989±25BP) is far earlier than any other anthropogenic sample dated from Star Carr. Given that there are two statistically consistent measurements from two different laboratories it seems unlikely that the measurements are in error, and these results are compatible with this timber being earlier than *onset organics 3178*. This makes it unlikely that the timber is part of the detrital wood scatter that has been pushed down into the underlying sand. This leaves two possibilities: either the timber was not worked and the recording is in error (which we do not think is likely), or it represents an earlier episode of human activity at the edge of the lake. One further sample has been dated from the lower part of the detrital wood scatter, an elk skull *<108941>* (Chapter 7), which lay at the interface between the basal sands (320) and the overlying fine detrital mud (317) and below the timber dated by *SUERC-59178*. *<108941>* has been included in the model for the detrital wood scatter, but we do not know its relationship to *onset organics 3178*. The detrital wood scatter continues into the overlying reed peat (312) where there are measurements on an antler frontlet and aurochs bone (*<99528>* and *SUERC-66180*) and on a birch bark roll from a higher level within the same deposit (*OxA-33668*). The detrital wood scatter ends before *top 3178*.

The third sediment profile that can be related stratigraphically to archaeological activity is Profile CII/2010, a vertical sequence of macrofossil samples taken from the west-facing section of Clark's cutting II. Five radiocarbon measurements are available from three dated levels. The relative sequence of dated samples in this component is illustrated in Figure 17.8. The age-depth model for profile CII/2010 is shown in Figure 17.9 and the model for the human activity represented by the worked material within the brushwood is shown in Figure 17.10. The earliest dated archaeological material that can be associated to this profile comes from a deposit of *Salix/Populus* sp. roundwood recorded immediately to the east of cutting II in 2013. This has been referred to as brushwood, though the deposit actually represents an accumulation of both unworked and

Figure 17.8: Harris matrix of dated samples from the component of the model including environmental profile CII 2010, the western platform and stratigraphically related deposits (grey lettering, *termini post quos*; ?, excluded from model; grey shading, extent of age-depth model) (Copyright Historic England, CC BY-NC 4.0).

Boundary top CII 2010

Combine 24.05m
[n=2 Acomb=103.7%(An= 50.0%)]

onset fen carr CII

TPQ fen flint

R_Date OxA-25239 [A:95]

start seasonal flooding CII
base of reed peat CII

Combine 23.495m
[n=2 Acomb=133.8%(An= 50.0%)]

onset organics CII

Boundary base CII 2010

P_Sequence CII 2010 [A:100]

Position (m OD)

Posterior density estimate (cal BC)

Figure 17.10: Probability distributions of radiocarbon dates from the brushwood. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

anthropogenically modified roundwood. This material has accumulated through a combination of natural processes (falling from trees at the lake shore) and human agency. The modified material dates a phase of human activity in this area of the site that included the trimming and working of roundwood.

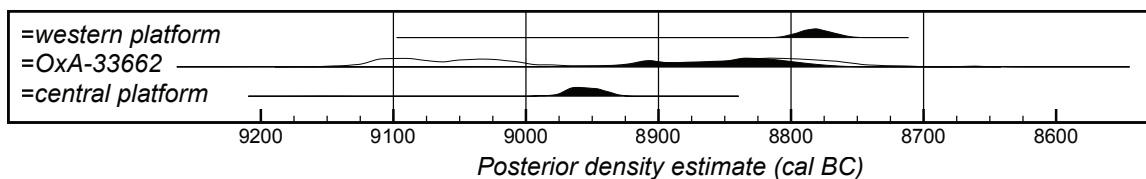One sample of worked roundwood (*OxA-32319*) has been dated from the basal sand (320). This provides a *terminus post quem* for the overlying western platform. Later than *onset organics CII*, seven samples have been dated from the final detrital mud (97=317) and twiggy layer (98) beneath the platform. These comprise two further samples of worked roundwood (*SUERC-59176* and *OxA-32055*) and three waterlogged twigs (*OxA-25200, OxA-26563* and *SUERC-36344*) from the fine detrital mud and two waterlogged twigs (*OxA-25199* and *SUERC-36343*) from the twiggy layer. One of the twigs (*OxA-25200*) seems to have been reworked and has been modelled as a *terminus post quem* for the overlying deposits. The western platform is also stratigraphically later than *start seasonal flooding CII,* based on the position of the worked timbers in cutting II relative to the macrofossil profile CII/2010.

Six worked timbers have been dated from the western platform (Chapter 6). Considerable difficulties have been encountered in producing accurate radiocarbon measurements on this material. Statistically consistent groups of measurements are available from timber <46> (Hd-30440, SUERC-40169, and OxA-26479; T'=0.3, T' (5%)=6.0, ν=2) and timber <48> (MAMS-18277 and SUERC-40170; T'=2.0, T' (5%)=3.8, ν=1). The measurements on timber <50>, however, are widely divergent (SUERC-40168, OxA-X-2475-22, Hd-30200, and Hd-30439; T'=35.9, T' (5%)=7.8, ν=3). The two measurements from Heidelberg are statistically consistent (T'=3.2, T' (5%)=3.8, ν=1) as are the two measurements from Oxford and East Kilbride (T'=0.4, T' (5%)=3.8, ν=1). However, the Heidelberg dates are anomalously recent in comparison to dates from material stratified above them. It seems that the Acid-Base Acid pretreatment protocol used at Heidelberg was not always effective, and that a bleaching step was required for this material. Hd-30167 from timber <418> seems to be anomalously recent for the same reason. Excluding these three measurements we have accurate dates on five timbers from the western platform. However, timber <46> is significantly earlier than the others (T'=41.5, T' (5%)=9.5, ν=4) and appears to have been salvaged from an earlier episode of activity (and to have been some decades old when reused; *reuse western*; Figure 17.19). The remaining radiocarbon measurements on the other four

Figure 17.9 (page 66): Probability distributions of radiocarbon dates in the age-depth model for environmental profile CII 2010. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

timbers are statistically consistent (T'=3.2, T' (5%)=7.8, ν=3). Although it was made up of several layers of wood, there was no intervening sediment and there was little vertical variation between the timbers. For these reasons we believe the platform was constructed as a single event, and so we have combined the dates on its timbers. This suggests that the western platform was constructed in *8805–8755 cal BC* (*95% probability; western platform*; Figure 17.14), probably in *8795–8765 cal BC (68% probability)*.

Lying on the surface of the platform were two pieces of roundwood (*453* and *455*) that must post-date its construction. In the overlying deposit, two samples of roundwood have been dated (*Hd-30166* and *OxA-25235*), although the latter appears to be reworked. Difficulties were also encountered in obtaining accurate measurements on the bark mat <99307> recovered from the reed peat above the platform (Chapter 30). The three measurements are not statistically consistent (T'=11.4, T' (5%)=6.0, ν=2). The Oxford measurements are anomalously old for their position in the stratigraphic sequence, but the *SUERC-59177* has good agreement with its position in the model (A: 109). Overlying all these samples are dates on a piece of waterlogged round wood (*SUERC-36347*) and a waterlogged *Corylus avellana* nut shell (*201*) from the overlying sediment. Stratigraphically later than these are the dates on macrofossils from *24.05m* at the top of Profile CII/2010.

Three more pieces of worked roundwood have been dated from brushwood recovered from the reed peat above the western platform (*OxA-32059*, *OxA-32320*, and *SUERC-59175*). However, the results are too early for this stratigraphic position and the wood appears to be reworked. They have thus been placed within the phase of human activity represented by the worked material within the brushwood (see above) and are later than *onset organics CII* and earlier than *Hd-30166* and *OxA-25235* from the overlying context. Five further samples of brushwood have been dated. Whilst these cannot be securely related stratigraphically to the western platform they must also fall within these stratigraphic boundaries. Two of these (*SUERC-36346* and *OxA-25202*) are unworked and simply provide constraints for the sequence. However, the other three have been humanly modified (*OxA-32060*, *SUERC-59170*, and *SUERC-59174*) and so, again, have been placed within the phase of human activity represented by the worked material within the brushwood.

One further sequence of natural deposits must be described before we outline the model for human activity at Star Carr. This is the sequence of samples recovered from trench SC22, the most easterly of the excavated trenches. The relative sequence of dated samples in this component is illustrated in 17.11. Four pieces of unworked roundwood have been dated from the coarse reed peat in the lower part of this trench (*Hd-30190, Hd-30168, <82705>, <82706>*). The two measurements on roundwood <82706> are statistically significantly different (T'=14.1, T' (5%)=3.8, ν=1). OxA-26478 appears to be anomalously old and has been excluded from the model. Four samples have been dated from the overlying context. Two pieces of roundwood (*SUERC-36355* and *OxA-25088*), the latter of which appears to be reworked, and two pieces of worked antler (OxA-16809–10), which produced anomalously young ages due to the incomplete removal of contaminants (see Table 17.3). Between these dated samples and those from the overlying context lay a scatter of worked flint, some of which was associated with one of the pieces of worked antler. The date of this assemblage has been estimated from the sequence of deposits and the surrounding radiocarbon dates (*SC22 scatter*). Four pieces of waterlogged wood were dated from the overlying wood peat; two of these appear to have been reworked (*SUERC-36356*; *roundwood 4.2*), whilst the others (*Hd-30192* and *SUERC-40163*) appear to provide reliable dates for this deposit.

We now return to the overall structure of the model for the chronology of human activity at Star Carr (Figure 17.2). The components of this model are either spatially discrete phases of human activity or discrete episodes. Where we have four or more effective likelihoods for a phase of activity these have been placed within boundaries so that they do not disproportionately affect the model outcomes. These likelihoods either cross-refer to the sequences already described (in which case they incorporate the constraints of those sequences) or are radiocarbon dates on anthropogenic samples (which may themselves be further constrained by limiting dates). For example, the phase of activity represented by the worked wood within the brushwood is represented by samples which cross-refer to the sequence illustrated in Figure 17.8. In contrast, Clark's area (Figure 17.15) is represented by samples which are unrelated to the stratigraphic sequences so far described. Some components, for example, that relate to the date of artefacts from VP85A (Figure 17.13) incorporate a mixture of the two.

The posterior distributions for the burning episodes identified by Dark (1998a) in her profile M1 are shown in Figure 17.12 and are derived from the age-depth sequence shown in Figure 17.4. One sample of sediment from around an artefact in VP85A (*CAR-924*) appears in the sequence illustrated in Figure 17.3. Additionally *CAR-925* dates the deposition of barbed point <245>, and *CAR-930*, which may have contained a component
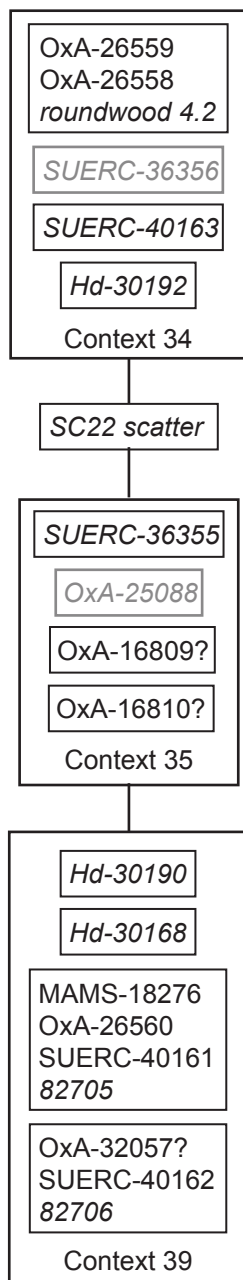
Figure 17.11: Harris matrix of dated samples from the component of the model in trench SC22 (grey lettering, *termini post quos*; ?, excluded from model; grey shading, extent of age-depth model) (Copyright Historic England, CC BY-NC 4.0).

of aquatic macrofossils, provides a *terminus post quem* for charcoal find <153>. A sequence of samples are available from around antler <216>; *CAR-922* from sediment around the artefact itself, is constrained by dates from sediment below (*CAR-1047*) and above (*CAR-1050*). This component of the model is shown in Figure 17.13.

The component for activity producing the detrital wood scatter (Figure 17.7) cross refers to dates for the onset of organic sedimentation and the base and top of the reed peat in Profile 3178 (Figure 17.6), and the
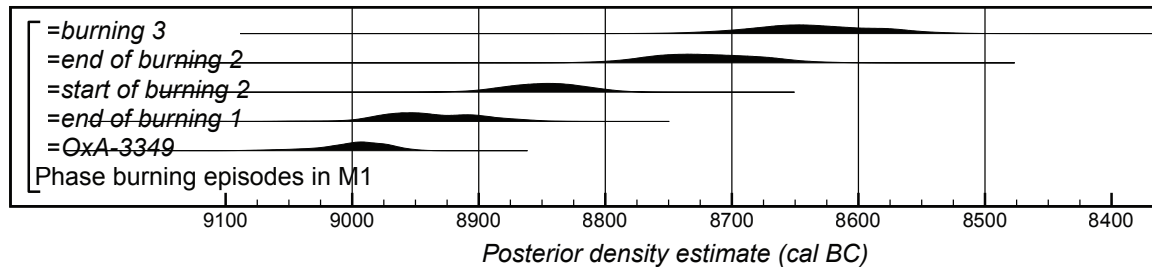
Figure 17.12: Probability distributions for the dates of the burning episodes identified in environmental profile M1 (*OxA-3349* dates the start of burning 1). The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).
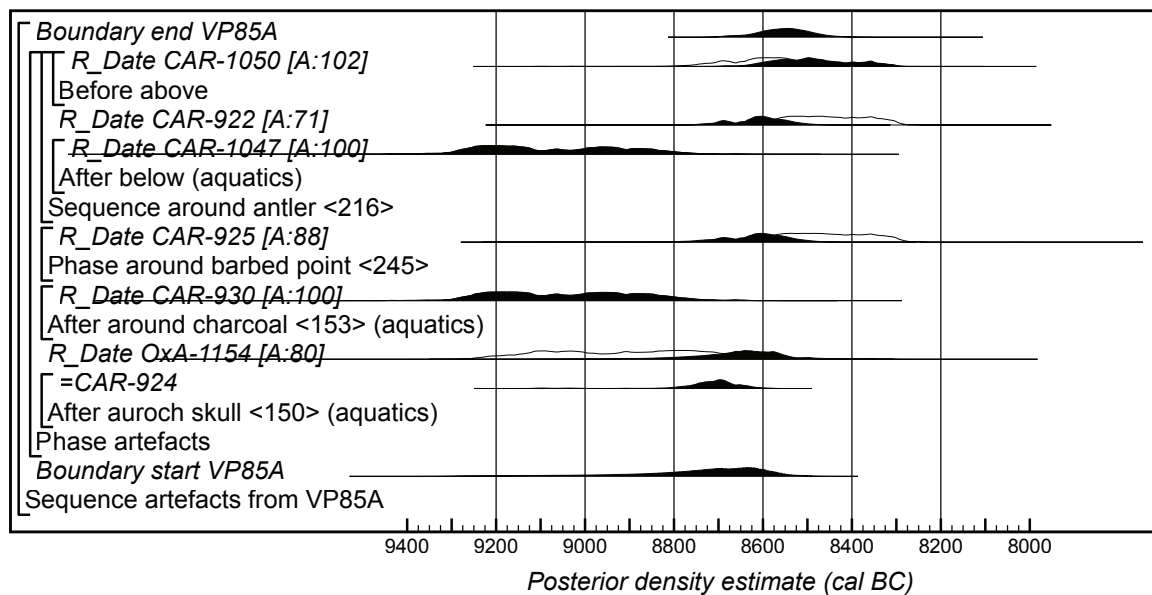
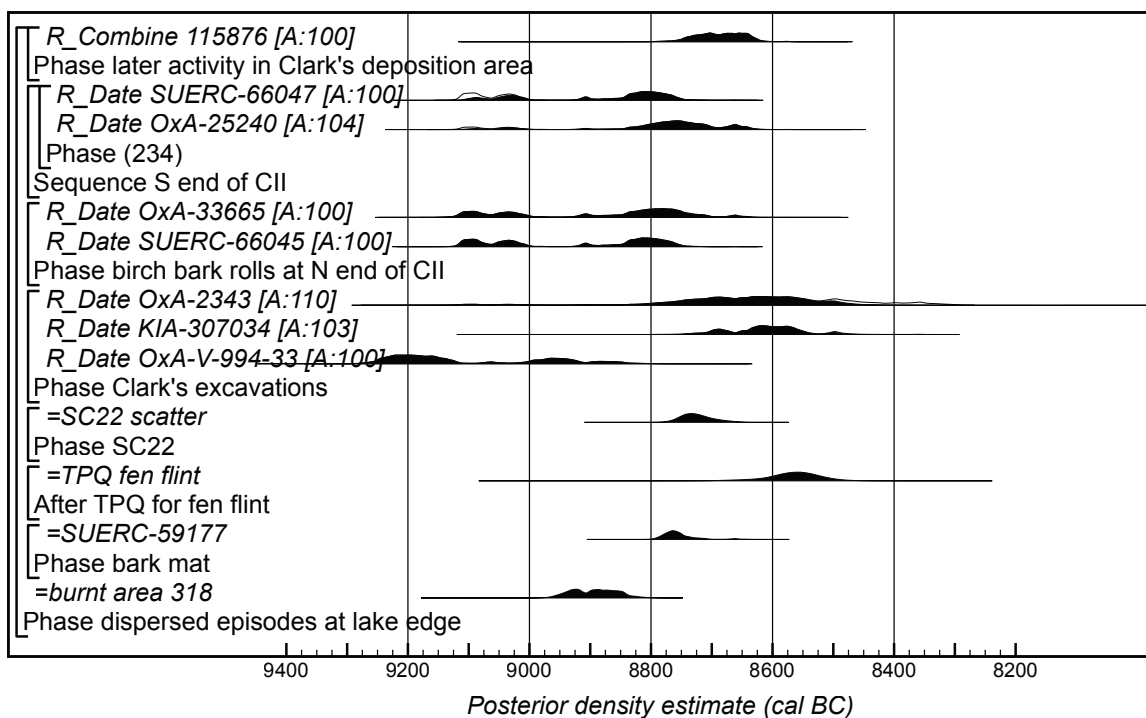**Figure 17.13:** Probability distributions for the dates of artefacts found in trench VP85A. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

component relating to activity represented by the worked wood in the brushwood layer (Figure 17.10) cross refers to the sequence illustrated in Figure 17.8.

The dates for the three platforms are shown in Figure 17.14. That for the western platform cross-refers to the sequence illustrated in Figure 17.8, and that for the central platform to the sequence illustrated in Figure 17.3. A single radiocarbon date *OxA-33662* on timber <113252> is available from the eastern platform. This timber is stratigraphically later than a bulk sample of waterlogged birch fruits and catkin scales from the underlying fine detrital mud (*SUERC-66037*). It also overlies the start of seasonal flooding recorded in the macrofossil profile taken from below this timber, which corresponds to the same dated horizon in the nearby environmental profile VP85A/2010 (Figure 17.4; *start seasonal flooding M1*). Above timber <113252> lay a waterlogged seed of *Prunus padus* and a fallen tree <113251> (*OxA-33713* and *SUERC-66036*). This suggests that the eastern platform was constructed in *8945–8760 cal BC (95% probability; OxA-33662; Figure 17.14), probably in 8915–8895 cal BC (9% probability) or 8880–8795 cal BC (59% probability)*.

=western platform
=OxA-33662
=central platform

9200   9100   9000   8900   8800   8700   8600

Posterior density estimate (cal BC)

Figure 17.14: Probability distributions for the construction dates of the platforms. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

Eight samples of worked bone and antler have been dated from the dense concentration of material culture recorded in 2015 between Clark's cuttings I and II, and the area to the south of Clark's excavations (Chapter 3) (*OxA-33674–7; SUERC-66177–8, SUERC-66182* and *SUERC-66186–7*). A further four samples have been dated from artefacts recovered by Tot Lord from the section of cutting II immediately after Clark's fieldwork (Dark et al. 2006). We believe that these derive from the same deposit of artefacts. These four artefacts were originally dated using the ion-exchange protocol at Oxford (Hedges and Law 1989; Law and Hedges 1989; OxA-4450, OxA-4451, OxA-4577–8). Replicate measurements were undertaken on these samples using the ultrafiltration protocol at Oxford described by Bronk Ramsey et al. (2000), although these samples had to be re-ultrafiltered and dated when the original protocol was found to be problematic (OxA-10808–9). All four samples were dated a third time using the improved ultrafiltration protocol at Oxford described by Bronk Ramsey et al. (2004a) (OxA-21236–9). The replicate measurements on each artefact are statistically consistent (Table 17.3), if OxA-4450 is considered to be anomalously recent. OxA-4451 is also considerably more recent than the other measurements on antler splinter <460>, and so OxA-4450 and OxA–4451 are both excluded from the model.

The radiocarbon dates on these artefacts form a very tight group, and indeed the radiocarbon ages on 11 of them are statistically consistent (T'=7.9, T'(5%)=18.3, ν=10), all but the weighted mean on frontlet <115876> (T'=22.9, T'(5%)=19.7, ν=11). This is compatible with these 11 artefacts being of exactly the same calendar date—potentially deriving from a single episode of deposition. This consistency is striking, and in our view there are two possible explanations. Either the weighted mean of the measurements on frontlet <115876> (SUERC-66177 and OxA-33674) is a statistical outlier, in which case the entire deposit is the result of one massive, very short episode of deposition, or over 90% of the material was deposited in such a concentrated period, but a small number of artefacts were deposited over the following decades. The component shown in Figure 17.15 incorporates the second reading, estimating the date of the concentrated deposition represented by the 11 artefacts with statistically consistent ages. <115876> is included separately as a discrete episode of deposition (Figure 17.17).

The model estimates that bone and antler artefacts began to be placed in Clark's deposition area in *9125–9090 cal BC (4% probability; start Clark area*; Figure 17.15) or *8915–8775 cal BC (91% probability)*, probably in *8850–8800 cal BC (68% probability)*. This deposition ended in *9100–9075 cal BC (3% probability; end Clark area;* Figure 17.15) or *8830–8710 cal BC (92% probability)*, probably in *8810–8755 cal BC (68% probability)*. It accumulated over a period of *1–145 years (95% probability; use Clark area;* Figure 17.19), probably for a period of *1–65 years (68% probability)*. However, it is clear from the shape of the posterior distribution (Figure 17.19) that a very short duration is probable. It should be noted that the bone and antler artefacts were recovered from within the fine detrital mud, with many artefacts lying on the basal sand.

A macrofossil profile recorded through Clark's area shows that the assemblage lies within sediments that formed in reed swamp in permanently standing water (Environmental Zone 1). However, it is *98% probable* that *start Clark area* (Figure 17.15) post-dates the transition to the shallower (potentially seasonally flooded) swamp in the adjacent, dated macrofossil profile CII/2010 (*onset seasonal flooding CII;* Figure 17.9). This suggests that the dated artefacts (and presumably the entire assemblage) must have sunk into the deposits from which they were recorded.

Four birch bark rolls (*OxA-33667, 115195* and *SUERC-66048–9*), from the reed peat in the vicinity of Clark's area have also been dated. This clearly evidences human activity in this area both before and after the deposition
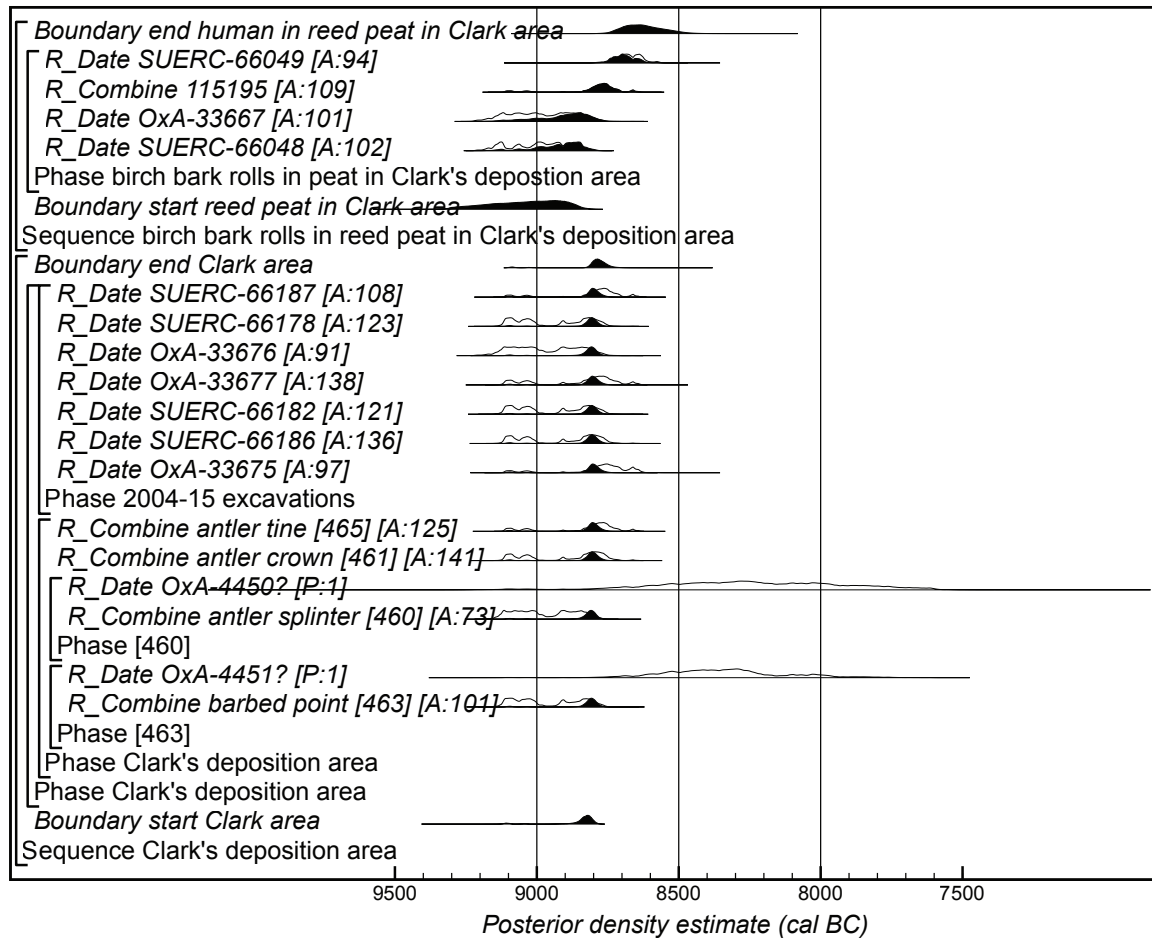
Figure 17.15: Probability distributions of dates on bone and antler artefacts in Clark's area, and carbonised birch bark rolls in reed peat in this location. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

of Clark's area (Figure 17.15). However, these birch bark rolls were all found at or above the levels of the artefacts in Clark's area. This indicates that the lighter birch bark rolls have not sunk.

Four samples on anthropogenic materials have been dated from the peat over marl in the area to the south of the western platform (*SUERC-66044*, *SUERC-66046* and *OxA-33666* on birch bark rolls, and *OxA-33678* on a tooth from the skeleton of a domestic dog; Figure 17.16). All four samples are later than *SUERC-36349*, a fragment of burnt reed from a bulk sample of the underlying reed peat and earlier than waterlogged twigs from an overlying layer of wood peat (*SUERC-36353* and *OxA-25241*).

A sequence of four birch bark rolls have been dated from deposits to the north of Clark's cutting III (bead manufacturing area; see Chapter 33) (Figure 17.16). *SUERC-66039* and *OxA-33663* come from the reed peat at a similar height of a base of a substantial flint scatter. *OxA-33664* and *SUERC-66043* come from the lower part of the overlying wood peat, within and towards the top of the flint scatter.

Figure 17.17 shows date estimates for dispersed episodes of human activity within the wetlands. These are simply constrained to be part of the overall period of human activity at Star Carr (Figure 17.2). The estimated date for burnt area (318) has been cross referenced from the sequence illustrated in Figure 17.3. The date on the bark mat (*SUERC-59177*) and the *terminus post quem* for the deposition of the fen flint interpolated from the age-depth model for CII/2010 (Figure 17.7), have been cross referenced from the sequence illustrated in Figure 17.8. The date for the flint scatter in SC22 (*SC22 scatter*) has been cross referenced from the sequence illustrated in Figure 17.11. Samples from two domesticated dogs (*OxA-V-994-33* and *KIA-307034*) and a resin cake (*OxA-2343*) from Clark's original excavations have been dated by previous researchers (Schulting and

Boundary end N of CIII
R_Date SUERC-66043 [A:96]
R_Date OxA-33664 [A:55]
Phase 310 (bead manufacturing level)
R_Date OxA-33663 [A:103]
R_Date SUERC-66039 [A:102]
Phase 312 (base of flint scatter)
Sequence birch bark rolls & bead manufacturing
Boundary start N of CIII
Sequence flint N of CIII
Boundary end peat over marl
R_Date OxA-25241 [A:100]
R_Date SUERC-36353 [A:100]
Before (233)
R_Date OxA-33678 [A:55]
R_Date SUERC-66044 [A:93]
R_Date OxA-33666 [A:91]
R_Date SUERC-66046 [A:102]
Phase activity in peat over marl
R_Date SUERC-36349 [A:88]
After base of (234)
Boundary start peat over marl
Sequence peat over marl

9400   9200   9000   8800   8600   8400   8200   8000   7800

Posterior density estimate (cal BC)

Figure 17.16: Probability distributions of dates on samples from the peat over the marl in the area south of the western platform, and from peat to the north of Clark's cutting III. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

R_Combine 115876 [A:100]
Phase later activity in Clark's deposition area
R_Date SUERC-66047 [A:100]
R_Date OxA-25240 [A:104]
Phase (234)
Sequence S end of CII
R_Date OxA-33665 [A:100]
R_Date SUERC-66045 [A:100]
Phase birch bark rolls at N end of CII
R_Date OxA-2343 [A:110]
R_Date KIA-307034 [A:103]
R_Date OxA-V-994-33 [A:100]
Phase Clark's excavations
=SC22 scatter
Phase SC22
=TPQ fen flint
After TPQ for fen flint
=SUERC-59177
Phase bark mat
=burnt area 318
Phase dispersed episodes at lake edge

9400   9200   9000   8800   8600   8400   8200

Posterior density estimate (cal BC)

Figure 17.17: Probability distributions of dates on samples from dispersed human activities along the lake edge. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

Richards 2009; Hedges et al. 1994; Roberts et al. 1998). Dates are also available on two birch bark rolls from the wood peat at the north end of cutting II (*SUERC-66045* and *OxA-33665*), and on a sample from the water-logged bow (*OxA-25240*) and a birch bark roll (*SUERC-66047*) from the reed peat to the south of the same trench, cross referenced from the sequence shown in Figure 17.16. Frontlet <*115876*>, which we interpret as later activity in the vicinity of Clark's deposition area is also placed in this component.

Finally, we consider the dates from the structures excavated on the dryland part of the site (Figure 17.18). Datable material was scarce, consisting of tiny fragments of carbonised wood only. Four statistically consistent measurements (T'=2.4, T'(5%)=7.8, ν=3) are available from postholes [177] and [181] and the central depression of the eastern dryland structure (*OxA-33700, SUERC-65232–3,* and *SUERC-65237).* Four statistically consistent measurements (T'=1.2, T'(5%)=7.8, ν=3) are also available from postholes [507] and [515] of the western dryland structure (*OxA-33571, OxA-33703, SUERC-65222* and *SUERC-65230).* Two intrusive, modern fragments of charcoal were dated from posthole [411] (SUERC-65231 and OxA33598; Table 17.3).

In contrast, the dates from the central dryland structure are widely scattered (Figure 17.18). Two samples from the upper fill of the central depression (*1955D* and *SUERC-65239*) have produced statistically consistent radiocarbon measurements (T'=0.2, T'(5%)=3.8, ν=1), although the third result from this deposit (*SUERC-65238*) is much later. Two statistically consistent results are also available from fragments of charcoal from posthole [338] (*SUERC-65240* and *OxA-33702*; T'=1.7, T'(5%)=3.8, ν=1). Between them, these results clearly span the entire period of human activity on the site. We consider it implausible that this structure could have stood for centuries and so must interpret the taphonomy of the dated material to come to a view on the time
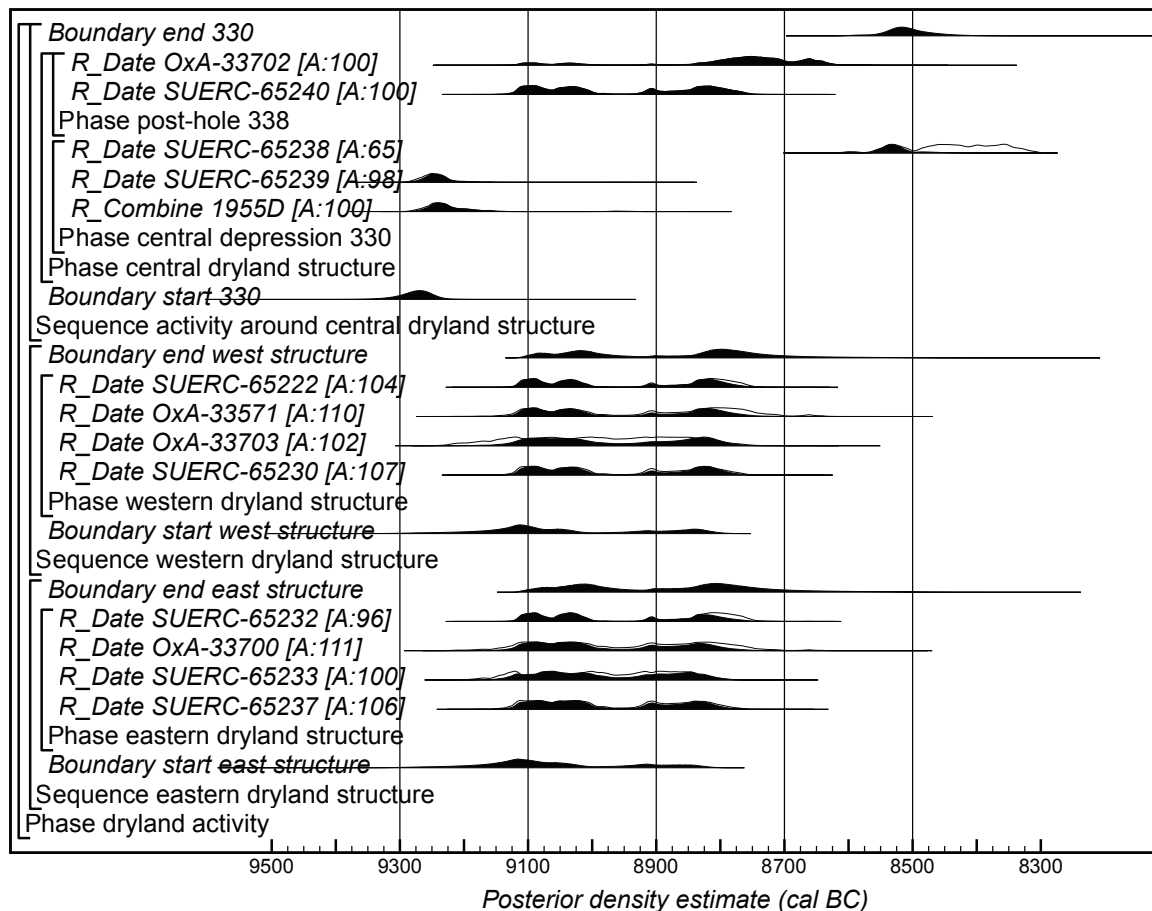
Figure 17.18: Probability distributions of dates on samples from the dryland structures. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

when it was used. The structure may have been used at the time when the charcoal which produced the two statistically consistently measurements from the hollow was deposited (*1955D* and *SUERC-65239*). Posthole [338] is part of a crescent of postholes around the edge of this hollow, and has produced two statistically consistent later results (*SUERC-65240* and *OxA-33702*). However, the presence of a scatter of burnt flint, outside the central structure centred to the west of the posthole, raises the possibility that the two samples from the posthole are dating this event rather than the structure. In addition, a pit/posthole [336], with a large concentration of burnt flint and bone, is situated less than a metre to the west of posthole [338] (see Figure 5.3): it is therefore possible that later burning events, possibly contemporary with the eastern structure, may have produced charcoal which was worked into posthole [338]. The sample from the central hollow dated by *SUERC-65238* is also, presumably, intrusive in this feature from a much later episode of activity on the site.

However, it is striking that all the radiocarbon ages from samples from the eastern and western dryland structures and posthole [338] of the central dryland structure are statistically consistent (T'=6.7, T'(5%)=16.9, ν=9). This is compatible with the suggestion that all these samples may relate to the same, relatively brief, episode of occupation. Indeed, the estimated durations for the eastern and western dryland structures (Figure 17.19) suggest a short use-life. The shape of these distributions also suggests that it is unlikely that either structure was constructed on the first peak on the probability distribution and demolished on the second.

The chronological model for human activity at Star Carr (Appendices 17.1–17.2) suggests that this began in *9385–9260 cal BC (95% probability; start Star Carr*; Figure 17.2) probably in *9335–9275 cal BC (68% probability)*. This activity ended in *8555–8380 cal BC (95% probability; end Star Carr*; Figure 17.2) probably in *8525–8440 cal BC (68% probability)*. However, as described above, we are concerned that due to preservation bias we have been unable to adequately sample stratigraphically later activity in drier deposits, and so it is possible that this date estimate is slightly too early. Overall, the site was in use for *735–965 years (95% probability; use Star Carr*; Figure 17.19), probably for *775–885 years (68% probability)*.
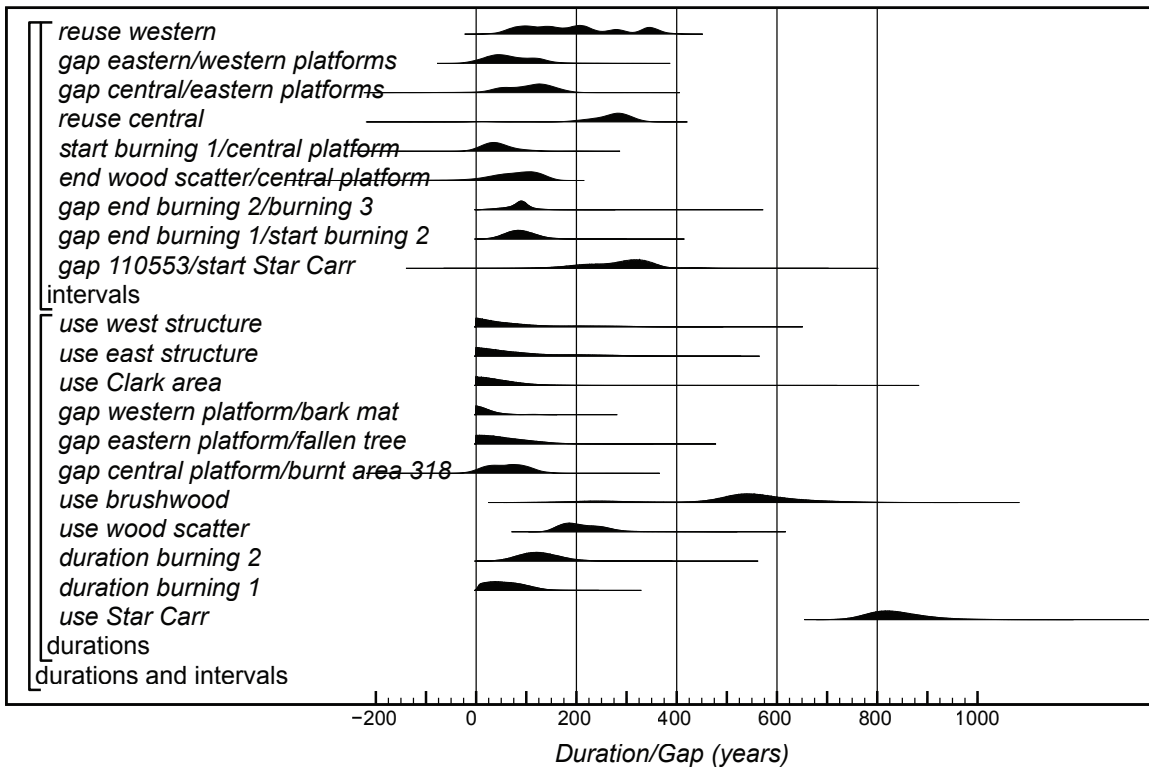
Figure 17.19: Probability distributions of key parameters for durations of archaeological activities and intervals between them, derived from the model defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).
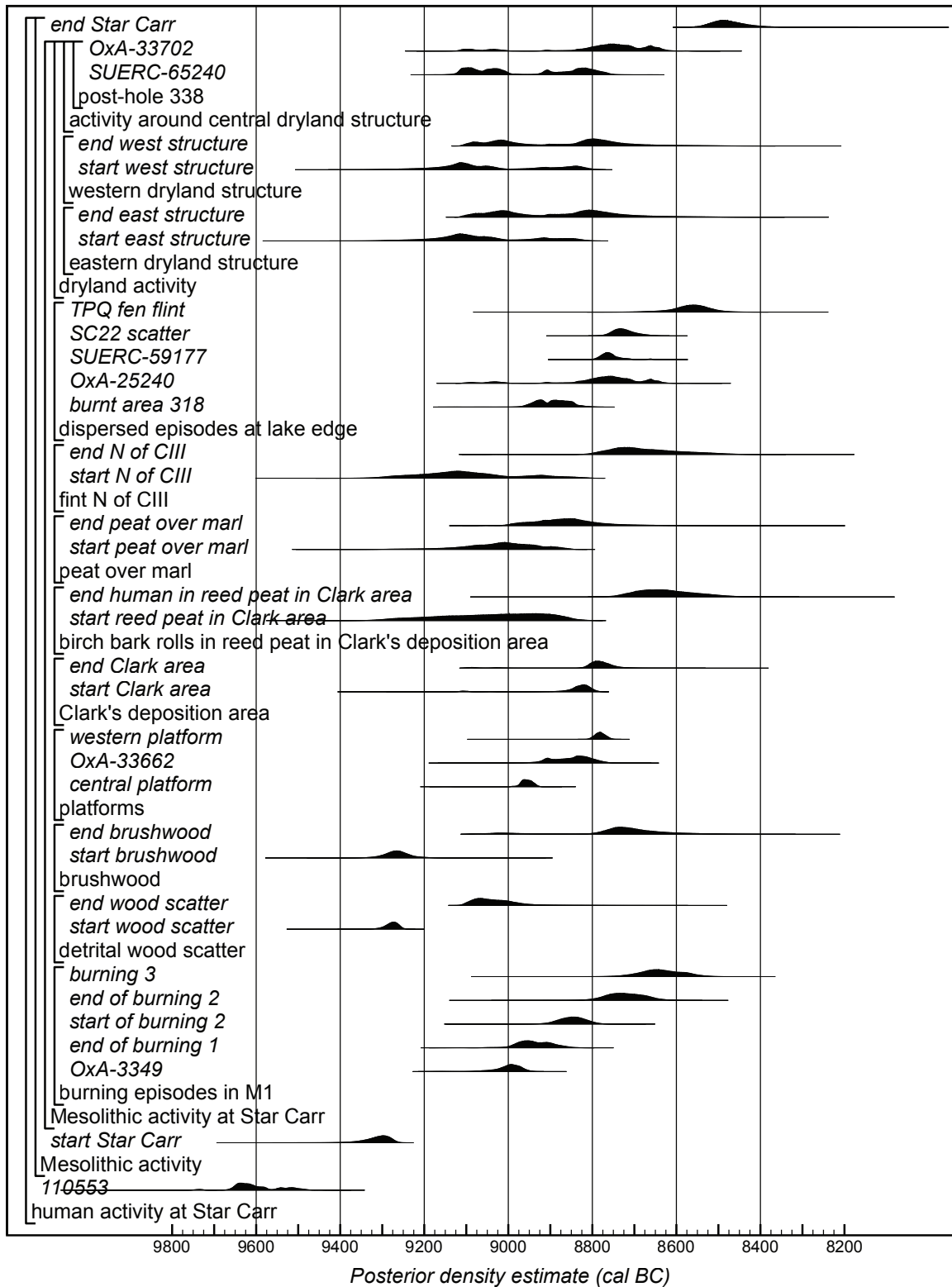
Figure 17.20: Probability distributions of key parameters of archaeological activities at Star Carr (*OxA-3349* is the start of burning 1, *OxA-33662* is the dated timber from the eastern platform, *SUERC-59177* is the bark mat, and *OxA-25240* is the bow), derived from the model defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

Parameter	Figure	Highest Posterior Density interval (cal BC)	
		(95% probability)	(68% probability)
110553		9745–9725 (1%) or 9670–9475 (94%)	9660–9575 (65%) or 9525–9510 (3%)
start Star Carr	17.2	9385–9260	9335–9275
end Star Carr	17.2	8555–8380	8525–8440
OxA-3349	17.20	9070–8945	9020–8965
end of burning 1	17.20	9015–8845	8980–8895
start of burning 2	17.20	8915–8785	8880–8815
end of burning 2	17.20	8805–8630	8770–8675
burning 3	17.20	8735–8535	8685–8580
start wood scatter	17.20	9315–9245	9290–9255
end wood scatter	17.20	9115–8915	9095–9000
start brushwood	17.20	9340–9190	9295–9235
end brushwood	17.20	9090–8920 (12%) or 8820–8510 (83%)	8785–8630
western platform	17.20	8805–8755	8795–8765
central platform	17.20	8985–8925	8970–8940
OxA-33662	17.20	8945–8760	8915–8895 (9%) or 8880–8795 (59%)
start Clark area	17.20	9125–9090 (4%) or 8915–8775 (91%)	8850–8800
end Clark area	17.20	9100–9075 (3%) or 8830–8710 (92%)	8810–8755
start reed peat in Clark area	17.20	9280–8845	9135–8875
end human in reed peat in Clark area	17.20	8745–8480	8710–8570
start peat over marl	17.20	9195–8855	9090–8925
end peat over marl	17.20	9015–8650	8955–8795
start N of CIII	17.20	9300–8850	9250–9025 (66%) or 8930–8915 (2%)
end N of CIII	17.20	8810–8485	8775–8610
TPQ fen flint	17.20	8670–8475	8605–8515
SC22 scatter	17.20	8775–8665	8755–8705
burnt area 318	17.17	8965–8820	8940–8910 (22%) or 8905–8845 (46%)
SUERC-59177	17.17	8800–8705 (94%) or 8665–8655 (1%)	8785–8745
OxA-25240	17.17	9105–9070 (2%) or 9060–9005 (6%) or 8920–8895 (1%) or 8865–8625 (86%)	8820–8700 (62%) or 8675–8650 (6%)
start east structure	17.20	9250–8820	9180–9020 (57%) or 8935–8895 (7%) or 8880–8840 (4%)
end east structure	17.20	9115–8630	9090–8965 (32%) or 8865–8735 (36%)
start west structure	17.20	9260–9005 (63%) or 8985–8795 (32%)	9175–9025 (51%) or 8920–8905 (2%) or 8880–8815 (15%)
end west structure	17.20	9110–8625	9095–8975 (31%) or 8840–8730 (37%)

Table 17.4: Highest Posterior Density intervals for key parameters of archaeological activities at Star Carr (*OxA-3349* is the start of burning 1, *OxA-33662* is the dated timber from the eastern platform, *SUERC-59177* is the bark mat, and *OxA-25240* is the bow), derived from the model defined exactly in Appendix 17.1.

Parameter	Highest Posterior Density interval (years)	
	(95% probability)	*(68% probability)*
Durations		
use Star Carr	*735–965*	*775–885*
use wood scatter	*135–310*	*160–250*
use brushwood	*160–360 (12%) or* *410–765 (83%)*	*470–655*
use Clark area	*1–145*	*1–65*
use east structure	*1–275*	*1–110*
use west structure	*1–285*	*1–100*
duration burning 1	*1–130*	*10–85*
duration burning 2	*45–215*	*80–165*
gap central platform/burnt area 318	*−15–140*	*15–105*
gap eastern platform/fallen tree	*1–155*	*1–80*
gap western platform/bark mat	*1–80*	*1–30*
Intervals		
gap 110553/Star Carr	*125–395*	*230–365*
gap end burning 1/start burning 2	*25–155*	*55–120*
gap end burning 2/burning 3	*20–135*	*65–110*
reuse central	*175–350*	*240–320*
reuse western	*45–310 (81%) or* *315–380 (14%)*	*70–230 (62%) or* *335–360 (6%)*
start burning 1/central platform	*1–105*	*1–60*
end wood scatter/central platform	*−55–170*	*40–140*
gap central/eastern platforms	*−5–205*	*50–160*
gap eastern/western platforms	*−25–170*	*10–120*

Table 17.5: Highest Posterior Density intervals for key durations of archaeological activities Star Carr and of intervals between them, derived from the model defined exactly in Appendix 17.1 (*see* Figure 17.19).

The character and intensity of occupation demonstrably varied across this period. Key parameters for human activity at Star Carr are illustrated in Figure 17.20, and Highest Posterior Density intervals for these distributions are given in Table 17.4. The relative order of key parameters is provided in Table 17.8. Key parameters for the durations of archaeological activities at Star Carr and intervals between them are shown in Figure 17.19, and Highest Posterior Density intervals for these distributions are given in Table 17.5. Discussion and further analysis of these date estimates are integrated with the site narrative in Chapter 9.

The lake edge environment

Each of the environmental profiles from Star Carr documents the gradual transition from reedswamp forming in standing water to increasingly shallower and ultimately terrestrialised wetland environments. This was driven by the accumulation of organic sediments, which caused the depth of water within the lake margins to become shallower, a process known as hydroseral succession (see Chapter 19). Whilst this was a gradual, ongoing process, there are a series of comparable horizons in each of the macrofossil profiles that reflect changes in the amount of water reaching the deposits. These have been used to divide the environmental sequences into three broad phases or zones; reedswamp in standing water (Zone 1), shallower to seasonally

flooded swamp (Zone 2) and fen/carr forming above the level of the lake water (Zone 3). These horizons have been dated, along with the start of organic sedimentation in each of the profiles.

The age-depth models for Profiles M1 and VP85A 2010, 3178 and CII 2010 are described above, as these sequences can be related by stratigraphy to archaeological activity (Figures 17.3–4, 17.5–6 and 17.8–9). However, a fourth environmental profile, Dark's Clark Site Profile (Dark 1998a, 141–6) has three radiocarbon dates on reed charcoal picked from known depths in the sediment. An age-depth model for this sequence, constructed on the same basis as those previously described is shown in Figure 17.21.

The results of this model are surprisingly different from those provided by the age-depth model for CII 2010 (Figure 17.9), which is only 5 m to the north. The date estimates for *onset organics DCS* and *start seasonal flooding DCS* (Figure 17.22; Table 17.6) in particular are much later than those from CII 2010. These estimates derive from interpolation of the age-depth model below the levels from which the material that was radiocarbon dated from Dark's Clark Site Profile was taken. In these circumstances, it is possible that the accumulation

Parameter	*Highest Posterior Density interval (cal BC)*	
	(95% probability)	*(68% probability)*
Environmental Zones		
first EZ1	9635–9445 (94%) or 9435–9410 (1%)	9580–9550 (14%) or 9535–9460 (54%)
last EZ1	9245–8970	9185–9015
first EZ2	9145–9010	9125–9055
last EZ2	9015–8850	8985–8900
first EZ3	8795–8605	8750–8655
last EZ3	8500–8215	8380–8265
Profile M1/VP85A 2010		
onset organics M1	9245–8970	9185–9015
start seasonal flooding M1	9020–8845	8985–8900
onset fen carr M1	8790–8585	8745–8635
Profile 3178		
onset organics 3178	9635–9445 (94%) or 9430–9410 (1%)	9580–9550 (14%) or 9535–9460 (54%)
start seasonal flooding 3178	9140–8985	9125–9055
SUERC-65223	8625–8470	8610–8530 (58%) or 8510–8490 (10%)
Profile CII 2010		
onset organics CII	9445–9255	9395–9310
start seasonal flooding CII	9150–8930	9080–9005
onset fen carr CII	8500–8210	8380–8265
Dark's Clark Site Profile		
onset organics DCS	9165–8585	8910–8670
start seasonal flooding DCS	8950–8570	8825–8695 (56%) or 8690–8645 (12%)
onset fen carr DCS	8770–8430	8720–8560

Table 17.6: Highest Posterior Density intervals for the establishment of the different environmental zones around the lake edge at Star Carr (*SUERC-65223* dates the onset of fen/carr in environmental profile 3178), derived from the model defined exactly in Appendix 17.1 (*see* Figure 17.22).
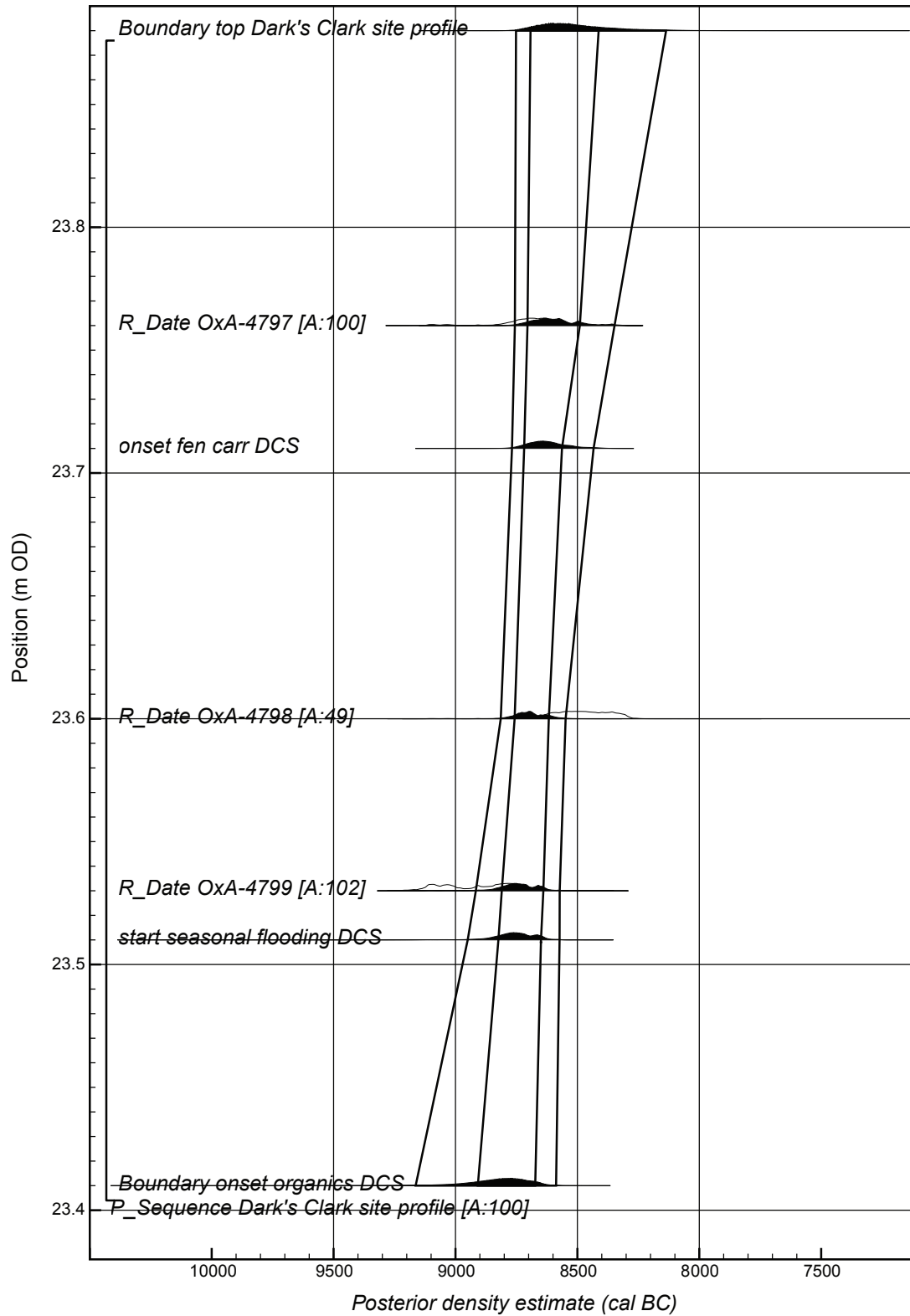
Figure 17.21: Probability distributions of radiocarbon dates in the age-depth model for Dark's Clark Site environmental profile. The format is as Figure 17.4. The overall model is defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0)

rate was much lower in the bottom part of this profile and so extrapolation from the faster accumulation rate higher up is invalid. Against this possibility is the near-constant accumulation rate visible in Profile CII 2010 (Figure 17.9). On balance, it seems more probable that the lower part of Dark's Clark Site Profile was subject to an episode of truncation or erosion in antiquity and so the date estimates relate to the re-establishment of organic sedimentation in this location rather than its initiation. For this reason, these two parameters have not been included in the modelling of the hydroseral succession.

Figure 17.22 shows the estimated dates for the three key hydroseric transitions in the four dated environmental profiles. In some cases, radiocarbon dates on bulk sediments which might contain an element of hard-water error are available that can provide limiting dates for the succession. By calculating the first and last event for each environmental transition, we can estimate the duration of each transition (Figure 17.23).

Onset of organic sedimentation around the lake edge began in *9635–9445 cal BC (94% probability; first EZ1*; Figure 17.22) or *9435–9410 cal BC (1% probability)*, probably in *9580–9550 cal BC (14% probability)* or *9535–9460 cal BC (54% probability)*. This is clearly (*100% probable*) earlier than the start of Mesolithic activity on the site. The start of organic sedimentation was very uneven around the shoreline, occurring first in Profile 3178, then in Profile CII 2010, and finally in Profile M1/VP85A 2010 (*98% probable*). The onset of seasonal flooding over the marl in the area south of the western platform could not be dated but must have occurred
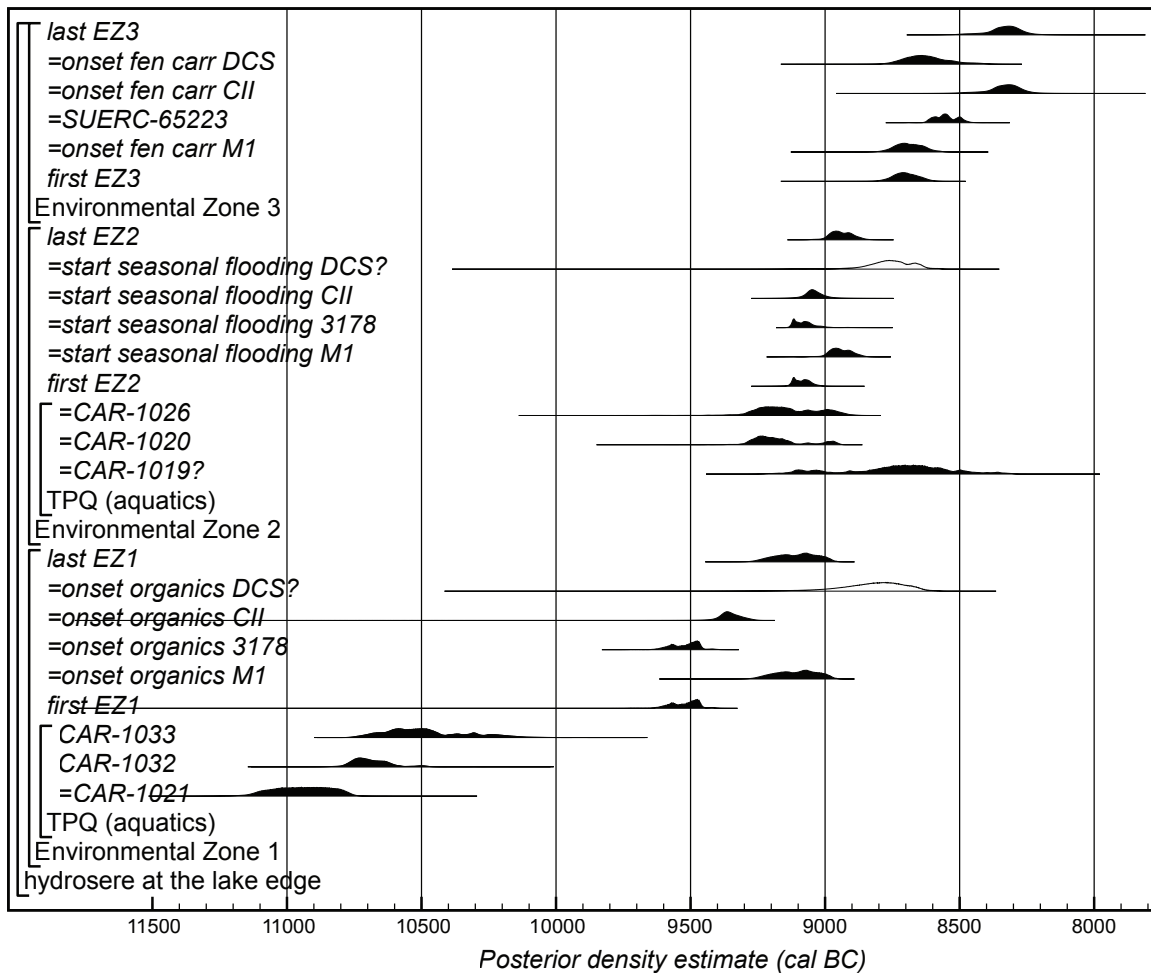
Figure 17.22: Probability distributions for the establishment of the different environmental zones around the lake edge at Star Carr (*SUERC-65223* dates on the onset of fen/carr in environmental profile 3178), derived from the model defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).
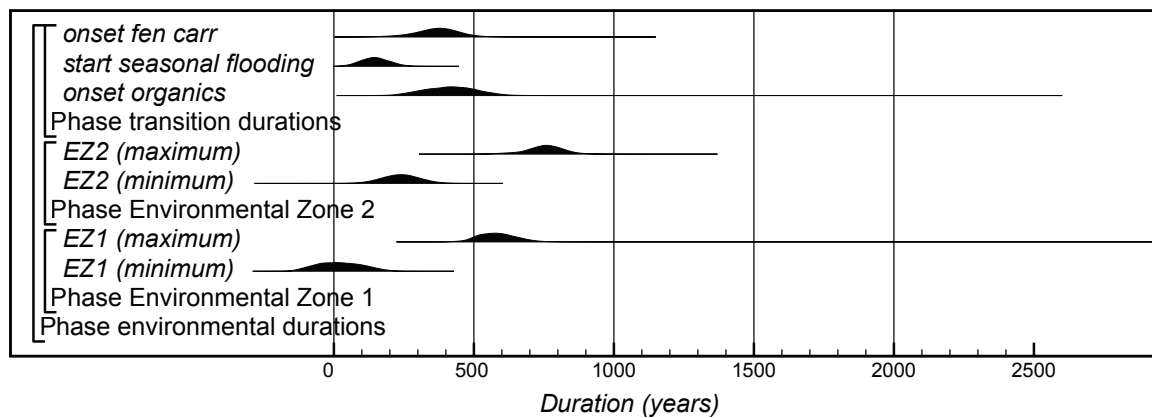
Figure 17.23: Probability distributions for the duration of the establishment of each environmental zone around the embayment and the minimum and maximum durations of each environmental zone, derived from the model defined exactly in Appendix 17.1 (Copyright Historic England, CC BY-NC 4.0).

Parameter	Highest Posterior Density interval (years)	
	(95% probability)	*(68% probability)*
Transition durations		
onset organics	*230–595*	*315–510*
start seasonal flooding	*45–250*	*90–200*
onset fen carr	*185–530*	*295–455*
Enviromental Zone durations		
EZ1 (minimum)	*−130–180*	*−70–105*
EZ1 (maximum)	*450–725*	*505–645*
EZ2 (minimum)	*100–375*	*170–310*
EZ2 (maximum)	*585–890*	*695–825*

Table 17.7: Highest Posterior Density intervals for the duration of the establishment of each environmental zone around the embayment and the minimum and maximum durations of each environmental zone, derived from the model defined exactly in Appendix 17.1 (*see* Figure 17.23).

before *9130–9000 cal BC (95% probability; SUERC-36349*; Figure 17.16), probably before *9120–9075 cal BC (55% probability)* or *9050–9030 cal BC (13% probability)*. Despite these variations, organic sediments were present across the lake edge by *9245–8970 cal BC (95% probability; last EZ1*; Figure 17.22), probably by *9185–9015 cal BC (68% probability)*.

   Although the sequence of change in the hydrosere is the same in all locations around the lake, it is possible (*58% probable*) that the onset of organic sedimentation along some parts of the shore may have post-dated the start of seasonal flooding elsewhere. This began in *9145–9010 cal BC (95% probability; first EZ2*; Figure 17.22), probably in *9125–9055 cal BC (68% probability)*. Environmental Zone 2 was fully established, including in the area over the marl in the area south of the western platform (cf. *SUERC-36349*; Figure 17.16) by *9015–8850 cal BC (95% probability; last EZ2*; Figure 17.22), probably by *8980–8900 cal BC (68% probability)*. The transition to seasonal flooding occurred around the lake edge within a century or two and was thus much less varied than the transition to organic sedimentation, which had taken several centuries to occur (*onset organics* and *start*

seasonal flooding; Figure 17.23; Table 17.7). Environmental Zone 1 persisted for longest in Profile M1/VP85A 2010 (*90% probable*). This probably reflects relatively small variations in the rates of peat formation across the lake edge, which may have been caused by differences in local vegetation and the accumulation of plant material. Broadly speaking, Environmental Zone 2 saw the most intensive human exploitation of the lake edge.

Reed swamp persisted around the shoreline for at least several centuries, in some places for many centuries, before fen/carr became established (*EZ2 (minimum)*; *EZ2 (maximum)*; Figure 17.23; Table 17.7). This began to form in *8795–8605 cal BC (95% probability; first EZ3*; Figure 17.22), probably in *8750–8655 cal BC (68% probability)*. Again, there is considerable variability in the dates at which fen/carr replaced reed swamp around the shoreline (*onset fen carr*; Figure 17.23; Table 17.7), with the earliest fen/carr probably appearing in Profile M1/VP85A 2012 (*74% probable*), and the latest in Profile CII 2010 (*98% probable*). Fen/Carr was fully established around the lake edge by *8500–8215 cal BC* (*95% probability; last EZ3;* Figure 17.22), probably by *8380–8265 cal BC (68% probability)*. As with the transition to seasonal flooding, this was probably due to localised variations in peat accumulation and the composition of the in-situ vegetation. Mesolithic occupation at Star Carr probably ended before the reed swamp had entirely disappeared (*95% probable*).

Conclusions

Dating Star Carr has been particularly challenging because, by the time of the recent excavations, many of the organic finds were in a severely degraded state. This made making accurate radiocarbon age determinations very challenging and, in some cases, impossible.

Nonetheless, the narrative told in Chapter 9 utilises the chronology presented here to untangle the order of episodes of activity that cannot be related by direct stratigraphy (Table 17.8). For example, we do now know the order in which the three lake-edge platforms were constructed (Figure 17.14). We have also untangled the duration and intensity of different episodes of human activity. The detrital wood scatter, for example, was clearly a place of habitual deposition for 200 years or so, whereas in Clark's area artefacts were placed by a single generation of people (be it in a single afternoon or over a few decades) (Figure 17.19). The modelled chronology also allows us to assess the contemporaneity of different activities. Deposition in the area of peat over the marl to the south of the western platform, for example, was clearly over by the time the western platform was constructed *(85% probable)*, but was probably contemporary with the construction of the central platform (*67% probable)* (Table 17.8; Figure 17.20).

But this is not really a human-scale narrative. Most of the date estimates provided by the model, even at 68% probability, span over a century (Table 17.4), and so in most cases we cannot write a narrative of generations and lifetimes. It is also a partial story, as we have clearly been able to integrate only a small part of the activity on the dryland into our tale (and that very loosely). But within the chronological resolution provided by the modelling, the human story is placed within its contemporary landscape, both in terms of the changing wetland environment of the lake edge and the changing landforms and climate of the Vale (Chapter 3; Blockley et al. 2018). What is more, the resolution that we have achieved is a major development within the context of the British (and broader European) Mesolithic and provides a far more refined chronology than is usually associated with the period.

Our third objective, comparing human activity at Star Carr with contemporary activity at other sites in Britain and Northwest Europe, brings the quality and reliability of the chronology proposed here into focus. As stated above, the state of preservation of the excavated material from the site has made dating Star Carr challenging, but there are 200 radiocarbon dates from a chronological model that incorporates reliably recorded information about the relative sequence of the dated samples. And more than 150 of those samples are on short-life, single entity samples (Ashmore 1999). This is more than half the radiocarbon measurements available from the first two millennia of the British Mesolithic (Conneller et al. 2016)!

The chronology presented here has rarely reached the scale of individual human experience, but we know that the folk who built the western platform may have had grandparents who told them about their grandparents' tales of building the eastern platform. We have perhaps created a crack in the fuzzy prehistory of the Mesolithic and moved a step closer towards reclaiming the history of the Mesolithic people of the Vale.

	last EZ1	first EZ2	last EZ2	first EZ3	last EZ3	OxA-3349	end of burning 1	start of burning 2	end of burning 2	burning 3	110553	start Star Carr	start wood scatter	end wood scatter	start brushwood	end brushwood	start peat over marl
first EZ1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	1%	100%	100%	100%	100%	100%	100%
last EZ1		58%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	1%	78%	3%	98%	79%
first EZ2			100%	100%	100%	96%	100%	100%	100%	100%	0%	0%	0%	90%	1%	99%	79%
last EZ2				100%	100%	0%	92%	99%	100%	100%	0%	0%	0%	9%	0%	89%	20%
first EZ3					100%	0%	0%	0%	14%	100%	0%	0%	0%	0%	0%	41%	0%
last EZ3						0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
start of burning 1 (OxA-3349)							100%	100%	100%	100%	0%	0%	0%	27%	0%	93%	44%
end of burning 1								100%	100%	100%	0%	0%	0%	9%	0%	89%	20%
start of burning 2									100%	100%	0%	0%	0%	2%	0%	85%	2%
end of burning 2										100%	0%	0%	0%	0%	0%	50%	0%
burning 3											0%	0%	0%	0%	0%	18%	0%
early worked timber (110553)												100%	100%	100%	100%	100%	100%
start Star Carr													100%	100%	100%	100%	100%
start wood scatter														100%	66%	100%	99%
end wood scatter															1%	96%	58%
start brushwood																100%	98%
end brushwood																	6%
start peat over marl																	
end peat over marl																	
central platform																	
eastern platform (OxA-33662)																	
western platform																	
start Clark area																	
end Clark area																	
start reed peat in Clark area																	
end human in reed peat in Clark area																	
start N of CIII																	
end N of CIII																	
burnt area 318																	
bow (OxA-25240)																	
bark mat (SUERC-59177)																	
SC22 scatter																	
TPQ fen flint																	
start east structure																	
end east structure																	
start west structure																	
end west structure																	

Table 17.8: Probabilities of the relative chronology of key parameters from Star Carr; the cells show the probability that the parameter listed at the left of the table is earlier than the parameter listed at the head of the table, e.g. the probability that *first EZ2* is earlier than *start Clark area* is 96%; the probability that *start Clark area* is earlier than *first EZ2* is 4% (i.e. 100% minus 96%).

end peat over marl	central platform	OxA-33662	western platform	start Clark area	end Clark area	start reed peat in Clark area	end human in reed peat in Clark area	start N of CIII	end N of CIII	burnt area 318	OxA-25240	SUERC-59177	SC22 scatter	TPQ fen flint	start east structure	end east structure	start west structure	end west structure	end Star Carr
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
99%	100%	100%	100%	97%	98%	68%	100%	51%	100%	100%	98%	100%	100%	100%	61%	93%	64%	93%	100%
100%	99%	100%	100%	96%	98%	65%	100%	42%	100%	100%	98%	100%	100%	100%	53%	95%	56%	95%	100%
81%	36%	98%	100%	91%	94%	24%	100%	13%	99%	79%	90%	100%	100%	100%	21%	62%	27%	62%	100%
7%	0%	1%	5%	1%	7%	0%	82%	0%	58%	0%	23%	15%	33%	98%	0%	11%	0%	12%	100%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%
96%	100%	100%	100%	93%	95%	42%	100%	22%	99%	100%	92%	100%	100%	100%	30%	73%	35%	73%	100%
81%	34%	98%	100%	92%	94%	24%	100%	14%	99%	79%	90%	100%	100%	100%	21%	62%	28%	62%	100%
42%	0%	47%	98%	65%	91%	4%	100%	3%	98%	18%	84%	100%	100%	100%	6%	46%	11%	51%	100%
8%	0%	1%	9%	1%	12%	0%	89%	0%	67%	0%	31%	24%	47%	99%	0%	13%	0%	15%	100%
3%	0%	0%	0%	0%	1%	0%	54%	0%	33%	0%	6%	2%	6%	85%	0%	5%	0%	5%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	97%	100%	96%	100%	100%	100%	100%	100%	100%	98%	100%	99%	100%	100%
96%	91%	97%	99%	93%	95%	50%	100%	28%	99%	96%	94%	100%	100%	100%	36%	83%	40%	82%	100%
100%	100%	100%	100%	100%	100%	95%	100%	93%	100%	100%	100%	100%	100%	100%	97%	100%	97%	100%	100%
19%	11%	15%	20%	14%	21%	6%	82%	3%	65%	13%	35%	30%	48%	94%	4%	20%	5%	21%	100%
100%	76%	96%	100%	94%	96%	46%	100%	29%	99%	92%	94%	100%	100%	100%	37%	78%	42%	78%	100%
	12%	56%	85%	63%	80%	10%	97%	6%	93%	36%	78%	89%	92%	99%	10%	46%	15%	49%	100%
		97%	100%	93%	94%	30%	100%	16%	99%	100%	90%	100%	100%	100%	25%	63%	31%	63%	100%
			95%	60%	88%	6%	100%	4%	98%	24%	83%	99%	100%	100%	7%	46%	12%	50%	100%
				2%	48%	0%	100%	0%	93%	0%	63%	100%	99%	100%	0%	25%	0%	29%	100%
					100%	6%	100%	4%	98%	14%	83%	100%	100%	100%	6%	46%	10%	51%	100%
						4%	99%	2%	91%	6%	63%	77%	94%	100%	3%	29%	3%	33%	100%
							100%	37%	99%	88%	94%	100%	100%	100%	45%	80%	49%	80%	100%
								0%	31%	0%	7%	2%	7%	77%	0%	5%	0%	5%	100%
									100%	93%	97%	100%	100%	100%	60%	89%	62%	89%	100%
										2%	21%	16%	30%	86%	1%	10%	1%	11%	100%
											88%	100%	100%	100%	13%	55%	20%	57%	100%
												52%	70%	99%	4%	27%	5%	29%	100%
													83%	100%	0%	19%	0%	21%	100%
														100%	0%	13%	0%	14%	100%
															0%	2%	0%	2%	100%
																100%	53%	85%	100%
																	18%	52%	100%
																		100%	100%
																			100%

Appendix 17.1: CQL2 code defining chronological model for Star Carr

```
Options()
{
 Resolution=1;
 ConvergenceData=TRUE;
 kIterations=20000;
};
Phase("Star Carr")
{
 Phase("central platform")
 {
  Sequence("M1 & VP85A 2010")
  {
   After("TPQs for onset organics")
   {
    R_Date("CAR-1027", 9800, 80);
    R_Date("CAR-1021", 11010, 120);
   };
   P_Sequence("VP85 2010 & M1",100,0,U(-2,2))
   {
    Boundary("onset organics M1")
    {
     z=23.29;
    };
    R_Date("OxA-3351", 9630, 100)
    {
     z=23.305, 0.0025;
    };
    Date("base of reed peat M1")
    {
     z=23.35;
    };
    R_Date("OxA-3350", 9500, 70)
    {
     z=23.365, 0.0025;
    };
    R_Date("OxA-3349", 9640, 70)
    {
     z=23.4175, 0.00125;
    };
    R_Date("OxA-3348", 9700, 70)
    {
     z=23.4525, 0.00125;
    };
    R_Date("SUERC-36339", 9600, 35)
    {
     z=23.47, 0.00625;
    };
    Boundary("start seasonal flooding M1")
    {
     z=23.486;
    };
```

```
Date("end of burning 1")
{
 z=23.49;
};
R_Date("OxA-3347", 9680, 70)
{
 z=23.5075, 0.00125;
};
R_Date("OxA-3346", 9560, 70)
{
 z=23.555, 0.0025;
};
Date("start of burning 2")
{
 z=23.57;
};
R_Date("OxA-3345", 9580, 70)
{
 z=23.5975, 0.00125;
};
R_Date("OxA-3344", 9360, 70)
{
 z=23.6525, 0.00125;
};
Date("end of burning 2")
{
 z=23.68;
};
R_Date("OxA-3343", 9420, 70)
{
 z=23.7075, 0.00125;
};
Boundary("onset fen carr M1")
{
 z=23.71;
};
Date("burning 3")
{
 z=23.73;
};
R_Date("OxA-3342", 9390, 70)
{
 z=23.7575, 0.00125;
};
Date("first hazel")
{
 z=23.79;
};
R_Date("OxA-4376", 9385, 115)
{
 z=23.82, 0.005;
};
R_Date("OxA-25247", 8865, 40)
```

```
 {
  z=23.88, 0.01;
 };
 Date("start hazel rise")
 {
  z=23.91;
 };
 R_Date("OxA-4377", 8940, 90)
 {
  z=23.94, 0.005;
 };
 Date("hazel 50 TLP")
 {
  z=23.96;
 };
 Date("1st hazel peak")
 {
  z=23.97;
 };
 Boundary("end M1")
 {
  z=23.99;
 };
 };
 R_Date("CAR-1022", 8670, 90);
};
Sequence("between onset organics and start seasonal flooding")
{
 Date("=onset organics M1");
 After("TPQs for start seasonal flooding M1")
 {
  R_Date("CAR-919", 9510, 80);
  R_Date("CAR-1026", 9680, 110);
 };
 Date("=start seasonal flooding M1");
};
Sequence("around central platform")
{
 Date("=onset organics M1");
 After("TPQs for central platform")
 {
  R_Date("CAR-1020", 9720, 80);
  R_Date("CAR-1019", 9410, 110)
  {
   color="red";
   Outlier();
  };
  R_Date("CAR-928", 9670, 120);
  Date("=OxA-3349");
 };
 After("reused timber")
 {
  R_Date("OxA-33574", 9735, 45);
```

```
};
Combine("central platform")
{
 R_Date("SUERC-65243", 9663, 31);
 R_Date("OxA-33731", 9675, 45);
 R_Date("SUERC-65247", 9629, 30);
 R_Combine("99726")
 {
  R_Date("SUERC-59168", 9650, 31);
  R_Date("OxA-32318", 9460, 65);
 };
 R_Combine("99738")
 {
  R_Date("OxA-32146", 9660, 45);
  R_Date("SUERC-59169", 9702, 45);
 };
 R_Date("CAR-926", 9240, 90)
 {
  Outlier("red");
  color="red";
 };
};
Phase("later than central platform")
{
 Combine("burnt area 318")
 {
 R_Date("SUERC-65241", 9606, 30);
 R_Date("OxA-33570", 9580, 50);
 };
 Sequence("225 & 224")
 {
 Phase("225")
 {
  R_Date("SUERC-36338", 9555, 35);
  R_Date("OxA-25246", 9515, 40);
  After("aquatics")
  {
   R_Date("CAR-924", 9320, 80);
  };
 };
 Phase("224")
 {
  R_Combine("S246")
  {
   R_Date("OxA-26561", 9305, 45);
   R_Date("SUERC-40160", 9415, 30);
  };
 };
 };
 Sequence("VP85A/2")
 {
  After("aquatics")
  {
```

```
    R_Date("CAR-1018", 9410, 110);
   };
   R_Date("CAR-1017", 8580, 90);
  };
 };
};
Sequence("upper part of VP85A/3")
{
 Date("=start seasonal flooding M1");
 After("aquatics")
 {
  R_Date("CAR-1025", 9480, 100);
  R_Date("CAR-1024", 9540, 110);
 };
 Phase("around level of auroch metatarsal <56>")
 {
  R_Date("CAR-923", 9030, 100)
  {
   color="red";
   Outlier();
  };
  R_Date("OxA-1176", 9700, 160)
  {
   color="red";
   Outlier();
  };
  R_Date("CAR-1023", 9290, 60);
 };
 Date("=CAR-1022");
};
};
P_Sequence("Profile 3178",100,0,U(-2,2))
{
 Boundary("base 3178")
 {
 z=23.035;
 };
 After("sand (320)")
 {
 R_Combine("110553")
 {
  R_Date("SUERC-65242", 9977, 30);
  R_Date("OxA-32056", 10010, 40);
 };
 };
 Date("onset organics 3178")
 {
 z=23.0475;
 };
 R_Date("SUERC-65229", 10095, 30)
 {
 z=23.0725, 0.00625;
 };
```

```
R_Combine("base of reed peat 3178")
{
 z=23.225, 0.00625;
 R_Date("SUERC-65228", 9559, 31);
 R_Date("OxA-33699", 9740, 65);
};
R_Combine("start seasonal flooding 3178")
{
 z=23.2475, 0.00625;
 R_Date("OxA-33698", 9555, 55);
 R_Date("SUERC-65227", 9583, 30);
};
R_Date("SUERC-65223", 9290, 30)
{
 z=23.66, 0.0125;
};
Boundary("top 3178")
{
 z=23.84;
};
};
Phase("western platform")
{
 P_Sequence("CII 2010",100,0,U(-2,2))
 {
 Boundary("base CII 2010")
 {
  z=23.42;
 };
 Date("onset organics CII")
 {
  z=23.44;
 };
 Combine("23.495m")
 {
  z=23.495;
  R_Date("OxA-25238", 9735, 40);
  R_Date("SUERC-36348", 9710, 35);
 };
 Date("base of reed peat CII")
 {
  z=23.56;
 };
 Date("start seasonal flooding CII")
 {
  z=23.57;
 };
 R_Date("OxA-25239", 9400, 40)
 {
  z=23.70;
 };
 Date("TPQ fen flint")
 {
```

```
 z=23.77;
};
Date("onset fen carr CII")
{
 z=23.87;
};
Combine("24.05m")
{
 z=24.05;
 R_Date("OxA-25242", 8810, 40);
 R_Date("SUERC-36354", 8845, 35);
};
Boundary("top CII 2010")
{
 z=24.08;
};
};
Sequence("western platform area")
{
Date("=onset organics CII");
Phase("below western platform")
{
 After("in basal sand")
 {
  R_Date("OxA-32319", 9540, 50);
 };
 R_Date("SUERC-59176", 9670, 31);
 R_Date("OxA-32055", 9766, 39);
 Sequence("98 & 97")
 {
  Phase("98")
  {
   R_Date("SUERC-36343", 9680, 30);
   R_Date("OxA-25199", 9765, 50);
  };
  Phase("97")
  {
   R_Date("SUERC-36344", 9590, 35);
   R_Date("OxA-26563", 9650, 45);
   After("reworked")
   {
    R_Date("OxA-25200", 9765, 45);
   };
  };
 };
Date("=start seasonal flooding CII");
};
Phase("western platform timbers")
{
 After("salvaged timbers")
 {
  R_Combine("timber [46]")
  {
```

```
  R_Date("Hd-30440", 9606, 22);
  R_Date("SUERC-40169", 9585, 30);
  R_Date("OxA-26479", 9595, 50);
 };
};
 Combine("western platform")
 {
 R_Combine("timber [50] other")
 {
  R_Date("SUERC-40168", 9510, 30);
  R_Date("OxA-X-2475-22", 9570, 90);
 };
 R_Combine("timber [48]")
 {
  R_Date("MAMS-18277", 9441, 26);
  R_Date("SUERC-40170", 9515, 45);
 };
 R_Date("Hd-30193", 9463, 18);
 R_Date("Hd-30201", 9451, 34);
};
 Phase("innaccurate measurements")
 {
 R_Combine("timber [50] Hd")
 {
  color="red";
  Outlier();
  R_Date("Hd-30439", 9302, 23);
  R_Date("Hd-30200", 9359, 22);
 };
 R_Date("Hd-30167", 8951, 18)
 {
  color="red";
  Outlier();
 };
 };
};
 Phase("93, bark matt & 84")
{
 Sequence("93 & 84")
{
 Phase("93")
 {
  R_Combine("453")
  {
  R_Date("SUERC-40164", 9445, 30);
  R_Date("OxA-25201", 9550, 45);
  };
  R_Combine("455")
  {
  R_Date("OxA-26562", 9545, 55);
  R_Date("SUERC-36345", 9485, 35);
  };
 };
```

```
 Phase("84")
 {
  After("reworked")
  {
   R_Date("OxA-25235", 9555, 45);
  };
  R_Date("Hd-30166", 9420, 21);
 };
};
 Phase("bark matt <99307>")
 {
  R_Date("OxA-32057", 9650, 38)
  {
   color="red";
   Outlier();
  };
  R_Date("OxA-32058", 9630, 38)
  {
   color="red";
   Outlier();
  };
  R_Date("SUERC-59177", 9502, 31);
 };
};
 Phase("83")
 {
  R_Date("SUERC-36347", 9275, 35);
  R_Combine("201")
  {
   R_Date("OxA-25236", 9165, 45);
   R_Date("OxA-25237", 9215, 40);
  };
 };
 Date("=24.05m");
};
Sequence("brushwood onset organics/84")
{
 Date("=onset organics CII");
 Phase("brushwood")
 {
  R_Date("SUERC-36346", 9590, 35);
  R_Date("OxA-25202", 9620, 50);
  R_Date("OxA-32320", 9615, 45);
  R_Date("OxA-32059", 9580, 40);
  R_Date("SUERC-59175", 9547, 31);
  R_Date("SUERC-59174", 9471, 31);
  R_Date("SUERC-59170", 9465, 31);
  R_Date("OxA-32060", 9696, 40);
 };
 Phase("84")
 {
  Date("=Hd-30166");
  After("reworked")
```

```
   {
    Date("=OxA-25235");
   };
  };
 };
};
Sequence("SC22")
{
 Boundary("start SC22");
 Sequence("SC22")
 {
  Phase("(39)")
  {
   R_Date("Hd-30190", 9611, 20);
   R_Date("Hd-30168", 9481, 20);
   R_Combine("82705")
   {
    R_Date("SUERC-40161", 9525, 30);
    R_Date("OxA-26560", 9540, 45);
    R_Date("MAMS-18276", 9433, 26);
   };
   R_Combine("82706")
   {
    R_Date("SUERC-40162", 9505, 30);
    R_Date("OxA-26478", 9755, 60)
    {
     Outlier();
    };
   };
  };
  Phase("(35)")
  {
   R_Date("OxA-16810", 9275, 40)
   {
    color="red";
    Outlier();
   };
   R_Date("OxA-16809", 9355, 40)
   {
    color="red";
    Outlier();
   };
   After("reworked")
   {
    R_Date("OxA-25088", 9580, 45);
   };
   R_Date("SUERC-36355", 9450, 35)
   {
   };
  };
  Date("SC22 scatter");
  Phase("(34)")
  {
```

```
  R_Date("Hd-30192", 9375, 20);
  R_Date("SUERC-40163", 9455, 30);
  After("reworked")
  {
  R_Date("SUERC-36356", 9560, 35);
  R_Combine("roundwood 4.2")
   {
    R_Date("OxA-26558", 9515, 45);
    R_Date("OxA-26559", 9525, 45);
   };
  };
 };
};
Boundary("end SC22");
};
P_Sequence("Dark's Clark site profile",100,0,U(-2,2))
{
Boundary("onset organics DCS")
{
 z=23.41;
};
Date("start seasonal flooding DCS")
{
 z=23.51;
};
R_Date("OxA-4799", 9500, 75)
{
 z=23.53;
};
R_Date("OxA-4798", 9260, 100)
{
 z=23.60;
};
Date("onset fen carr DCS")
{
 z=23.71;
};
R_Date("OxA-4797", 9385, 80)
{
 z=23.76;
};
Boundary("top Dark's Clark site profile")
{
 z=23.88;
};
};
Sequence("human activity at Star Carr")
{
Boundary("start Star Carr");
Phase("human activity at Star Carr")
{
 Phase("burning episodes in M1")
 {
```

```
 Date("=OxA-3349");
 Date("=end of burning 1");
 Date("=start of burning 2");
 Date("=end of burning 2");
 Date("=burning 3");
};
Sequence("artefacts from VP85A")
{
 Boundary("start VP85A");
 Phase("artefacts")
 {
  After("auroch skull <150> (aquatics)")
  {
   Date("=CAR-924");
  };
  R_Date("OxA-1154", 9500, 120);
  After("around charcoal <153> (aquatics)")
  {
   R_Date("CAR-930", 9660, 110);
  };
  Phase("around barbed point <245>")
  {
   R_Date("CAR-925", 9260, 100);
  };
  Sequence("around antler <216>")
  {
   After("below (aquatics)")
   {
    R_Date("CAR-1047", 9690, 110);
   };
   R_Date("CAR-922", 9250, 80);
   Before("above")
   {
    R_Date("CAR-1050", 9310, 80);
   };
  };
 };
 Boundary("end VP85A");
};
Sequence("detrital wood scatter")
{
 Boundary("start wood scatter");
 Phase("detrital wood scatter")
 {
  Sequence("detrital wood scatter")
  {
   After("onset organics")
   {
    Date("=onset organics 3178");
   };
   Phase("317")
   {
    R_Date("SUERC-59178", 9723, 31);
```

```
 Sequence("108966-7 & 109030")
  {
   R_Combine("108967")
   {
    R_Date("OxA-32062", 9645, 45);
    R_Date("SUERC-59184", 9611, 37);
   };
   R_Combine("108966")
   {
    R_Date("OxA-32061", 9680, 45);
    R_Date("SUERC-59180", 9608, 39);
   };
  };
  R_Date("SUERC-59179", 9743, 31);
  R_Date("OxA-33671", 9520, 45);
  R_Date("SUERC-66181", 9780, 32);
  R_Date("OxA-33673", 9585, 45);
 };
 Date("=base of reed peat 3178");
 Sequence("312")
 {
  Phase("lower")
  {
   R_Combine("99528")
   {
    R_Date("SUERC-66179", 9538, 35);
    R_Date("OxA-33672", 9545, 45);
   };
   R_Date("SUERC-66180", 9553, 33);
  };
  R_Date("OxA-33668", 9570, 45);
 };
 };
 Sequence("108941 & 109559")
 {
  R_Combine("<108941>")
  {
   R_Date("OxA-32063", 9820, 45);
   R_Date("SUERC-59185", 9779, 40);
  };
  Date("=SUERC-59178");
 };
 Span("use wood scatter");
 };
 Boundary("end wood scatter");
 Date("=SUERC-65223");
 };
 Sequence("brushwood")
 {
 Boundary("start brushwood");
 Phase("brushwood")
 {
  Date("=SUERC-59176");
```

```
 Date("=OxA-32319");
 Date("=OxA-32055");
 Date("=OxA-32059");
 Date("=OxA-32320");
 Date("=OxA-32060");
 Date("=SUERC-59175");
 Date("=SUERC-59174");
 Date("=SUERC-59170");
};
Boundary("end brushwood");
Span("use brushwood");
};
Phase("platforms")
{
 Date("=western platform");
 Date("=central platform");
 Sequence("eastern platform")
 {
  After("317")
  {
   R_Date("SUERC-66037", 9762, 29);
   Date("=start seasonal flooding M1");
  };
  Phase("eastern platform")
  {
   R_Date("OxA-33662", 9525, 45);
  };
  Before("312")
  {
   R_Date("OxA-33713", 9320, 50);
   R_Date("SUERC-66036", 9512, 29);
  };
 };
};
Sequence("Clark's deposition area")
{
 Boundary("start Clark area");
 Phase("Clark's deposition area")
 {
  Phase("Clark's deposition area")
  {
   Phase("[463]")
   {
    R_Combine("barbed point [463]")
    {
     R_Date("OxA-10808", 9505, 60);
     R_Date("OxA-21236", 9561, 38);
    };
    R_Date("OxA-4451", 9120, 150)
    {
     color="red";
     Outlier();
    };
```

```
    };
  Phase("[460]")
  {
   R_Combine("antler splinter [460]")
   {
    R_Date("OxA-21237", 9585, 39);
    R_Date("OxA-10809", 9530, 55)
    {
    };
   };
    R_Date("OxA-4450", 9060, 220)
   {
    color="red";
    Outlier();
   };
  };
   R_Combine("antler crown [461]")
   {
   R_Date("OxA-4577", 9670, 100);
   R_Date("OxA-21238", 9485, 38);
   };
   R_Combine("antler tine [465]")
   {
   R_Date("OxA-21239", 9468, 38);
   R_Date("OxA-4578", 9590, 90);
   };
  };
  Phase("2004-15 excavations")
  {
   R_Date("OxA-33675", 9465, 45);
   R_Date("SUERC-66186", 9518, 35);
   R_Date("SUERC-66182", 9531, 35);
   R_Date("OxA-33677", 9490, 45);
   R_Date("OxA-33676", 9560, 45);
   R_Date("SUERC-66178", 9529, 35);
   R_Date("SUERC-66187", 9479, 35);
  };
  };
  Boundary("end Clark area");
  Span("use Clark area");
 };
 Sequence("birch bark rolls in reed peat in Clark's deposition area")
 {
  Boundary("start reed peat in Clark area");
  Phase("birch bark rolls in peat in Clark's depostion area")
  {
  R_Date("SUERC-66048", 9600, 28);
  R_Date("OxA-33667", 9580, 45);
  R_Combine("115195")
  {
   R_Date("OxA-33669", 9465, 45);
   R_Date("OxA-33670", 9490, 45);
  };
```

```
  R_Date("SUERC-66049", 9389, 29);
 };
 Boundary("end human in reed peat in Clark area");
};
Sequence("peat over marl")
{
 Boundary("start peat over marl");
 After("base of (234)")
 {
  R_Date("SUERC-36349", 9510, 35);
 };
 Phase("activity in peat over marl")
 {
  R_Date("SUERC-66046", 9577, 28);
  R_Date("OxA-33666", 9640, 40);
  R_Date("SUERC-66044", 9562, 29);
  R_Date("OxA-33678", 9680, 50);
 };
 Before("(233)")
 {
  R_Date("SUERC-36353", 8890, 35);
  R_Date("OxA-25241", 8883, 39);
 };
 Boundary("end peat over marl");
};
Sequence("flint N of CIII")
{
 Boundary("start N of CIII");
 Sequence("birch bark rolls & bead manufacturing")
 {
  Phase("312 (base of flint scatter)")
  {
   R_Date("SUERC-66039", 9552, 30);
   R_Date("OxA-33663", 9550, 40);
  };
  Phase("310 (bead manufacturing level)")
  {
   R_Date("OxA-33664", 9660, 45);
   R_Date("SUERC-66043", 9448, 27);
  };
 };
 Boundary("end N of CIII");
};
Phase("dispersed episodes at lake edge")
{
 Date("=burnt area 318");
 Phase("bark mat")
 {
  Date("=SUERC-59177");
 };
 After("TPQ for fen flint")
 {
  Date("=TPQ fen flint");
```

```
 };
 Phase("SC22")
 {
  Date("=SC22 scatter");
  Date("=OxA-16810")
  {
   Outlier();
   color="red";
  };
  Date("=OxA-16809")
  {
   Outlier();
   color="red";
  };
 };
 Phase("Clark's excavations")
 {
  R_Date("OxA-V-994-33", 9680, 55);
  R_Date("KIA-307034", 9342, 41);
  R_Date("OxA-2343", 9350, 90);
 };
 Phase("birch bark rolls at N end of CII")
 {
  R_Date("SUERC-66045", 9519, 29);
  R_Date("OxA-33665", 9500, 45);
 };
 Sequence("S end of CII")
 {
  After("base of (234)")
  {
   Date("=SUERC-36349");
  };
  Phase("(234)")
  {
   R_Date("OxA-25240", 9470, 45);
   R_Date("SUERC-66047", 9518, 29);
  };
  Before("(233)")
  {
   Date("=SUERC-36353");
   Date("=OxA-25241");
  };
 };
 Phase("later activity in Clark's deposition area")
 {
  R_Combine("115876")
  {
   R_Date("SUERC-66177", 9431, 32);
   R_Date("OxA-33674", 9345, 50);
  };
 };
 };
  Phase("dryland activity")
```

```
{
Sequence("eastern dryland structure")
{
 Boundary("start east structure");
 Phase("eastern dryland structure")
 {
  R_Date("SUERC-65237", 9556, 30);
  R_Date("SUERC-65233", 9587, 32);
  R_Date("OxA-33700", 9540, 55);
  R_Date("SUERC-65232", 9519, 31);
  Span("use east structure");
 };
 Boundary("end east structure");
};
Sequence("western dryland structure")
{
 Boundary("start west structure");
 Phase("western dryland structure")
 {
  R_Date("SUERC-65230", 9542, 30);
  R_Date("OxA-33703", 9585, 55);
  R_Date("OxA-33571", 9515, 50);
  R_Date("SUERC-65222", 9524, 30);
  Span("use west structure");
 };
 Boundary("end west structure");
};
Sequence("activity around central dryland structure")
{
 Boundary("start 330");
 Phase("central dryland structure")
 {
  Phase("central depression 330 ")
  {
   R_Combine("1955D")
   {
    R_Date("OxA-33569", 9710, 50);
    R_Date("OxA-33701", 9765, 55);
   };
   R_Date("SUERC-65239", 9754, 32);
   R_Date("SUERC-65238", 9221, 30);
  };
  Phase("post-hole 338 ")
  {
   R_Date("SUERC-65240", 9536, 31);
   R_Date("OxA-33702", 9460, 50);
  };
 };
 Boundary("end 330");
};
};
};
Boundary("end Star Carr");
```

```
 Span("use Star Carr");
};
Order("archaeological summary")
{
 Phase("lake edge environment")
 {
  Date("=first EZ1");
  Date("=last EZ1");
  Date("=first EZ2");
  Date("=last EZ2");
  Date("=first EZ3");
  Date("=last EZ3");
  Date("=onset organics M1");
  Date("=onset organics 3178");
  Date("=onset organics CII");
  Date("=start seasonal flooding 3178");
  Date("=start seasonal flooding CII");
  Date("=start seasonal flooding M1");
  Date("=onset fen carr M1");
  Date("=SUERC-65223");
  Date("=onset fen carr CII");
 };
 Phase("burning events")
 {
  Date("=OxA-3349");
  Date("=end of burning 1");
  Date("=start of burning 2");
  Date("=end of burning 2");
  Date("=burning 3");
 };
 Date("=110553");
 Date("=start Star Carr");
 Date("=start 330");
 Date("=start wood scatter");
 Date("=end wood scatter");
 Date("=start brushwood");
 Date("=end brushwood");
 Date("=start peat over marl");
 Date("=end peat over marl");
 Date("=CAR-930");
 Date("=OxA-33678");
 Date("=OxA-33574");
 Date("=central platform");
 Date("=OxA-V-994-33");
 Date("=start east structure");
 Date("=end east structure");
 Date("=start west structure");
 Date("=end west structure");
 Phase("post-hole 338 ")
 {
  Date("=OxA-33702");
  Date("=SUERC-65240");
 };
```

```
  Date("=burnt area 318");
  Date("=OxA-33662");
  Date("=start N of CIII");
  Date("=end N of CIII");
  Date("=start reed peat in Clark area");
  Date("=end human in reed peat in Clark area");
  Date("=timber [46]");
  Date("=western platform");
  Date("=OxA-25240");
  Date("=start Clark area");
  Date("=end Clark area");
  Date("=115876");
  Date("=SUERC-59177");
  Date("=SC22 scatter");
  Date("=TPQ fen flint");
  Date("=end 330");
  Date("=CAR-922");
  Date("=CAR-923");
  Date("=OxA-1154");
  Date("=CAR-925");
  Date("=CAR-924")
  {
   color="gray";
  };
  Date("=OxA-2343");
  Date("=KIA-307034");
  Date("=end Star Carr");
 };
Phase("archaeological differences")
 {
  Difference("gap 110553", "start Star Carr", "110553");
 };
Phase("archaeological intervals")
 {
  Sequence("burning")
  {
   Date("=OxA-3349");
   Interval("duration burning 1");
   Date("=end of burning 1");
   Interval("gap end burning 1/start burning 2");
   Date("=start of burning 2");
   Interval("duration burning 2");
   Date("=end of burning 2");
   Interval("gap end burning 2/burning 3");
   Date("=burning 3");
  };
 Sequence("central platform/burnt area 318")
  {
   Date("=OxA-3349");
   Interval("start burning 1/central platform");
   Date("=central platform");
   Interval("central platform/burnt area 318");
   Date("=burnt area 318");
```

```
 };
 Sequence("western platform and bark mat")
 {
  Date("=western platform");
  Interval("gap western platform/bark mat");
  Date("=SUERC-59177");
 };
 Sequence("eastern platform and overlying tree")
 {
  Date("=OxA-33662");
  Interval("gap eastern platform/fallen tree");
  Date("=SUERC-66036");
 };
};
Phase("Lake edge environment")
{
 Phase("hydrosere at the lake edge")
 {
  Phase("Environmental Zone 1")
  {
   After("TPQ (aquatics)")
   {
   Date("=CAR-1021")
   {
    color="gray";
   };
   R_Date("CAR-1032", 10710, 90)
   {
    color="gray";
   };
   R_Date("CAR-1033", 10520, 90)
   {
    color="gray";
   };
   };
   First("first EZ1");
   Date("=onset organics M1");
   Date("=onset organics 3178");
   Date("=onset organics CII");
   Date("=onset organics DCS")
   {
    color="red";
    Outlier();
   };
   Last("last EZ1");
  };
  Phase("Environmental Zone 2")
  {
   After("TPQ (aquatics)")
   {
   Date("=CAR-1019")
   {
    color="red";
```

```
 Outlier();
 };
 Date("=CAR-1020")
 {
  color="gray";
 };
 Date("=CAR-1026")
 {
  color="gray";
 };
 };
 First("first EZ2");
 Date("=start seasonal flooding M1");
 Date("=start seasonal flooding 3178");
 Date("=start seasonal flooding CII");
 Date("=start seasonal flooding DCS")
 {
  Outlier();
  color="red";
 };
 Last("last EZ2");
 };
 Phase("Environmental Zone 3")
 {
  First("first EZ3");
  Date("=onset fen carr M1");
  Date("=SUERC-65223");
  Date("=onset fen carr CII");
  Date("=onset fen carr DCS");
  Last("last EZ3");
 };
 };
 Phase("hydrosere at the lake edge (orders)")
 {
  Order("Environmental Zone 1")
  {
  Date("=onset organics M1");
  Date("=onset organics 3178");
  Date("=onset organics CII");
  Date("=onset organics DCS");
 };
  Order("Environmental Zone 2")
  {
  Date("=start seasonal flooding M1");
  Date("=start seasonal flooding 3178");
  Date("=start seasonal flooding CII");
  Date("=start seasonal flooding DCS");
 };
  Order("Environmental Zone 3")
  {
  Date("=onset fen carr M1");
  Date("=SUERC-65223");
  Date("=onset fen carr CII");
```

```
  Date("=onset fen carr DCS");
 };
 Order("overlaps")
 {
  Date("=last EZ1");
  Date("=first EZ2");
  Date("=last EZ2");
  Date("=first EZ3");
 };
};
Phase("environmental calculations")
{
 Phase("Zone durations within profiles")
 {
 Phase("M1")
 {
  Difference("EZ1 M1", "=start seasonal flooding M1", "=onset organics M1");
  Difference("EZ2 M1", "=onset fen carr M1", "=start seasonal flooding M1");
 };
 Phase("3178")
 {
  Difference("EZ1 3178", "=start seasonal flooding 3178", "=onset organics 3178");
  Difference("EZ2 3178", "=SUERC-65223", "=start seasonal flooding 3178");
 };
 Phase("CII")
 {
  Difference("EZ1 CII", "=start seasonal flooding CII", "=onset organics CII");
  Difference("EZ2 CII", "=onset fen carr CII", "=start seasonal flooding CII");
 };
 Phase("DCS")
 {
  Difference("EZ1 DCS", "=start seasonal flooding DCS", "=onset organics DCS");
  Difference("EZ2 DCS", "=onset fen carr DCS", "=start seasonal flooding DCS");
 };
 };
 Phase("variations within transitions")
 {
 Phase("onset organics (start Environmental Zone 1)")
 {
  Difference("OO M1 3178", "=onset organics 3178", "=onset organics M1");
  Difference("OO M1 CII", "=onset organics CII", "=onset organics M1");
  Difference("OO M1 DCS", "=onset organics DCS", "=onset organics M1");
  Difference("OO 3178 CII", "=onset organics CII", "=onset organics 3178");
  Difference("OO 3178 DCS", "=onset organics DCS", "=onset organics 3178");
  Difference("OO CII DCS", "=onset organics DCS", "=onset organics CII");
 };
 Phase("start seasonal flooding (start Environmental Zone 2)")
 {
  Difference("SSF M1 3178", "=start seasonal flooding 3178", "=start seasonal flooding M1");
  Difference("SSF M1 CII", "=start seasonal flooding CII", "=start seasonal flooding M1");
  Difference("SSF M1 DCS", "=start seasonal flooding DCS", "=start seasonal flooding M1");
  Difference("SSF 3178 CII", "=start seasonal flooding CII", "=start seasonal flooding 3178");
```

```
  Difference("SSF 3178 DCS", "=start seasonal flooding DCS", "=start seasonal flooding 3178");
  Difference("SSF CII DCS", "=start seasonal flooding DCS", "=start seasonal flooding CII");
 };
 Phase("start fen carr (start Environmental Zone 3)")
 {
  Difference("SFC M1 3178", "=SUERC-65223", "=onset fen carr M1");
  Difference("SFC M1 CII", "=onset fen carr CII", "=onset fen carr M1");
  Difference("SFC M1 DCS", "=onset fen carr DCS", "=onset fen carr M1");
  Difference("SFC 3178 CII", "=onset fen carr CII", "=SUERC-65223");
  Difference("SFC 3178 DCS", "=onset fen carr DCS", "=SUERC-65223");
  Difference("SFC CII DCS", "=onset fen carr DCS", "=onset fen carr CII");
 };
 };
 Phase("Environmental Zone 1")
 {
  Difference("EZ1 (minimum)", "first EZ2", "last EZ1");
  Difference("EZ1 (maximum)", "last EZ2", "first EZ1");
 };
 Phase("Environmental Zone 2")
 {
  Difference("EZ2 (minimum)", "first EZ3", "last EZ2");
  Difference("EZ2 (maximum)", "last EZ3", "first EZ2");
 };
 Phase("transition durations")
 {
  Difference("onset organics", "last EZ1", "first EZ1");
  Difference("start seasonal flooding", "last EZ2", "first EZ2");
  Difference("onset fen carr", "last EZ3", "first EZ3");
 };
 };
 Order("onset reed peat")
 {
  Date("=SUERC-36349");
  Date("=base of reed peat 3178");
  Date("=base of reed peat M1");
  Date("=base of reed peat CII");
 };
 Phase("base reed peat differences")
 {
  Difference("SUERC-36349/CII", "base of reed peat CII", "SUERC-36349");
  Difference("SUERC-36349/3178", "base of reed peat 3178", "SUERC-36349");
  Difference("SUERC-36349/M1", "base of reed peat M1", "SUERC-36349");
 };
 };
```

Appendix 17.2: CQL2 code calculating additional parameters for Star Carr (using prior distributions calculated by the model defined in Appendix 17.1)

```
Options()
{
 Resolution=1;
 kIterations=20000;
};
 Phase("Star Carr additional calculations")
{
 Phase("invoke priors")
 {
  Sequence("dummy")
  {
   R_Simulate("a", -9000, 50);
   R_Simulate("b", -9000, 50);
  };
  Prior("timber_46_","/timber_46_.prior");
  Prior("OxA_33574","/OxA_33574.prior");
  Difference("gap central platform/burnt area 318", "burnt_area_318", "central_platform");
  Difference("gap end wood scatter/central platform", "central_platform", "end_wood_scatter");
  Difference("start burning 1/central platform", "central_platform", "OxA_3349");
  Difference("reuse central", "central_platform", "OxA_33574");
  Difference("gap central/eastern platforms", "OxA_33662", "central_platform");
  Difference("gap eastern/western platforms", "western_platform", "OxA_33662");
  Difference("reuse western", "western_platform", "timber_46_");
 };
 Order("EZ3")
 {
  Prior("onset_fen_carr_CII","/onset_fen_carr_CII.prior");
  Prior("onset_fen_carr_DCS","/onset_fen_carr_DCS.prior");
  Prior("onset_fen_carr_M1","/onset_fen_carr_M1.prior");
  Prior("SUERC_65223","/SUERC_65223.prior");
 };
 Phase("human activity at Star Carr")
 {
  Prior("110553","/110553.prior");
  Phase("Mesolithic activity")
  {
   Prior("start_Star_Carr","/start_Star_Carr.prior");
   Phase("Mesolithic activity at Star Carr")
   {
    Phase("burning episodes in M1")
    {
     Prior("OxA_3349","/OxA_3349.prior");
     Prior("end_of_burning_1","/end_of_burning_1.prior");
     Prior("start_of_burning_2","/start_of_burning_2.prior");
     Prior("end_of_burning_2","/end_of_burning_2.prior");
     Prior("burning_3","/burning_3.prior");
    };
    Phase("detrital wood scatter")
    {
     Prior("start_wood_scatter","/start_wood_scatter.prior");
```

```
 Prior("end_wood_scatter","","/end_wood_scatter.prior");
};
Phase("brushwood")
{
 Prior("start_brushwood","","/start_brushwood.prior");
 Prior("end_brushwood","","/end_brushwood.prior");
};
Phase("platforms")
{
 Prior("central_platform","","/central_platform.prior");
 Prior("OxA_33662","","/OxA_33662.prior");
 Prior("western_platform","","/western_platform.prior");
};
Phase("Clark's deposition area")
{
 Prior("start_Clark_area","","/start_Clark_area.prior");
 Prior("end_Clark_area","","/end_Clark_area.prior");
};
Phase("birch bark rolls in reed peat in Clark's deposition area")
{
 Prior("start_reed_peat_in_Clark_area","","/start_reed_peat_in_Clark_area.prior");
 Prior("end_human_in_reed_peat_in_Clark_area","","/end_human_in_reed_peat_in_Clark_area.prior");
};
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{
 Prior("start_peat_over_marl","","/start_peat_over_marl.prior");
 Prior("end_peat_over_marl","","/end_peat_over_marl.prior");
};
Phase("fint N of CIII")
{
 Prior("start_N_of_CIII","","/start_N_of_CIII.prior");
 Prior("end_N_of_CIII","","/end_N_of_CIII.prior");
};
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{
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 Prior("OxA_25240","","/OxA_25240.prior");
 Prior("SUERC_59177","","/SUERC_59177.prior");
 Prior("SC22_scatter","","/SC22_scatter.prior");
 Prior("TPQ_fen_flint","","/TPQ_fen_flint.prior");
};
Phase("dryland activity")
{
 Phase("eastern dryland structure")
 {
  Prior("start_east_structure","","/start_east_structure.prior");
  Prior("end_east_structure","","/end_east_structure.prior");
 };
 Phase("western dryland structure")
 {
  Prior("start_west_structure","","/start_west_structure.prior");
  Prior("end_west_structure","","/end_west_structure.prior");
 };
```

```
  Phase("activity around central dryland structure")
  {
   Phase("post-hole 338")
   {
    Prior("SUERC_65240","/SUERC_65240.prior");
    Prior("OxA_33702","/OxA_33702.prior");
   };
  };
 };
 Prior("end_Star_Carr","/end_Star_Carr.prior");
 };
};
Phase("durations and intervals")
{
 Phase("durations")
 {
 Prior("use Star Carr","/use_Star_Carr.prior");
 Prior("duration_burning_1","/duration_burning_1.prior");
 Prior("duration_burning_2","/duration_burning_2.prior");
 Prior("use_wood_scatter","/use_wood_scatter.prior");
 Prior("use_brushwood","/use_brushwood.prior");
 Date("=gap central platform/burnt area 318");
 Prior("gap_eastern_platform_fallen_tree","/gap_eastern_platform_fallen_tree.prior");
 Prior("gap_western_platform_bark_mat","/gap_western_platform_bark_mat.prior");
 Prior("use_Clark_area","/use_Clark_area.prior");
 Prior("use_east_structure","/use_east_structure.prior");
 Prior("use_west_structure","/use_west_structure.prior");
 };
 Phase("intervals")
 {
 Prior("gap_110553","/gap_110553.prior");
 Prior("end_burning_1_start_burning_2","/end_burning_1_start_burning_2.prior");
 Prior("end_burning_2_burning_3","/end_burning_2_burning_3.prior");
 Date("=gap end wood scatter/central platform");
 Date("=start burning 1/central platform");
 Date("=reuse central");
 Date("=gap central/eastern platforms");
 Date("=gap eastern/western platforms");
 Date("=reuse western");
 };
 };
};
```

Climate Research

Simon Blockley, Ian Matthews, Adrian Palmer, Ian Candy, Rebecca Kearney,
Pete Langdon, Catherine Langdon, Ashley Abrook, Paul Lincoln,
Amanda Farry, Chris Darvill and Laura Deeprose

Introduction

This chapter explores the analyses of records from a former lake, Lake Flixton, which allows us to reveal the local record of climatic and environmental change that is compared to the archaeological record in Chapter 9. While the general pattern of climate change for the North Atlantic and European region is known from records such as the Greenland ice cores (Chapter 4) it is essential to have a detailed understanding of records from nearby sites. This is partly because the expression of climate change is different regionally, but also for human groups it is the local environmental response to climate change that matters most. Fortunately for the Star Carr project, the site is located next to Lake Flixton; this is a natural archive for preserving past climatic and environmental data in the form of chemical changes to the lake water, pollen profiles that record changes in the local vegetation and insects that reflect different taxa with a range of temperature tolerances, which can in turn be used to reconstruct average temperatures. This chapter outlines the different methods used to examine the Lake Flixton record and summarises the main climatic and environmental changes that occurred during the period of Mesolithic human occupation in the area.

Methods

To establish the optimum location for extracting a palaeoenvironmental archive adjacent to the archaeological sites of Star Carr and Flixton Island, a detailed auger survey was undertaken. Dutch gouges, Russian corers and percussion drilling equipment were used to both record the base of the lake sediment sequences, and associated basal sediment types (Palmer et al. 2015). Russian corers and piston drilling equipment were then used to recover sediment that detailed the changing environments (Figure 18.1). The basin survey also suggested that there was significant variation in the topography of the basin and that only the deepest parts of the basin were likely to collect material from the very early period of deglaciation (Figure 18.2). Seven locations in the basin were sampled (Figure 18.2) and sections close to the Star Carr site (core B) had evidence of substantial marl formation suitable for more detailed analyses; further details of the sediment sequences can be found in Palmer et al. (2015).

Figure 18.1: Piston coring of sediments in the deep lake sequence (core B from Palmer et al. 2015) used for palaeoenvironmental reconstruction in this chapter and detailed in Blockley et al. 2018) (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 18.2 (page 115): Adapted from Figures in Palmer et al. (2015). Top left: Lake Flixton at its maximum extent with the location of major archaeological sites on the lake's margins. Bottom left: Location of key sites and contours for the eastern sector of Lake Flixton, including the location of the previous major bathymetric survey by Cloutman (1988a). The shaded area depicts the more detailed auger survey conducted by Palmer et al. (2015), which has been updated through subsequent work and extends the survey to the north. The results of this survey are presented (top right) with the major contours at 25, 20 and 15 m highlighted, allied to the position of the cores recovered during the course of this study. This depicts the likely topography immediately after the retreat of ice from the eastern Vale of Pickering characterised by a series of basins with different depths and area extents to the north of Flixton Island, which is the higher ground to the south of the study area. The evidence suggests that the distinctive palaeo-Hertford river channel as postulated by Cloutman (1988) does not exist. A summary of the stratigraphy in key cores recovered from the basins are presented in the figure to the bottom right. These demonstrate that there are often lake deposits which represent a series of abrupt climate shifts from the Dimlington Stadial (LFA 1), the relatively warm period of the Windermere Interstadial (LFA 2A), the abrupt cooling of the Loch Lomond Stadial (LFA 3) and the onset of the current Interglacial, the Holocene (LFA 4) (Reprinted from Palmer et al. 2015. Copyright (2015) with permission from Elsevier).
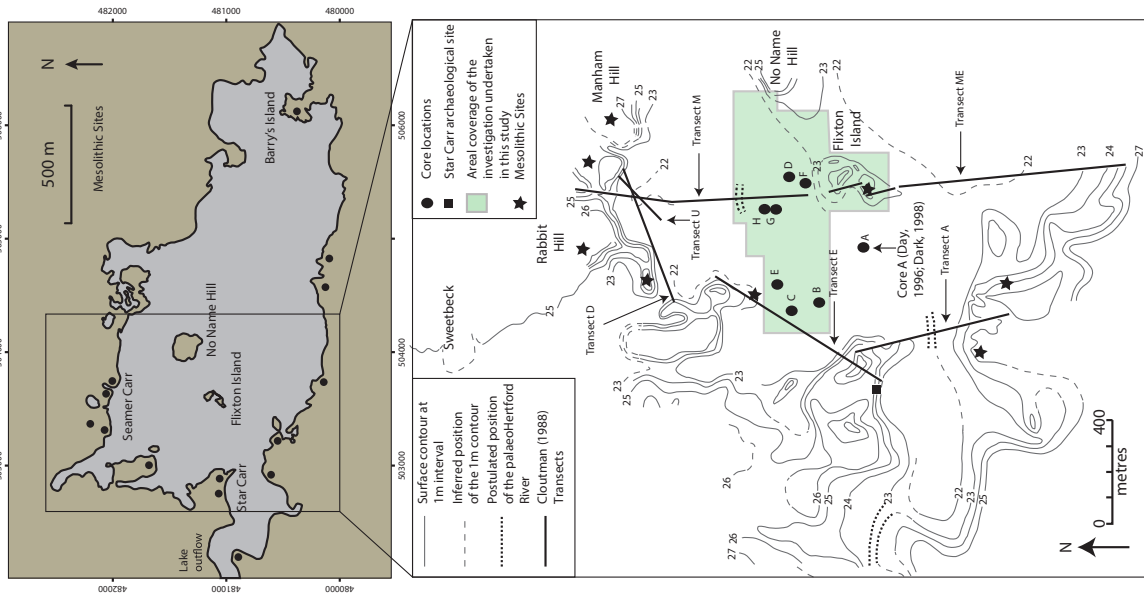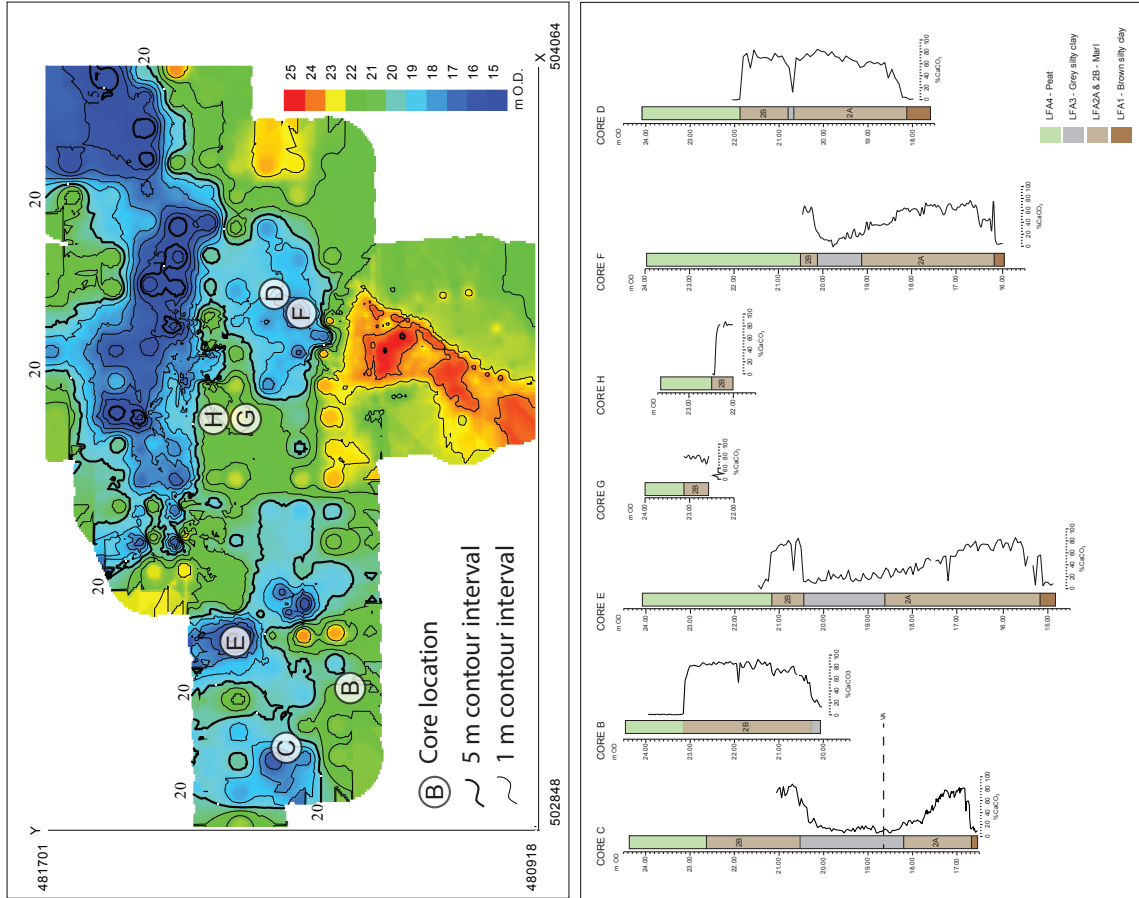
Borehole cores were opened in the laboratory and aligned using the stratigraphic overlaps to present the full lithostratigraphy of the record. They were then classified according to the Troels-Smith (1955) scheme. Subsamples were taken to account for the dominant stratigraphic layers in the core and, where possible, any sedimentary transitions. Basic sedimentological descriptions of the cores were supported by measurements of magnetic susceptibility, organic content, calcium carbonate content, particle size and pollen analysis. Sediment cores taken from close to Star Carr and Flixton Island revealed multiple coring locations with deep lacustrine sediments suitable for palaeoenvironmental analyses, and cores close to archaeological sites at Star Carr and Flixton Island were selected for further analyses. The cores closest to Star Carr (B and C) were analysed in the greatest detail and are discussed below.

The core material from boreholes close to Star Carr (Figure 18.2) was used to reconstruct the past climate at Star Carr through three major proxies: pollen, chironomids (non-biting midges) and stable isotopes. Samples of identified plant macrofossils were also picked for radiocarbon dating and age modelling of the sediments for comparison of the deep lake cores and the lake edge archaeological record. Additionally, the cores were also examined for the presence of cryptotephra to aid in the process of age modelling (see Blockley et al. 2018 and Palmer et al. 2015 for details of the radiocarbon and tephra analyses).

Pollen sampling was undertaken, in part to compare the stratigraphic record from the lake with previous studies but also with the vegetation record from monoliths taken through the archaeology (monolith M1 and the macrofossil and wood record from Star Carr). Pollen samples were taken with a 1 cm^3 volumetric sampler washed, deflocculated in sodium pyrophosphate and sieved at 125 and 15 microns before extraction using heavy liquid separation. Samples were spiked with *Lycopodium* spores to allow for quantification of pollen concentration and analysed using a research grade biological microscope (full details are available in Blockley et al. 2018). Samples for the study of macrofossil plant remains were disaggregated and sieved to 0.3 mm, avoiding the use of any organic chemicals where material is likely to be needed for dating. They were examined using low-power reflected light and transmitted light microscope.

Chironomid larvae occupy a large range of aquatic habitats and they are found in most freshwater environments. The larvae possess a chitinous head capsule, which is shed at various stages of development. The head capsules from the 3rd and 4th instars (developmental stages) are typically preserved in lake sediments as fossils, and hence can be extracted from the sediments and typically identified to genus or species morphotype. This allows the past chironomid fauna to be reconstructed and chironomids have long been shown to be excellent indicators of temperature as this influences their emergence, flight, swarming, maturing of eggs and sexual activity (Pinder 1986). Many studies have documented the influence of temperature on chironomid distribution and how they can be used to reconstruct past summer temperatures (e.g. summaries in Brooks 2006; Walker & Cwynar 2006). Sediment samples for chironomids (usually ~2 cm^3 wet weight) were disaggregated in 10% KOH and then sieved to remove the small particles <90 μm, whilst retaining all head capsules. The samples were next placed in a sorting tray where chironomid head capsules were picked out using fine forceps. The head capsules were mounted on microscope slides in Hydro-Matrix and identified under ×400 magnification. Current subfossil chironomid taxonomy is based on Brooks et al. (2007). A total of 122 chironomid samples were analysed from Star Carr core B and C covering the Early Holocene and Loch Lomond stadial transition (the Loch Lomond Stadial is the British term for a cooling event at the end of the Late Glacial that broadly equates to the Younger Dryas in continental Europe and Greenland Stadial 1). The sample data were analysed using a transfer function for summer temperatures developed from Norwegian lakes (Brooks and Birks 2001), which yielded quantitative summer temperature reconstructions.

In addition to chironomid analyses parallel samples were taken for isotopic analyses of lake carbonates. The δ^{18}O value of lacustrine carbonate is primarily controlled by 1) the temperature at which carbonate mineralisation occurs and 2) the δ^{18}O value of the lake water. The second factor is determined by the δ^{18}O of rainfall which is controlled by a range of factors, including air temperature, amount of rainfall, seasonality of rainfall and distance from the moisture source (Rozanski et al. 1992; Rozanski et al. 1993; Darling 2004). Stable carbon isotopic ratios reported as δ^{13}C are determined by a range of factors in a lake setting including the amount of organic input and productivity in a lake, and, at this site, also inwash of minerogenic carbonate from the surrounding chalk. The latter is an indicator of a detrital component to the lake record and we have excluded any paired isotope samples where the carbon isotope δ^{13}C value rises above 2, as this is close to the value of the surrounding bedrock (see Blockley et al. 2018). A total of 200 isotope samples were taken from the Star Carr core B over sediment depth 2 to 5 m below current soil surface; approximately 20–23 m OD, with the period covering the Early Holocene (2–3 m) analysed in greatest detail and 26 samples were taken from core C between 2.83 m

and 4 m depth in core (c. 21 to 19.83 m OD). Carbonate samples for oxygen and carbon isotopic analyses were sampled at 10 mm, disaggregated in sodium hexametaphosphate and sieved over a 63 micron mesh with the greater than 63 micron fraction used for further analyses. The remaining sample was treated with hydrogen peroxide to remove organics, weighed in a microbalance, and oxygen and carbon isotopes were measured on the liberated fraction of CO_2 after reaction with phosphoric acid at 90°C. Isotopic measurements are reported with reference to VPDB standard (Blockley et al. 2018).

Results

Auger survey

The transect auger survey and the detailed deep coring results are presented in Figure 18.2 (adapted from Palmer et al. 2015). The surface topography outlined in Figure 18.2 represents the deepest measured position where the base of the auger reached glacial deposits, measured relative to current sea level. These reveal a series of small isolated basins within the lake topography, consistent with kame and kettle topography often associated with deglaciated landscapes.

Analyses of the basal sediments recorded in the augers was also compared to the detailed stratigraphy of sediments analysed from cores extracted using Russian corers and mechanical coring. These detailed cores (Figure 18.2) show brown and grey silty clays, and marls, all overlain by peat deposits. These are also compared to magnetic susceptibility measurements and calcium carbonate concentrations. These deposits relate to different processes of deposition in the lake and can be taken broadly to indicate key time periods in the evolution of the lake from basal brown clay sediments, laid down in the early postglacial environment, with two phases of marl deposition during warmer conditions, separated by grey clays marking a cold reversal. This depositional sequence has been interpreted as marking the succession from early Interstadial marl and carbonate rich sediments, Loch Lomond Stadial clays and Holocene marls and peat. Combining these data with the basin survey has led to a model of changing hydrology in the lake suggesting that the lake fluctuated in size and depth over time, linked to changes in the wider environment. In particular the study suggested that water levels dropped during the Loch Lomond Stadial and then rose into the Early Holocene.

Palaeoenvironmental and palaeoclimatic records

The chironomid inferred temperature and $\delta^{18}O$ and $\delta^{13}C$ results from the detailed palaeoclimate study of borehole B from the transect survey are presented in Figure 18.3. This record has marl accumulation from 21.1 m to 20.2 m OD (2 m to 5.2 m below ground surface). A dip in calcium carbonate values and a thin clay layer at 3 m (21.9 m OD) is thought to represent a hiatus in sedimentation at this point in the core due to lowering of the water table during the Loch Lomond Stadial. Thus this core captures environmental and climatic conditions during both the Late Glacial Interstadial and Early Holocene (the transition is marked on Figure 18.3 at a core depth of 3 m). The data to the left of the line marked 'hiatus' is the section covering Early Holocene sedimentation in this record, although it is likely that in this core there is a lag between the start of the Holocene and the start of sedimentation, due to the OD height of the core and the time taken for the water table to rise after the Loch Lomond stadial. Interestingly, however, in this record it seems that in terms of both isotopic ratios and chironomid inferred temperatures the climate conditions in the Early Holocene are similar to those during the Late Glacial Interstadial.

Due to this hiatus, further investigation was undertaken on the transition between clay and marl from 3 m to 5 m in core C (Figure 18.2). This core was known to have a much more extensive record of Loch Lomond stadial sedimentation and is located deeper in the basin, and is thus less likely to have been cut off from sediment supply during periods of low lake level in the Loch Lomond stadial. In addition, this core was known to contain the Vedde Ash tephra, dating to the mid Loch Lomond stadial at a depth of 5.26 m (Palmer et al. 2015), demonstrating sedimentation during the mid Loch Lomond stadial in the form of grey silts and clays that shift to marl formation at 21.5 m OD. As with core B this core was analysed for chironomids and $\delta^{18}O$ and $\delta^{13}C$, and these are detailed in Figure 18.4. Finally, both cores have detailed pollen profiles for comparison with the lake records. These are shown in full in Blockley et al. (2018), but summary pollen data is also shown in Figures 18.5 and 18.6.
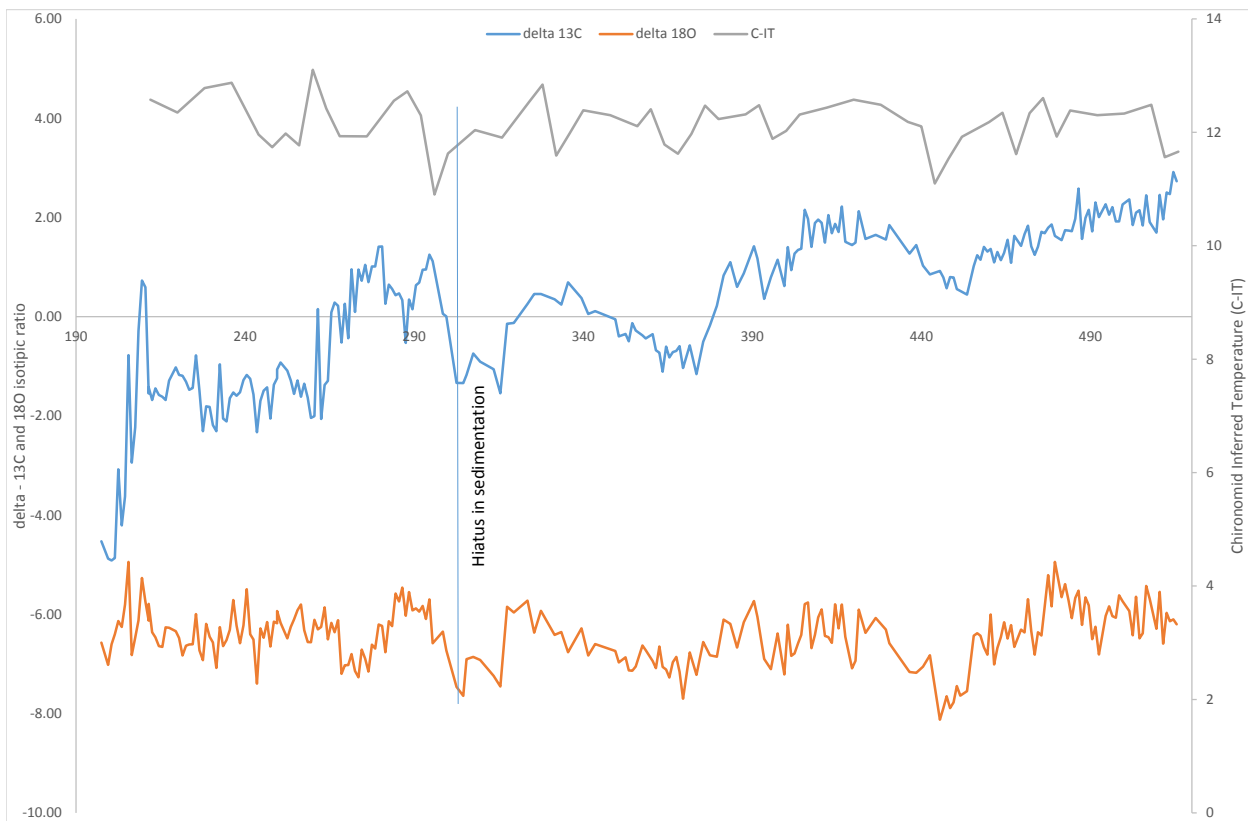
Figure 18.3: Chironomid inferred temperatures and δ¹⁸ O from core B, close to Star Carr. The x-axis provides depth of sediment within the core: the position at 3 m core depth marks the hiatus in the record during the Loch Lomond stadial/Early Holocene (Copyright Star Carr Project, CC BY-NC 4.0).
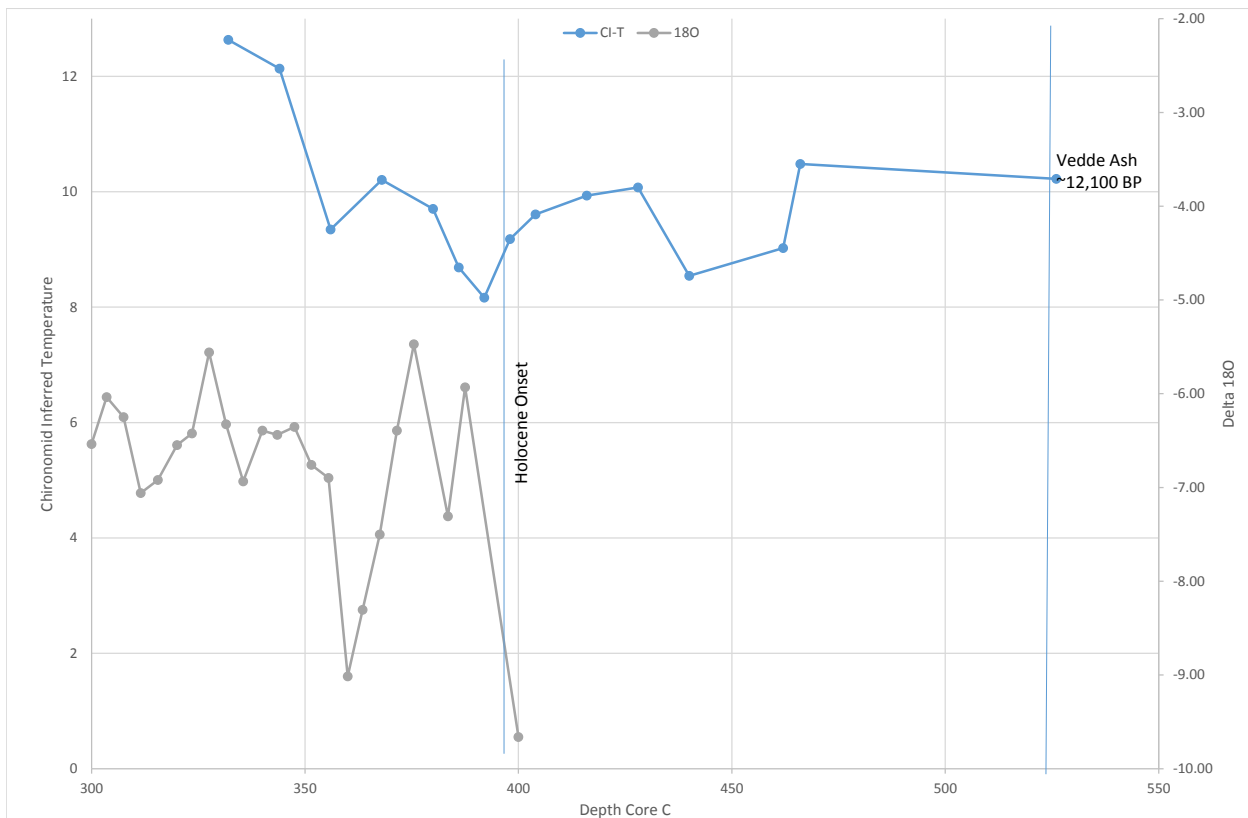
Figure 18.4: Chironomid inferred temperatures (CI-T) and δ¹⁸O from core B covering the Loch Lomond stadial to Holocene boundary and showing the baseline values around the Vedde ash tephra (Copyright Star Carr Project, CC BY-NC 4.0).
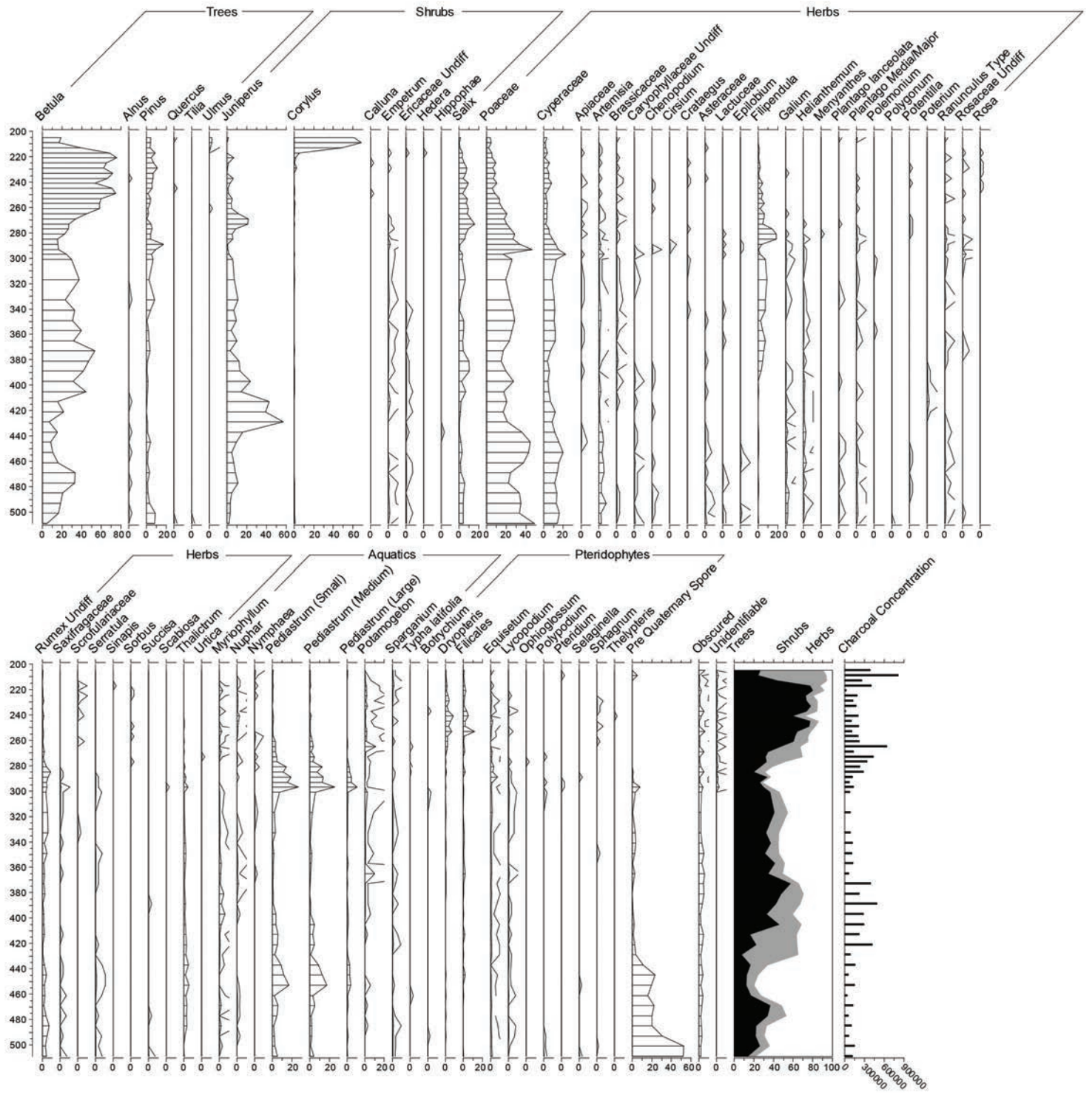
Figure 18.5: Core B percentage pollen taxa (Copyright Star Carr Project, CC BY-NC 4.0).
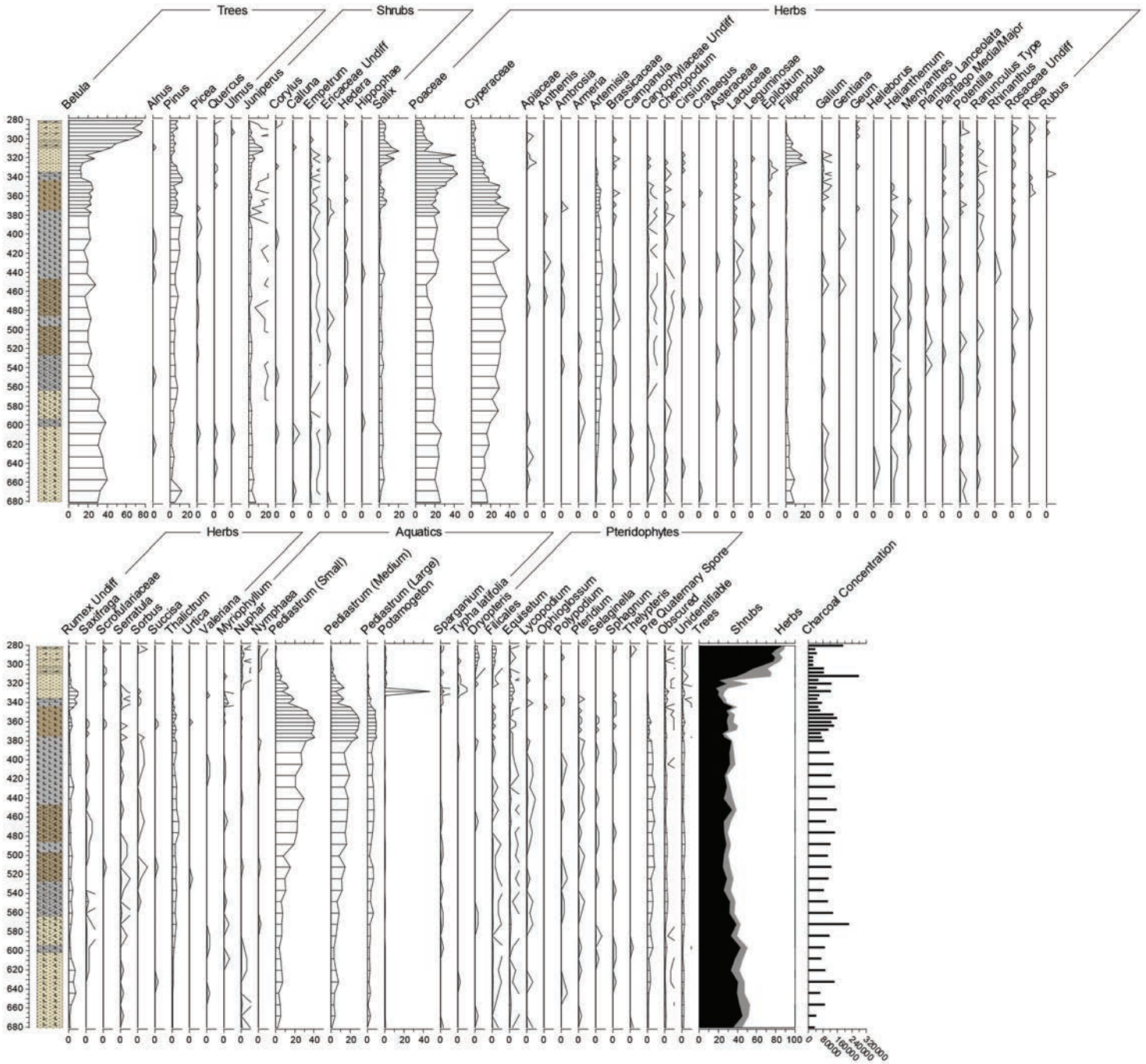
Figure 18.6: Core C percentage pollen taxa (Copyright Star Carr Project, CC BY-NC 4.0).

In core B the palaeotemperature proxies show a shift out of Loch Lomond stadial conditions at a depth of 3.87 to 3.85 m below ground surface, with a sharp shift in the oxygen isotopes, but more muted shift in chironomids, suggesting that summer temperatures at the start of the Holocene were still not significantly above the baseline Loch Lomond stadial conditions seen in the values around the time of the Vedde ash at 5.26 m. The Early Holocene continues to be unstable in these cores with fluctuations at 3.75 m and 3.56 m. In core B

the chironomid inferred temperatures and δ¹⁸O values also indicate a fluctuating Early Holocene climate after the onset of Holocene sedimentation in this core. The δ¹⁸O shows shifts of -2 per mille from initial Holocene warming just after 3 m to the first of several Early Holocene troughs. These values are equivalent to fluctuations in δ¹⁸O seen in the preceding Late Glacial and these are mirrored by temperature fluctuations of c. 2°C in the chironomid record, again consistent with Late Glacial values.

In order to compare these data to the archaeological record of Star Carr and nearby Flixton Island (where Long Blade archaeological material has been located) the cores were radiocarbon dated. These dates, along with tephra information, were incorporated into a Bayesian sequence model (Blockley et al. 2018) and this was tied into the Star Carr environmental monolith record using common pollen taxa changes found in both cores. The details of this, along with their relationship to the archaeology of the area, are discussed in detail in Chapter 9.

Conclusions

This work has combined a range of palaeoenvironmental indicators taken from lake boreholes close to the Star Carr site. The advantage of this approach is that it has allowed the climatic and environmental signal close to the area of human occupation to be examined in detail. These environmental records suggest that around the time of human occupation of Star Carr there were significant climatic fluctuations, beginning with the shift out of the cold preceding stadial, but with two further shifts in Early Holocene climate. These transitions, identified in a range of proxies are the backdrop for the human occupation of the site and are discussed alongside the archaeological record in Chapter 9.

Palaeoenvironmental Investigations

Barry Taylor and Enid Allison

Introduction

Palaeoenvironmental studies have been an integral part of research at Star Carr since Clark's first excavations at the site (Walker and Godwin 1954). Since then, a series of increasingly detailed studies have been undertaken, which have created an incredibly precise record of the local environment throughout the time the site was occupied (Cloutman and Smith 1988; Dark 1998a). Rather than replicate this work, the current project has sought to establish in more detail the environmental conditions associated with assemblages of archaeological material in order to provide a better record of the original depositional context. By bringing this together with the results of previous work at the site, it is possible to describe in more detail the environmental context in which the inhabitation of the site took place.

Previous work

The first palaeoenvironmental investigations at Star Carr were carried out between 1949 and 1951 by Harry Godwin and Donald Walker, and were undertaken as part of Grahame Clark's excavations at the site (Walker and Godwin 1954). Their work focused primarily on the analysis of the peat stratigraphy recorded in the trenches, and plant macrofossils from the archaeological horizons, which they used to establish the character of the environment contemporary with human activity. The results were brought together with pollen analysis from samples taken from Clark's cutting II, and data from a series of cores taken through the sediments beyond the extent of the excavations to create the first environmental history of the site.

By the mid-1980s developments in palaeoecological methods, and the greater availability of radiocarbon dating, allowed a more detailed study of the lake edge environments to be carried out, this time by Ed Cloutman under the auspices of the Vale of Pickering Research Trust (Cloutman and Smith 1988). Tim Schadla-Hall had recently completed large-scale excavations and surveys of the Mesolithic landscape at Seamer Carr, to the northeast of Star Carr. As part of this work, Cloutman had used pollen profiles taken at intervals through the lake edge deposits to map the extents of the wetland environments and track their development over time
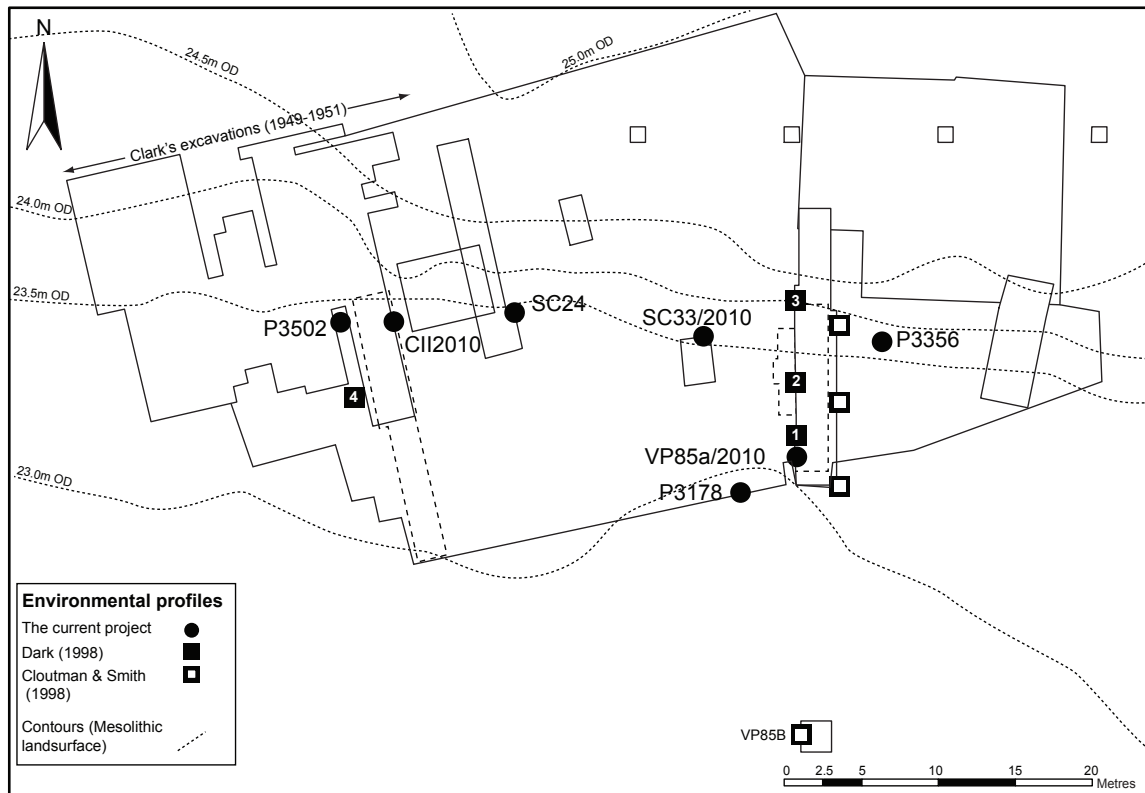
Figure 19.1: Location of environmental sampling points at Star Carr, 1985–2015. The profiles recorded by Dark (1998a) are 1: profile M1; 2: profile M2; 3: profile M3, 4: Clark Site profile (Adapted from Taylor et al. 2017. Copyright Cambridge University Press (2017) reprinted with permission).

(Cloutman 1988a; Cloutman 1988b). Adopting a similar approach at Star Carr, Schadla-Hall under the auspices of the Vale of Pickering Research Trust excavated two new trenches (trenches VP85A and B) through the lake edge deposits c. 30 m to the east of the area investigated by Clark. Four pollen profiles were recorded at points along their sections (three from VP85A, one from VP85B) (Figure 19.1). The profiles were correlated using horizons within the pollen and peat stratigraphies (Cloutman 1988b, 48–51), and an absolute chronology was established from radiocarbon dates obtained from samples taken from each of the pollen profiles and from sediments within the trench.

Cloutman's work demonstrated the dynamic nature of the lake edge environments, which exhibited a significant degree of change during the early centuries of the Mesolithic. However, subsequent re-evaluation of this work suggested that the radiocarbon chronology established by Cloutman was incorrect, and that the estimates for the timing and duration of environmental change and its relationship to the human occupation of the site were unreliable (Mellars 1990). To resolve this, further work was carried out at the site in the 1990s by Petra Dark, supported again by the Vale of Pickering Research Trust (Dark 1998b; Mellars and Dark 1998). Adopting a similar approach to that of Cloutman, Dark recorded three new pollen and plant macrofossil profiles from trench VP85A, and a fourth profile close to Clark's cutting II (Figure 19.1). High-resolution pollen analysis was undertaken on one of the profiles (profile M1) in order to detect subtle changes in vegetation that could be the result of human action, whilst the analysis of micro- and macro-charcoal was carried out to detect episodes of burning. New radiocarbon dates were obtained on two of the profiles, and Bayesian models were constructed to provide a more precise chronology for the environmental sequence.

Dark's work established a far more detailed record for the timing and nature of the wetland environments at the site. Though her work generally agreed with the environmental sequence defined by Cloutman, Dark

showed that the changes to the character of the wetland occurred throughout the time that people inhabited the site (Dark 1998b). What is more, some of the changes observed in the pollen profiles coincided with increased levels of micro- and macro-charcoal suggesting that changes to the local vegetation were actually the result of deliberate human action.

Objectives of the current project

Whilst these various research programmes have led to a very detailed record of the changing character of the environments at Star Carr, a number of issues remained unresolved by the time the current project began. The first and perhaps most crucial of these was the environmental context of the archaeological material recorded from the site. Initially, this related to the large assemblage of bone and antler artefacts recorded by Clark, the context of which has been debated and re-interpreted since the late 1970s but without the data to properly resolve the issue (e.g. Price 1982; Chatterton 2003; Mellars 2009). However, as it became clear that activity within the wetland was more extensive and varied than previously thought, the need to establish the environmental context of material from other parts of the site became increasingly important.

The second issue was the relationship between the local environment and the Mesolithic groups that inhabited the site. Although Dark's work had shown that the wetland vegetation was cleared by burning, there had been little discussion of other ways in which people would have engaged with the different plant communities, such as their potential as foods or raw materials. What is more, whilst the environmental records clearly showed that the nature of the environment, including the character of the local vegetation, changed during the time the site was occupied, little attention had been paid to the effects this would have had on people's lives.

As both of these issues require a good understanding of highly localised environmental conditions, it was decided to use a combination of plant macrofossil and insect analysis based on samples taken from a number of locations around the site close to the archaeological material. This included several contiguous sequences of samples taken through the lake edge deposits in order to record the changing character of the environment through time, as well as shorter sequences taken from discrete areas of archaeological activity. The results were correlated with the analyses carried out by Dark, and a programme of radiocarbon dating was undertaken to establish the chronology for the environmental sequences from the site (Chapter 17, Figures 17.22 and 17.23 and Table 17.6).

Sampling strategy

Insect and plant macrofossil analysis was carried out on samples taken from six locations during the excavations between 2010 and 2015 (Figure 19.1). Three profiles (VP85A/2010, CII/2010 and profile 3178) were recorded through the complete sequence of detrital muds and peats at the edge of the lake in order to define the character of the local environment throughout the period that Star Carr was occupied. Of these, two (VP85A/2010 and CII/2010) were analysed for both insects and plant macrofossils, whilst the third (P3178) was analysed for plant macrofossils only. A fourth profile (SC24) made up of non-contiguous samples from the sedimentary sequence in trench SC24, was analysed for insects.

Profile VP85A/2010 was recorded from samples taken from the west facing section of trench VP85A during the 2010 excavation. It lies immediately adjacent to Dark's profile M1 and includes deposits adjacent to the central platform. CII/2010 was recorded from samples taken from the east facing section of Clark's cutting II in 2010. The western platform runs through the deposits sampled by this profile, and flint deposited during later episodes of activity at the site were recorded on either side of the sampling point. Profile 3178 was recorded from the samples taken from the north-facing section of trench 34 during the 2014 excavation. The deposits sampled by this profile include part of the detrital wood scatter and associated faunal material.

A series of partial plant macrofossil profiles were recorded in order to establish the environmental context of particular assemblages of material. Profile 3052 was recorded from samples taken during the excavation of the baulk between Clark's cutting I and II and provides contextual information for the large assemblage of bone and antler artefacts recorded in this area. Profile SC33/2010 (insects and plant macrofossils) was taken from samples adjacent to a scatter of worked flint recorded in trench SC33, whilst profile 3356 was recorded from sediments closer to the edge of the Early Mesolithic wetland, in order to establish the context of several discrete scatters of flint and a red deer antler frontlet <113901>.

Plant macrofossil analysis

Methodology

All of the profiles were derived from a contiguous sequence of samples 25–50 mm thick taken during the excavations. These were subsampled in the laboratory (50 ml), and disaggregated by boiling in a 10% solution of sodium hydroxide. The material was then washed through nested sieves (2 mm–125 microns) and examined under a Nikon SMZ45T stereo microscope at ×10–×40 magnification. Material from the 2 mm–250 micron sieves that could be identified to a taxonomic level (typically seeds, fruits, nuts/nutlets, oospores and catkin bud scales) were counted, with the exception of moss stems and water lily seed fragments (see below). The results were quantified and displayed using the C2 data analysis software (Juggins 2010).

Small fragments of water-lily seed, indeterminate aquatic plant tissue, fern sporangia and any highly fragmented but identifiable plant macrofossils, were quantified on a scale of relative abundance (0=absent, 1=sparse, 2=present, 3=abundant).

Description of the results

The three complete profiles (VP85A/2010, CII/2010 and profile 3178) show a very similar pattern in terms of the range and quantities of plant macrofossils, and how these change over time. These have been divided into three main environmental/chronological zones on the basis of the changing composition of the assemblages. The partial profile recorded from samples taken during the excavation of the baulk between Clark's cuttings I and II (profile 3205) matches very closely the pattern observed in the lower half of the other three profiles (corresponding to Zone 1 and the base of Zone 2). Given their similarity, these profiles will be discussed together (Figures 19.2–19.4).

Zone 1

The basal samples contain plant macrofossils from a range of aquatic, emergent and terrestrial plant species. This is indicative of a lake edge location where the remains of plants growing in situ have become mixed with material that has washed in from other parts of the lake or has been transported from vegetation growing on the nearby lake shore.

At the sampling points, reeds were growing in standing water, given the consistent presence of aquatic plant and bryozoan macrofossils and the high proportion of *Phragmites* sp. leaf and rhyzome within the matrix of the peat. This was presumably common reed (*Phragmites australis*) as this is the only native species (Haslam 1972). A diverse range of emergent species were also present in the surrounding area, notably sedge (*Carex*), including greater tussock edge (*C. paniculata*), species of bulrush (*Typha* sp.) and bur-reed (*Sparganium* sp.), club-rush (*Schoenoplectus lacustris*) and bogbean (*Menyanthes trifoliata*). With the exception of club-rush and bur-reed, these all occur consistently in each of the profiles and the plants were probably growing at the site itself.

Aquatic material is also well represented. Of this, the oospores of the aquatic algae stonewort (Characeae) and seeds of the floating aquatic plants white and yellow water-lily (*Nymphaea alba* and *Nuphar lutea*) are known to be highly dispersive, and the parent plants may have been growing some distance from the sampling points (Zhao et al. 2006; Koff and Vandel 2008). In contrast, species of pondweed (*Potamogeton* sp.), which are well represented in all three profiles, were probably growing more locally, as their seeds sink quickly and tend not to travel far from their source (Koff and Vandel 2008). The statoblasts of *Cristatella*, a freshwater bryozoan, may also have derived from communities growing close by, as the submerged stems of emergent plants form one of its principal habitats (e.g. Wood 2001, 501).

The source of the arboreal plant macrofossils is also likely to be local, indicating both the proximity of the sampling points to the shore, and the presence of birch (*Betula* sp.), which from the fruits was predominately white or downy birch (*B. pubescens*), species of poplar (*Populus* sp.), probably aspen (*P. tremula*) on the basis of the catkin scales, and to a lesser extent willow (*Salix* sp.) at the water's edge. Bud scales of birch have a limited dispersal, and their occurrence as macrofossils has been shown to reflect the nearby presence of this tree (Greatrex 1983, 775, 784). This is probably also true of the large bud scales of poplar. Furthermore, the consistent
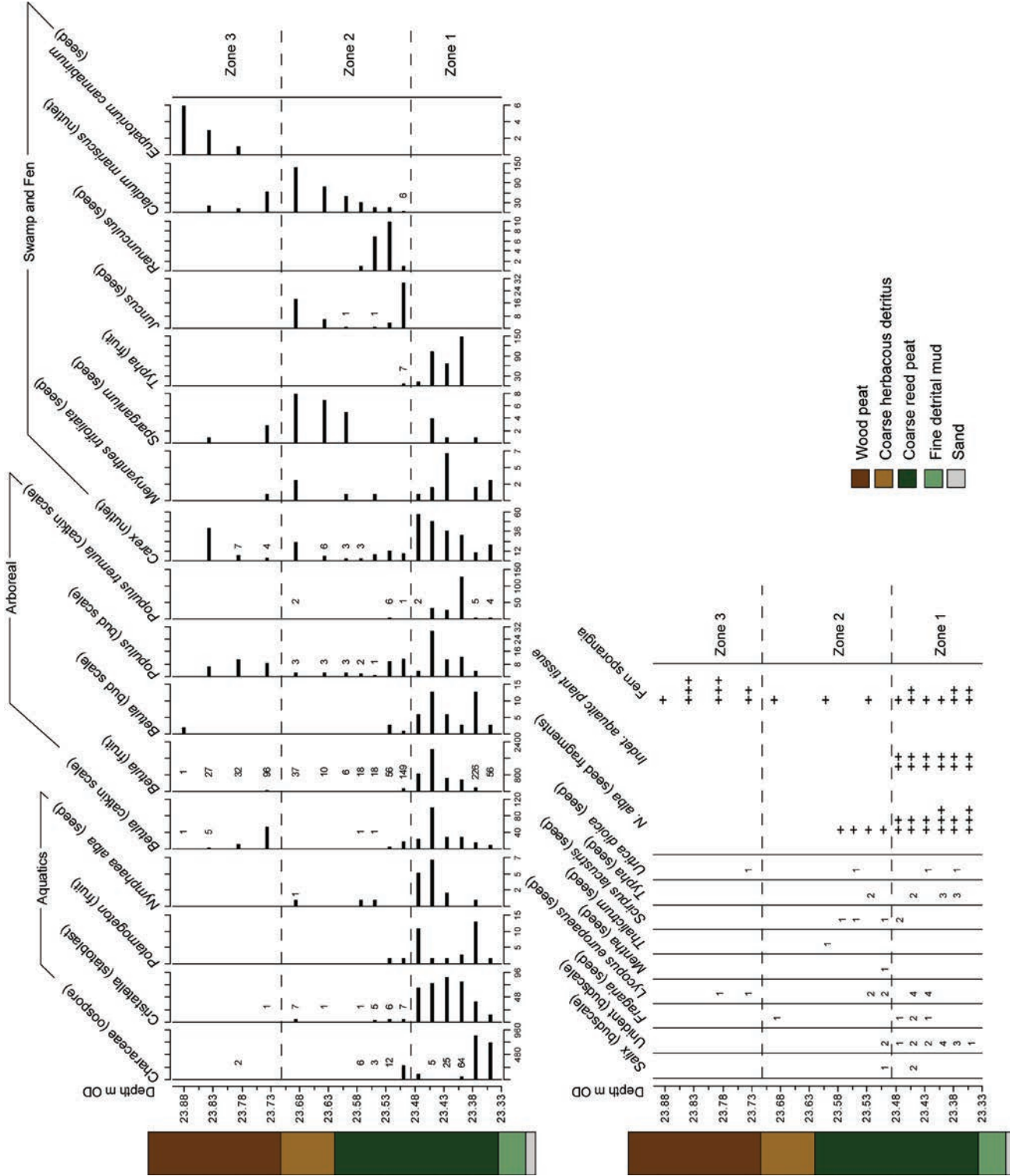
Figure 19.2: Plant macrofossils from profile VP85A/2010 (Adapted from Taylor et al. 2017. Copyright Cambridge University Press (2017) reprinted with permission).
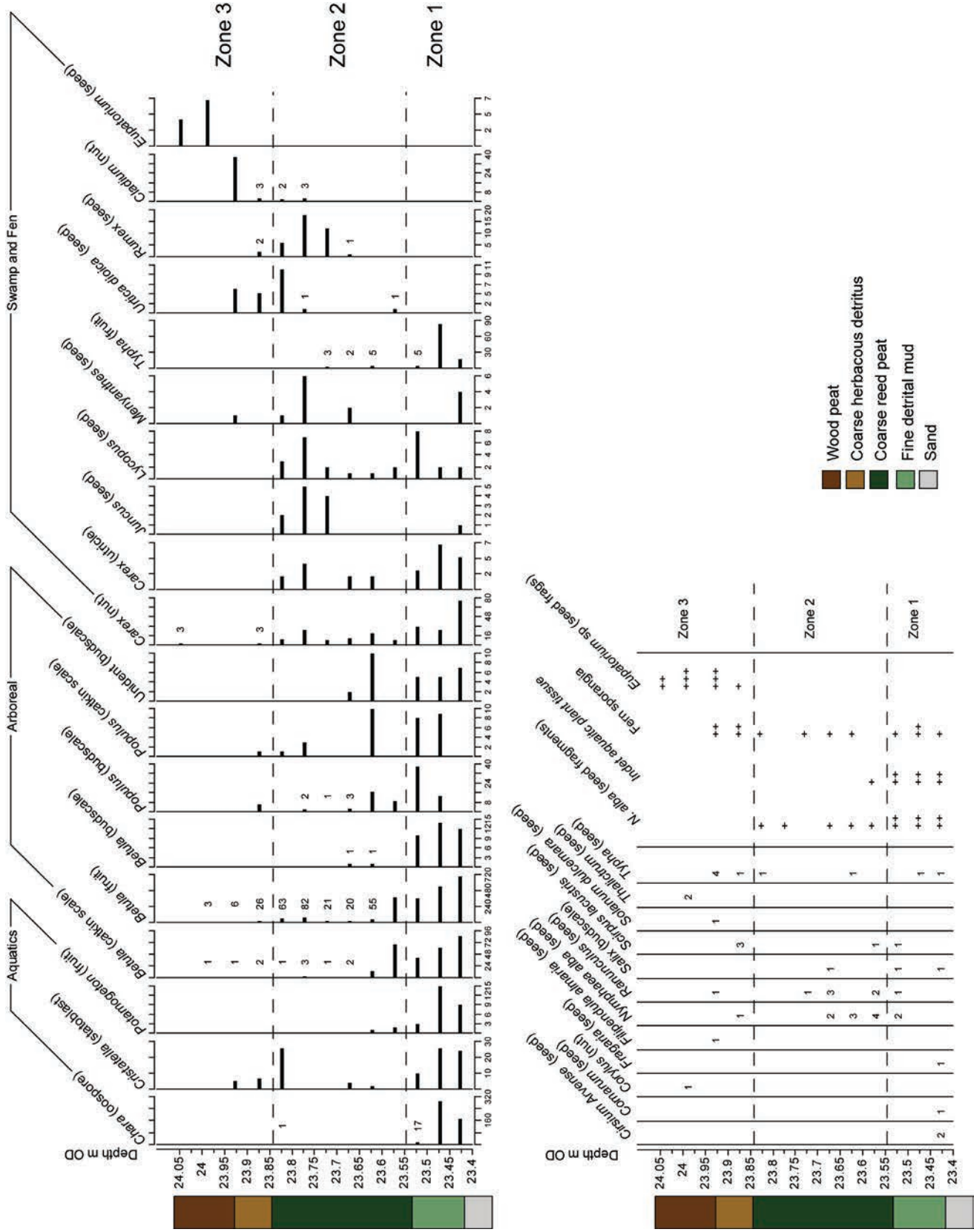
Figure 19.3: Plant macrofossils from profile CII/2010 (Adapted from Taylor et al. 2017. Copyright Cambridge University Press (2017) reprinted with permission).
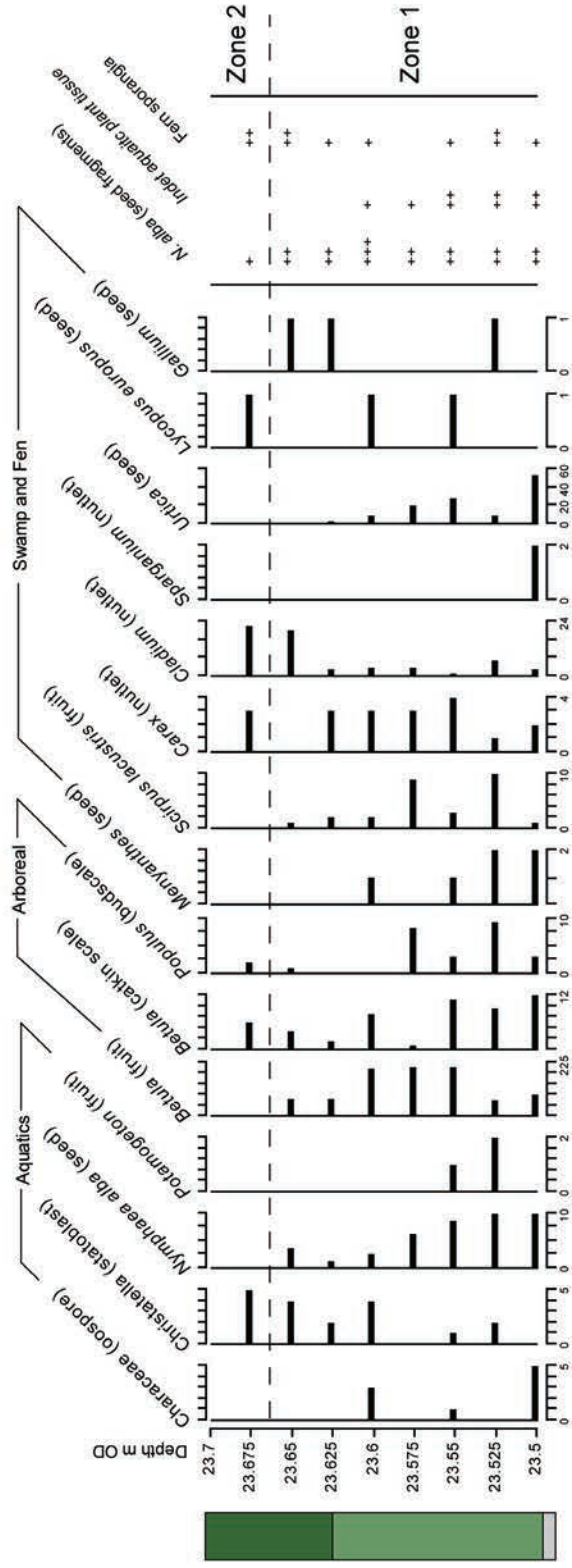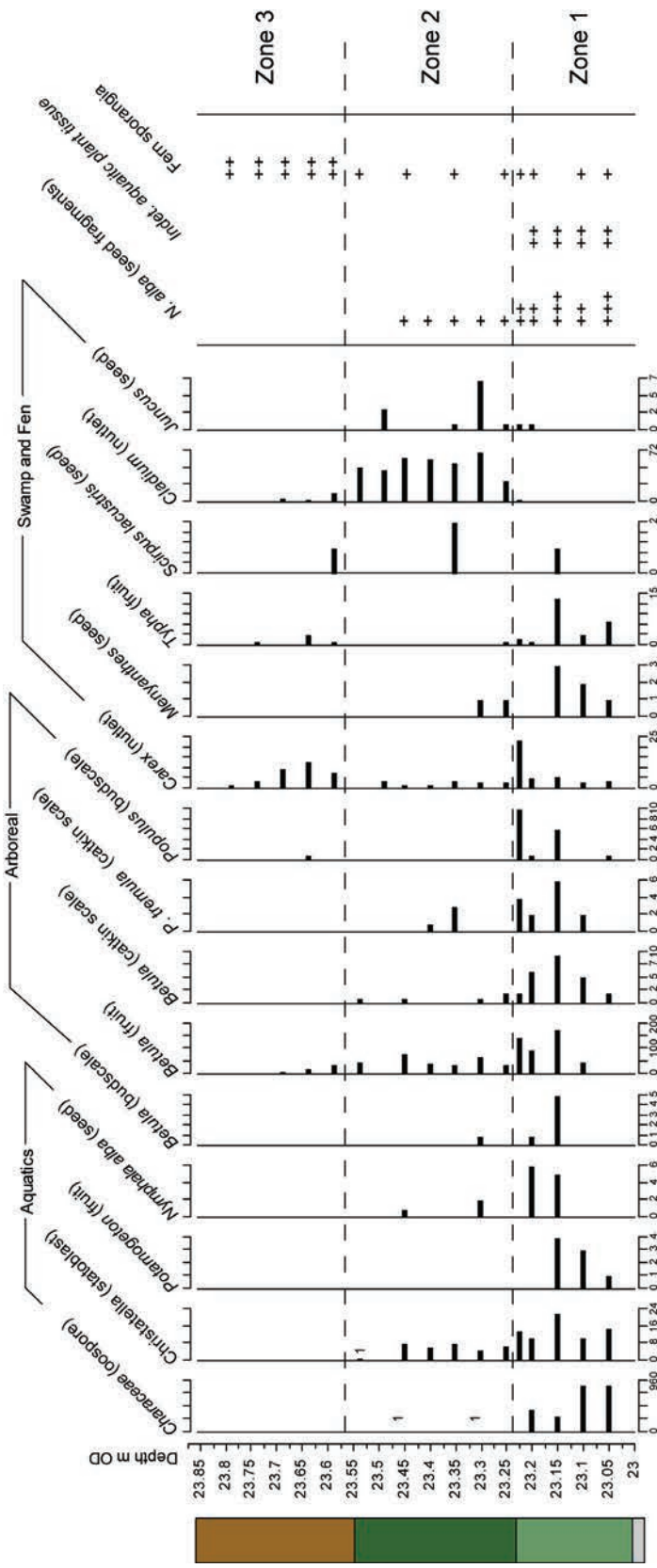
Figure 19.4: Plant macrofossils from profile P3178 (left) and P3502 (right) (Adapted from Taylor et al. 2017. Copyright Cambridge University Press (2017) reprinted with permission).

occurrence of leaf and bark fragments within the sample matrix, and roundwood within the peat suggests that shrubs or trees were present nearby, and that their branches extended out over the water. Other terrestrial or fen species are much more poorly represented, reflecting the more limited dispersal of their seeds. The exception is nettle (*Urtica dioica*), which occurs consistently in P3502, and was probably present on the adjacent shore. Gypsywort (*Lycopus europaeus*), a wetland plant suited to lake edges, may also have been growing locally given its sporadic occurrence in all of the profiles.

Zone 2

The start of the second zone is marked by a reduction in the quantity of aquatic plant and bryozoan macrofossils, which then occur more sporadically and in lower quantities than before. This can be seen most clearly in VP85A/2010, where there is a simultaneous decline in the number of *Cristatella* statoblasts, and the abundance of water-lily seed fragments and aquatic plant material at 23.5 m OD, after which there is an overall reduction in the quantity of aquatic material. A similar pattern can be seen in CII/2010 and P3178, and to a lesser extent P3502 where the fall in the abundance of water-lily seed fragments occurs around the same time as a reduction in the overall number of aquatic material.

This does not reflect a decline in the overall abundance of these species within the lake, as they are all well represented in contemporary deposits in other parts of the basin (e.g. Taylor 2011; 2012). Instead, it suggests a shift to a shallower environment, due to either a fall in lake level, the accumulation of sediments or a combination of the two. This reduced the amount of material being transported onto the site, and limited the local growth of aquatic communities (particularly in the case of *Cristatella*). More tentatively, it could mark the point where deposits went from being permanently to seasonally submerged.

The number and range of wetland and terrestrial plant macrofossils also changes from the start of this zone, with the remains of the emergent plants sedge, bogbean, and bulrush, the arboreal species birch and poplar, and nettles all becoming more sparse. Given that these plants are suited to different habitats, and that their decline corresponds with the fall in aquatic material, this is probably the result of the lower volume of material being transported to the sampling points by water and the reduced source area of the samples. That said, it is possible that some of the plants, particularly those that prefer to grow in deeper water, may have moved further from the lake edge. The exception is the emergent plant saw-sedge (*Cladium mariscus*), which increases in VP85A/2010 and profile 3178, and at the top of profile 3205. As this rise occurs at the same stratigraphic position in three of the four profiles, it probably reflects the local growth of the plant across the site. Common reed was also growing in the local area, as its tissue continued to be recorded within the coarse component of the peat.

Zone 3

The absence of aquatic material, including water-lily seed fragments from the matrix of the peat, and the paucity of aquatic plant macrofossils from the samples marks the point where the deposits began to form above the level of the lake. This would have further reduced the source area of the profiles, leading to the lower range and number of plant macrofossils present in the samples. Based on the composition of the peat, herbaceous plants were growing at all of the sampling points, whilst the increase in sporangia reflects the local growth of ferns. Seeds of the fen plant hemp agrimony (*Eupatorium cannabinum*) also occur in all three of profiles, albeit in very small numbers, suggesting its presence within the local area.

Profile SC33/2010

Only a small number of samples were analysed from this trench, with the aim of establishing the environmental context of a scatter of lithic material. As such, they have not been divided into environmental zones in the same way as the more complete profiles (Figure 19.5).

Within the lower samples (between 23.63 m and 23.73 m OD) aquatic, terrestrial and emergent taxa was well represented. Aquatic material occurred as both complete plant macrofossils (water-lily seeds, pondweed fruits), and statoblasts of *Cristatella*, and as fragmentary plant material within the sample matrix, and its presence suggests that the lake water was reaching the area as the deposits were forming. Common reed stems formed much of the coarse component of the peat and probably reflect the local growth of the plant. However,

Height m OD VP85A	Height m OD CII	Height m OD P3178	Height m OD P3178	Description
	23.37–23.42	22.98–23.0	23.48–23.50	Coarse sand with a high proportion of fine detrital mud. (Context 320)
23.29–23.35	23.42–23.56	23.00–23.24	23.50–23.62	Fine detrital mud with a high coarse component of monocot stem/leaf (inc. *Phragmites* cf. *australis*) and unidentifiable herbaceous material, with smaller quantities of round wood. (Context 317)
23.35–23.61	23.56–23.87	23.24–23.54	23.62–23.72	Coarse reed peat of horizontally bedded monocot stem/leaf (inc. *Phragmites* cf. *australis*) and unidentifiable herbaceous material. Levels of preservation deteriorated in the upper half of the deposit and the quantity of unidentifiable herbaceous material increased. Large quantities of roundwood were recorded in the lower half of this deposit in cutting II. (Context 312)
23.61–23.71	23.87–23.96	23.54–23.85	Not present	Coarse herbaceous detritus made up of unidentifiable herbaceous plant material (some forming thin layers and including *Phragmites* cf. *australis* stem/leaf), *Cladium mariscus* rhizomes, and smaller quantities of woody detritus and aerial round wood. (Context 312)
23.71–23.93	23.96–24.09	Not present	Not present	Coarse wood peat made up of horizontally bedded aerial round wood and root wood, unidentifiable woody detritus and smaller quantities of unidentifiable herbaceous material. (Context 310)

Table 19.1: Sediment descriptions for profiles VP85A/2010, CII/2010, P3178 and P3502 and the corresponding archaeological context. The reed peat and the overlying coarse herbaceous detritus both correspond with context (312).

sedges were also present at the site given the high numbers of nutlets. The terrestrial material is dominated by arboreal taxa, reflecting the presence of birch and poplar (probably aspen) at the nearby shore.

Above 23.73 m OD, aquatic material was only present in the form of water-lily seed fragments within the peat matrix, which disappeared in the uppermost sample (23.78–23.82 m OD). Arguably, this decline began in the lower samples, as both the quantity and range of aquatic material fell after 23.68 m OD. This is likely to reflect a gradual reduction in the volume of water reaching the area, after which the deposits began to form above the level of the lake (from 23.78 m OD). Common reed continued to be recorded within the peat and was probably still growing in the immediate area, though a range of other emergent and fen plants, notably bogbean, gypsywort and a species of meadow-rue (*Thalictrum* sp.) were present in the wider area. The rise in sporangia in the upper sample may reflect the local growth of ferns.

Profile 3356

A short sequence of samples was taken through sediments close to a red deer antler frontlet and several caches of flint. The sediments were highly humified and plant macrofossil preservation was extremely poor. Given the small quantities of material present, this profile has not been tabulated and the results will simply be described.

The basal samples (spanning a depth of 0.1 m) contained a small assemblage of very poorly preserved aquatic and arboreal plant macrofossils (pondweed fruits and birch catkin scales and fruits respectively), sedge nutlets, and very large numbers (over 1700) of rush (*Juncus* sp.) seeds. Though the preservation of the material was generally poor, making a full interpretation difficult, these deposits are likely to have been forming below the level of the lake, with rushes growing in the area.
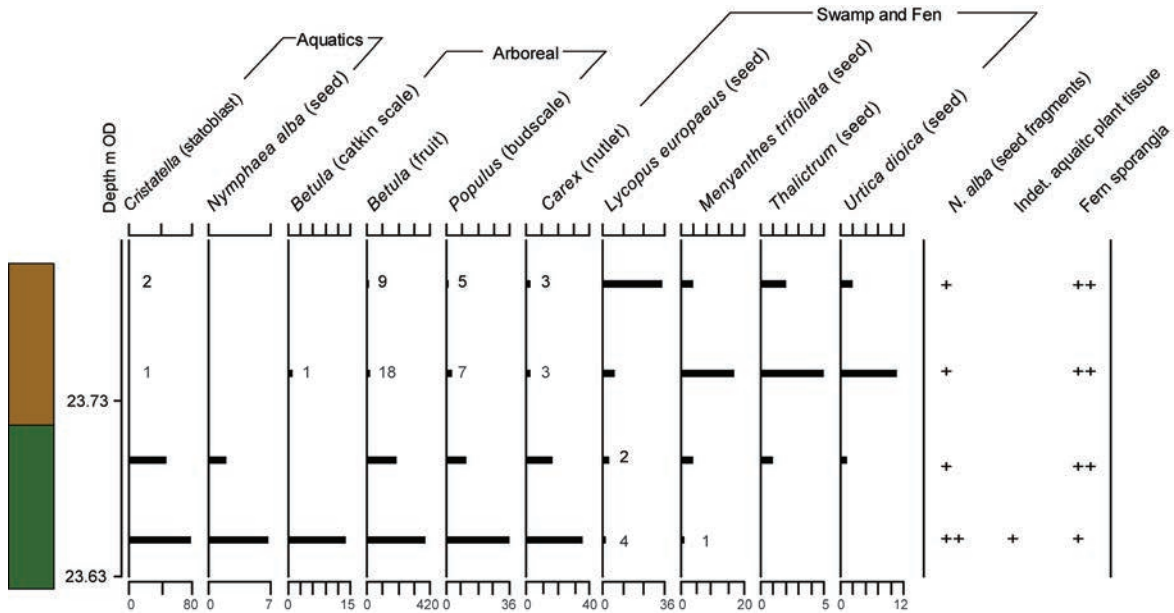
Figure 19.5: Plant macrofossils from profile SC33/2010 (Copyright Star Carr Project, CC BY-NC 4.0).

Above this, both the quantities and preservation of material declined sharply. Aquatic material was absent; birch catkin scales and sedge nutlets occurred occasionally. Given the decline in preservation it is difficult to tell the nature of the environment that these deposits formed in.

Comparison with Dark's environmental profiles

Plant macrofossil analysis was carried out by Dark on samples from V85A (profiles M1-3) and from the core taken adjacent to Clark's cutting II (Clark Site profile) (Dark 1998b). The samples were taken primarily for the analysis of macro-charcoal and in some cases were based on relatively small volumes of material (see Dark 1998a, 116). It should be noted that the levels (in metres OD) cited in Dark (1998b) are incorrect, and that the following discussion will refer to the corrected levels that are based on surveys carried out during the current programme of fieldwork.

Plant macrofossil profile M1

This profile lay immediately adjacent to profile VP85A/2010 and sampled the same deposits. However, whilst the results should be closely comparable there is considerable divergence. The basal samples of Dark's profile show a similar pattern to Zone 1 in VP85A/2010, with both aquatic and arboreal material well represented. However, above a level of 23.49 m OD (Dark's Zone M1-2 and above), the two profiles diverge; aquatic material disappears from M1 earlier than it does in VP85A/2010, whilst sedge occurs more sporadically, and saw-sedge appeared much later and had a more limited distribution. Given the proximity of the two profiles this cannot be the product of taphonomy or differences in patterns of vegetation. Instead, as the profiles diverge at the point where the overall number of plant macrofossil declines, it is likely to be a product of the smaller sample size recorded by Dark, with the assemblage significantly under-represented in profile M1.

Plant macrofossil profiles M2-3

Again, these profiles were based on a smaller sample size, and some material may be under-represented. That said, a comparable range of plant species were present, including the aquatic plant pondweed, and the emergent

plants sedge, bogbean, and (to a lesser extent) saw-sedge in M2, and the fen plant hemp-agrimony in the upper half of M3.

Dark's Clark Site profile

This profile lay just over 6 m south of CII/2010 and 28 m west of VP85A/2010 and was based on a larger sample volume than the other profiles recorded by Dark. Broadly speaking, it shows a far greater similarity with the profiles recorded as part of this project, both in terms of the range of plants represented and their changing quantities. The basal samples show relatively high levels of aquatic, emergent and arboreal plant macrofossils, all of which subsequently decline, after which saw-sedge becomes more abundant. As the aquatic material disappears towards the top of the profile the range of plant macrofossils declines further.

Dark's pollen profile M1

Broadly speaking, the results of Dark's pollen analysis and the plant macrofossils from VP85A/2010 compare well, with each detecting a range of emergent, aquatic and terrestrial flora. The records for emergent vegetation compare particularly well, with the high Poaceae pollen values corresponding with the abundance of common reed stem and leaf in the peat, whilst the occurrence of the pollen of bulrush (*Typha latifolia*), would suggest that this is the source of the bur-reed fruits recorded in the plant macrofossil profiles. Similarly, the increase and decline in Cyperaceae pollen (Dark's zone M1-3) matches that of the saw-sedge nutlets in Zone 2, again suggesting that both profiles are recording the same local patterns of vegetation. The short-term increase in marsh fern spores in Dark's Zone M1-2b is not matched by any change in the occurrence of sporangia, and the plant was probably not growing around the sampling point.

However, the more substantial rise in its spores in the upper half of the profile occurs at roughly the same time as the increase in sporangia and probably reflects the expansion of the plant across this part of the site. Unsurprisingly, terrestrial flora is better represented in the pollen profile, reflecting its wider source area. Of the arboreal species, birch is well represented in both profiles and shows a broadly similar pattern of abundance. The lack of aspen in Dark's profile may be an issue of taphonomy, as its pollen is known to survive very poorly and the species is often better represented as a plant macrofossil (Dark 1998a). However, the low levels of willow macrofossils in relation to the pollen cannot be explained in this way and suggest that either the tree was not close enough to the shore for material to deposited into the peat or that its macrofossils were not recognised.

Insect analysis

Methodology

Sub-samples with weights of up to 1 kilogram were processed in the Archaeology Department, University of York. Each was washed onto 0.3 mm mesh and paraffin flotation was carried out to extract insect remains broadly following the methods of Kenward et al. (1980). The peats were rather intractable and processing was carried out as gently as possible to avoid damaging delicate organic remains which resulted in the incomplete disaggregation of some material. The paraffin flots were initially stored in water but subsequently transferred to jars of industrial methylated spirits. Scanning was carried out using a low-power binocular microscope (×10–×45) and remains of beetles (Coleoptera) and bugs (Hemiptera) were removed onto damp filter paper for examination. The state of preservation of remains was recorded using the system of Kenward and Large (1998) where fragmentation (F) and erosion (E) are scored on a scale from 0.5 (superb) to 5.5 (extremely decayed or fragmented). Identification was by comparison with modern material and reference to standard published works. Ecological groups used in analysis are based on those of Kenward et al. (1986) and Kenward (1997). Proportions of aquatics in each sample have been calculated as percentages of the whole assemblage while proportions of all other groups, including wetland/waterside taxa, have been calculated as percentages of the terrestrial fauna. Nomenclature follows Duff (2012) for Coleoptera, Aukema and Rieger (1995–2006) for Heteroptera and Wilson et al. (2015) for Homoptera. Other invertebrate remains were recorded semi-quantitatively as present, common or abundant.

Description of the results

Taxa recorded from the main three sequences are listed in Table 19.2; hosts of plant and tree associated species are shown in Table 19.3.

The uppermost samples from VP85A/2010, CII/2010 and SC24 produced few identifiable remains (corresponding to plant macrofossil Zone 3). The insect assemblages from lower in the sequences (corresponding to plant macrofossil Zones 1 and 2) all show a similar pattern in terms of the species that are present and their distribution throughout the profiles and will be discussed together (Figure 19.6).

Aquatic insects account for between 10% and 32% of the assemblages from individual samples and waterside and wetland taxa, for 18% to 49% of terrestrial taxa. Generally, the species present are indicative of still to slowly flowing, well-vegetated, swampy water margins, with some evidence of more open water from insects such as pond skaters (*Gerris*), which hunt their prey on the surface film. *Haliplus confinis*, found in base-rich waters where stoneworts (Characeae) are present, occurs throughout the profiles (though slightly sporadically in CII/2010 and SC24), as do *Cyphon* spp. and donaciine beetles, which are characteristic of swampy well-vegetated environments with standing water. Submerged vegetation within the lake is indicated by the leaf beetle *Donacia versicolorea* found on pondweeds, while the weevil *Tanysphyrus lemnae* would have lived on duckweed (*Lemna*) growing on the water's surface. Other commonly recorded taxa found among aquatic vegetation in still water include *Hygrotus inaequalis* and the water bug *Microvelia*. Many of the aquatics are found in rather shallow water but *Hyphydrus ovatus* is typical of deep, richly vegetated, permanent, still-water bodies (Foster and Friday 2011, 106) which must have existed further from the sampling point.

There were consistent records of three species of riffle beetle (Elmidae) in the lower parts of CTII/2010 and VP85A/2010. Riffle beetles require clean, clear, well-oxygenated water and the species represented are typically found under stones in running water in streams and rivers or more rarely in stony lakes (Holland 1972). *Hydraena gracilis* (recorded from a single sample) is found in running water under stones or in moss upon them (Hansen 1987, 63). Although the basal substrate of the lake does include gravel and some larger boulders, much of this was covered by detrital mud and marl by the time these insects were deposited. It is possible that sands and gravels remained exposed further out in the lake, with the disappearance of riffle beetles higher in the sequences being a result of increased or wider accumulation of sediments. However, a more likely source for this group of insects might perhaps have been a small stream entering the lake close to the site.

A number of the insects recorded are associated with particular species of emergent and waterside vegetation. *Donacia obscura* found on Cyperaceae, especially sedges, occurs throughout much of the lower half of CII/2010 and VP85A/2010, and sedges are also indicated by the weevil *Limnobaris dolorosa*. *Donacia marginata* and *D. simplex* are both found on bur-reeds, *Prasocuris phellandrii* feeds on waterside Ranunculaceae, especially marsh marigold (*Caltha palustris*); the ladybird *Coccidula rufa* is usually associated with a growth of reeds (*Phragmites*), rushes and bulrush (Majerus 1994, 142); while waterside moss was indicated by *Hebrus* species. *Coelostoma orbiculare* (a typical fenland water beetle recorded throughout the sequences) is usually associated with mosses in rafts of floating vegetation and at water margins (Foster et al. 2014, 72). There were some indications of muddy conditions: *Elaphrus cupreus*, for example, is usually found on muddy, densely vegetated ground at the water's edge, and *Ilybius ater* occurs in stagnant water over vegetated mud or peat, typically at the very edges of ponds (Foster and Friday 2011, 55). *Dryops,* which lives in wet waterside mud, was recorded only from the upper half of VP85A/2010 and SC24/2010.

The assemblages also reflect the proximity of the sampling points to the drier ground beyond the water's edge, providing evidence for terrestrial habitats above the shore. A range of insects indicate that trees and/or shrubs grew close to the lake, in some places probably shading the water. *Elasmucha grisea* and *Oncopsis* cf. *tristis* are well represented in the lower samples in all three sequences, whilst *Elasmostethus interstictus* and *Kleidocerys resedae* occur more sporadically; all these bugs are associated with birch. Species of *Phratora*, which feed on willow and poplars, are also well represented (particularly *P. vitellinae* which occurred in most samples from SC24/2010). The occurrence of *Crepidodera* and *Chrysomela* (not *C. aenea*) throughout the profiles also reflects the presence of willows and/or poplars. The local growth of oak (*Quercus*) is hinted at by the presence of *Calosoma inquisitor* (identified from a partial elytron with distinctive asperities) in one of the lower samples from VP85A/2010. This arboreal ground beetle feeds on caterpillars associated with oaks (Luff 2007, 39), and the record tentatively suggests that the tree was present in the local landscape (though this remains to be confirmed through plant macrofossil analysis). Based on the occurrence of *Brachypterus* in the lower samples of

Thirty samples were examined; the number of samples in which each taxon occurred is shown in curved brackets. Nomenclature of beetles (Coleoptera) and bugs (Hemiptera) follows Duff (2012), Aukema and Rieger (1995–2006) and Wilson et al. (2015). Ecological codes are shown in square brackets as follows: d – damp ground/waterside; l – wood; m – heath/moorland; oa – outdoor taxa (unable to live and breed in buildings or accumulations of decomposing matter); ob – probable outdoor taxa; p – herbaceous plants; rd – dry decomposer; rf – foul decomposer; rt – eurytopic decomposer; sf – facultative synantropes; st - typical synanthropes; t – trees/scrub; u – uncoded; w – aquatic.

ANNELIDA
Oligochaeta sp. (earthworm) egg capsules (4)

CRUSTACEA
Cladocera spp. (water flea) ephippia (9)

INSECTA
DERMAPTERA (earwigs)
Dermaptera sp. (2)

HEMIPTERA: HETEROPTERA (true bugs)
Elasmostethus interstictus (Linnaeus) [oa-t] (2)
Elasmucha grisea (Linnaeus) [oa-t] (14)
Sehirus sp. [oa-p] (4)
Cydnidae sp. [oa-p] (3)
Pentatomoidea sp. and sp. indet. [oa] (11)
Anthocoris sp. [oa-p] (3)
Temnostethus gracilis Horvath [oa-t] (3)
Cymus sp. [oa-p] (1)
Drymus sylvaticus (Fabricius) [oa-p] (3)
Drymus sylvaticus or *ryei* [oa-p] (3)
Drymus sp. indet. [oa-p] (3)
Ischnodemus sabuleti (Fallén) [oa-p] (1)
Kleidocerys resedae (Panzer) [oa-t] (2)
Peritrechus geniculatus (Hahn) [oa-p] (1)
Scolopostethus decoratus (Hahn) [oa-p-m] (1)
Stygnocoris sabulosus (Schilling) [oa-p] (6)
Stygnocoris sp. [oa-p] (2)
?*Stygnocoris* sp. [oa-p] (1)
Trapezonotus sp. [oa-p] (4)
Lygaeidae spp. and sp. indet. [oa-p] (13)
Mecomma ambulans Fallén [oa-p] (1)
Miridae sp. [u] (1)
Corixidae sp(p). [oa-w] (9)
Corixidae sp(p). nymphs (4)
Gerris sp. [oa-w] (13)
Hebrus pusillus (Fallén) [oa-p-d] (2)
Hebrus ?*pusillus* (Fallén) [oa-p-d] (2)
Hebrus ruficeps Thomson [oa-p-d] (7)
Hebrus sp. indet. [oa-p-d] (6)
Chartoscirta sp. [oa-d] (6)
Saldidae sp. indet. [oa-d] (3)
Microvelia sp. [oa-w] (12)
Heteroptera spp. and sp indet. [u] (10)

HEMIPTERA: HOMOPTERA (planthoppers etc)
?*Aphrophora* sp. [oa-p] (5)
Oncopsis cf. *tristis* (Zetterstedt) [oa-t] (7)
Delphacidae spp. [oa-p] (25)
Centrotus cornutus (Linnaeus) [oa-t] (1)
Auchenorhyncha/Fulgoromorpha spp. [oa-p] (23)
Strophingia ericae (Curtis) [oa-p-m] (3)
Psylloidea sp. [oa-p] (3)

TRICHOPTERA (caddis flies)
Trichoptera sp(p). wing fragments (7)
Trichoptera sp(p). larval fragments (8)
Trichoptera sp. larval cases (5)

DIPTERA (flies)
Bibionidae sp. leg spines and fragments (18)
?Bibionidae sp. puparia (2)
Hippoboscidae sp. puparia ?*Lipoptena cervi* (Linnaeus) (1)
Diptera spp. (1)
Diptera spp. puparia (16)

HYMENOPTERA (ants, wasps and bees)
Formicidae spp. (ants) (5)
Hymenoptera Aculeata spp. (10)
Hymenoptera Parasitica spp. (15)

COLEOPTERA
GYRINIDAE (whirligig beetles)
Gyrinus spp. [oa-w] (17)

HALIPLIDAE (crawling water beetles)
Haliplus confinis Stephens [oa-w] (14)
Haliplus ?*confinis* Stephens [oa-w] (5)
Haliplus (*Haliplus*) sp. [oa-w] (4)
Haliplus sp. [oa-w] (2)

NOTERIDAE (burrowing water beetles)
Noterus crassicornis (Müller) [oa-w] (1)
Noterus sp. indet. [oa-w] (10)

DYTISCIDAE (predaceous diving beetles)
Agabus bipustulatus (Linnaeus) [oa-w] (3)
Agabus or *Ilybius* spp. [oa-w] (21)
Ilybius ater (De Geer) [oa-w] (10)
Colymbetes fuscus (Linnaeus) [oa-w] (1)
Rhantus sp. [oa-w] (8)
Acilius sp. [oa-w] (2)
Hygrotus inaequalis (Fabricius) [oa-w] (11)
Hygrotus sp. indet. [oa-w] (3)
Hyphydrus ovatus (Linnaeus) [oa-w] (3)
Hydroporinae spp. [oa-w] (18)
Dytiscidae spp. [oa-w] (7)

CARABIDAE (ground beetles)
Calosoma inquisitor (Linnaeus) [oa-t] (1)
Leistus sp. [oa] (1)
Notiophilus sp. [oa] (1)
Elahrus cupreus Duftschmid [oa-d] (4)
Trechus rivularis (Gyllenhal) [oa-d] (3)
Trechus obtusus or quadristriatus [oa] (4)
Trechus sp. indet. [oa] (2)
Ocys harpaloides (Audinet-Serville) [oa] (1)
Bembidion spp. [oa] (3)

Table 19.2: *Continued*

Pterostichus minor (Gyllenhal) [oa-d] (3)
Pterostichus nigrita or *rhaeticus* [oa-d] (3)
Pterostichus diligens (Sturm) [oa-d] (6)
Pterostichus strenuus (Panzer) [oa] (2)
Pterostichus diligens or *strenuus* [oa] (2)
Pterostichus sp. and sp. indet. [oa] (3)
Agonum cf. *fuliginosum* (Panzer) [oa-d] (1)
Agonum thoreyi Dejean [oa-d] (7)
Agonum sp(p). and sp. indet. [oa] (10)
Bradycellus ?*harpalinus* (Audinet-Seville) [oa] (1)
Harpalini sp. [oa] (1)
Paradromius linearis (Olivier) [oa] (1)
Odacantha melanura (Linnaeus) [oa-d] (2)
Carabidae spp. and sp. indet. [ob] (21)

HELOPHORIDAE (grooved water scavengers)
Helophorus sp. [oa-w] (1)

HYDROCHIDAE
Hydrochus brevis or *carinatus* [oa-w] (1)
Hydrochus sp. indet. [oa-w] (6)

HYDROPHILIDAE
Anacaena ?*limbata* (Fabricius) [oa-w] (4)
Anacaena sp. indet. [oa-w] (9)
Chaetarthria sp. [oa-d] (6)
Enochrus sp. [oa-w] (3)
Hydrobius fuscipes (Linnaeus) [oa-w] (21)
Laccobius sp. [oa-w] (6)
Hydrophilinae spp. [oa-w] (27)
Coelostoma orbiculare (Fabricius) [oa-w] (13)
Cercyon convexiusculus Stephens [oa-d] (6)
Cercyon ?*convexiusculus* Stephens [oa-d] (3)
Cercyon ?*sternalis* Sharp [oa-d] (2)
Cercyon tristis or *granarius* [oa-d] (1)
Cercyon convexiusculus/tristis group [oa-d] (14)
Cercyon sp. indet. [u] (5)
Megasternum concinnum (Marsham) [rt] (14)

HYDRAENIDAE (minute moss beetles)
Hydraena gracilis Germar [oa-w] (1)
Hydraena spp. [oa-w] (27)
Limnebius aluta Bedel [oa-w] (13)
Limnebius sp. [oa-w] (8)
Ochthebius minimus (Fabricius) [oa-w] (11)
Ochthebius cf *minimus* (Fabricius) [oa-w] (8)
Ochthebius sp. indet. [oa-w] (4)
PTILIIDAE (featherwing beetles)
Ptenidium sp. [rt] (1)
Acrotrichis sp(p). [rt] (12)

LEIODIDAE (round fungus beetles)
Leiodidae spp. [u] (7)

SILPHIDAE (carrion beetles)
Silpha atrata Linnaeus [u] (3)
Silphidae sp. [u] (2)

STAPHYLINIDAE (rove beetles)
Acidota crenata (Fabricius) [oa] (2)
Acidota cruentata Mannerheim [oa] (13)
Acidota sp. [oa] (3)

Anthobium sp. [oa] (2)
Lesteva longoelytrata [oa-d] (1)
Lesteva sp. [oa-d] (1)
Olophrum spp. [oa] (2)
Eusphalerum minutum (Fabricius) [oa-d] (5)
Omalium sp. [rt] (1)
Omaliinae sp(p). [u] (13)
Megarthrus sp. [rt] (3)
Metopsia clypeata (Müller) [rt] (3)
Proteinus sp. [rt] (1)
Arrhenopeplus tesserula (Curtis) [rt] (2)
Pselaphinae spp. [u] (19)
Mycetoporus spp. [u] (4)
Sepedophilus spp. [u] (3)
Tachinus rufipes (Linnaeus) [u] (2)
Tachinus spp. [u] (13)
Tachyporus sp. [u] (6)
Tachyporinae sp. [u] (1)
Aleocharinae spp. [u] (29)
Scaphisoma agaricinum (Linnaeus) [l] (1)
Scaphisoma boleti (Panzer) [l] (1)
Anotylus rugosus (Fabricius) [rt] (6)
Oxytelus laqueatus (Marsham) [rf] (1)
Aploderus caelatus (Gravenhorst) [rt] (1)
Bledius sp. [oa] (1)
Carpelimus sp(p). [u] (8)
Oxytelinae sp. [u] (1)
Stenus spp. [u] (29)
Euasthetus sp. [oa] (1)
Lathrobium sp. [u] (10)
Ochthephilum fracticorne (Paykull) [oa-d] (2)
Paederus sp. [oa-d] (3)
Rugilus sp. [rt] (4)
Paederinae sp. [u] (1)
Erichsonius cinerascens (Gravenhorst) [oa-d] (5)
Erichsonius sp. indet. [oa] (2)
Neobisnius sp. [u] (2)
Xantholinus linearis or *longiventris* [rt-sf] (1)
Xantholinini sp. [u] (2)
Staphylininae spp. [u] (23)

LUCANIDAE (stag beetles)
Sinodendron cylindricum (Linnaeus) [l] (4)
?*Sinodendron cylindricum* (Linnaeus) [l] (1)

GEOTRUPIDAE (earth-boring dung beetles)
Geotrupes sp. s.l. [oa-rf] (10)

SCARABAEIDAE (dung beetles and chafers)
Aphodius spp. [ob-rf] (8)
Euheptaulacus villosus (Gyllenhal) [oa] (5)
Euheptaulacus sp. indet. [oa] (2)
Serica brunnea (Linnaeus) [oa-p] (22)
?Scarabaeoidea sp. [u] (1)

SCIRTIDAE (marsh beetles)
Microcara testacea (Linnaeus) [oa-d] (2)
Cyphon padi (Linnaeus) [oa-d] (21)
Cyphon spp. and sp. indet. [oa-d] (30)

DASCILLIDAE (orchid beetles)

Dascillus cervinus (Linnaeus) [oa-p] (1)

BYRRHIDAE (pill beetles)
Simplocaria sp. [oa-p] (1)
Cytilus sericeus (Forster) [oa-p-m] (1)
Byrrhus sp. [oa-p] (2)
Byrrhidae sp. [u] 91)

ELMIDAE (riffle beetles)
Esolus or *Normandia* [oa-w] (6)
Limnius volkmari (Panzer) [oa-w] (1)
Oulimnius sp. [oa-w] (3)
Elmidae sp. indet. [oa-w] (1)

DRYOPIDAE (long-toed water beetles)
Dryops sp. [oa-d] (4)

HETEROCERIDAE (mud beetles)
Heterocerus sp. [oa-d] (2)

ELATERIDAE (click beetles)
Denticollis linearis (Linnaeus) [u] (3)
?*Agriotes* sp. [oa-p] (2)
Dalopius marginatus (Linnaeus) [oa-t] (21)
Elateridae spp. [ob] (19)

CANTHARIDAE (soldier beetles)
Cantharis sp. [ob] (1)
Cantharidae sp. [ob] (3)

PTINIDAE (woodworm and spider beetles)
Ptilinus pectinicornis (Linnaeus) [l-sf] (4)
Dorcatoma ?*dresdensis* Herbst [l] (2)

DASYTIDAE (soft-winged flower beetles)
Dasytes sp. [l] (4)

SPHINDIDAE
Aspidiphorus orbiculatus (Gyllenhal) [oa] (3)

KATERETIDAE (short-winged flower beetles)
Brachypterus sp. [oa-p] (7)

NITIDULIDAE (sap and pollen beetles)
Epuraea sp. [u] (1)
Glischrochilus sp. [u] (1)
Nitidulidae sp. [u] (6)

SILVANIDAE (flat bark beetles)
Silvanus sp. [l-t] (1)
Silvanidae sp. [l-t] (1)

LAEMOPHLOEIDAE (lined flat bark beetles)
Cryptolestes sp. [u] (1)

PHALACRIDAE
Phalacridae sp(p). [oa-p] (3)

CRYPTOPHAGIDAE (silken fungus beetles)
Cryptophagus spp. [rd-sf] (2)
?*Micrambe* sp. [u] (1)
Atomaria spp. [rd] (5)
?*Atomaria* sp. [rd] (2)
Cryptophagidae sp(p). [u] (6)

CERYLONIDAE
Cerylon ferrugineum Stephens [l-t] (2)
Cerylon sp. and sp. indet. [l-t] (8)

COCCINELLIDAE (ladybirds)
Coccidula rufa (Herbst) [oa-p-d] (11)
Scymnus sp. [oa-p] (3)
Chilocorus bipustulatus (Linnaeus) [oa-p-m] (9)
Coccinella unidecimpunctatus Linnaeus [oa-p] (2)
Coccinellidae sp. [oa-p] (3)

CORYLOPHIDAE
Orthoperus sp. [rt] (1)
Corylophidae sp. [rt] (10)

LATRIDIIDAE (minute brown scavenger beetles)
Latridius minutus group [rt-st] (6)
Corticaria sp. [rt-sf] (4)
Corticariinae spp. [rt] (21)
Latridiidae sp. [u] (1)

MYCETOPHAGIDAE (hairy fungus beetles)
Pseudotriphyllus suturalis (Fabricius) [l] (1)
Litargus connexus (Geoffroy) [l] (1)
CIIDAE (minute tree fungus beetles)
Ciidae spp. [l-t] (2)
?Ciidae sp. [l-t] (1)

SALPINGIDAE
Salpingus planirostris (Fabricius) [l-t] (1)
Salpingus sp. indet. [l-t] (3)
?Salpingidae sp. [l-t] (2)

ANTHICIDAE (ant-like flower beetles)
Omonadus sp. [rt] (1)

SCRAPTIDAE (false flower beetles)
Scraptidae sp. [u] (5)

CERAMBYCIDAE (longhorns)
Rhagium mordax (De Geer) [l] [l-t] (1)
Grammoptera sp. [l-t] (1)
Pogonocherus hispidus (Linnaeus) [l-t] (1)
Cerambycidae sp. [l-t] (1)

CHRYSOMELIDAE (leaf and seed beetles)
Bruchinae sp. [u] (1)
Macroplea sp. [oa-p-w] (2)
Donacia cinerea Herbst [oa-p-d] (1)
Donacia marginata Hoppe [oa-p-d] ((5)
Donacia obscura Gyllenhal [oa-p-d] (11)
Donacia semicuprea Panzer [oa-p-d] (1)
Donacia simplex Fabricius [oa-p-d] (4)
Donacia versicolorea (Brahm) [oa-p-d] (2)
Donacia ?*versicolorea* (Brahm) [oa-p-d] (1)
Donacia spp. and sp. indet. [oa-p-d] (13)
Plateumaris discolor (Panzer) [oa-p-d] (1)
Plateumaris ?*discolor* (Panzer) [oa-p-d] (2)
Plateumaris sericea (Linnaeus) [oa-p-d] (1)
Plateumaris sp. [oa-p-d] (3)
?*Plateumaris* sp. [oa-p-d] (2)
Plateumaris or *Donacia* sp(p). [oa-p-d] (20)

Table 19.2: *Continued*

Lema or *Oulema* sp. [oa-p] (1)
Bromius obscurus (Linnaeus) [oa-p] (12)
Chrysolina fastuosa (Scopoli) [oa-p] (1)
Prasocuris phellandrii (Linnaeus) [oa-p-d] (7)
?*Chrysomela populi* Linnaeus [oa-t] (1)
Chrysomela sp. (not *aenea*) [oa-t] (8)
Phratora laticollis Suffrian [oa-t] (1)
Phratora vitellinae (Linnaeus) [oa-t] (8)
Phratora ?*vitellinae* (Linnaeus) [oa-t] (1)
Phratora vulgatissima (Linnaeus) [oa-t] (3)
Phratora sp. indet. [oa-t] (4)
?*Phratora* sp. indet. [oa-t] (2)
Chrysomelinae sp(p). [oa-p] (6)
Galerucella sp. [oa-p] (6)
Galeruca tanaceti (Linnaeus) [oa-p] (2)
Lochmaea caprea (Linnaeus) [oa-t] (1)
Galerucinae sp. indet. [oa-p] (3)
Phyllotreta nemorum group [oa-p] (1)
Altica sp. [oa-p] (1)
Crepidodera spp. [oa-p] (9)
Sphaeroderma ?*testaceum* (Fabricius) [oa-p] (2)
Alticini spp. [oa-p] (3)
Chrysomelidae spp. [oa-p] 16)

RHYNCHITIDAE (tooth-nosed snout weevils)
Rhynchitidae sp. [oa-p] (1)
APIONIDAE (seed weevils)
Oxystoma sp. [oa-p] (1)
Apionidae spp. [oa-p] (17)

ERIRHINIDAE (wetland weevils)
?*Notaris acridulus* (Linnaeus) [oa-p-d] (1)
?*Thryogenes* sp. [oa-p-d] (1)
Tanysphyrus lemnae (Paykull) [oa-p-w] (10)

CURCULIONIDAE (weevils)
Anthonomus sp. [oa-p] (2)

Gymnetron/Mecinus sp. [oa-p] (2)
Isochnus ?*foliorum* (Müller) [oa-t] (8)
?*Rhamphus* sp. [oa-t] (2)
Bagous sp. [oa-p-w] (1)
Limnobaris dolorosa (Goeze) [oa-p-d] (2)
Limnobaris sp. indet. [oa-p-d] (5)
Ceutorhynchus contractus (Marsham) [oa-p] (2)
Ceutorhynchus ?*contractus* (Marsham) [oa-p] (1)
Micrelus ericae (Gyllenhal) [oa-p-m] (4)
Nedyus quadrimaculatus (Linnaeus) [oa-p] (2)
Rhinoncus sp. [oa-p] (1)
Ceutorhynchinae spp. [oa-p] (14)
?*Cossonus linearis* (Fabricius) [l] (1)
Cossoninae sp. [l] (1)
Phyllobius ?*argentatus* Linnaeus) [oa-p] (1)
Phyllobius roboretanus or *viridicollis* [oa-p] (4)
Phyllobius sp. [oa-p] (8)
Polydrusus pterygomalis Boheman [oa-t] (8)
Phyllobius or *Polydrusus* sp(p). [oa-p] (5)
Sitona sp. [oa-p] (3)
?*Sitona* sp. [oa-p] (2)
Tropiphorus sp. [oa-p] (1)
Scolytus rugulosus (Müller) [l-t] (1)
Taphrorhynchus sp. [l-t] (2)
Scolytinae sp. [l-t] (1)
Curculionidae spp. and sp. indet. [oa-p] (26)
Coleoptera spp. and spp. indet. [u] (29)
Insecta spp. larval fragments (22)

ARACHNIDA
Acarina spp. (mites) (28)
Aranae spp. (spiders) (4)
Pseudoscorpiones sp. (pseudoscorpions) (1)

BRYOZOA
Cristatella mucedo Cuvier statoblast

Table 19.2: Insects and other invertebrates from profiles VP85a/2010, CTII/2010 and SC24.

Species	Food and habitat preferences
Elasmostethus interstictus	Main food is birch
Elasmucha grisea	Associated with birch and birchwoods
Ischnodemus sabuleti	Hosts include reed-grass (*Phalaris*), tufted hair-grass (*Deschampsia cespitosa*) and reeds in marshes, in summer can be found in dry sunny fields
Kleidocerys resedae	On catkins of birch and alder
Scolopostethus decoratus	On heathland
Temnostethus gracilis	On the trunks and twigs of lichen encrusted deciduous trees, rocks or walls, feeding on bark lice and other small insects
Oncopsis cf tristis	Associated with birch
Strophingia ericae	On heathers (*Calluna vulgaris* and *Erica*)
Calosoma inquisitor	The adults are arboreal in oak woodland

Species	Food and habitat preferences
Odacantha melanura	Reed beds
Serica brunnea	The larvae feed at the roots of turf
Dascillus cervinus	The larvae feed at the roots of short vegetation
Cytilus sericeus	Mostly found on heaths and moorland in Britain
Dalopius marginatus	In wooded places or scrub
Denticollis linearis	Typically in woodland or scrub
Aspidophorus orbiculatus	On slime moulds
Brachypterus spp.	On nettles (*Urtica*)
Coccidula rufa	Principally on reeds (*Phragmites*), rushes (*Juncus*) and bulrushes (*Typha*) in wetland
Chilocorus bipustulatus	Heather heathland and conifer scrub
Bruchinae sp.	Associated with leguminous plants (Fabaceae)
Macroplea sp.	On submerged vegetation
Donacia cinerea	Adults usually found on bulrushes (*Typha*)
Donacia marginata	Found on branched bur-reed (*Sparganium erectum*)
Donacia obscura	Usually found on various Cyperaceae, especially bottle sedge (*Carex rostrata*)
Donacia semicuprea	Adults and larvae usually found on reed sweet grass (*Glyceria maxima*)
Donacia simplex	Adults eat the leaves of bur-reeds (*Sparganium*) which are probably also the larval food plant
Donacia versicolorea	Adults and larvae usually on pondweeds (*Potomogeton*) especially broad-leaved pond weed *P. natans*
Plateumaris discolor	Adults usually found on sedges (*Carex*)
Plateumaris sericea	Adults usually found on bur-reeds (*Sparganium*)
Lema or *Oulema* sp.	Feeds on the leaves of grasses and cereals
Bromius obscurus	Principally found on rosebay willowherb (*Chamerion angustifolium*); also other willowherbs (*Epilobium*)
Prasocuris phellandrii	Adults feed on marsh marigold (*Caltha palustris*) and also on other waterside Ranunculaceae; also found on leaves of other marginal plants including waterside umbellifers
?*Chrysomela populi*	Adults and larvae usually feed on the leaves of willows and poplars
Phratora laticollis	Adults and larvae feed on poplars including aspen
Phratora vitellinae	Adults and larvae feed on the leaves of willows and poplars
Phratora vulgatissima	Adults usually on willows, possibly on aspen, larvae usually on sallows and goat willow
Galeruca tanaceti	In open habitats feeding on a wide range of food plants including yarrow (*Achillea millefolium*), common knapweed (*Centaurea nigra*), cuckooflower (*Cardamine pratensis*), mouse-ears (*Cerastium*), devil's-bit scabious (*Succisa pratensis*) and speedwells (*Veronica*)
Lochmaea caprea	Adults are usually found on willows and birches, the larvae usually feed on willow
Phyllotreta nemorum gp	On wild and cultivated crucifers
Crepidodera spp.	On willows, poplars and aspen
Sphaeroderma ?*testaceum*	On Asteraceae, especially thistles (*Carduus* and *Cirsium*), and sometimes common knapweed (*Centaurea nigra*)
Oxystoma sp.	On vetches (*Vicia* and *Lathyrus*)
Notaris acridulus	On semi-aquatic grasses; reed sweet-grass (*Glyceria maxima*) is a common host in Continental Europe
Isochnus ?*foliorum*	On willows

Table 19.3: *Continued*

Species	Food and habitat preferences
Limnobaris dolorosa	On sedges (*Carex*)
Limnobaris spp.	On sedges (*Carex*)
Ceutorhynchus contractus	In waste and open places on crucifers (Brassicaceae)
Micrelus ericae	On heathers (*Calluna* and *Erica*)
Nedyus quadrimaculatus	On nettles (*Urtica*)
Rhinoncus sp.	The various species are found on *Persicaria* and *Rumex*
Sitona spp.	The foodplants are various legumes (Fabaceae)
Scolytus rugulosus	Bark beetle usually found on trees and shrubs of the Rosaceae family
Tanysphyrus lemnae	On duckweed (*Lemna*)

Table 19.3: Habitat and food preferences of plant-associated beetles and bugs. Eurytopic taxa have been excluded. Main sources: Cox (2007), Majerus (1994), Morris (2002, 2008, 2012), Nau (2004), Southwood and Leston (1959).

all three profiles, nettles (*Urtica*) were also present locally and may have been growing along with willow and poplar on the damp soils at the water's edge.

Areas of relatively open ground with herbaceous vegetation and grasses were also present. *Bromius obscurus*, a leaf beetle associated with the shade intolerant rosebay willow-herb (*Chamaerion angustifolium*), was found in 12 samples spanning the range of the peat sequence, indicating areas of open ground close to the shore. Willow-herb is a pioneer species often associated with clearings, burnt areas and beaver activity, and its presence may reflect disturbance and clearance events in the local woodlands. Areas of open, and possibly disturbed, ground were also indicated by records of *Galeruca tanaceti* found in a variety of open habitats on herbaceous vegetation, *Sphaeroderma ?testaceum* found on members of the daisy family (Asteraceae, particularly thistles (*Cirsium* and *Carduus*)), and the occasional occurrence of the ground beetle *Paradromius linearis* (single find in the base of CII/2010). The scarabaeid beetle *Euheptaulacus villosus* recorded from samples towards the bases of all three sequences is found in exposed sunny places in vegetable matter or dung, or under stones (Jessop 1986, 19).

Insects associated with heather (*Calluna vulgaris* and *Erica*) and heathland habitats are a consistent presence in all three sequences, albeit in small numbers. The ladybird *Chilocorus bipustulatus* is present throughout the deposits, while *Strophingia ericae*, a jumping plant louse, and the weevil *Micrelus ericae* were represented in the lower parts of the profiles. There were also occasional records of *Scolopostethus decoratus* and *Cytilus sericeus*, both typical of heathland.

Decomposer beetles were represented in limited numbers with the majority of taxa typical of decaying organic material on damp ground or by water. Very few can be regarded as synanthropic to any degree (i.e. favoured by human activities). *Latridius minutus* group, recorded from several samples across the three sequences, is a typical synanthrope but also occurs in grass tussocks and other natural situations. At least some parts of the sequences would have formed during periods of human activity beside the lake, but intensive activity very close to the shore (that might have attracted greater numbers of decomposers) may have been restricted because of the swampy conditions. Beetles found on dead and rotting wood occur throughout the profiles in small numbers and they may be largely related to the presence of older trees and associated dead wood habitats. They include *Dasytes* in the lower samples in CII/2010, the larvae of which live in rotting wood, and *Ptilinus pectinicornis*, a member of the woodworm family, in the lower half of VP85A/2010. Some species associated with rotting wood occur in the same samples as the timbers of the western and central platforms, such as *Sinodendron cylindricum* (in VP85A/2010) and a bark beetle (Scolytinae) in CII/2010. However, there is no notable increase in the abundance of this group within these deposits compared to elsewhere in the sequences.

Evidence for the presence of larger animals (in the form of dung) occurs at low levels throughout the profiles (1–2% of the fauna in some samples). The dung beetle *Geotrupes* occurs throughout the lower half of VP85A/2010 and more sporadically elsewhere, while records of *Aphodius* spp. were from the lower half
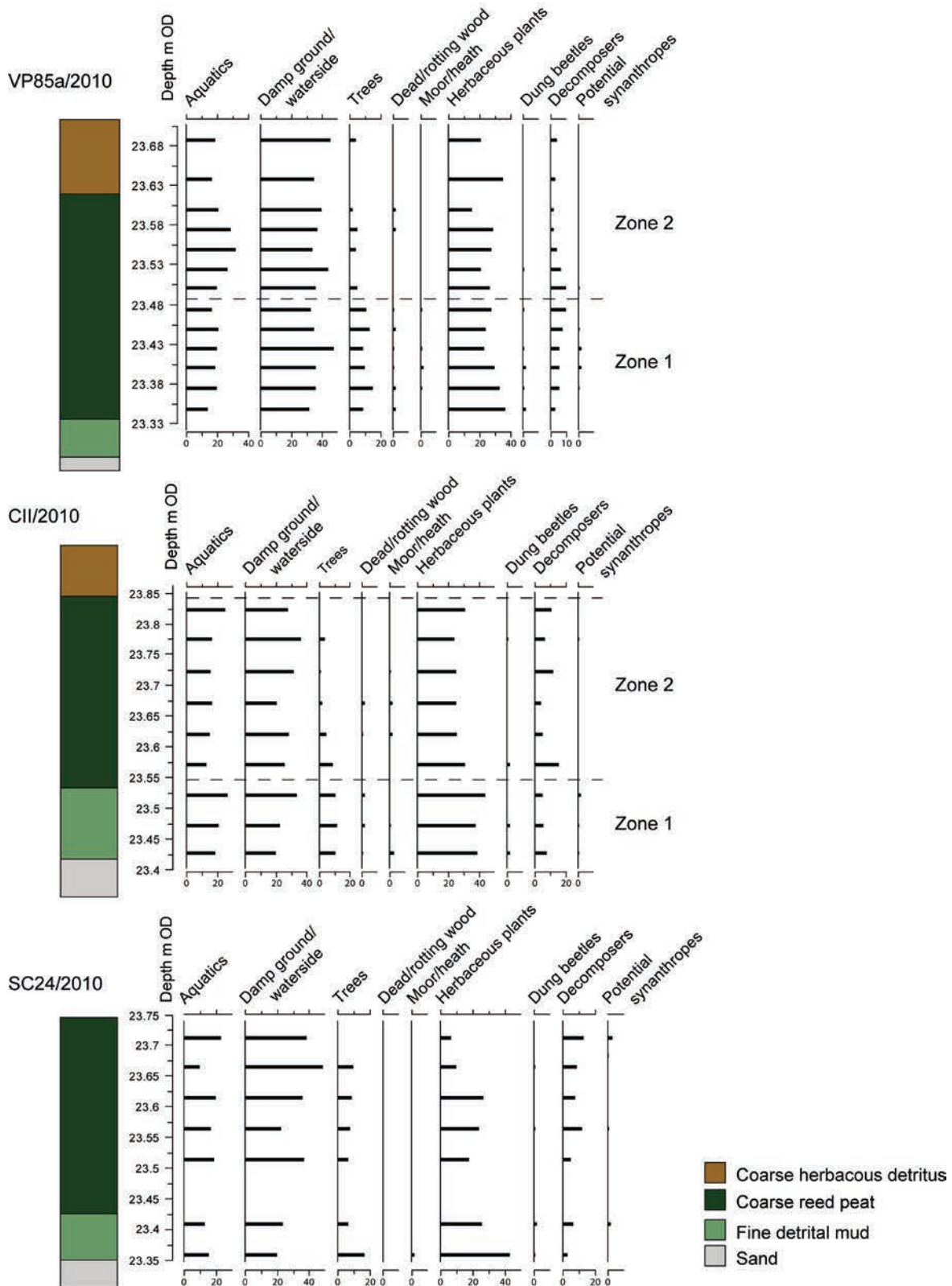
Figure 19.6: Proportions of insect taxa representing different ecological groups from VP85a/2010, CII/2010 and SC24/2010. Proportions of aquatics have been calculated as percentages of the whole assemblage. The remaining groups have been calculated as percentages of terrestrial taxa. (R - Riffle beetles present, B - *Bromius obscurus* present) (Copyright Star Carr Project, CC BY-NC 4.0).

of all three profiles. Both taxa are primarily associated with herbivore dung but some *Aphodius* are more rarely found in rotting vegetable matter and they can occur in flood debris, while *Geotrupes* can be found at exuding sap (Jessop 1986, 15, 20-25). The rove beetle *Oxytelus laqueatus,* recorded from the upper half of CII/2010, is generally found in dung while *Euheptaulacus villosus*, recorded from the basal samples in all three sequences, occurs in dung but not exclusively. The proportions of this group of beetles indicate low level and perhaps irregular grazing by natural populations of herbivores. Puparia of a hippoboscid fly, possibly *Lipoptena cervi* an ectoparasite of deer, were recovered from single samples from VP85A/2010 and SC33. The puparia drop from the host onto the ground where they remain until the adult deer ked emerges to find a new host.

Finally, several insect species recorded from various parts of the profiles are either confined to, or at least more typical of, the southern parts of England at the present day, suggesting a relatively warm climate at Star Carr throughout much of the period represented by the sample profiles (though the resolution of the samples may not be sufficient to detect short-lived climatic fluctuations).

Chronological variations

Broadly speaking, the character of the assemblage reflects a mixed wetland of well-vegetated standing water with areas of open water and muddy, wetland edge throughout the time that the deposits were being laid down. There is a slight tendency towards an increase in both aquatic and waterside/wetland species through the profiles, though no evidence for a major increase in water level or the development of more open conditions.

Insect evidence indicated that trees and/or shrubs were growing close to the lake at least throughout the time period corresponding to plant macrofossil Zones 1 and 2, the proportion of insects associated with trees falling somewhat in Zone 2. There is also some indication that fen-like conditions with litter became more prevalent over time, with species indicative of mud, such as *Limnebius aluta* and *Dryops*, becoming more frequent in samples corresponding approximately to plant macrofossil Zone 2. However, conditions at the site remained wet, with areas of standing water either at, or in the vicinity of, the sampling points.

In all of the profiles there is a gradual reduction in the concentration of insect remains within the samples over time, with a pronounced fall in VP85A/2010 occurring after 23.611 m OD, in CII/2010 after 23.8211 m OD and in SC24 after 23.71 m OD. This most likely corresponds primarily to a gradual shift to a drier depositional environment resulting in incomplete anoxic waterlogging of the deposits and consequent poorer survival of insect material. However, a reduction in the quantities of material being transported to the site may also have been a factor. Numbers of individual specimens were particularly low in the uppermost samples in all three sequences (from 23.711 m OD in VP85A/2010, 23.8711 m OD in CII/2010 and 23.76 m OD in SC24). Conditions close to the sampling points appear to have remained wet, however, with aquatic and waterside species present throughout, albeit in much smaller numbers than previously.

The state of preservation of sclerites was varied throughout the deposits and also within samples, and no overall trend towards poorer levels of preservation in different parts of the sequences was observed. The variability in preservation can at least partly be explained by the robusticity of particular species. Whirligig beetles (*Gyrinus*), Donaciinae species, ground beetles (Carabidae) and taxa associated with dead wood and bark were consistently better preserved than many other remains. Many of the wood-associated beetles are relatively robust species, but it is also possible that their particularly good preservation in comparison with other remains may be a result of them having entered the deposits within wood, which provided some protection against decay. *Cyphon*, *Haliplus* and various Hydrophilinae, which were common in many of the samples, are relatively poorly sclerotised and therefore likely to be more easily affected by any factors causing erosion. Remains of some leaf beetles (Chrysomelidae other than donaciines) and some weevils (Curculionidae) were often particularly poorly preserved, which limited their close identification.

SC33

In addition to the main sequences described above, a short sequence of four samples was recorded from trench 33 in order to characterise the environments within which an assemblage of archaeological material had been recorded. As this was only a partial profile it has been described separately.

Insect remains were common in the lowermost sample with frequency declining with depth. The main implications are for well vegetated water margins. *Cyphon* species were particularly common, indicating swampy conditions with shallow standing water. Several species of donaciine leaf beetles, found on emergent and waterside vegetation, were also represented. As in the lower parts of the main profiles, a riffle beetle suggested an input of clean clear running water and terrestrial environments were hinted at by the weevils *Micrelus ericae* and *Nedyus quadrimaculatus* which feed on heathers and nettles respectively.

Another species worthy of note is *Aspidophorus orbiculatus,* a beetle found on slime moulds (Myxomycetes) which generally occur on very moist decayed material such as old tree stumps (Findlay 1967, 190).

Above 23.78 m OD, the quantities of insect material declined, though the taxa present suggested a similar range of local environments (notably the continued presence of *Cyphon* species, as well as *Dryops*, which is indicative of waterside muds).

The environmental context of activity at Star Carr

Introduction

Drawing together the results of the insect and plant macrofossil analyses, and the results of Dark's work at the site, it is possible to present a revised environmental record for the site, and to establish the depositional environment of much of the archaeological material and as such, the environmental context of human activity at the site.

The environmental sequence

The environmental sequence has been divided into three zones, reflecting changes to the lake edge wetland identified in the plant macrofossil profiles. As previous research has shown, these changes were driven by the ongoing accumulation of organic sediments in the shallow waters of the lake margins, which began shortly before the start of the Early Mesolithic. As these accumulated, the surface of the sediment came closer to the level of the lake, allowing plants less tolerant of deeper water to colonise the edges of the lake, whilst plants suited to deeper conditions began to expand further into the lake (Figure 19.7).

Zone 1

Based on both the radiocarbon dating (Figure 17.22) and the stratigraphic relationships between artefacts and the environments sequences, wetland environments were already well established at Star Carr by the time Mesolithic groups first inhabited the site and organic sediments were starting to form in the shallow lake margins. The plant macrofossils and the composition of the peat indicates that this early wetland consisted of a reedswamp of emergent vegetation growing in standing water. Common reed formed a significant component of this environment and probably formed extensive beds across much of the excavated area. However, both the insect and plant macrofossils also indicate the presence of a suite of other emergent plants growing at the site, notably bulrush, bogbean, several species of sedge and species of bur-reed and rush. Common club-rush may also have been present, possibly forming discrete stands in deeper water beyond the reed beds, along with some of the aquatic plants, particularly pondweed but perhaps also water-lily.

The depth of the water and the location of the shoreline is difficult to determine, though minimum lake levels can be estimated from the presence of aquatic plant material in the basal samples of the environmental profiles. Water was clearly above the sampling points at P3178 and CII/2010 by the time Mesolithic activity began (which would also place the VP85A/2010 and SC24 sampling points under water). Of these, the base of CII/2010 lies at the highest elevation (23.42 m OD), which provides an absolute minimum level for the lake at this date, though given that this sampling point was probably permanently submerged, the water level must have been above that (+23.42 m OD). Aquatic material was also present in several of the spot samples taken from the peat where it overlay the basal land-surface at an elevation of 23.92 m OD. Given that water must have been present for this material to be deposited, this provides an upper minimum level for the lake. However, it was not possible to date these samples due to the paucity of identifiable plant material within them, and it is possible that the peat they were within was slightly later than (i.e. formed after) the bases of the main plant
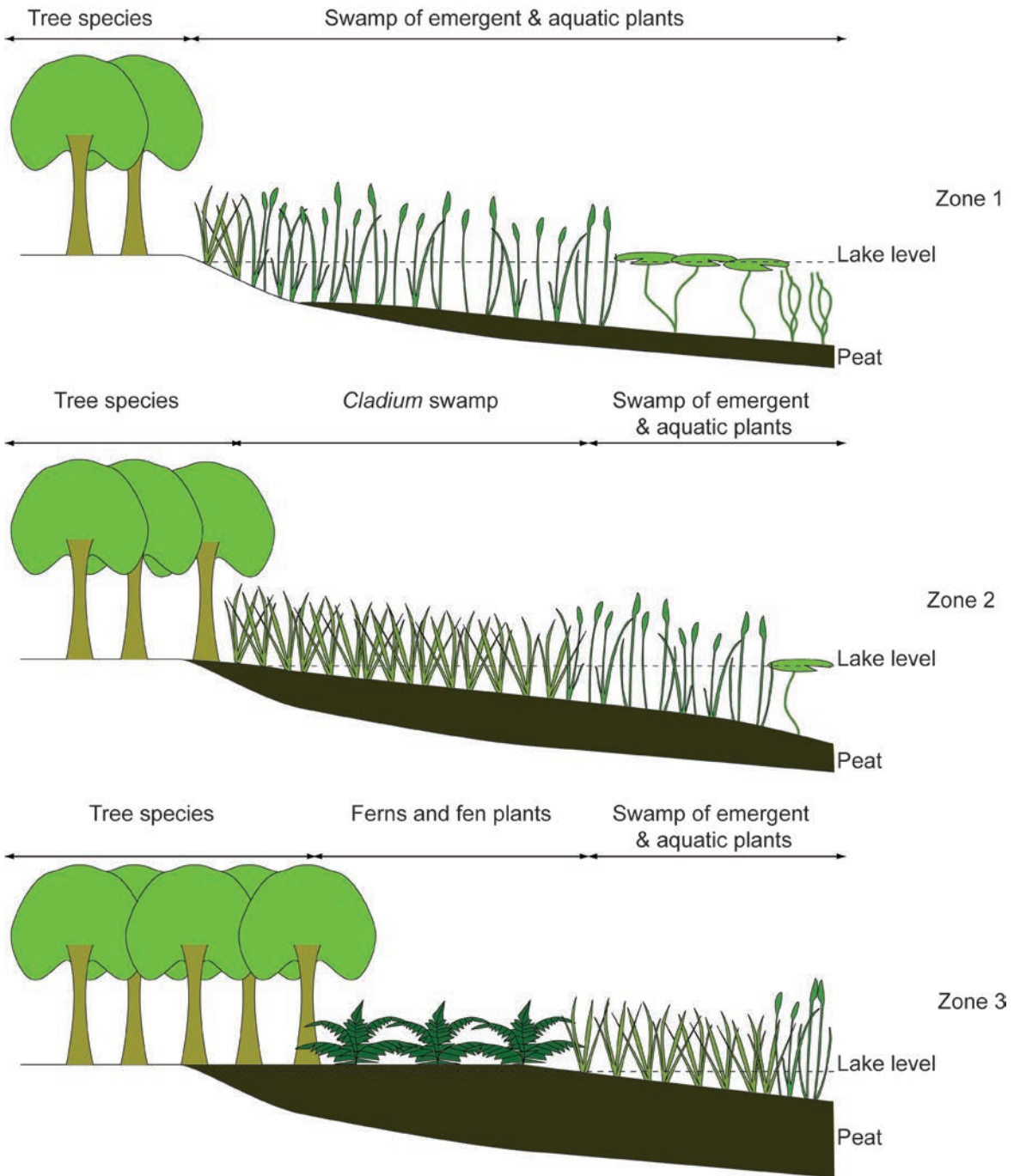
Figure 19.7: Schematic representation of the hydroseral succession at Star Carr (Adapted from Taylor et al. 2017. Copyright Cambridge University Press (2017) reprinted with permission).

macrofossil profiles. As such, 23.92 m OD is an estimated minimum level for the Early Mesolithic lake, but it is possible that the water was slightly shallower (+23.42 m OD) when people first arrived at Star Carr, and that it then rose in the early centuries of activity at the site. From this, the minimum depth of water over each of the sampling points can be established as P3178 +0.36 m–0.86 m; VP85A/2010 +0.09 m–0.59 m; SC24 +0.07 m–0.57 m; CII/2010 up to 0.5 m; S3502 up to 0.43 m.

The maximum level of the lake is unlikely to have been significantly higher given the tolerances of the main plant species. Common reed can grow in up to 2 m of water (Haslam 1970), but its optimum conditions in lake edge environments occur in up to 1.2 m of water (Haslam 1970, 874, table 5) and it performs best in up to 0.5 m of water (Rodwell 1995, 142). With the exception of club-rush, the other emergent plants tend to be found at the shallower end of this range. Bur-reed can grow in up to 1 m of water (though some species are more common in shallower water), and bulrush is rare in water more than 0.5 m deep (Preston and Croft 1997, 270). Assuming plant growth occurred within similar tolerances in the Early Holocene, it is unlikely that the depth of water over the deepest sampling points (P3178) was more than 1 m and was probably lower.

The area around the lake shore is likely to have been at least periodically submerged (perhaps seasonally flooded), maintaining a damp waterlogged substrate where plants such as marsh fern (which was present in low quantities at the base of Dark's M2 pollen profile (Dark 1998b, 134 figure 11.6a)), nettles and (perhaps) gypsywort were present, probably along with common reed, rushes and sedges. White/downy birch, aspen and probably willow were also growing at the water's edge, their branches probably extending out over the reedswamp and perhaps shading out some of the emergent vegetation leaving areas of open, shallow water. Dead and rotting wood and plant litter may also present in this area, probably accumulating from branches falling from the lake-side trees and from material washed onto the shore through the regular rising and falling of the lake.

Determining the character of the local vegetation on the drier ground beyond the limit of the lake is harder. From Dark's pollen analysis, birch woodland with an understory of male fern was clearly present in the surrounding area (Dark 1998b, 127) and may have covered parts of the dry ground area at Star Carr. However, areas of open, possibly disturbed ground colonised by rosebay willow-herb were present, and grasses, nettles, and other herbaceous plants may also have been established. The insect remains suggest the presence of a stream running into the lake somewhere on the site, though its exact location cannot be established.

Whilst there is little evidence for any significant change in the character of this environment throughout the remainder of the zone, the accumulation of organic sediments would have caused conditions to become boggier, and the depth of water to gradually become shallower (though the surface level of the lake does not appear to have fallen).

Zone 2

The start of this zone is marked by a transition to shallower conditions within the lake edge wetland, and more tentatively a shift from a permanent to a periodically flooded environment. Whilst this appears as an abrupt change in the environmental profiles, it may have been the result of an ongoing process, as the accumulation of sediment gradually brought the surface of the peat closer to the level of the lake.

This transition to a shallower environment altered the composition of the wetland vegetation. Saw-sedge, a wetland plant tolerant of shallow or waterlogged conditions, was probably present from the start of the zone, perhaps initially limited to shallower areas close to the shore. However, the increase in the quantities of its macrofossils, and the corresponding rise in Cyperaceae pollen in Dark's M1 and Clark Site profiles, suggests that it gradually expanded across the site throughout the zone. Common reed was still growing within the excavated area, though this may have become more sparse later in the zone, given the decline in its pollen (Dark 1998b), and may have begun to colonise the areas of deeper water further from the shore.

The character of the wetland vegetation was also altered by deliberate human action during this period. The first episode of burning recorded by Dark began during the later stages of Zone 1, but its impact on the local vegetation occurred at the transition to Zone 2. In Dark's pollen profile M1, this is marked by a dramatic reduction in the quantity of grass (Poaceae) pollen, probably reflecting the clearance of areas of the reedbed by burning (Dark 1998b, 130). These lower levels of Poaceae persist for some time, suggesting that the open areas were maintained or new clearings were being created.

The depth of water in this zone is hard to establish. Based on the modern habitat preferences of saw-sedge (e.g. Preston and Croft 1997, 278), the excavated area is unlikely to have been under more than 0.4 m of water at the start of the zone, whilst the paucity of aquatic plant macrofossils and the more limited source area of the profiles would strongly suggest that it was considerably shallower. What is more, the volume of water reaching the site continued to fall throughout the zone, as reflected in the increasingly sporadic occurrence of aquatic

plant and bryozoan macrofossils and the more limited source area of the profiles. However, conditions clearly remained wet, with the insect assemblages indicating the presence of areas of stagnant standing water in the local area.

Closer to the shore, where the basal topography was higher, the deposits may have been more consistently above the level of the lake allowing plants less tolerant of permanently submerged conditions to become more established. This may have included wetland species of fern (perhaps marsh fern), given the increased quantities of sporangia in P3502. Many of the other wetland plants recorded in the plant macrofossil and insect samples may also have been growing in this environment, particularly gypsywort (which is intolerant of standing water), but perhaps also species of rush, bur-reed and wetland members of the *Ranunculus* family. Aspen and/or willow may also have been growing at the water's edge, given the continued presence of roundwood within the deposits (particularly in the area of cutting II and trench 24), and birch trees (including white/downy birch) were close enough for fruits and catkin scales to be deposited within the peat.

Zone 3

From the start of this zone the wetland deposits were forming above the level of the lake, and the area was only subjected to very occasional flooding. The radiocarbon dating shows that the transition to this zone was not contemporaneous between the different dated sampling points (Figure 17.22), and parts of the site may have been intermittently flooded whilst others remained beyond the reach of the lake waters. Ground conditions would have remained wet and boggy, and the occurrence of insect taxa suited to stagnant standing water from cutting II/2010 and VP85A/2010 could reflect the presence of small, discrete pools.

The composition of the peat indicates the local growth of herbaceous plants, whilst the increased levels of sporangia, coupled with the much higher fern spore values in Dark's profiles (Figure 19.7, see also Dark 1998b, 126, figure b), probably reflects the expansion of ferns onto the peat. The fen plant hemp agrimony occurs in several of the macrofossil profiles and may have been growing at the site. The continued presence of trees at the wetland edge is indicated by the presence of two large trunks in trench SC24 (species unknown). Species of poplar (probably aspen) were still growing close enough to deposit bud scales into the peat, and birch was still growing at the site (though not necessarily in the immediate vicinity of the wetland).

The archaeological contexts

The detrital wood scatter

The detrital wood scatter lies on a northwest-southeast alignment, with its southeastern side running c. 1 m from VP85A/2010, and its southern edge running into the trench section at P3178 (Chapter 6). The lowest lying material lay directly upon the basal sand (320), whilst the assemblage spanned the detrital mud (317) and extended into the lower part of the reed peat (312). Associated with the scatter is an assemblage of antler and animal bone (including an antler frontlet and pieces of worked antler beams), which was densest towards the south of the trench. This material also spanned the basal sand, detrital mud and the base of the reed peat. The vertical distribution of the wood and associated faunal material spans much of Zone 1, which is in agreement with the radiocarbon dating of the material (Figures 17.7 and 17.22). Where the scatter runs into profile 3178, it lies towards the base of the zone, whilst the levels of most of the wood and all the artefacts in the southern part of the scatter spans the vertical range of the zone in both P1378 and VP85A/2010.

The earliest material was deposited into standing water, between approximately half a metre and a metre deep at its southern extent, but shallower at its northern end as the basal topography rose towards the shore. Common reed was growing across this part of the site, though a range of other emergent plants may also have been present. Deposits of detrital mud and peat would have built up during the time that this assemblage was being deposited, probably burying older material, and causing conditions to become shallower and boggier. There is no indication of any change in the local vegetation during this time. By the time the latest artefacts were deposited, the level of the lake was much closer to the surface of the sediments (though the area was probably still permanently submerged). As sediments continued to accumulate, the area of the detrital wood scatter

may have been built up slightly higher than the surrounding parts of the site, possibly remaining visible as a ridge of higher ground and/or taller vegetation.

Brushwood

Small quantities of wood-working debris, worked antler and several pieces of flint were recorded from the detrital mud (317) and reed peat (312) between cutting II and SC24, within a dense concentration of unworked roundwood (Chapter 6). Both the worked and unworked material spanned the range of Zone 1 and much of Zone 2 in profile CII/2010. This indicates that the earliest episodes of deposition occurred in standing water, probably no more than half a metre deep, and possibly less, becoming increasingly shallow towards its northern extent as the basal topography rose towards the shore. Material continued to be deposited as conditions became shallower and, potentially, only periodically flooded. The composition of the peat suggests the local presence of common reed throughout this period.

The context of the timber platforms

Timbers from each of three platforms lay within the deposits sampled by the environmental profiles (Chapter 6). The lowest layer of timbers from the central platform lay 1.3 m to the north of VP85A/2010, and one of the overlying timbers was immediately adjacent to the profile. A timber from the western platform ran 0.45 m to the south of CII/2010, whilst the southern extents of eastern platform ran through the same sedimentary sequence that was sampled in P3178. In all three cases, the basal timbers lay at or just above the transition to Zone 2. This would place the platforms in very shallow water, certainly no more than 0.4 m deep, and probably significantly less. In the case of the central platform, which was constructed from three layers of timber that included entire trees, its upper surface may have been permanently above the water, whilst the eastern and western platforms, which were laid down slightly later, may have been at least seasonally exposed. Insects from samples directly below a timber in SC24 (Sample 411/H) and from samples at the same level as the timbers in CII/2010 and VP85A/2010 indicate well-vegetated water margins and permanently wet conditions.

Broadly speaking, saw-sedge had begun to grow across parts of the site during the time the platforms were laid down, though other species were also present, notably sedges, common reed, and bur-reed (the presence of the latter is indicated in the insect samples). Local patterns of vegetation are harder to deduce. In VP85A/2010, the composition of the peat directly beneath one of the timbers shows that common reed was growing at or close to the area when the central platform was constructed, and the lack of saw-sedge in profile CII/2010 could (tentatively) reflect the absence of this plant around the western platform. A final point worth noting is that the preservation of the material in both of the complete insect profiles is markedly poorer in samples adjacent to the timbers of the platform. This could possibly reflect a greater degree of ground disturbance caused by more intensive human activity in the areas around the platforms.

Central platform lithics cache

A small, discrete concentration of worked flint was recorded on the southern edge of the central timber platform (Chapter 8). The material has a very narrow vertical range (c. 35 mm) and spans the transition between Zones 1 and 2 in profile VP85A/2010. As such, its depositional context will be the same as that of the central platform.

The context of Clark's area

Profile 3502 established the context of the large assemblage of faunal material, and worked flint, bone, and antler recorded from the baulk between Clark's cuttings I and II. The lowest artefacts rested directly over the basal substrate and the assemblage spanned the lower part of the sequence of deposits, corresponding with Zone 1 in P3502. A more diffuse scatter of material, including faunal remains, flint, and worked wood and antler, extended to the south and west of this area. These artefacts were recorded from the fine detrital mud (317) and the base of the overlying reed peat (312), and correspond (in terms of their levels) with Zone 1 and

the base of Zone 2 in profiles 3502 and CII/2010. However, the radiocarbon dating shows that this assemblage was deposited in a short-lived event early in Zone 2 and has probably sunk into the underlying sediments (Figures 17.15 and 17.22). As such, deposition occurred in a similar environment to the the western platform, in an area of very wet, boggy ground that was either periodically flooded by the lake or which lay beneath very shallow water, with wetland plants, including reeds and saw-sedge in the local area. Localised variations in the rates of deposition may have created small areas of relatively drier ground, whilst the insect assemblages indicate the continued presence of areas of permanent, stagnant water. In addition, towards the southern extent of the assemblage, conditions would have got significantly wetter, as a slight slope in the basal topography would have left the area under a greater depth of water.

The burnt area 318 and associated flint scatter

Profile SC33 provides the environmental context for a dense scatter of flint that was recorded in the north east of trench SC33 during the 2010 excavations, and which forms part of a more extensive scatter that was recorded in 2013 (Chapter 8). In SC33, the base of the densest part of the scatter lay at c. 23.71 m OD. The plant macrofossil and insect samples were taken from the south-facing section of the trench, c. 1 m from the centre of the scatter, and the samples span the deposits within which the flint was recorded. A discrete burnt area within the peat, context [318], was recorded c. 2 m to the west and lay between 23.72 m and 23.75 m OD (Chapter 32).

The plant macrofossils show that the lake waters were still reaching this part of the site at the time the flint was deposited and the burning occurred, though the volume of water was decreasing and conditions were becoming more shallow. This fits well with the results of the radiocarbon dating, which places the formation of the burnt area after the transition to Zone 2 (Table 17.8). Local conditions would have been wet but not necessarily permanently flooded, though discrete areas of standing water would have persisted in the surrounding area. The insects reflect a swampy, well-vegetated environment whilst the coarse component of the peat indicates the growth of reed in the immediate area.

The bark mat

The bark mat was recorded during the 2013 excavations (Chapter 30). It lies at an elevation of c. 23.6 m OD within the upper deposits of reed peat. Profile CII/2010 lies c. 10 m to the west. The level of the mat in relation to the CII/2010 profile places it within Zone 2, indicating wet conditions, possibly periodically flooded. Insect remains from a sample from the same horizon in trench SC24 (2.5 m to the east, sample 411/E) reflect fen-like conditions and the presence of bur-reeds, sedges and wetland members of the Ranunculaceae family.

Later wetland activity

A relatively dense scatter of flint was recorded from the top of the reed peat and the base of the overlying wood peat just to the east of the area investigated by Clark (Chapter 8). Part of this assemblage ran through the deposits sampled by CII/2010 (several pieces were recorded as the samples were being taken), the majority falling between 23.79 m and 23.85 m OD. This places it at the top of Zone 2, just before the local transition to a terrestrial fen environment. At this point the deposits were probably only subjected to occasional flooding, though ground conditions would have still been wet and boggy. Ferns and herbaceous plants (possibly including hemp agrimony) were present in the immediate area, and trees may have been growing at the wetland edge a few metres to the east (around trench SC24).

Lake edge flint cache (Finds No <113150-170>) and red deer frontlet <113901>

The flint caches (Chapter 8) and frontlet (Chapter 26) lay in moderately humified wood peat, c. 1.2 m south of profile 3356. Plant macrofossil preservation in this area was very poor, with no material surviving at the level at which the artefacts was recorded. The point at which aquatic material was no longer being deposited in the peat was detected within the samples some 0.15 m lower than the artefacts, and could tentatively indicate that the area was above the level of the lake by the time these were deposited.

Conclusions

The palaeoenvironmental investigations have provided a more detailed account of the context in which archaeological material was deposited and within which human activity took place. It is clear from the contexts of the archaeological material that people engaged with these environments, wading through water or thick mud as they walked from the shore into the lake edge reedswamp. It is also clear that the character of the environments forming around the edge of the lake at Star Carr changed throughout the time that people inhabited the site. Whilst wetland succession was too slow to be perceived, people would have been aware of earlier episodes of activity within (and buried by) the wetland. The detrital wood scatter may have remained visible as a topographic feature by the time the later platforms were built, and pieces of timber, animal bone and antler may also have been visible amongst the plant detritus and forming peat. Later, the platforms themselves became buried, but again may have remained visible as features within the reed and saw-sedge swamp. At some times it may have appeared that the lake edge was consuming the objects and materials that were deposited into it. The large assemblage of bone and antler artefacts in the area investigated by Clark had sunk into a lower context, a process that may have occurred during the lives of people living at the site. This perception of things being consumed by the wetland may also have been apparent during times of lower lake level, when animal bones and other artefacts may have become visible amongst the vegetation.

PART 9
Sediments

'As the occupational debris descended the slope towards the lake the organic content was recovered in a progressively better state of preservation: by Zone D rolls of birch bark and disconnected pieces of birch wood began to appear; by Zone E the birch flooring was more intact and animal remains were sometimes in better condition; and by Zone G conditions for the survival of certain organic materials were as good as anywhere on the site.'

(Clark 1954, 1–2)

CHAPTER 20

Sediments and Stratigraphy

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Charlotte Rowley, Charles French and Helen Williams

Introduction

Broadly speaking, the sedimentary sequence encountered at Star Carr can be divided into three units: the underlying basal geology, the sequence of wetland deposits that accumulated at the edge of the lake and the deposits that lay beyond the lake shore. These latter two units have been referred to as the 'wetland' and 'dryland' areas, reflecting the character of the environments forming in these areas during the time Star Carr was occupied. However, in reality this distinction is less clear, as wetland processes were responsible for some of the later deposits that formed over the areas of dryland beyond the lake shore. Within these broad groups are other stratigraphic units that are the result of anthropogenic activity, notably the digging and subsequent infilling of features such as pits and postholes. These occur, almost exclusively, on the dryland and reflect the actions of Mesolithic people living at the site.

This chapter sets out the geology of the local area before describing the main stratigraphic sequence of sediments recorded at the site. The results of micromorphology from the dryland have informed our interpretation of the sediments further and will also be reported here. All context records, plans, sections and specialist reports are archived in the Archaeological Data Service (https://doi.org/10.5284/1041580).

Geology

The underlying bedrock is the Lower Cretaceous Speeton Clay Formation of mudstone which formed in an environment dominated by shallow seas, depositing fragments of silicate materials as mud, silt, sand or gravel. This is covered (potentially up to an estimated 35 m thickness) with Quaternary 'superficial' deposits which persist throughout the Vale of Pickering (Ford et al. 2015, 7). These consist mainly of glacial till of presumed Devensian (Weichselian) age, glacio-lacustrine laminated clays and silts, fluvio-glacial sands and other indeterminate sands and gravels which could be river gravels, fluvio-glacial outwash spreads or reworked material

Figure 20 (page 151): South facing section in SC23 (Copyright Star Carr Project, CC BY-NC 4.0).

from periglacial processes (solifluction). These Quaternary deposits are of variable thickness and are rarely absent from the site's region of the Vale. Boreham et al. (2011a, 2011b) identified pockets of grey clay on site, between the sands, gravels and clayey till. These are probably reworked blocks of Speeton Formation mudstone.

The glacial till of Devensian age is a diamicton (a poorly sorted sediment of highly variable particle size) which was initially eroded from the landscape, and then deposited by the expansion and then contraction of the ice sheets at the end of the last glacial period (see Chapter 4). In a study of the Devensian tills from Holderness, the fine fraction consisted of 60–80% of the deposits, with the dominant minerals in this fraction being kaolinite and illite clays supplemented by quartz (Bell 2002).

Stratigraphy

The sequence of deposits can largely be summarised as presented in Figure 20.1 and Table 20.1. Other contexts which have been assigned to discrete areas of the site are mentioned in the text.

Description	Context number
Topsoil	1
Upcast from Hertford cut	300
Desiccated upper peat	301
Grey/brown clay	302
Hillwash/buried soil	316
Mineral sediment/B horizon	308
Wood peat	310
Reed peat	312
Detrital mud	317
Coarse sand	320
Basal gravel	319

Table 20.1: Key contexts found across the site.
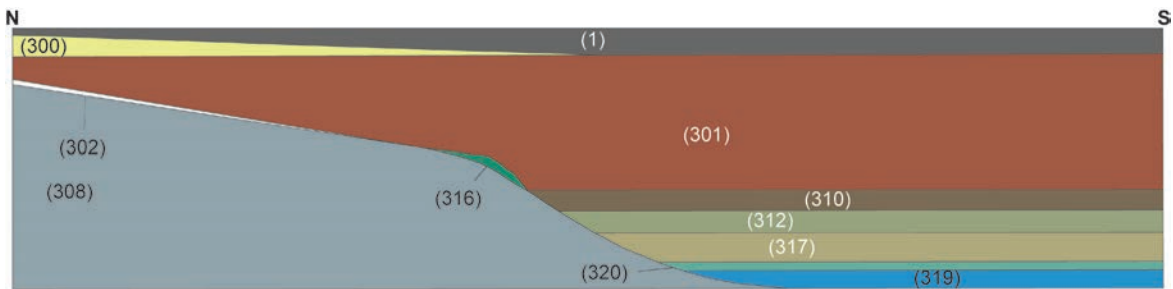
Figure 20.1: Key deposits covering both the dryland and wetland areas (Copyright Ben Elliott, CC BY-NC 4.0).

Figure 20.2 (page 155): Grey marl in the foreground of the trench with the 'enigmatic features' having been excavated. Behind this are the basal sands and stones, and further up slope the remains of the western platform, with the dryland in the top half of the photograph (Copyright Sue Storey, CC BY-NC 4.0).

Wetland stratigraphy

The wetland stratigraphy was first recorded in the series of small trenches that were excavated through the lake edge deposits between 2004 and 2010, and the auger surveys carried out in 2005–6 (see Chapter 3). These focused on the southern edge of the main peninsula, close to the area investigated by Clark (SC04, SC21–22, SC24, SC33, and the re-excavation of VP85A and cutting II), the southern end of the peninsula (SC20) and the eastern side of the peninsula (SC30–31). Initially, these deposits were described and numbered separately within each trench. However, as work progressed it became clear that the stratigraphy was broadly uniform across the site, with the same sequence of deposits present in each of the trenches. It also became apparent that some of the variations within the deposits that were observed in individual trenches, and which had been assigned separate context numbers, actually reflected changing levels of organic preservation and localised differences in sedimentation within what was essentially the same stratigraphic unit. This is particularly true of the reed and wood peats, which had been sub-divided into a series of separate contexts within each trench, but which represented the same broad deposit. From 2013, when trench SC34 was excavated, a standard set of context numbers were assigned across the site, and the earlier stratigraphic records were incorporated into them.

Across the lower-lying areas of trench SC34 (and the trenches within it), the basal mineral deposit was a poorly sorted sandy gravel (319). This extended as far as the c. 23.75 m OD contour, where it was replaced with mixed mineral deposit, varying from clay to a silty gravel (308), which sloped upwards towards the north, forming the lake edge and, beyond this, the dryland. During the 2006 excavations, a thin layer of fine detrital mud (42) was recorded within the sands and gravels in trench SC22. This may represent the remains of a late-glacial interstadial deposit, sealed by the formation of sands and gravels during the subsequent stadial, a horizon also noted at Seamer Carr (Cloutman 1988b).

In the central part of trench SC34, the sandy gravel was overlain by a deposit of marl (477, 501 and 502), a carbonate precipitate, which formed a distinct mound up to c. 0.4 m in depth. A group of 23 possible features were recorded as being cut/eroded into the top of the marl deposits (Figure 20.2). These may be anthropogenic in origin, though given their location in the base of the lake, they are more likely to be the result of natural processes such as localised spring activity. Based on the pollen stratigraphy from comparable deposits elsewhere around the lake (e.g. Cummins 2003; Taylor 2012), the marl may have formed within the first centuries of the Holocene.

Where the marl was absent, the sand and gravel graded into a layer of poorly sorted sand (320), which included a component of fine-grained organic material. This in turn graded into a deposit of fine detrital mud (317) containing a high coarse component of plant material, including the stems and leaves of *Phragmites* reeds and smaller quantities of small, thin twigs. This deposit directly overlay the marl in the central part of the trench. In trench SC24, a thin layer made up almost entirely of very small, thin twigs within a fine detrital matrix (98) was also present over the coarse sand. Subsequent excavation shows this to be a discrete spread of material and forms part of the detrital mud (317).

The coarse component of the detrital mud increased with height, and the deposit graded into a coarse reed peat (312), made up of horizontally bedded herbaceous plant material including the stems and leaves of *Phragmites* reeds, and a smaller component of roundwood (particularly towards the northern end of the deposit). The preservation of the plant material (particularly the herbaceous component) deteriorated towards the top of the deposit, which also contained intrusive root material. The reed peat ended with a sharp transition to a moderately humified wood peat (310), made up of roots, indeterminate woody detritus and a smaller component of poorly preserved herbaceous plant material that extended northwards across much of the dryland area. In several trenches (SC24, SC33 and VP85A) a thin layer of much darker, compacted and humified peat was present within the wood peat. This may reflect a short-lived fall in the local water-table, which caused the peat to dry out and humify before peat formation resumed. Thin layers and discrete lenses of a blue-grey clay were also recorded within the upper parts of the reed peat (312) and the lower wood peat (310) in trenches SC24 and Clark's cutting II and may represent in-washing of mineral sediment from the adjacent dryland area.

In all of the trenches, the wood peat became increasingly humified both with height and with proximity to the shallower parts of the wetland area and the dryland parts of the site. Overlying the deposit was a very humified black, fissured peat (301) that extended across the wetland and dryland parts of the site, over which was a peaty topsoil (1).

A similar sequence was recorded along the western sides of the peninsula, where it forms the side of the embayment (trenches SC2, SC20 and SC21) and its eastern side, where it formed the edge of the main lake basin (trenches SC30 and 31). Here the marl was not present and the detrital muds (317) formed directly over the coarse sand (320).

Dryland

The deposits on the dryland can be broken down into four main units: topsoil (1), humified, desiccated peat (301), a thin layer of grey/brown clay (302), and a mineral deposit, the nature of which varied across the site (308). The flint and bone found on the dryland tended to occur towards the base of the organic clay and within the mineral deposit. At the northernmost end of the Star Carr field a thick layer of redeposited sands and gravels (300) lay beneath the modern topsoil. This derives from cleaning out the River Hertford at regular intervals. Below this upcast was a buried topsoil dating to the early twentieth century (307).

Below the topsoil (or at the north of the site, the buried topsoil) was the humified, desiccated peat (301). This was mid-dark grey brown in colour, friable in texture, and with extensive fissuring, and was made up entirely of a fine grained organic sediment. In places the peat contained patches of iron oxides which had precipitated out of the sediment, forming areas of orange powder (see Chapter 22). In shallower parts of the site the peat contained small patches of the underlying mineral sediment and occasionally, flint artefacts. These are the result of plough damage, which has brought up material from the lower horizons. However, the deposit itself postdates the occupation of Star Carr, probably forming towards the end of the Early Mesolithic (see Chapter 4).

The peat graded into a grey/brown clay layer (302), with bioturbation making the interface between the two indistinct. Micromorphological analysis was undertaken on samples from this layer and the underlying basal mineral deposit (308). This shows that the thin layer of grey/brown clay (302) represents the Mesolithic soil horizon and the top of the underlying sediment (308) is likely to have been a calcitic, very fine sand/silt of a brown earth (Bw horizon) (Figure 20.3). These results match those from an earlier programme of micromorphological analysis undertaken on samples recovered from the dryland area in 1989, which showed that the upper mineral deposits represented an Early Holocene paleosol, and occupation surface (Mellars 1998).

The basal mineral deposit (308) was much lighter in colour (grey or yellow) compared to the overlaying deposits; however, there was a very diffuse interface due in part to bioturbation (notably the actions of roots and microfauna). The composition of this basal mineral deposit varied considerably between the excavated areas but should be considered as part of the same stratigraphic unit. Across much of trench SC34 the sediment was composed of a firm clay, previously identified in auger surveys carried out in the 1990s, where it was interpreted as the fill of a natural channel (Mellars and Dark 1998). In some areas, notably around trench SC24 and the area immediately to the southwest of this trench, this basal mineral sediment consisted of a mixed sandy gravel with a variable clay content. Similar variability was noted during augering of the peninsula.

The gleying/'greying' in 308 is the result of a secondary process which came about through the rise and fall of the groundwater table in the past, which has led to leaching and the depletion/removal of organic matter and other fine material, and the 'homogenisation' of any former soil structure. Eventual permanent waterlogging has caused reduction/air exclusion and the grey colour of this material (Lindbo et al. 2010), combined with the secondary formation of abundant micritic calcium carbonate as the lake margin dried out (Durand et al. 2010) leading to a change in size class and composition.
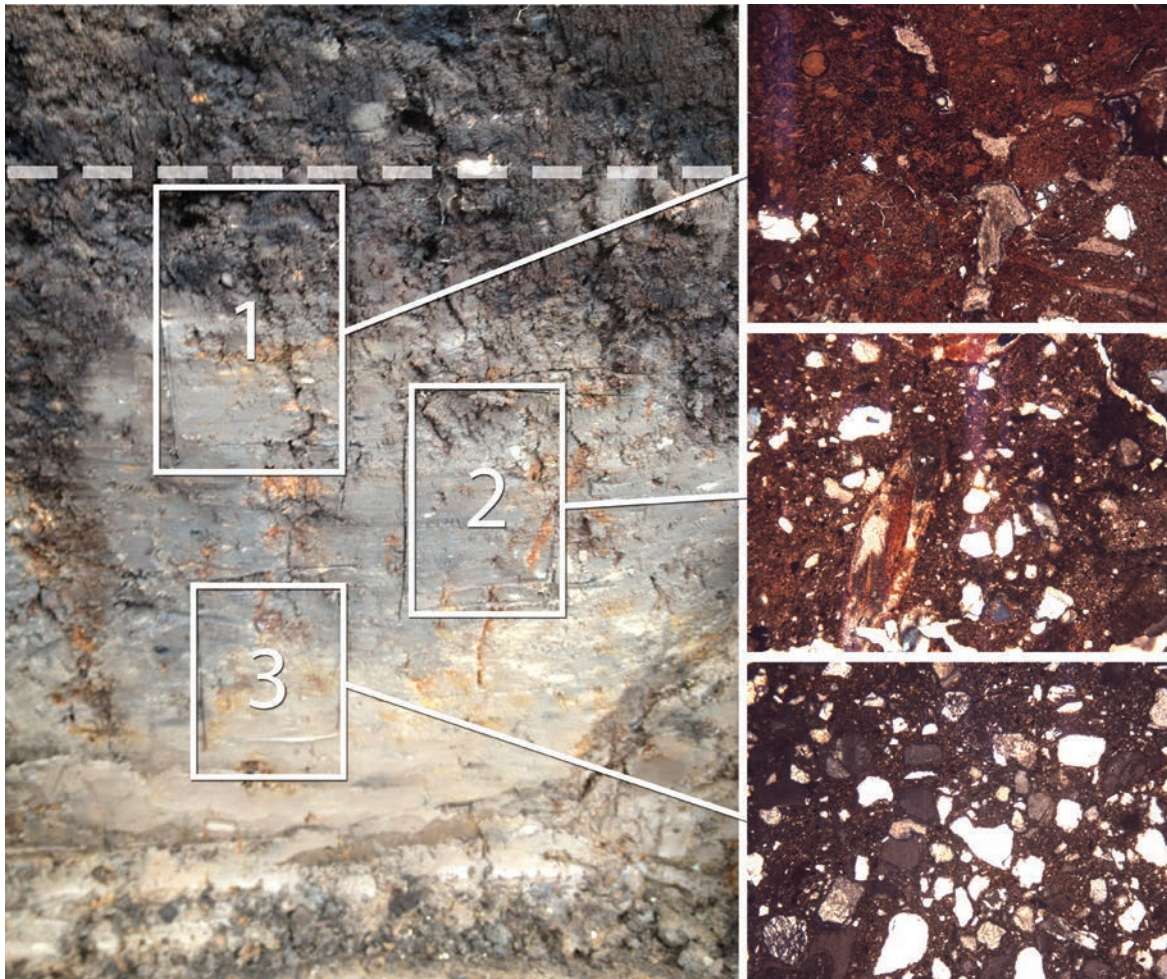
Figure 20.3: Samples taken for micromorphological analysis (sampling: HW, analysis: CF). The dashed line indicates the suggested original Mesolithic surface. The slides show that the grey sediment beneath the highly desiccated peat is a sandy clay loam, and appears to be the remnants of a weakly developed B horizon of brown earth soil (Copyright Star Carr Project, CC BY-NC 4.0).

Anthropogenic deposits

Most of the flint and pieces of bone in this area were found in the deposits (302) and (308); some bone and flint were found well into the mineral sediment (308), in some places to a depth of over 0.1 m. Both lithics and bone can move within soil profiles due to bioturbation, but in some cases groupings of animal bone were found together well below the top of the mineral sediment. This suggests that animal bones either became worked into the soil or in some cases may have been placed in pits which were not visible during excavation due to the subsequent gleying process.

A series of features were recorded cutting into the basal mineral deposit (308). The first of these were recorded in 2008 during the excavation of trench SC23 and consisted of a shallow, irregular hollow [148], with two fills (149 and 125) surrounded by a series of smaller stake or postholes. None of these features were visible in the overlying deposit. The features are thought to form a structural arrangement (the eastern structure) focused on the large, central hollow (Chapter 5).

A larger concentration of 58 features was recorded just to the west of these during the 2014 excavations of trench SC34. These included a second structure (the central structure), again made up of a deliberately cut hollow [330] with two fills (331 and 325) as well as several other arrangements of features that could have potentially served a structural function (Chapter 5). A relatively large pit/posthole [336]/(337) was located to the southwest of the structure and contained an unusual collection of flint (Chapter 8) and burnt bone (Chapter 7) and a slightly larger pit/posthole [451], filled by (452) and (461) was excavated to the southwest of the central occupation area, situated on the edge of the lake (Figure 20.4). These features were associated with a spread of darker material, mostly a friable sandy silt, which has been interpreted as a buried soil of occupation deposit (Figure 20.4). This was assigned two context numbers, (326) and (440), but was essentially the same deposit. Across this area was a spread of soft, fine sand (311), which was encountered below the desicated upper peat (301). A third scatter of cut features was recorded to the east of trench SC34, forming a further structural arrangement (the western structure) (Chapter 5).

The features were all slightly ephemeral when observed in plan, and whilst it was possible to identify them as they were exposed, their edges remained indistinct and difficult to distinguish from the surrounding sediment. This is probably due to a combination of the gleying process described above, and bioturbation, where root and worm action has mixed the fills of the features with the deposits that they were cut into.

Conclusions

With the exception of the basal mineral sediments in both the wetland and dryland areas, most of the deposits present at Star Carr are the result of natural processes that occurred throughout the time the site was occupied. The lower sequence of peat deposits (the detrital mud, reed peat and wood peat) accumulated at the edge of the lake and reflect the gradual transition from shallow water reedswamp to terrestrial fen and carr that resulted through a process of hydroseral succession (see Chapter 19). Archaeological material was present throughout these deposits, reflecting tasks carried out within the wetlands or the deposition of material into this area.

Broadly contemporary with these on the adjacent dryland was the layer of grey/brown clay (302), which represents the remains of the Early Mesolithic ground surface. The interface between (302) and (308) was disturbed and the sediments have since changed due to gleying processes. Context (308) contained the majority of the archaeological material and had been cut through by a series of deliberately cut hollows, stake and postholes, and pits.

The one type of feature that is notable by its absence is the hearth; either as a formalised arrangement of stones or staining on the Mesolithic ground surface. This is unlikely to be the result of later truncation, as the subsequent formation of peat towards the end of the Early Mesolithic (and the later deposition of upcast from the River Hertford) have undoubtedly protected the Mesolithic horizon, reducing the impact of ploughing and other activities. As such the absence of hearths would appear to be real. However, this does not mean that people were not lighting fires, or that hearths were not present on the site. As Sergant et al. (2006) note, stone-lined hearths are generally quite rare on Mesolithic sites, whilst taphonomic processes (notably bioturbation) can remove traces of burning from the original land surface (Sergant et al 2006, 999), and as noted above, there is evidence of both bioturbation and gleying at Star Carr. What is more, hearths are clearly represented in the large quantities of burnt flint, often in discrete clusters, that have been recorded at Star Carr (see Chapter 8),
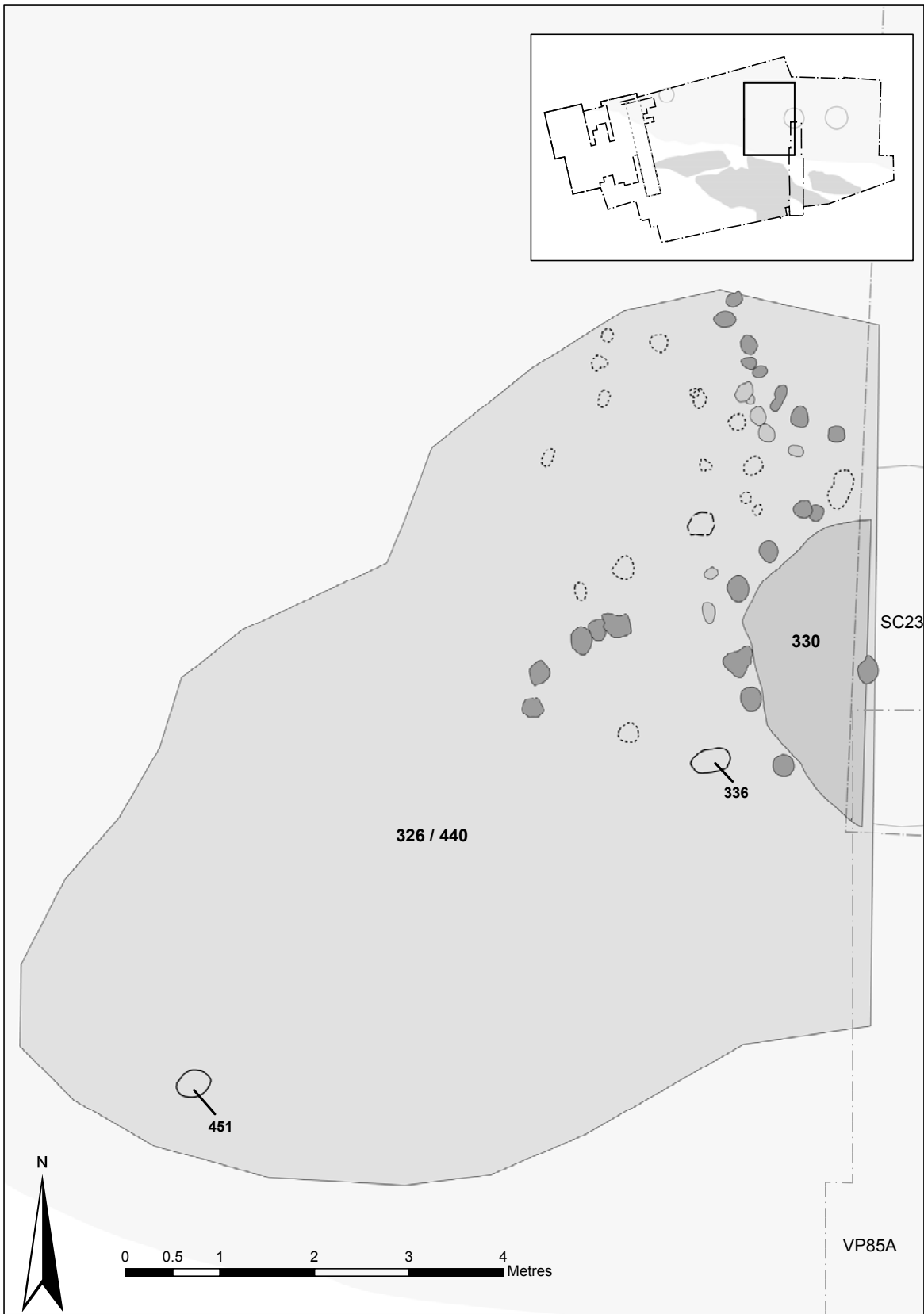
Figure 20.4: Plan of the features in the central area (Copyright Star Carr Project, CC BY-NC 4.0).

and charcoal records, both as micro-charcoal found within the eastern structure and discrete patches of char-coal found at the lake edge (Chapter 32). Taken together, the evidence points to the setting of hearths on the Early Mesolithic ground surface, without either pits or arrangements of stones around them.

The upper part of the sedimentary sequence in both the wetland and dryland areas is largely the result of the later development of the wetlands, with peat-forming environments encroaching above the lake shore and over what had previously been the Mesolithic terrestrial land surface (see Chapter 4). The cause of this development is currently poorly understood. However, the gleying of the mineral deposits indicates a rising water table, which may have been sufficient to trigger peat formation on the low-lying parts of the terrestrial landscape. These later peat deposits, both on the dryland and wetland parts of the site, are highly humified and very badly preserved, reflecting the subsequent drainage of this landscape.

Geochemistry of the Central and Western Structures

Charlotte Rowley, Charles French and Nicky Milner

Introduction

Multi-element soils analysis is a well-established avenue of research within archaeological projects (e.g. Entwistle and Abrahams 1997; Wilson et al. 2008; Linderholm 2010; Dore and López Varela 2010). However, comprehensive horizontal surveys of sites have most often been applied to sites with clear structures or limits; either natural (such as cave floors, as in Homsey and Capo 2006) or anthropogenic (such as buildings, e.g. Middleton and Price 1996; Vyncke et al. 2011). These confine the potential zones of activity and also often provide a degree of protection by sheltering the sediments.

In contrast, perhaps because Mesolithic sites do not tend to have clear structures, there has been very little multi-elemental analysis carried out on sites of this period. Where it is undertaken, it is sometimes carried out vertically through the sediments as opposed to looking for horizontal spatial patterning (Mikołajczyk and Schofield 2016). However, where remnants of buried soils are present, either in situ or redeposited in shallow features, there is the possibility that ephemeral geochemical signatures of past activities could be identified (Wilson et al. 2008).

The research undertaken at Star Carr aimed to explore the potential of multi-element soil geochemistry in Mesolithic contexts, as well as to see what information the results could provide about spatial activities across the site. Two areas with potential were sampled: the central and western dryland structures. Micromorphology was also undertaken within the central structure. Soil samples from both areas were analysed using inductively coupled plasma atomic emission spectroscopy (ICP-AES) in the laboratory. Patterning of seven key individual elements are analysed here. Grouping Analysis, a cluster analysis method deploying a k-means++ algorithm, was conducted on ArcGIS 10.4.1 and Principal Component Analysis was conducted on SPSS 24 and OriginPro 2016.

Figure 21.1: Sampling over the central structure: the eastern trench edge is at the top of the photo and the western platform can be seen in the bottom right corner (kite photograph taken by Sue Storey) (Copyright Sue Storey, CC BY-NC 4.0).

Methods

Sampling

The sampling took place in 2014 when excavating the central structure and surrounding occupation spread and in 2015 when excavating the western structure. The central area was chosen because it revealed postholes and an adjacent, delimited spread of sediment which was significantly different to the surrounding deposits (termed 'occupation spread') and which is thought to have been a very thin buried soil (Chapter 20). Two sets of samples were taken from both the top of the central structure and from lower down in the context, towards the base. The uppermost sample results are considered in this study. In addition, sample blocks for micromorphology were taken from the central structure. For most of the rest of the dryland, the transition between degraded peat and underlying clayey deposits was not clearly defined (Chapter 20). In total, 189 samples were selected from around the central structure occupation spread, including seven control samples taken from the underlying clay (308: remnants of the B horizon grading into till; from here referred to as till).

The area around the western structure was much less clear and this was only sampled because it appeared to have darker smears within it, possible postholes and large quantities of flint (Chapters 5 and 8). Twenty-four samples were taken from this area at the level where the potential postholes had been noticed, at about 0.1 m below the interface between contexts (302: grey/brown clay) and (308) (Chapter 20).

The method of sampling had been trialled at the site of Flixton Island 2 in 2012 (Rowley in prep). A total of 505 samples were taken from Star Carr in spits on a 0.5 m × 0.5 m grid (aligned with the 1 m site grid).
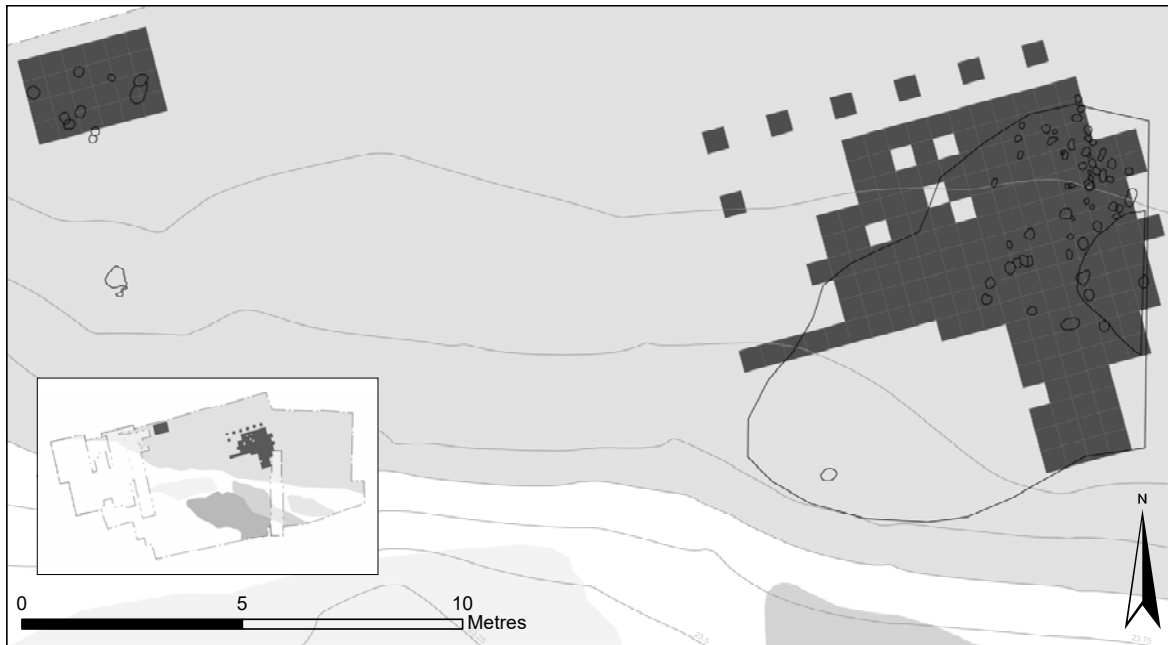
Figure 21.2: The grid of soil samples examined using ICP-AES, shaded in dark grey. Most of the samples cover the occupation spread (Chapter 20) and structures contiguously, but seven separate squares were also sampled from the till to the north of the central structure area (Copyright Charlotte Rowley, CC BY-NC 4.0).

Samples were taken using trowels (cleaned between each sample) with the sampling team wearing a fresh set of non-powdered nitrile gloves per sample. Samples of around 100 g were taken from a cleaned back, freshly excavated surface. The soil was placed into aluminium foil packets to exclude light and then placed individually into labelled resealable bags. In the lab, a pilot study of 29 samples was first submitted for ICP-AES to test whether there would be any differentiation in the results. The results suggested potential for spatial differentiation in the elemental composition of the sediment and so a larger sample was selected.

ICP-AES analysis

Multi-element analyses using ICP-AES (Wilson et al. 2008) were carried out by ALS Global using the aqua regia digestion method (ALS Minerals 2009). ICP-AES was conducted on dried, sorted fine fractions by ALS Global (procedure code: ME-ICP41). Samples were decomposed in aqua regia in a graphite heating block. The resulting solution was diluted to 12.5 ml with deionised water and then analysed. ALS Minerals Loughrea, a subdivision of ALS Global, conducted the analyses on either a Varian 725 RD ICP-OES system or an Agilent Technologies ICP-OES system (Louise Clarke, ALS Global, pers. comm. 2016). The spectrometers used a method template containing 61 analytical lines and 28 interferent lines. The detection limits of this method for the seven elements discussed in this chapter are summarised in Table 21.1. The results are corrected for inter-elemental spectral inferences by ALS Global.

A total of 35 elements were analysed. From the results, six elements were selected for this statistical study as they made the highest contributions to the composition of the samples: aluminium (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg) and phosphorus (P). Manganese (Mn) was also included because it showed a high degree of variability across site (from 17 ppm up to 700 ppm). These are all standard elements considered in other soil analysis applications. Other elements available, such as sulfur, were minor or trace contributors to these specific samples and will be considered in future work.

It should be noted that aluminium, iron and manganese are all naturally occurring precipitates in the soils on the site, and particularly in subsoils on top of the clayey till substrate, from the gradual weathering and

Element	Symbol	Units measured in	Lower limit (same units)	Upper limit (same units)
Aluminium	Al	%	0.01	25
Calcium	Ca	%	0.01	25
Iron	Fe	%	0.01	50
Potassium	K	%	0.01	10
Magnesium	Mg	%	0.01	25
Manganese	Mn	ppm	5	50000
Phosphorus	P	ppm	10	10000

Table 21.1: Detection limits for key elements discussed in this chapter when analysed through ICP-AES, as conducted by ALS Global.

solifluction due to the erratic water levels in the general area. As the structures are on the dryland area of the site, they are better drained but they will still have been saturated from time to time and subject to groundwater level fluctuations post-occupation. As such, iron, manganese, aluminium and possibly calcium enrichment may be related to groundwater fluctuations, being potentially derived from the substrate below the site.

Grouping Analysis

The results of the analyses were integrated as attributes of a polygon representing the sampling grid on ArcGIS. Plots of the individual elements' spatial distributions were symbolised using the Jenks natural breaks option, which divides data into classes based on natural groups in the data itself (in this case into five groups). Grouping Analysis, available in the Spatial Statistics toolbox, was selected as one of the methods to further explore the output dataset from the ICP-AES analyses. The output results from this tool are in the form of a visual plot of grouped samples based on multiple attributes as well as a breakdown of the groupings' traits. This provides an easy-to-understand means of exploring and visually examining the data. Like other algorithms for cluster and component analysis, it is a way of looking for trends in more complex datasets with higher numbers of variables that may correlate positively or negatively. However, the solution of a model from any cluster analysis algorithm is classed as computationally difficult ('NP-hard'), so it is not possible to ensure the optimal solution has been found from one run or one tool. As such, results must be compared and interpreted judiciously but can inform about the underlying structures in the dataset (ESRI nd).

The ArcGIS Grouping Analysis tool clusters features based on trends in their attributes and symbolises features accordingly to produce a visual plot. In this case, sample squares were grouped by their elemental composition traits measured in parts per million. The values are automatically standardized by the tool, using a z-transform, to reduce over-influence of variables with naturally large variances. Groupings were purely based on elemental composition, not the spatial proximity of samples to each other. The groupings were not spatially constrained, i.e. samples did not need to be contiguous to be grouped. A k-means++ algorithm is utilised for calculating the clusters with this setup (Arthur and Vassilvitskii 2007).

One potential issue might be that the samples might be grouped because they are close together and are therefore naturally similar. In order to test this, repeat runs were conducted first on the data from the contiguous samples from both structures, but not the till. Similarly, further repeat runs were conducted on the contiguous samples from just the central occupation area. The group patterning, seen in the analyses for the complete sample, were maintained across the repeat runs and therefore the general variance in different areas does not appear to have been influential in the formation of the groups.

The tool has to be told where to grow the analysis of groups from, called 'seed features'. Once seeds are identified, all data points are assigned to the most similar seed feature. A mean data centre is then computed for each group and the points are repeatedly assigned to the closest centre until the model is stable. The number of seeds that are used to grow the groups is the same as the number of groups being defined (e.g. specifying for six groups means six seeds will be employed). These seeds can be prespecified, completely randomised or selected by the tool to optimise group differentiation after random initialisation. Here the latter (optimised)

method was selected. As such, there can still be slight variations in results from repeated runs of the tool due to the randomness in initialisation.

The Grouping Analysis tool can statistically suggest the optimal number of groups, based on the highest pseudo F-statistics. The results of this varied due to the randomised seed initialisation of each run. The optimal number of groups established by repeat runs of the algorithm on the upper dataset suggested between six and 10 but more likely at the higher end of that range (nine or 10). Four repeat runs of the tool when set to identify nine statistical groups in the upper dataset identified several reasonably consistent groupings. For the lower dataset, the suggested optimal numbers were between seven and 12, but eight was most commonly generated and again produced reasonably consistent groupings. These ranges suggest that the patterning of the elements in the samples is complex but the consistency of groupings both between repeat runs on the same dataset and when comparing the upper and lower datasets of the central structure supports the identification of robust groupings. This is unsurprising given the interplay of many natural processes affecting the soils at Star Carr, as well as any potentially compounding influences from anthropogenic processes.

Principal Component Analysis

The ICP-AES results were also loaded into SPSS 24 and OriginPro 2016 as datasheets in order to run Principal Component Analysis (PCA). K-means clustering, as employed for the grouping analysis, aims to group the *samples* themselves. PCA, on the other hand, aims to reduce the dimensions in the data by grouping *variables* into linear, uncorrelated variates (linear combinations called components) that capture as much of the variance as possible (Ding and He 2004; Field 2009). As such, if the scores on components identified using PCA group together and are consistent with the groupings identified from the k-means++ clustering then it would suggest support for the groupings based on the geochemistry.

Principal Component Analysis (PCA) was conducted in OriginPro 2016 and with no rotation applied in SPSS. The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis (KMO = 0.702, rating 'good' and all KMO values for individual variables were > 0.5, the acceptable limit, according to Field 2009). Bartlett's test of sphericity χ^2 (10) = 437.189, p < 0.001, indicated that correlations between items were sufficiently large for PCA. Preliminary evaluation of intercorrelation between variables led to the exclusion of certain elements available in the ICP-AES dataset to improve robustness of the model. As such, five of the seven elements were incorporated into the established robust final statistical model: aluminium (Al), calcium (Ca), iron (Fe), magnesium (Mg) and manganese (Mn). Phosphorus and potassium had to be excluded on the grounds they generally did not correlate well with any of the other five elements or each other and therefore could not be included confidently in the linear components identified.

One component had an eigenvalue over Kaiser's criterion of 1 which would explain just 58.96% of the variance in the global dataset if extracted on its own. By Joliffe's criterion of 0.7, we could extract three variables. The scree plot showed a point of inflexion that would justify retaining three components, although values still dropped off further after the inflexion. All communality values were above the recommended threshold of 0.7 after extraction, which indicates that the amount of variance in each variable is adequately explained by the retained factors. Given the small (yet theoretically adequate) sample size, the communality values generated, the convergence of the scree plot and Joliffe's criterion on three components, the number of components on the final analysis was taken as three. This explained 91.95% of the variance in the samples.

Results

Micromorphology

The micromorphology sample blocks from the central structure (sample 2007, tins 1 to 3) and particularly the tin highest up in the stratigraphy, contained moderate to minor amounts of degraded bone (c. 10% in the upper tin, as shown in Figure 21.3(a)), charred organics (< 50μm), ash (< 2%, Figure 21.3(b)) as well as amorphous sesquioxide and phosphate replaced plant tissue (c. 10%, Figure 21.3(c)) and groundmass 'cemented' with amorphous sesquioxides. In summary, this suggests that while the sediments contained anthropogenic debris that had possibly been within the structure, they were disturbed and mixed and the bone had evidently been affected by the acidity and groundwater fluctuations.

a) Phosphatised, partially degraded bone in sample 2007, tin 1 (4.5 mm frame width; plane polarized light)

b) Ash in the groundmass of sample 2007, tin 1 (4.5 mm frame width; plane polarized light)

c) Sesquioxide and phosphate replaced plant tissues and bone in sample 2007, tin 1 (4.5 mm frame width; plane polarized light)
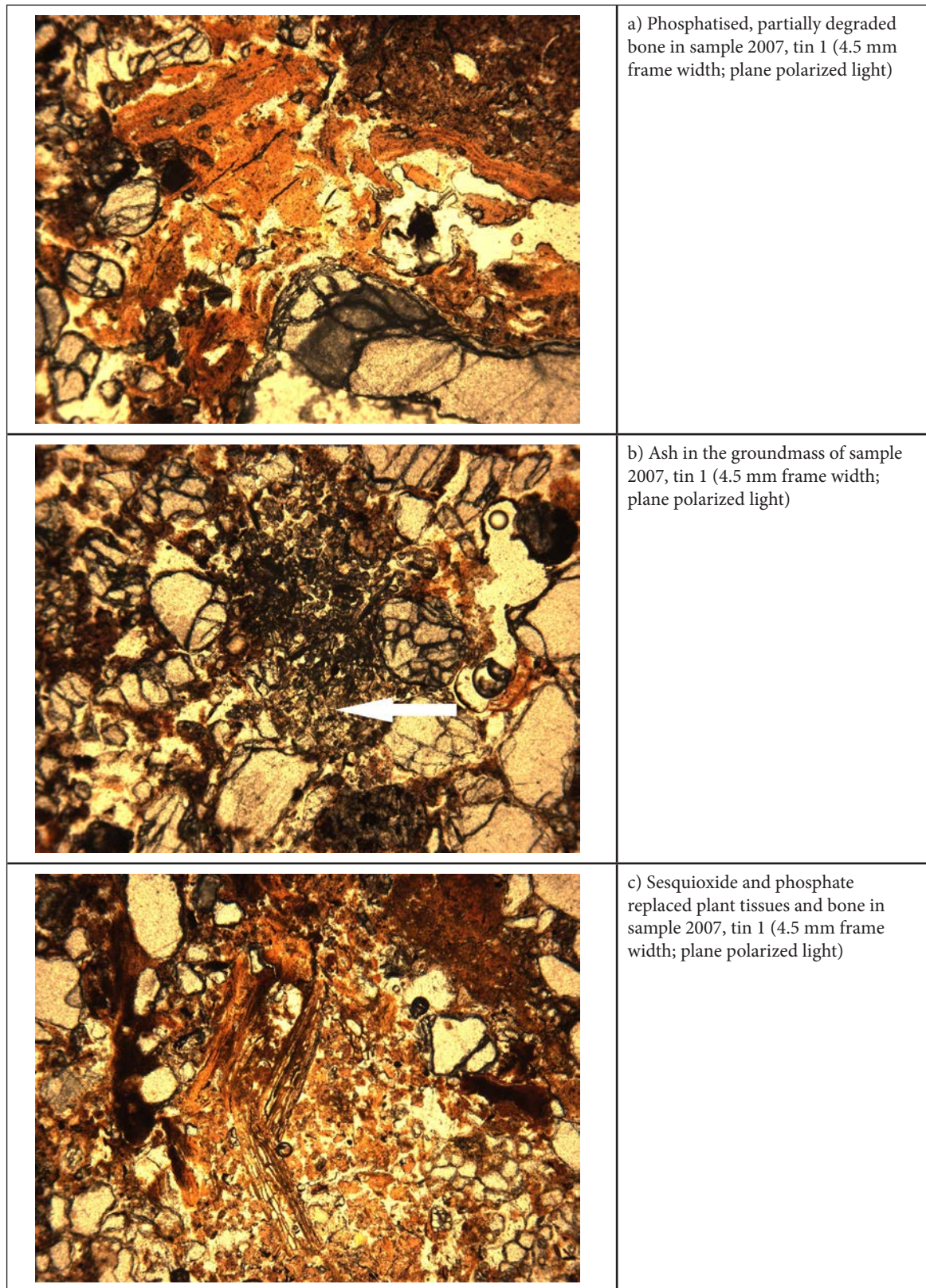
Figure 21.3: Relevant features identified from the micromorphological analysis on the blocks from the central structure (Copyright Charles French, CC BY-NC 4.0).

Assessing the background values

Assessing the background values of elements is not straightforward because glacial till is inherently highly variable in material composition, being largely composed of redeposited material from across potentially very long distances; therefore we would expect this to be reflected to some extent in the samples from site. However, to give a sense of the general geochemical composition of the till, the descriptive statistics from the till samples more than 1 m from the recorded occupation spread contexts are provided in Table 21.2.

In comparison, Boston (2007) conducted a geochemical examination by ICP mass spectrometry of a sample of glacigenic sediments from eastern England, the closest sites being from Skipsea and Filey (Table 21.3). As expected, she found the till composition reflected complex deposition dynamics and a high degree of variation. Despite this, for many elements a general similarity of concentrations for certain elements in parts per million (ppm) could be seen to differentiate the different till samples from different sites. Interestingly, however, Boston found that different tills from the same site could not be geochemically differentiated even when visually distinct (Clare Boston, pers. comm. 2016). Overall, Boston's work illustrates the variance in samples seen from tills across the east of the UK which can be compared with the geochemical readings from Star Carr.

Value (ppm)	Al	Ca	Fe	K	Mg	Mn	P
Minimum	3500	1300	7100	200	700	17	90
Maximum	31200	20000	46500	1700	6100	703	4750
Range	27700	18700	39400	1500	5400	686	4660
Mean	11320	3990	18907	646	3180	125	735
Median	11500	3600	18000	500	3300	94	580
Mode	11100	3500	17500	500	3500	88	550
Std. deviation (popul.)	3978	1892	5665	363	965	98	622

Table 21.2: Descriptive statistics for the major and key minor elements measured from samples recorded as till at Star Carr (values in parts per million).

Value (ppm)		Al	Ca	Fe	K	Mg	Mn	P
Skipsea tills	Minimum	4610.5	4322.5	6384.2	5689	517.3	113.9	1680.8
	Maximum	67988.2	134020.4	38636.1	21227.7	10612.2	965.9	12507.2
Filey tills	Minimum	17256.8	5930.3	19372.4	9438.7	629.3	301.1	11.7
	Maximum	42021.9	88532.7	43319.2	23397.3	11534.6	569.6	1321.1

Table 21.3: Boston's readings in parts per million for tills at Skipsea and Filey, on the east coast, Yorkshire, from ICP-MS analysis (extracted from Boston 2007).

Individual elemental results for the central occupation area

Values in ppm, displayed grouped by natural breaks (in the local dataset only)	Analysis
Aluminium **Al (ppm)** 3500.00 - 7000.00 7000.01 - 10300.00 10300.01 - 14400.00 14400.01 - 20000.00 20000.01 - 31200.00 0 2.5 5 Metres	There are three main areas which show fairly widespread evidence of aluminium depletion (shown in blue): the central structure hollow, the area to the west of the occupation spread and the southernmost squares. The area to the north (part of the occupation spread) has average readings (yellow). It has long been established that clay consists of aluminium silicates with impurities (cf. Weems 1903; Kerr 1952; Brindley 1952), and the patterning which clearly delimits the structure may suggest less clay in the sediment within the hollow. In contrast, there is a strong peak (red) next to pit/posthole [336] (to the southwest of the central structure) the fill of which contained an interesting collection of flint including some burnt pieces (Chapter 8) and 26 pieces of bone, the vast majority of which had been heat affected (Chapter 7).
Calcium **Ca (ppm)** 1300.00 - 2900.00 2900.01 - 4300.00 4300.01 - 6200.00 6200.01 - 9100.00 9100.01 - 20000.00 0 2.5 5 Metres	Calcium can be enhanced by bone (and tooth) refuse and therefore has been found enhanced on agricultural sites where these are consistently incorporated into soil enrichment practices (e.g. Entwistle et al. 2000). Therefore, it is possible in a Mesolithic context that enhancement could suggest activities involving bone processing of some sort, dependent on intensity and preservation. Here the readings for the central structure and its environs are average or slightly depleted. The area to the northwest is generally depleted, but there are patches of higher readings in the area to the southwest of the structure. It has been noted from the micromorphology that some fragments of bone exist within the structure and this may account for the average and slightly elevated readings for this element in that area. In addition, calcium, along with phosphorus and potassium, was found to be elevated in the vicinity of a wood fired oven in a modern earthen floored house studied by Middleton and Price (1996). Therefore, these readings might relate to the burnt material in pit/posthole [336]. There is also one square to the north which has higher than average readings.
Iron **Fe (ppm)** 7100.00 - 13800.00 13800.01 - 17700.00 17700.01 - 21500.00 21500.01 - 27900.00 27900.01 - 46500.00 0 2.5 5 Metres	Iron differences in soil tend to result from redox processes causing it to go into solution as Fe II compounds and then redeposit as insoluble Fe III. It is shown from the micromorphology results that iron had precipitated in the structure. In fact, orange powder was visible in areas of the dryland and probably results from the oxidation of pyrite (see Chapter 22). Nevertheless, in this plot, the central structure is defined by relative depletion of the deposits, as is the area to the west of the spread. The area to the north is mixed. The area to the southwest of the structure shows higher-than-average readings. Homsey and Capo (2006) found that iron increased with clay content and thus it is possible that the sediments within the structure are relatively depleted because there is a lower clay content here.
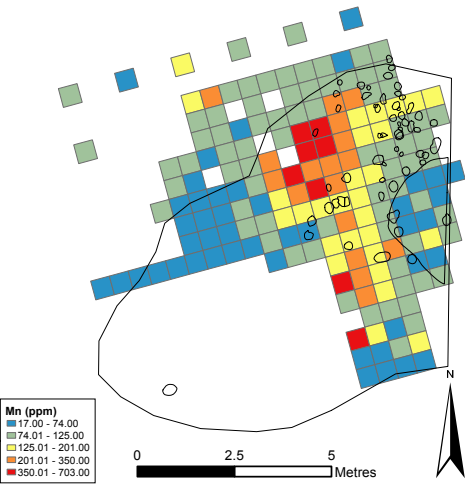
Values in ppm, displayed grouped by natural breaks (in the local dataset only)	Analysis
Potassium K (ppm) 200.00 - 400.00 400.01 - 600.00 600.01 - 900.00 900.01 - 1300.00 1300.01 - 1700.00 0 2.5 5 Metres	The presence of potassium can generally be enhanced by activities involving plants and has been associated with occupation areas (Middleton and Price 1996; Entwistle et al. 2007). This could be from deposition of residual wood ash as seen sometimes, but inconsistently, in modern wood-burning contexts (Scotter 1963). Potassium salts are highly soluble so would likely disappear through leaching within a short period after the fires that deposited them, but they could potentially fix in the clay content of the soil and till (Stanford 1947; Oonk et al. 2009). In this case, most of the occupation area, particularly the central structure, are relatively depleted; whereas the till and the edge of the occupation area appears to be relatively enhanced. This is either related to the nature of the soils (the enhanced area is generally more clayey and the occupation spread is more of a sandy/clayey loam) or there is some depletion due to the nature of the occupation.
Magnesium Mg (ppm) 700.00 - 1800.00 1800.01 - 2700.00 2700.01 - 3400.00 3400.01 - 4300.00 4300.01 - 6100.00 0 2.5 5 Metres	Magnesium can correlate with potassium, and is also generally thought be associated with plant nutrients, wood ash, and wood burning (see Scotter's 1963 work on forest fires; Middleton and Price 1996; Oonk et al. 2009). Again, the salts are soluble but might fix in the clays given suitable conditions (Oonk et al. 2009). The patterning for this element shows depletion within the central structure and some to the area to the west, as well as to the south of the structure. High readings to the southwest of the structure surround pit/posthole [336] containing burnt material. The pattern is dissimilar to potassium in that the rest of the occupation spread shows average and higher than average readings. Although ash was found within the micromorphology samples from the structure, its presence was so small and relatively infrequent that it was unlikely to increase the elements noticeably, explaining the discrepancy with these results.
Manganese Mn (ppm) 17.00 - 74.00 74.01 - 125.00 125.01 - 201.00 201.01 - 350.00 350.01 - 703.00 0 2.5 5 Metres	Manganese tends to be associated with iron as both are frequently found in redox-induced deposits (Lindbo et al. 2010). This mineral is mainly depleted across the area except for the central part of the occupation spread which has no obvious relationship to any archaeological features or any patterns from other elements. This would suggest this is a natural phenomenon, and indeed manganese oxide is found to occur in delimited areas across the site.

Figure 21.4: *Continued*

Values in ppm, displayed grouped by natural breaks (in the local dataset only)	Analysis
Phosphorus	Phosphorus is the most well-established elemental indicator of anthropogenic enhancement in soils (Entwistle et al. 2007; Oonk et al. 2009). It is often enhanced by middening, food processing and other depositions of excrement, animal remains and plant nutrients. It is chemically relatively stable and therefore persistent in most soils (though note, as such, it will move with the soils if they are physically moved). There is clear patterning with this element, with the northern area of the sampled area being depleted and the area to the southwest of the central structure being enriched.

Figure 21.4: Plots of the central structure readings for each of the key elements, displayed by Jenks natural breaks in the non-normalized readings (in parts per million) (Copyright Charlotte Rowley, CC BY-NC 4.0).

The elements are analysed individually in Figure 21.4. The symbology displays the elements relative to the complete dataset from around the central structure. In summary, the central structure is defined in some of the plots, notably by aluminium, magnesium, iron and, to some degree, manganese. All of these can be affected by groundwater and depletion in these elements may be related to differential drainage in this feature. Middleton and Price (1996) found that aluminium, iron and magnesium all correlated well in an ethnographic study of a modern earthen floored residence and its surroundings. They argued the correlation was best explained by natural geochemical processes as the former two often co-occur as sesquioxides. When considering how pairs of elements correlate, aluminium and iron, and aluminium and magnesium, had the only two Pearson correlations above 0.7 from the Star Carr dataset, at 0.794 and 0.738 respectively, on a scale where zero is no correlation and one is 100% correlation. However, this cannot solely account for the depletion of these elements distinguishing the central structure.

In addition, phosphorus is often an indicator of human activity and whilst it is relatively elevated to the southwest of the structure, it is average/depleted in the squares of the structure. This perhaps suggests that the interior was kept relatively clean of waste from activities or at least treated differentially, with the area to the southwest of the structure being where refuse may have been deposited, either deliberately or accidentally, or otherwise influenced by the use of pit/posthole [336].

Grouping Analysis results for the central and western occupation areas

In order to examine these potential patterns further, Grouping Analysis was undertaken. Again, the results suggest some possible areas of interest. The first is the central structure, which has also been grouped with the western area of the central occupation spread (group 5 on Figure 21.5). These areas tend to be relatively depleted in most of the elements. In terms of the structure, we know that this area had been hollowed out and would have gradually filled up with sediment being brought in, perhaps on feet and maybe plants used as flooring. Importantly, this sediment would be different to the surrounding sediment and this may be why some elements are shown to be relatively depleted. For instance, clay often contains relatively high levels of aluminium and if the sediment that accumulated within the hollow was sandier than the surrounding area, this would have the apparent effect of 'diluting' aluminium content in this specific context. The western edge of the central area (also defined as group 5 in purple), does not relate to any features; however, there is the possibility that another

structure had been built in this location but is no longer visible archaeologically, in terms of having clearly defined postholes or a hollow.

Group 2, coloured red in Figure 21.5, is dominant across a large proportion of the area. This is from the occupation spread area (Chapter 20). Within this are two distinct patches of group 3 (green). The northern spread of group 3 appears to be bounded by a semi-circle of postholes. These areas are not particularly clear when examining the individual elements except perhaps for manganese, and if this is a natural occurrence of this element it may be skewing the grouping analysis to some degree. However, it is clear that the grouping analysis distinguishes between the till (group 8, grey) and there was a clear distinction on the ground between these squares of till and the occupation area spread.

The general area to the southwest of the structure is the most complicated and has resulted in potentially five more groupings. Phosphorus and aluminium are relatively enhanced in this area, next to pit/posthole [336]. The actual values of phosphorus range from 90–4750 ppm across the whole sampled area. All of the values above 2000 ppm (totalling seven sample readings) are within this area to the southwest of the central structure. These moderately enhanced levels of phosphorus do not suggest truly sustained intensive middening, animal processing or similar but might suggest a localised, potentially anthropogenic influence from general occupation or decomposing organic remains. It is possible that the entrance to the structure is at this southwest location and waste from the structure was deposited here, or that other activities such as food processing or the discard of bodily fluids occurred in this spot.

A total of 24 samples were taken from the western structure. These samples were generally found to be consistent in composition with the samples identified as till from the north of the central structure occupation area (Figure 21.5; grey squares). The exception to this was the southwestern-most sample square that consistently grouped with the central structure grouping when analysed within the complete dataset, and was similarly depleted of most elements relative to other samples from the western structure, except for phosphorus and calcium, which were near average so still not high. The probable reason for this pattern around the western structure is that the samples were taken from much further down the soil profile, in most cases about 0.1 m into the clayey sediment. Therefore, it is perhaps not surprising that these readings are similar to those taken as control samples in the till.

Principal component analysis on the central occupation area

Principal component analysis based on five elements (Al, Ca, Fe, Mg, Mn) also supported the interpretation that there was consistent depletion in the values from the central structure and occupation area relative to the

Figure 21.5: The western structure and central structure areas, with nine groupings specified for the complete dataset (Copyright Charlotte Rowley, CC BY-NC 4.0).

till; the principal linear combinations of the variables separated out clear clusters from the structure samples and occupation spread contexts but these were compared to the more varied (less well clustered) till samples.

Principal component analysis revealed that the samples from the structure and occupation area formed localised groupings within statistical regions based on the readings of the five elements that could be incorporated into the model. The biplot (Figure 21.6) illustrates the relationships identified between the five variables (the vectors) and also the individually projected data (the scatter plot) in the space of the first two components (i.e. the most significant components).

Loading vectors that are close to one another indicate closely correlated variables. In addition, the closer to the axes, the more that element loads on the component represented by that axis. The loading vectors show that aluminium heavily loads on PC1, which is the most important component. Aluminium is in the same graph quadrant as magnesium and manganese. Magnesium and manganese are most strongly correlated to each other, but the other elements are less closely correlated to one another.

The projected scores show that those readings from the central structure (in red) group close together. They plot closest to the calcium vector, suggesting they are slightly more influenced by calcium than the other elements. However, the graph illustrates again how these samples are relatively depleted in all elements relative to most of the other samples (particularly manganese), considering their position on the left-hand side of the graph, opposite to the direction of the variable vectors. The structure readings do not overlap with the till sample scores (in black) at all, and only overlap or come close to some of the light and dark occupation spread (light and dark blue respectively) and southwest of structure (orange) sample scores.

The southwest of structure sample scores are most disperse in how they load onto these two components. They mainly overlap with till and dark occupation spread samples but they are generally dispersed quite differently, mostly being in the upper-right quadrant of the plot, i.e. with positive loading scores on both components. This suggests they are also quite different in nature, and this seems to relate to their iron and calcium content.

Conclusions

This study highlights the importance of careful sampling because the work is very time consuming and processing a large sample is relatively expensive. With hindsight, the samples from the western structure were sampled from too far down the soil profile. However, conducting geochemical analyses on the sediments from the central area has provided interesting data which correlates with archaeological features. The results show some interesting patterning in the area around the central structure and in particular the filled hollow of the central structure was clearly defined using the Grouping Analysis tool and the PCA. It had been assumed that an activity area, such as a structure, might have higher readings; however, this area appears to be relatively depleted in elements compared to other sampled areas, and this may be a result of keeping this area cleaner of waste products compared to other areas. This group 5 is also evident to the west of the central occupation spread: unfortunately this area was not fully sampled, but in the future it might be possible to assess more samples and test whether this group is well defined in that region, i.e. whether another structure may have existed in this area but was not visible as an archaeological feature.

The other area of particular interest is to the southwest of the structure, which may have been just outside the entrance to the central structure and which also featured an unusual pit/posthole filled with burnt flint and bone. This area appears to be more indicative of an occupied area featuring higher phosphorus/phosphate levels. Phosphorus/phosphate analysis is often favoured by archaeologists as it is often enhanced significantly by a wide variety of anthropogenic activities in relatively stable forms. However, analysing the phosphorus in isolation would not have facilitated the identification of the central structure at Star Carr. Middleton and Price (1996, 679) found that phosphorus was not a key element for the differentiation of interior spaces in their ethnoarchaeological study of a modern earthen floored house in a Mexican village either, probably due to the deliberate removal of organic debris from the structure. Phosphorus is probably the most reliable element for identifying a generally occupied area but, importantly, it is through the combined elemental readings, rather than studying individual elements in isolation, that groupings were identified at Star Carr. Therefore, perhaps the most important result of this work is that the method has potential: even though features are often lacking on Mesolithic sites, it may be possible to delimit 'invisible' structures in the future.
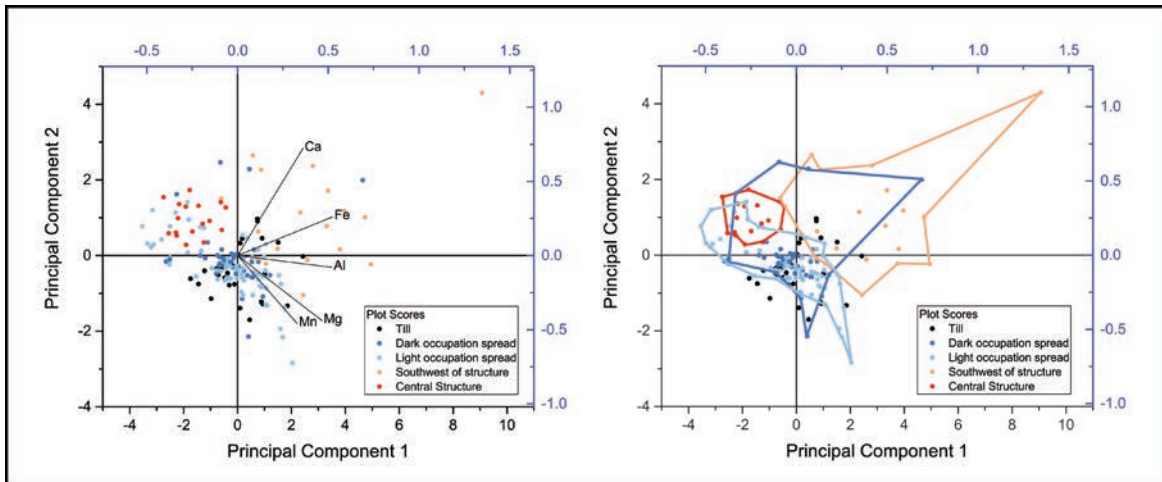
Figure 21.6: (left) a biplot illustrating the relationships between 1) the five elements (depicted as variable vectors) and their contribution to the components, 2) the individually projected data points for each sample and therefore 3) the relationship between the variable loadings on the components and the elements as shown by their proximity on the graph; data points are symbolised by area; (right) a plot of the same individually projected sample data points, highlighting the relationship of samples from different areas to the components (made by connecting the most dispersed points of each spread) (Copyright Charlotte Rowley, CC BY-NC 4.0).

CHAPTER 22

Deterioration and Conservation

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Introduction

Deterioration of the deposits at Star Carr became an area of major concern from 2006. Whilst large numbers of lithics were uncovered, organic artefacts were noticeably sparse compared to the previous excavations (Clark 1954; Mellars et al. 1998; Milner et al. 2011), even in the waterlogged parts of the site, which had previously yielded a wide range of organic material. During excavations in 2006 (trench SC22), two clusters of severely compressed worked antler were discovered which had to be excavated on plinths of peat (Figure 22.1). In 2007, in SC24 others were in such advanced states of degradation that they were 'only tentatively identifiable as antler' (Milner et al. 2011, 2823). In 2007, only two certain pieces of bone were found in the wetland trench SC24. One was observed to be spongy in texture, and the other was termed a 'jellybone' having completely lost any mineral content, leaving only the collagen matrix (Milner 2007; Milner et al. 2011). In 2008, a further 'jellybone' was found in SC29 in the field to the north of the Hertford Cut. In the dryland trench SC23 fragments of unidentified bone were found, but all were largely chalky and brittle.

These discoveries were in stark contrast to the remarkable organic remains that had been uncovered in Clark's (1954) excavation. Although robust data regarding the preservation of organic remains from the 1949–1951 excavations is lacking, the robustness of the museum collections, and the sheer abundance of organic artefacts found, suggests that across the majority of the excavated area, conditions were largely conducive to organic preservation (Clark 1954). Similarly, based on excavations by the Vale of Pickering Research Trust during the 1980s (Mellars and Dark 1998), the wealth of organic archaeological and environmental evidence suggests that even delicate plant remains were still reasonably well preserved across the Star Carr site.

In addition to the disparity in the preservation quality of organic materials between excavations, a number of unusual features were identified by excavators, which provided further evidence of localised environmental changes around the site (Needham 2007). Orange residues forming in the flotation tank in 2007 (used to sieve the excavated sediments for small finds) were characterised by their colour as iron oxide, indicative of reactive sediments (Schwertmann and Cornell 2000; Needham 2007). Similar residues had been identified by excavators in and around the site, often appearing to develop within the sediments following exposure to air.

Figure 22.1: Artefacts excavated in 2006 and 2007: (left) flattened antler from trench SC22, lifted on a plinth of peat; (right) 'jellybone' from trench SC24, displaying alarming flexibility (Reprinted from Milner et al. 2011. Copyright (2011) with permission from Elsevier).

Evidence for the peat having shrunk was first observed during excavations in 1985 and 1989 (Mellars and Dark 1998). Between 2004 and 2005, further concerns were raised following field walking and test pitting, during which time it was noticed that the previously invisible slope to the lake edge could now be observed (Milner et al. 2011). Finally, photographic comparison between the re-excavation of Clarks' cutting II trench in 2010 and photographs from the original excavations provided convincing documentation of the extent of peat shrinkage (High et al. 2016b). Based on wider knowledge of waterlogged environments, it was proposed that this shrinkage was almost certainly due to localised land drainage (e.g. Schwarzel et al. 2002; Bain et al. 2011).

These observations have resulted in the instigation of several studies, undertaken both on site and on the artefacts themselves, with the aims of understanding why these changes may have happened, what timescales are likely to have been involved and what effect these changes might have on any remaining archaeology. An initial geochemical survey was carried out by Andy Needham in 2007, followed by a large-scale, English Heritage/Historic England funded geochemical assessment of the site in 2008 and 2010, published by Boreham et al. (2011a; 2011b). English Heritage/Historic England also funded a hydrological investigation, undertaken by Tony Brown and colleagues (Bradley et al. 2012; Brown et al. 2013). Analyses of the organic remains in 2007–9, reported in Milner et al. (2011) was followed by a four-year Natural Environment Research Council (NERC) collaborative PhD project by Kirsty High at the University of York with York Archaeological Trust, which linked the deterioration of the organics with the geochemistry of the site (Brown et al. 2013; High et al. 2015; High et al. 2016a).

The majority of the results from these studies have been published in scientific journals and theses (Needham 2007; Boreham et al. 2011a; Boreham et al. 2011b; Brown et al. 2013; Milner et al. 2011; High 2014; High et al. 2015; 2016a; 2016b; in press); the intention of this review is to bring these studies together and set out an overview of the outcomes of this research, as it relates to many of the materials studied in the following chapters. In addition, it is now possible to map the conditions of the bone, antler and wood against the site conditions in order to correlate site conditions with artefact deterioration. Finally, this chapter sets out the issues faced in conservation of the artefacts and ecofacts.

Sediment deterioration

Geochemical changes

In 2007, pH values recorded during excavations at Star Carr were found to be lower than pH 3 in the southern end of wetland trench SC24 (Needham 2007). This led to the hypothesis that the poor preservation observed in the organic material from the 2006 and 2007 excavations was likely to be linked to geochemical changes, primarily this high acidity. An extensive survey was carried out aimed to build upon this initial evidence, and ascertain the extent of the potential acidification (Boreham et al. 2011a; Boreham et al. 2011b). The survey involved analysis of a series of cores, encompassing three transects across the site at 2 m resolution. Two of these cut through previous trenches with the aim of establishing any influence of excavation on the chemistry of the sediments.

The sequences were measured for pH and redox at 0.1 m depth intervals. The pH of sediments analysed in the field differed hugely, spanning between pH < 2 and 8.43. Sediments also tended to become more acidic with depth, with the region of the archaeology displaying some of the lowest pH values (Figure 22.2), whilst below the archaeology, pH tended to rise again. Identical analysis was carried out on archived auger cores (removed during excavations in 1985 and stored at the University of Cambridge in the intervening years), where similar variability in pH was observed.

The survey also examined the underlying geology of the site, correlating this with the geochemical data. Most significantly, pyrite-rich Speeton or Kimmeridge clay outcrops of varying thickness lie between the peat and the alluvium gravels in places, and these appeared to correlate with areas of increased acidity (Figure 22.2). In contrast, where the peat is underlain by thick gravel rather than clay, pH tended to be higher. Closer to the lake edge, an increase in pH was also observed, attributed to carbonate-rich lake marls contributing to a buffering effect (Boreham et al. 2011b). This correlated with the recovery of better preserved organic artefacts, for example, in and around the re-excavation of Clark's cutting II in 2010 (Milner 2010).
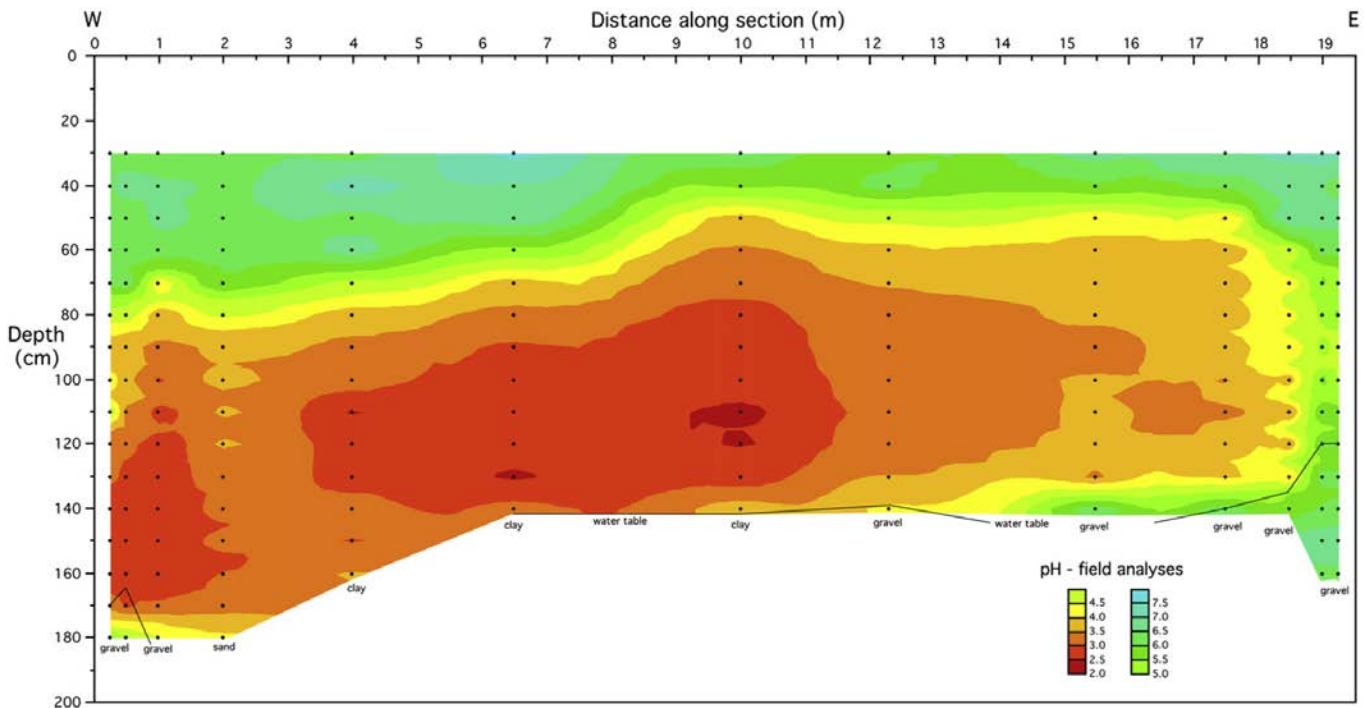
Figure 22.2: pH measurement recorded across transect 2 (Boreham et al. 2011b). This transect ran from trench VP85A in the east to trench SC24 in the west. The spatial variability is significant and appears to correlate with differences in the underlying geology. Image adapted from Boreham et al. (2011b) (Reprinted from Milner et al. 2011. Copyright (2011) with permission from Elsevier).

The concentrations of sulfur were also found to be elevated throughout each transect. High concentrations were often associated with elevated iron concentrations, leading to the hypothesis that both originated from pyrite (FeS_2) in the underlying clay deposits (Boreham et al. 2011b). In addition, sulfur concentrations tended to be higher towards the base of the sequences, indicating that the source of the sulfur was from below the sequence. These observations, along with high sediment sulfate: sulfide ratios, provided significant evidence to suggest that the high acidity at Star Carr is the result of the dissolution and subsequent oxidation of iron sulfides to sulfate, eventually leading to the formation of sulfuric acid (Equation 1).

$$FeS_{2\,(s)} + 3O_{2\,(g)} + 2H_2O_{(l)} \longrightarrow Fe^{2+} + 2SO_4^{2-} + 4H^+ \qquad \text{Equation 1.}$$

Other tests seemed to confirm this hypothesis. Time-dependent analysis, where pH measurements were taken at intervals of several minutes following exposure to air, showed that in samples already displaying acidity, pH decreased logarithmically, demonstrating a tendency to undergo oxidation rapidly upon exposure to air (e.g. Patrick and Mahaptra 1968). Changes in redox potential, as well as iron II: iron III ratios between the field and lab, further confirmed the vulnerability to oxidation displayed by the sediments at Star Carr.

Of greater concern was the observation that where the auger survey transected through previously excavated trenches, some evidence for a 'halo' effect was observed; pH was increased in the backfill and extended horizontally into fresh sediments, compared to the surrounding sediment. This may also explain the better preservation in Clark's cutting II in 2010, and provided the first indication that excavation of the site may itself modify the burial environment.

In 2013, a smaller-scale investigation was carried out during archaeological excavations (High 2014). Rather than provide new data, the aim of these analyses was to test the observations from the 2009 study and establish whether the extremes in geochemistry reported in 2007 and 2011 were permanent.

In the 2013 study, redox potential and pH measurements were recorded across the surface of the excavated trench in association with organic finds, and as such were opportunistic rather than systematic. However, the analysis clearly confirmed the vast spatial (horizontal and vertical) variation across the site, with the lowest pH measured nearest the archaeology (assessed by measuring every 0.1 m down the trench wall). Changes in pH following exposure were again evident, similar to the time-dependent study reported by Boreham et al. (2011b).

pH values ranged from almost neutral to less than 2 (Figure 22.3), with elevated (> 400 mV) redox measurements in parts of the site confirming the reactivity of the sediments. Samples taken close to the backfill of previously excavated trench VP85A were much less acidic than those in a newly excavated trench. An explanation for this could be that neutralised topsoil was mixed into the peat during backfilling in 1985, further supporting the proposal by Boreham et al. (2011b) that excavation of the site may significantly alter the burial environment. In 2016, a supplementary pH measurement was taken on a bulk soil sample (S3599) taken from Clark's baulk, underneath the faunal remains. The pH of this sample was measured as 3.93 at 24.5 ºC.

As part of the 2013 study, elemental analysis (carbon, nitrogen, sulfur and hydrogen content) was carried out on several samples using a Thermo Flash 2000 Elemental Analyser (see High 2014). Sulfur content ranged from 1.4–20%, again with high levels of spatial variability. As soils typically range from 0.005–0.05% sulfur content (Steinbergs et al. 1962), this confirms that levels of sulfur across the site are extremely elevated, as first reported by Boreham et al. (2011a; 2011b). Minimal correlation is seen between pH and sulfur content, although there did seem to be a lower level of carbon present in samples with a higher pH. This could suggest that a higher clay content (characterised by a lower carbon content) leads to increased buffering of any acidity (e.g. Dypvik 1984).

Hydrological changes

Following the geochemical survey, it became clear that the most likely cause of site acidification was the formation of sulfuric acid via sulfide oxidation (Equation 1). The most likely cause of this was considered to be a loss of waterlogging at the site, leading to the introduction of air into the previously saturated (and therefore geochemically stable) sediments. The evidence for loss of waterlogging at Star Carr was already clear; the peat shrinkage and a distinct lack of water in the excavated trenches when compared to early excavations, indicated that the site was not always permanently saturated.

To provide conclusive data affirming this loss of waterlogging, as well as determining whether this was a permanent or seasonal, recent or historic scenario, hydrological assessment of the area surrounding Star
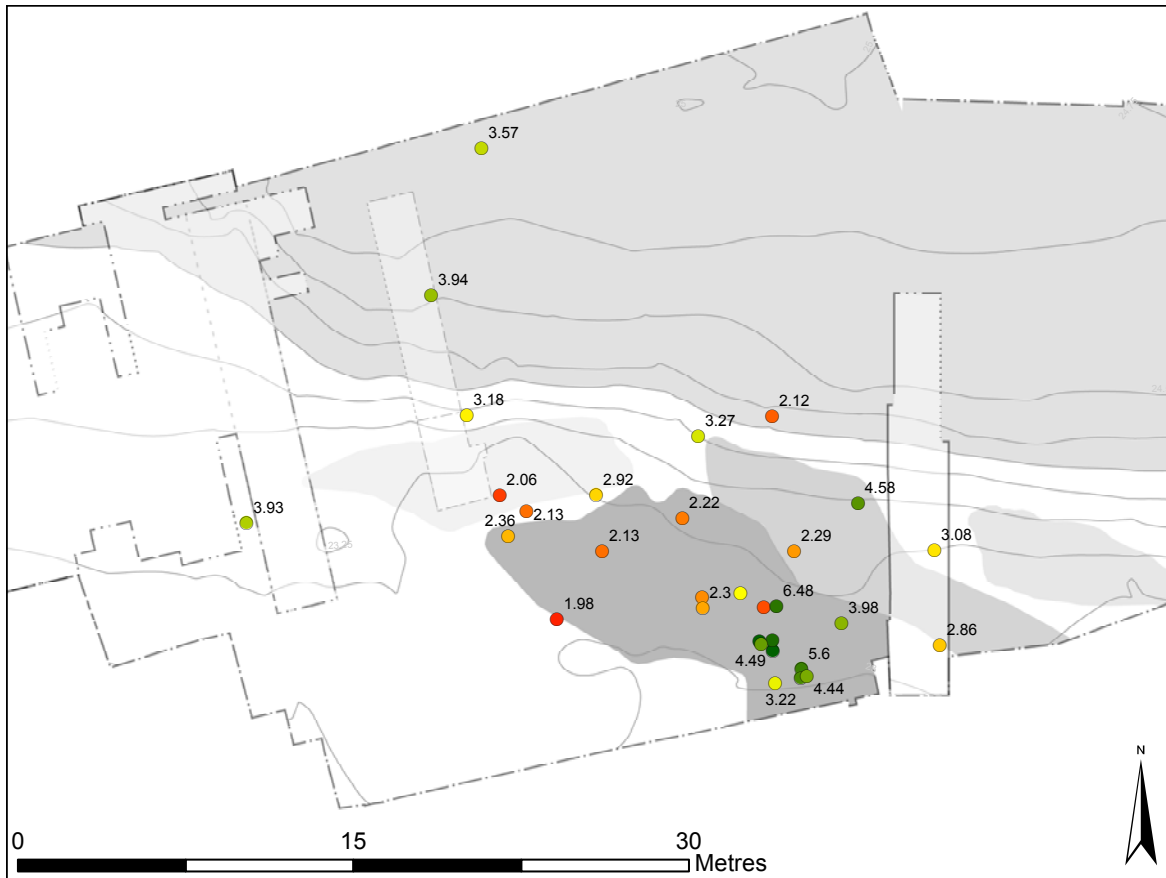
Figure 22.3: Plot of pH values measured in 2013 by KH across the surface of SC34 (with some pH values labelled for reference), including the 2016 reading from Clark's baulk. Values ranged from pH 6.58 (darkest green) to 1.98 (darkest red) (Copyright Star Carr Project, CC BY-NC 4.0).

Carr was undertaken. The first study, carried out by the University of Southampton, aimed to determine the source of groundwater at the site and infer the effects that drainage may be having on the land (Brown et al. 2013). This was undertaken using computer modelling as well as by collating existing hydrological data from the British Atmospheric Data Centre, the Environment Agency and the British Geological Survey. These data indicated that the insertion of an underground drainage system in the year 2000 may have lowered the water table by as much as 0.5 m, and as such resulted in the Star Carr site effectively being isolated from any regional hydrological influences. Measurements of water levels in a series of dip-wells between September 2010 and September 2011 confirmed these findings, further suggesting that recent drainage at the Star Carr site had occurred, and was the result of field drainage rather than wider hydrological influences (Bradley et al. 2012).

Isotopic analysis of hydrogen and oxygen present in groundwater can be used to identify the source of the groundwater, as processes occurring during the water cycle cause the relative proportions of heavy and light isotopes to alter (Bradley et al. 2007). Isotopic analysis was therefore carried out during both studies, on water samples taken from the dip-wells, the nearby Hertford cut, the bordering field ditches and a nearby chalk spring that is understood to originate directly from a local limestone aquifer underlying the Star Carr site. Results from this analysis suggested that the groundwater is likely to originate from precipitation, rather than any local aquifers, thus further confirming the hydrological isolation of the Star Carr site and the hypothesis that the insertion of the field drains was the primary cause of loss of waterlogging at the site.

The current understanding of geochemical and hydrological conditions

The geochemical and hydrological investigation summarised here have provided significant evidence that the Star Carr site permanently contains localised regions of incredibly high acidity. However, less acidic areas do exist, particularly where the presence of marl appears to have caused a buffering effect, or in proximity to previous excavations where a halo effect has increased the pH. High redox values and rapid further acidification upon exposure indicate that the sediments are highly vulnerable and reactive, meaning that the site is likely to be at risk from continued acidification, resulting in an even lower pH than already recorded in parts of the site.

High levels of sulfur and iron have led to the hypothesis that acidification has been caused by the solubilisation of pyrite originating from the underlying Speeton and Kimmeridge clay deposits (Boreham et al. 2011b). When exposed to oxygen (i.e. by loss of waterlogging), sulfuric acid is formed, in a process similar to acid rock drainage (Equation 1).

Although agricultural activities such as fertilisation may also have some contribution (Needham 2007), hydrogen and oxygen isotope analysis and the pattern of sulfate concentrations in the sediments suggest that the source of the sulfur lies primarily below the archaeology (Boreham et al. 2011a; Boreham et al. 2011b; Brown et al. 2013). The hydrological isolation of the site (Brown et al. 2013) also suggests that the source of sulfur is likely to be from the geology, rather than external factors such as the nearby landfill site. The spatial variations in pH and redox potential across the Star Carr site are more difficult to interpret; regions of high acidity lie in close proximity to almost neutral sediments. Boreham et al. (2011a) discuss the role played by differences in the sediments directly underlying the peat deposits in causing these inconsistencies. Areas of lake marl near the lake edge appear to have caused a buffering effect. In addition, lower pH where thin layers of clay lie between the peat and the gravelly bedrock could be explained by restricted movement of the water table; this means that when the water levels drop below the level of the archaeology, they take longer to rise again, resulting in greater oxidation of sulfides. Boreham et al. (2011a) suggest that if the water table was constantly above this clay lens, the effects would be benign or even beneficial. A lowered water table therefore appears to be the most significant event, instigating the formation of sulfuric acid in the archaeological horizon at Star Carr, and has been attributed to the insertion of field drains in the year 2000 (Brown et al. 2013). An additional consequence of this loss of waterlogging is the severe peat shrinkage observable across the site. This is likely to be a completely irreversible change (Schwarzel et al. 2002).

Material deterioration

Scope of study

A number of other examples have previously demonstrated the severity by which altered water tables can affect organic archaeology. These include Flag Fen, where documented peat shrinkage has affected the Bronze Age timbers left in situ (Pryor 1991) and Fiskerton, where drainage of the site was observed to result in the almost complete loss of archaeological bone (Williams et al. 2006). However, the pH reported at Star Carr presents a uniquely harsh burial environment; experimental studies rarely consider pH as low as at Star Carr, and as such an understanding of organic preservation under these conditions is limited, although it would be reasonable to expect conditions to have a detrimental effect. In particular, at low pH previous studies have indicated that hydroxyapatite in bone is vulnerable to dissolution, and the cellulose in wood to acid hydrolysis (e.g. Gordon and Buikstra 1981; Fengel and Wegener 1984).

A great deal of the recent diagenesis research at Star Carr has focused attention on the state of preservation of the organic remains excavated (bone, antler and wood). This has ranged from visual assessment (Milner 2007) to the more in-depth chemical analysis (Milner et al. 2011).

The results from this initial assessment initiated a wider study carried out by KH in which the organic deterioration was related to the geochemistry of the site. In addition, work was undertaken by the bone, antler and wood specialists to score levels of deterioration and information potential. As there was no direct correlation between these two types of observation, and the assessment of the condition of the assemblage could not be carried out in a conventional manner, a tailor-made scoring system was created by RK, BE and MB. For example, a highly demineralised specimen while being considered poorly preserved may still hold the potential to

allow species and element to be established, and even in some cases, for the identification of modifications such as butchery evidence.

Bone and antler

Assessment of bone and antler preservation carried out during excavations in the 1950s and 1980s was limited to visual analysis. Clark (1954, 7) described the majority of both bone and antler as robust and firm. However, some pieces, such as the barbed points, found on what would have been dryland were described as 'dark in colour and soft as leather' (Clark 1954, 1). Excavations in 1985 and 1989 uncovered a large array of well-preserved faunal material, although a number of fragments of bone were assessed to be in a poor state of preservation (Rowley-Conwy 1998), but further detail was not reported.

In 2009, metrical analysis was carried out on antler recovered from all three phases of excavation (Milner et al. 2011). Results showed that whilst antler excavated by Clark had largely preserved its original shape and texture, antler excavated in the 1980s (Mellars and Dark 1998) was visibly more flattened, and those from the most recent excavations even more so. This was taken as further evidence that peat shrinkage had occurred, possibly resulting in compression, or flattening, of the organic remains.

Two 'jellybone' samples were discovered in 2007 and 2008 (Milner et al. 2011), both in areas of the site with very low recorded pH (between 2.5–3 and approximately 3.4 respectively; Boreham et al. 2011b). Analysis of the two 'jellybones' was carried out shortly after excavation (Milner et al. 2011). Histological integrity was determined by optical microscopy and transmission electron microscopy (TEM), showing that both bones were almost completely demineralised, with elevated total amino acid concentrations further confirming the extent of this demineralisation. However, the low levels of amino acid racemisation (employed as a measure of collagen damage) indicated that deterioration may either have occurred very rapidly, or that any deteriorated collagen had leached out of the bone, reducing the observed racemisation.

In 2010, significant quantities of faunal remains were uncovered in the backfill of Clark's cutting II (Chapter 7). Although an initial assessment determined these to be reasonably well-preserved, some deterioration was visible several weeks following excavation. These observations include longitudinal splitting of rib bones due to rapid formation of crystals within the structure, and the formation of orange deposits on the surface of larger bones (determined to be iron-based) (Figure 22.4). Similarly, in 2013 a few examples were identified where a hard, cement-like layer was found adhered to the cortical bone surface shortly after excavation. Chemical analysis of this material has revealed it to be a mixture of hydroxyapatite (excreted from the degrading bone) and fragments of the surrounding sediments which adhere and then harden. In other bones, demineralisation also appeared to have occurred post-excavation, with the development of 'jelly-like' areas in the bones (Figure 22.5).

Figure 22.4: Examples of bone with crystals creating 'bubbles' under the cortical bone (left) and pushing completely through the cortical bone (right) (Copyright Becky Knight, CC BY-NC 4.0).

Figure 22.5: An example of a bone which shows severe deterioration in the form of collagen excretions (Copyright Michael Bamforth, CC BY-NC 4.0).

Further chemical analysis of selected samples of bone revealed substantial differences in bone preservation across the site, again reflecting the differences in site geochemistry (High et al. 2016b). Analysis of both the amino acid content and bone mineral of several samples recently excavated from Star Carr has shown primarily that bone from the dryland areas of Star Carr contain very little collagen, yet hydroxyapatite is still present. Elevated aspartic acid racemisation indicated that what little collagen remains is highly degraded.

In contrast, the discovery of large numbers of 'jellybones' during the 2013 excavation season, which contain almost no hydroxyapatite, suggest an alternative mode of deterioration in the wetland areas of the site. The low levels of aspartic acid racemisation suggest either that degraded fragments of collagen are quickly leached away or that loss of hydroxyapatite has occurred so recently that collagen breakdown has not yet had chance to occur (High et al. in press). This supports the results obtained in 2007–8, leading to the conclusion that some bones are literally being washed away, making it unlikely that bone in that state of preservation would survive in situ for very long. The significant difference in racemisation values across the Star Carr site indicate that localised geochemical conditions may be causing accelerated deterioration of the bone collagen only in very specific areas.

The chalky deposits which developed on some bones post-excavation, as well as several bones from both the wet and dryland contexts excavated between 2010 and 2013, were analysed using powder X-ray diffraction, to examine the structure of any remaining hydroxyapatite (High et al. 2016b; High et al. in press). The diffraction patterns of the chalky deposits, as well as some bone from the wetland areas indicated an overwhelming presence of gypsum (calcium sulfate) rather than hydroxyapatite (calcium phosphate). Such dramatic alteration of bone mineral has not previously been reported, but is almost certainly the result of such high concentrations

of sulfur in the burial environment. Currently, the implications of such a transformation are not understood; however, bone mineral is known to play a vital role in protecting bone collagen (e.g. Collins et al. 2002; Hedges 2002), suggesting a significantly detrimental effect on the state of preservation of the organic remains.

Composed of mineralised collagen, antler is likely to undergo similar degradation mechanisms to bone. However, the lower degree of mineralisation may make it more vulnerable to acidification (e.g. O'Connor 1987). During excavations in 2013, further evidence for antler deterioration was uncovered. Several pieces were identified as too degraded to remove intact, and several displayed a jelly-like texture, indicative of loss of hydroxyapatite (demineralisation). Although much of the antler was described as in generally reasonable condition, flattening (presumably due to peat compression) was again a major problem and led to a limitation on the quality of archaeological information that could be ascertained. However, the variability in the quality of the antler was of particular note; these variations are probably a reflection of the variations in the geochemistry of the site. Whilst in some instances the worked surfaces were excavated intact, allowing a full traceological analysis of the piece (Chapter 24), in other instances demineralisation has destroyed the surface details.

Each faunal specimen has been rated first for its preservation and then for its information potential based on a series of categories (Tables 22.1 and 22.2). Due to the complicated nature of the preservation issues, in some cases more than one of the nine preservation categories was applied to a single specimen. For information potential, each individual specimen was scored from 1–5. These scores are logged on the faunal spreadsheet which is archived in ADS.

Figures 22.6 and 22.7 display plots of the bone and antler artefacts across site, colour-coded by their robustness and information potential respectively. As can be seen for robustness, the most robust artefacts are found

Preservation Category	Definition
A	Material is robust and intact
B	Material is intact but fragile
C	Material is partially fragmented
D	High fragmentation
E	Material is compressed and misshapen
F	Leaching white mineral excretion and/or pooling to form cysts under the cortical bone, but not delaminating
G	Delamination of the cortical bone and mineral eruptions (including milky white excretion)
H	Partial demineralisation with varying patches of robust and soft bone
I	Complete demineralisation resulting in total loss of structure (jellybone)

Table 22.1: Preservation scoring system. Categories E–I represent the extreme range of conditions which are specific to Star Carr.

Information Potential	Definition
1	Highly fragmented or complete lack of identifiable surfaces/characteristics; result is the inability to identify the specimen at all
2	Fragmentation/compression only allows broad species/element categories to be identified
3	Only the general shape and structure survives to allow for identification to be established
4	Majority of characteristics are available to allow identification but there is a small amount of damage
5	Material is pristine; looks like modern bone; the specimen is easily identifiable and it is possible to yield a complete analysis

Table 22.2: Information potential scoring system.
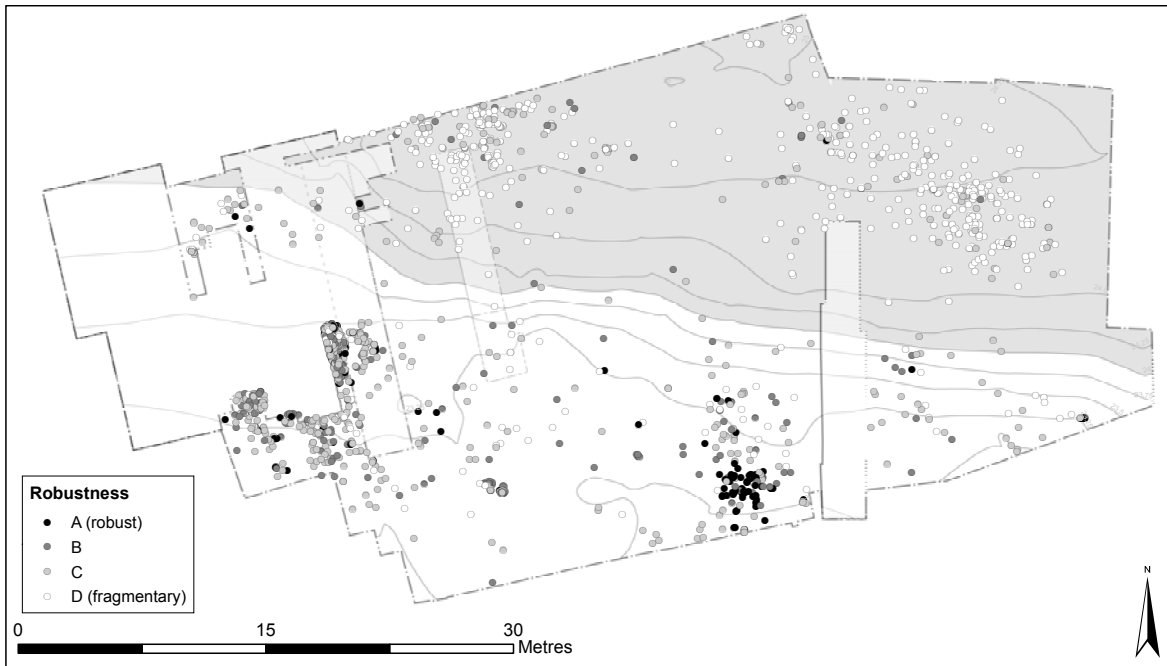
Figure 22.6: Plot of all bone and antler artefacts rated by robustness from robust (black, rating A) to fragmentary (white, rating D) (Copyright Star Carr Project, CC BY-NC 4.0).
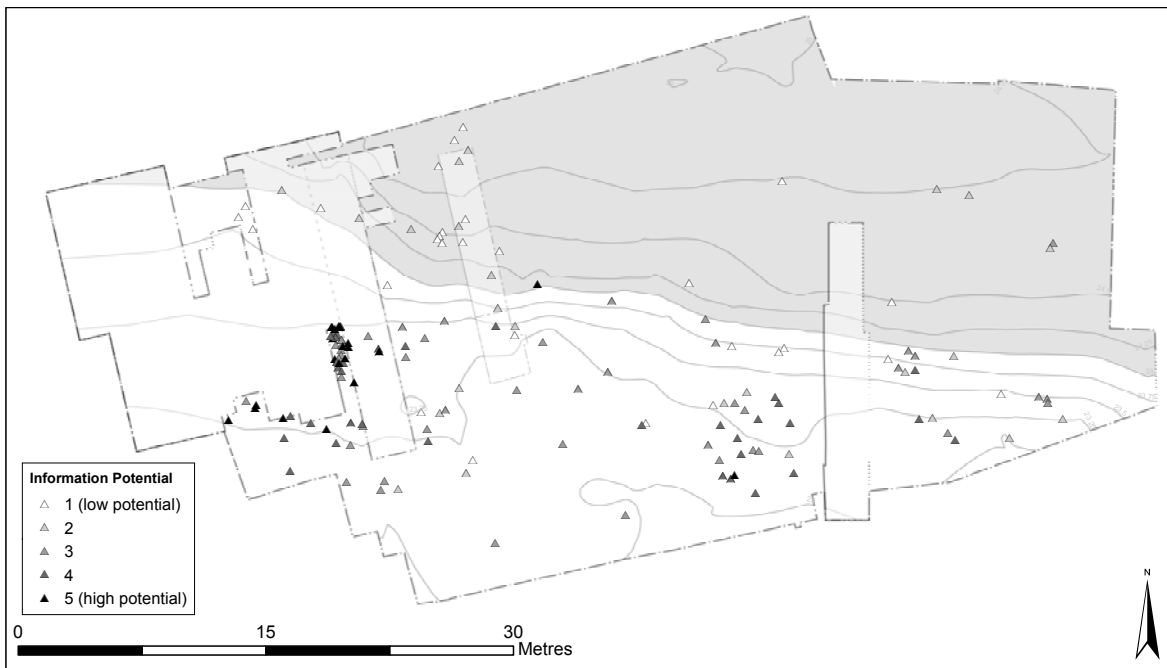
Figure 22.7: Plot of all bone and antler artefacts rated by information potential from excellent (black, rating 5) to poor (white, rating 1) (Copyright Star Carr Project, CC BY-NC 4.0).
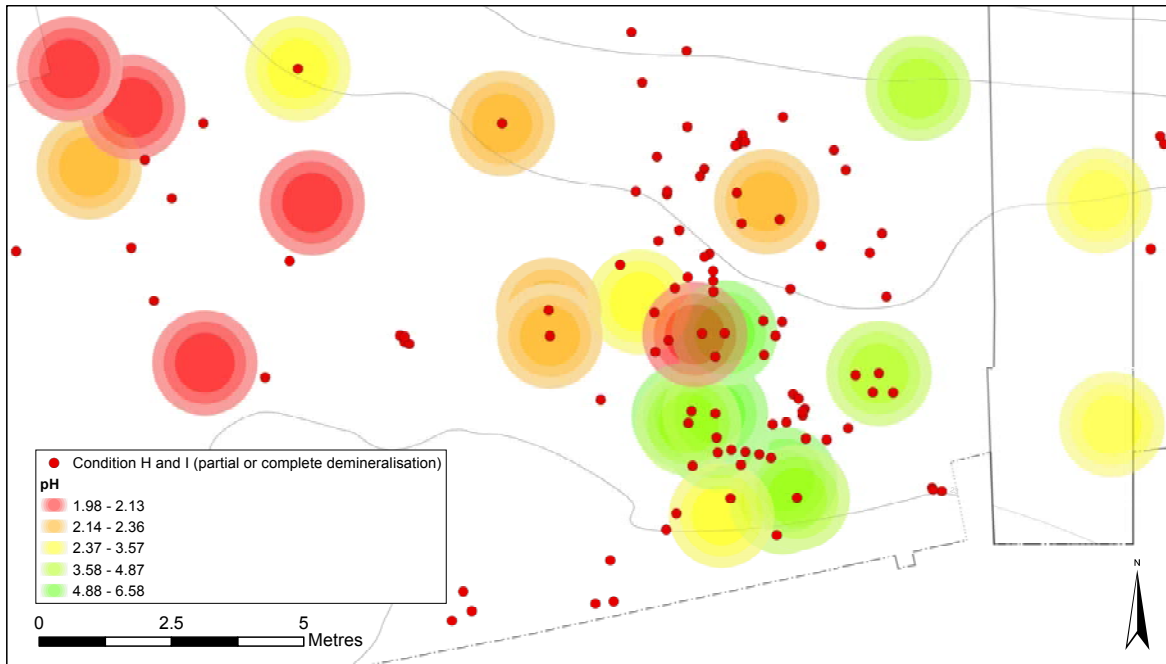
Figure 22.8: The pH values around the detrital wood scatter together with partially or completely demineralised bone and antler artefacts (Copyright Star Carr Project, CC BY-NC 4.0).

in the wetland, particularly in Clark's area and also the cluster around the detrital wood scatter, to the west of trench VP85A, an area of neutral pH readings. The information potential ratings produce a fairly similar pattern with the highest potential in the areas of better preservation. Further examination of the area around the detrital wood scatter, where robustness and information potential is favourable, shows that even in this area, with less acidic conditions, partial or complete demineralisation has occurred (Figure 22.8). It is therefore important not to assume that less acidic areas will be safer from these issues.

Overall, the best preservation found on the site was in Clark's area in 2015, from within the section of baulk. This contained a tightly packed accumulation of wood, bone and antler that was much more robust than in other areas of the site, and which appeared to be similar in condition to the material originally excavated by Clark. It would appear that this very small pocket of sediment had been buffered somehow, either by the quantity of bone and antler in this area, and/or by near-neutral backfill (as observed in Clark's cutting II re-excavated in 2010), and the area of marl to the south.

Wood

Descriptions of wood from the original excavations suggest that it was soft because roots had grown through the artefacts. However, visual records show that it retained the macroscopic appearance of wood (Clark 1954). Images of the excavations in 1985 and 1989 also show the wood to be macroscopically identifiable as wood, although in some instances it was difficult differentiating between the timbers and the surrounding peat matrix (Taylor 1998b). The surface data recorded from these timbers is the clearest fine-grained evidence of woodworking recorded from Star Carr. Wood has never been retrieved from the dryland parts of the site; however this is not surprising, as archaeological wood only usually survives when biological activity has been suppressed, for example by waterlogging (Blanchette et al. 1990; Florian 1990).

Wood excavated in 2006 and 2007 was visually observed to be well preserved but on handling was found to be extremely delicate (Milner et al. 2011), meaning great care had to be taken at all stages of excavation, cleaning and storage to ensure that vital surface data were protected. The peat-wood interface was often very difficult

to define and as a result wood was difficult to analyse. Where possible, the condition of the wood was further assessed by York Archaeological Trust using scanning electron microscopy (SEM) imaging and standard decay tests such as density and maximum water content (μmax) (Milner et al. 2011). This analysis showed that little or no cellulose was remaining in much of the wood, leaving only a lignin-rich skeleton. Again, preservation appeared to vary across the site, although the major damage was concluded to be due to compression, rather than chemical or biological deterioration.

More in-depth analysis in 2013 supported these observations; analysis by FT-IR, gas chromatography and SEM showed that although much of the cellulose within the Star Carr wood was degraded, it was not unusually so. Comparison with samples from Must Farm and Flag Fen (considered examples of exceptionally well-preserved archaeological wood), showed that for a site the age of Star Carr, the wood was still as well-preserved as could be expected. In an archaeological context, this means that information such as primary conversion, species and growth ring data can still be determined and fine-grained surface detail, such as tool facets, are sometimes visible.

The analysis in 2013 aimed to tie in the organic deterioration with the site geochemistry, and this showed some alarming results (High et al. 2016b). Analysis of the surface pH of many excavated samples showed that upon excavation, the pH of the wood drastically decreased. Furthermore, a timber that had been excavated in 2007 and kept in storage showed a surface pH of much less than 1; far lower than has ever been recorded at the site itself. Chemical analysis of this timber revealed extensive degradation, with both the lignin and cellulose completely broken down, likely due to acid hydrolysis (see High et al. 2016b). These observations demonstrate that the influence of the harsh burial environment at Star Carr extends beyond excavation and suggests that drying out of the site will be highly detrimental to the continued survival of any remaining wood. Introduction of oxygen to the wood will lead to increased acidity within the wood structure, making it then vulnerable to chemical modification.

During the 2013–2015 excavations all individually recorded pieces of wood were scored for condition. The condition scale developed by the Humber Wetlands Project was adopted at Star Carr (Table 22.3). The condition scale is based primarily on the clarity of surface data. Material is allocated a score dependent on the types of analyses that can be carried out, given the state of preservation. The condition score reflects the possibility of a given type of analysis but does not take into account the suitability of the item for a given process. If preservation varies within a discrete item, the section that is best preserved is considered when assigning the item a condition score. In addition to the condition score assigned to each item, further information regarding condition, taphonomy and damage was noted on the individual wood sheets as appropriate.

An overview of the assemblage is given in Table 22.4. The most common condition score is a 3/moderate, describing material where the primary conversion is visible, identification to taxa is possible and growth ring data is visible. Fine-grained surface data such as tool facets may be visible. Fine grained surface data is very unlikely to be visible for material that scores less than a 3, whereas it generally will be visible for material that scores more than a 3. Although preservation was highly variable at an extremely localised level, condition generally improved both as depth and distance from the lake edge increased. This is particularly evident in the areas around the eastern and western platforms; however, condition was again much better in Clark's area even closer to the lake edge (Figure 22.9).

Condition score	Museum conservation	Technology analysis	Woodland management	Dendro-chronology	Taxonomic identification
5 excellent	+	+	+	+	+
4 good	–	+	+	+	+
3 moderate	–	+/–	+	+	+
2 poor	–	+/–	+/–	+/–	+
1 very poor	–	–	–	–	+/–
0 non-viable	–	–	–	–	–

Table 22.3: Condition scale, after Van de Noort et al. (1995): Table 15.1.

Condition score	Brushwood area Frequency	Detrital wood scatter Frequency	Central platform Frequency	Eastern platform Frequency	Western platform Frequency	Clark's deposition area Frequency	Other Frequency	All Frequency	All %
5 excellent	5	21	0	0	1	4	1	**32**	**0.7**
4 good	1042	388	51	4	23	197	60	**1765**	**39.1**
3 moderate	926	651	91	11	66	235	109	**2089**	**46.3**
2 poor	95	129	73	30	51	14	20	**412**	**9.1**
1 very poor	2	5	12	5	0	0	10	**34**	**0.8**
0 non-viable	0	0	0	0	0	0	0	**0**	**0.0**
unrecorded	0	135	49	0	0	0	0	**184**	**4.1**
total	*2070*	*1329*	*276*	*50*	*141*	*450*	*200*	*4516*	*100.0*

Table 22.4: Condition score of wood assemblage (including full records and rapid recording records).
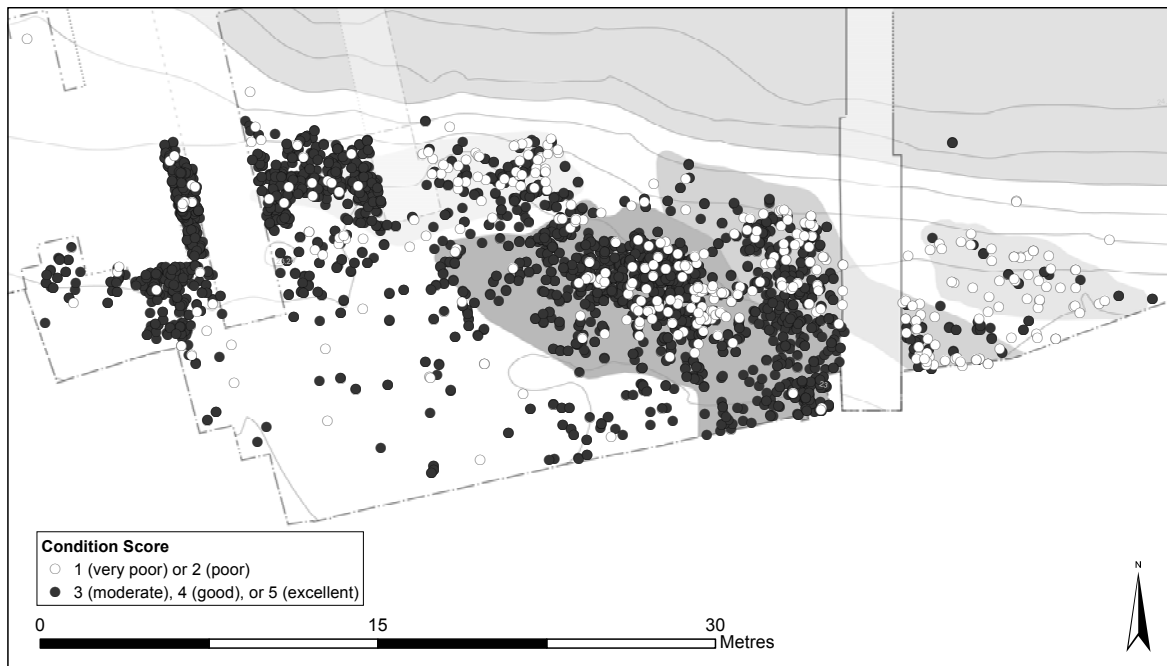
Figure 22.9: Plot of condition score of wood assemblage of pieces rated 3 or greater (moderate, good or excellent) against pieces rated < 3 (poor or very poor) for wood with survey data (2179 pieces) (Copyright Star Carr Project, CC BY-NC 4.0).

The wood assemblage has been damaged by compression as the site has dewatered and the waterlogged deposits have shrunk in the vertical plane. By measuring the vertical and horizontal diameter of wood that originally had a circular cross section, the degree of vertical compression can be mapped (Figure 22.10). In the most extreme cases, wood has been compressed by 97%. The mean average of compression is 39% (N = 937) (Figure 22.11).

Based on the assumption that the majority of worked items will have been trimmed to length with an edged tool (such as a flint adze or axe), the distribution of the presence of surviving tool marks and tool facets can be considered as a proxy indicator of condition (Figure 22.12). Survival of tool faceting is much lower than would normally be expected and is thought to be a result of the extreme age of the material. The majority of the ends of items, where tool faceting is most likely to be present, are degraded and can be seen to 'feather' away.

The long history of excavation at the site provides a rare opportunity to view the effects of intrusive trenching on the burial environment, within waterlogged deposits. Excavations during the current campaign revealed several areas either adjacent to or immediately beneath previous trenches.

The greatest time gap between exposures related to the excavation of the baulk between Clark's cutting I and cutting II within Clark's Area (1948 to 2015: 67 years). Surprisingly, despite lying beneath an unfinished trench and between two previous trenches, the material seen in the baulk was perhaps the best-preserved wood encountered during the current campaign. Wood directly beneath backfill or in contact with it to either side did not appear to have suffered any notable effect from the previous trenching. The animal bone and antler was also in good condition and it has been suggested that this may have been due to less acidic ground conditions, pH levels perhaps being stabilised to some extent by alkaline marl mixed into Clark's backfill. However, although this may account for the relatively good condition of the bone and antler, pH levels have been shown to have little effect on the stability of the wood. It must therefore be surmised that the historic trenching has had little impact on the in situ wood deposits in this area.

Timbers of the western platform that had previously been exposed in the base of an unnumbered trench cut by Clark in 1951 tell a similar story. Despite bearing the physical scars from hand cleaning (the edges of the
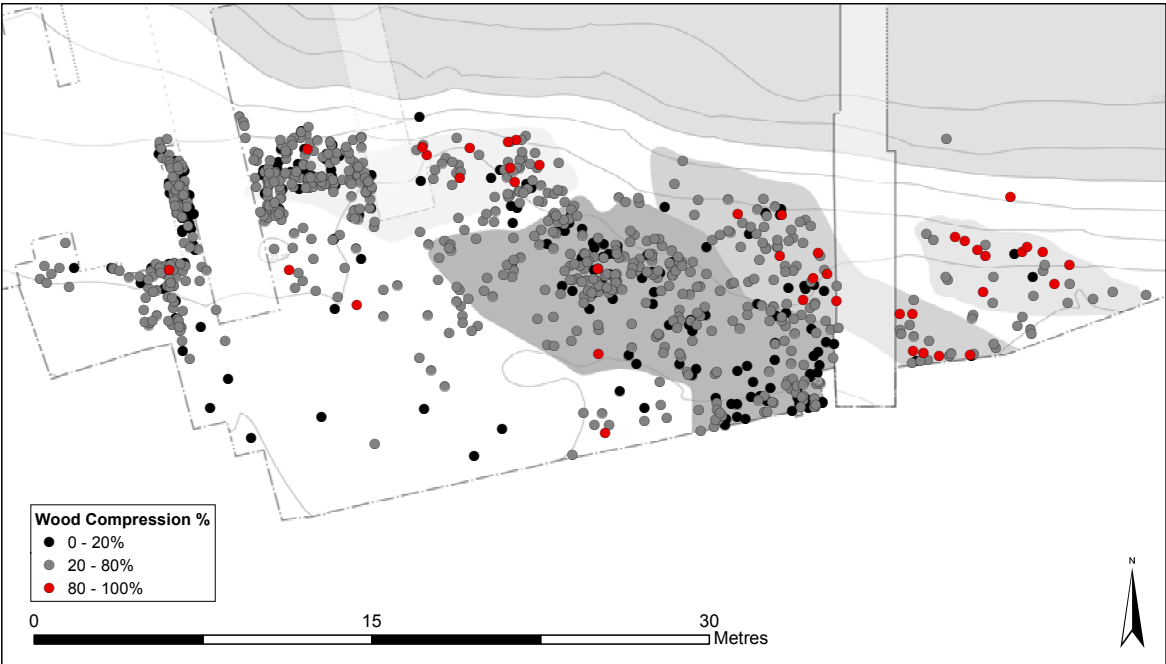
Figure 22.10: Vertical compression of wood assemblage (for full records only) (Copyright Star Carr Project, CC BY-NC 4.0).
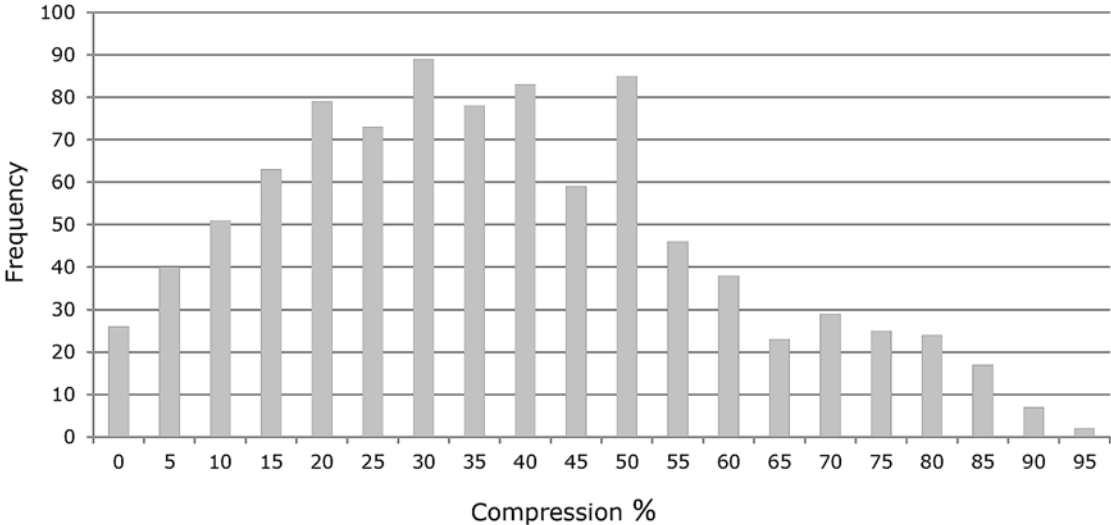
Figure 22.11: Histogram of vertical compression of wood assemblage (N = 937, full records only) (Copyright Star Carr Project, CC BY-NC 4.0).
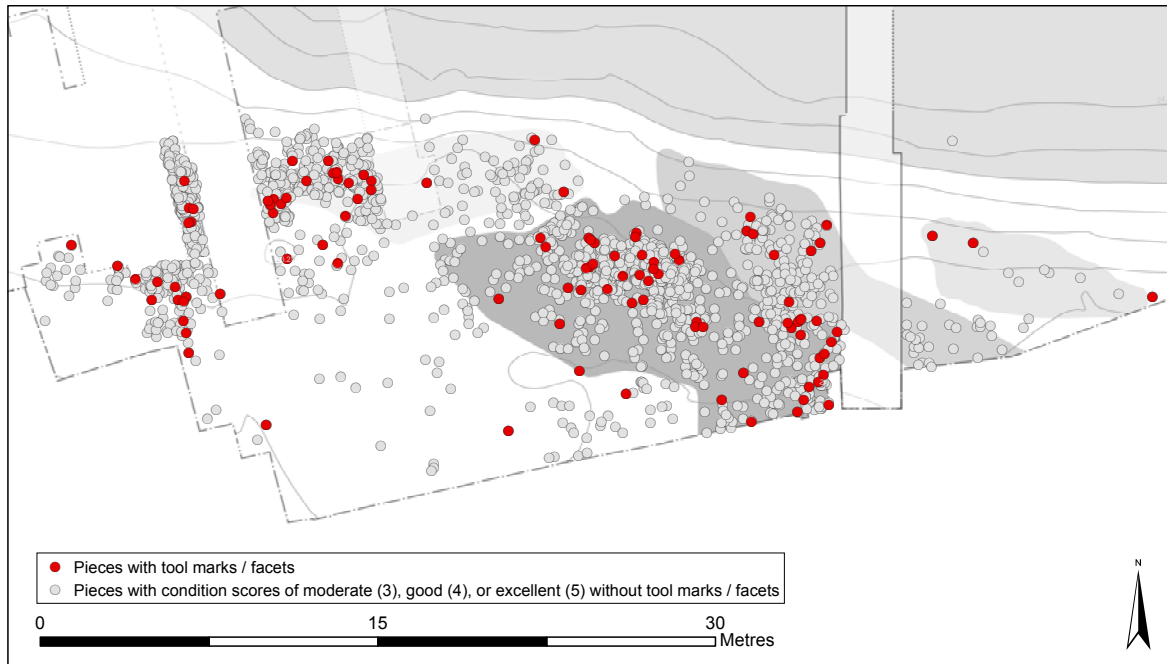
Figure 22.12: Map of tool marks and facets as proxy for information potential (Copyright Star Carr Project, CC BY-NC 4.0).

trench were clearly scored into the upper surfaces of several timbers), there was almost no apparent deterioration to the timbers.

In contrast, the timbers of the central platform, previously exposed by the 1980s excavations in trench VP85A, showed clear differential preservation when excavated in 2013 (less than 30 years later). The extent of trench VP85A was marked by orange iron salts precipitating out at the point of contact between backfill and in situ deposits. In addition, there were increased levels of surface degradation on the timbers which had previously been exposed. In sum, the detrimental effects of the previous exposure were very spatially limited, with no perceptible 'bleed in' of increased degradation away from the limits of the historic exposure.

Surprisingly, perhaps the most extreme effect of re-burial and subsequent re-excavation was seen over a single year. A few items within the detrital wood scatter were exposed during the 2013 excavations, re-buried for nine months and then re-exposed for the 2014 excavations. Many of these items suffered rapid decay, being noted to change from a good/moderate condition to a poor/very poor condition.

Although subjective, these observations show that the effects of cutting intrusive trenches into waterlogged deposits are sensitive to extremely localised conditions, and that even across a relatively small area, the effects of such trenching on the surrounding deposits are highly variable.

The impact for conservation of artefacts

The issues discussed above present a particularly challenging situation in terms of conservation of the waterlogged remains from Star Carr. Not only are we mitigating against the effect of waterlogging but also the effect of the complex chemical make-up of the burial deposits and the build-up of contaminants within the material. As such the conservation of the assemblage is unusual, with very little literature or past treatments to draw on. It should also be noted that some timbers excavated from the platform found in trench VP85A in 1985 were conserved and are currently stored at the University of York. These have not preserved well; they are crumbly with yellow powder exuding from them and produce a highly sulfurous smell.

Due to the conditions, not all the material excavated can be conserved and a strategy was drawn up as part of the English Heritage/Historic England Assessment process (Milner et al 2013a, 2014). The majority of the bone and antler has been retained for conservation but the pieces which were in the worst states of preservation,

some categorised G-I and which had in some cases completely disintegrated, could not be saved. Given the large size of the waterlogged wood assemblage recovered from recent excavations at Star Carr and the homogenous nature of sub-groups within the assemblage, it is neither desirable nor practical to conserve or subsequently store the assemblage in its entirety. As such, a sub-sampling strategy was devised to ensure that items displaying a representative sample of the types of woodworking evidence recorded within the assemblage are conserved and subsequently retained, as well as the artefacts. Below is a summary of the conservation strategies undertaken to treat the material, based on studies done at York Archaeological Trust.

A previous study of bone from anoxic sites including Star Carr showed the presence of pyrite framboids and gypsum within the structure as well as deterioration by slow chemical hydrolysis and the action of sulfate reducing bacterial (Turner-Walker 2009). To mitigate against these effects is very challenging especially as the material would not tolerate chemical chelating treatments. There was also a very high degree of variation in the condition of the bone and antler, as outlined above, with some appearing to be in very good condition, some having undergone some degradation and softening and some having broken down entirely with no mineral content surviving.

The bone and antler material was therefore split into three categories for the purposes of the conservation treatment of good, fair and poor condition and placed into tanks. They were put through a regime of washing in tap water to try to flush out as many contaminants as possible. The washing was monitored by collecting samples and testing the iron content of the wash water. The antler frontlets were put through cascade washing to speed up the process and prevent build-up of sulfate reducing bacteria. It was not possible to be very specific about the end-point of the washing process but in this case the washing was deemed complete after approximately three months. At this point the material which was decalcified was put through a pre-treatment of glycerol to act as a protector and consolidant during drying. More robust material was dried using controlled air drying with consolidation undertaken where necessary. Once dry, the bone and antler went through further surface cleaning and consolidation where necessary, using appropriate conservation grade materials.

The wood from the site has gone through significant deterioration, both by compression and by breakdown of both lignin and cellulose and by the introduction of contaminants which lead to further attack once the material has been excavated. The conservation process, as with the bone and antler, therefore has to mitigate against the effect of compression and waterlogging, but also against the build-up of contaminants such as sulfur and iron which lead to acid attack.

As such, the initial stages of the conservation process aimed to remove as much sulfur and iron as possible using a combination of washing and chelating treatments. However, it will not have been possible to remove all such contaminants. Once the washing stage was complete, the wood was put through a standard conservation treatment using Polyethylene Glycol (PEG) and freeze-drying, and with further surface work being done, post-drying where necessary to remove excess PEG and to join fragments were necessary.

After drying and surface treatments the material is stable but the storage environment will be an important factor in its future stability. High humidity and oxygen levels in storage could lead to the oxidation and acid attack within the material. The storage environment should therefore look to provide a relative humidity which is fairly dry (between about 30–40% relative humidity) and as low in oxygen levels as possible. However, despite both conservation intervention and provision of beneficial storage conditions, the material may still continue to deteriorate, given the levels of contamination and the difficulty in mitigating against this.

Because of the extreme conditions of this site and the problems with conservation, a number of artefacts have been recorded in 3D using image-based modelling and photogrammetry. The wood from the timber platforms for instance, were modelled on site (see Chapter 6), and the headdresses have been modelled using structure-from-motion. However, it was not possible to do this for all material excavated due to the development of the technology during the project and the time it takes for this to be carried out, as well as associated costs in terms of staffing. Nevertheless, this is an approach which could be adopted in the future for sites such as this which suffer from severe forms of degradation.

Conclusions

Analyses of antler, bone and wood from Star Carr show that site conditions are contributing to their rapid deterioration. Whilst the variations in the geochemistry make it difficult to say for certain whether site conditions have changed recently, comparison between material from Clark's excavations and material excavated recently,

since 2004, suggests that far fewer bones are present in the well-preserved state first reported by Clark (1954), with the exception of Clark's area excavated in 2015. This makes it highly likely that rapid site deterioration has occurred within the last few decades. This is supported by the recent geochemical and hydrological surveys, which seem to suggest that drying out and subsequent acidification of the site occurred following the installation of field drains in 2000.

Whilst high sediment acidity has been shown to be the major cause of loss of bone at Star Carr (High et al. 2015, High et al. 2016b), it is likely that peat compression caused by drying out of the site is the major cause of deterioration in wooden artefacts. However, the two factors are clearly closely linked. Presence of sulfides was not necessarily a problem until loss of waterlogging allowed oxidation to proceed, resulting in the extreme and irreversible acidification of the deposits. Furthermore, the suggestion that groundwater may be percolating through the archaeology in areas of the site (Brown et al. 2013) means that any diagenetic processes will be accelerated as degradation products are 'washed away' (Hedges et al. 1995; Williams et al. 2006).

Our research has shown the importance of understanding the surrounding geology and hydrological features surrounding an archaeological site before any modifications to the local environment occur. Critically, the variability in both pH and organic preservation at Star Carr shows just how influential the underlying geology is to the chemical stability of a waterlogged site. This variability may also mean that very different management strategies may need to be considered for different parts of Star Carr or other sites similarly affected. The observed 'halo effect', where increased acidity is observed following excavation, further highlights the care that must be taken during management of the site.

Research into the effects of the site conditions on bone and wood show that material still buried at Star Carr is at risk, particularly if site conditions were to alter further (High 2014; High et al. in press). For example, a particularly dry summer may result in further reduction of the water table, resulting in increased acidity as more reactive sulfides are oxidised. This would lead to further demineralisation of bone and loss of cellulose in wood. This is clearly a concern given that less than 10% of the total area of the site has been excavated.

Analysis of organic materials carried out in recent years has indicated that although localised areas of moderate or neutral pH still exist, resulting in the recovery of some well-preserved artefacts, large parts of the Star Carr site are now so deteriorated that there can be little hope for the recovery of substantial archaeological data from organic artefacts. Whilst this seemingly rapid and recent deterioration of the Star Carr deposits can be viewed as a disaster for Star Carr itself, it has also given us the opportunity to study and monitor these changes. The lessons that have been learnt from the site can now be used to better protect other similar sites.

PART 10
Animals

'*Like it or not, this rich site had been stressed and re-assessed in some form or other almost annually; the archaeological pack has chased after the only juicy bone apparently available, gnawing at it and extracting the marrow of its information base.*'

(Schadla-Hall 1988, 27)

Faunal Remains: Results by Species

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Oliver Craig and Matthew Collins

Introduction

The faunal remains from the original excavations were studied by Frederic Fraser and Judith King of the then Department of Zoology, British Museum (Natural History), and the bird bones were identified by Marjorie Platt of the Royal Scottish Museum, Edinburgh. The collection was noted as being important because it contained several animals now absent from the fauna of this country and there was enough material to give an impression of the composition of the fauna at the start of the postglacial period in Yorkshire (Clark 1954, 70).

Clark, in his synthesis chapter, highlights the importance of red deer, roe deer, elk, aurochs and pig [*sic*] in terms of their relative abundance and suggests that it is likely that the 'total bag' of these species would have been twice as much. In doubling these figures and then converting to dead weight, clean carcass weight and calories, he suggested that a group of four families (comprising an active man, a moderately active woman and three children) could live off this food supply (approximately 50,000 kg) for 6 1/4 years (Clark 1954, 16). However, it was noted that it cannot be assumed that all the meat was consumed on site and some could have been dried for use elsewhere.

We now know that the nature of occupation was highly complex: the site is much larger than previously thought, it spans c. 800 years and the faunal remains that survive are only likely to be a small percentage of what was used and deposited. In addition, we know that Clark did not retain everything: bone, antler and flint appear to have been purposefully deposited in several parts of the backfill which will have skewed previous analyses. What had been collected was then dispersed across a number of museums mainly around England, but also farther afield, which makes it harder to re-examine.

The faunal remains found in the recent excavations at Star Carr are generally in fairly poor condition (Chapter 22). Nevertheless, even some of the really badly preserved bones have revealed important data using both traditional zooarchaeological techniques, as well as biomolecular approaches such as Zooarchaeology by Mass Spectrometry (ZooMS) and stable isotope analysis. Our recent excavations have resulted in the discovery of some new species to add to Clark's list. In addition, the open area excavation, 3D plotting, application of GIS and the dating programme allowed us to take a new approach and consider the variability of the data through time and across space (see Chapter 7).

Figure 23 (page 193): Fracturing long bones for marrow extraction (Copyright Aimée Little, CC BY-NC 4.0).

The faunal remains from 2004–2010 were initially assessed by Sarah Viner, Rachael Parks and Cluny Johnson (reports in the ADS) but the whole assemblage has been reanalysed by BK who has been the faunal remains specialist since 2012 and was onsite throughout the 2013–2015 seasons. A large quantity of sediment was also sampled for flotation (see Chapter 15) and a significant quantity of bone fragments were retrieved from this, though much remains unidentified to species or element. This chapter begins by outlining the original assemblage and subsequent reinterpretations. It then presents the methodologies used in examining the faunal assemblage. An overview of taphonomic factors is given, followed by an overview of the quantification of species across the site. The different species are then detailed in turn, in terms of spatial distribution, elements, age and sex where possible, seasonality where possible, modifications by carnivores and humans, palaeopathology, and the MNI. The faunal remains data have been collated on a spreadsheet which is available via the ADS and spatial data is available allowing all specimens which have been 3D recorded to be plotted (https://doi.org/10.5284/1041580).

The original assemblage and subsequent reinterpretations

In the faunal remains chapter in the original monograph (Clark 1954), the total number of identified specimens (hereafter NISP) were not provided but the minimum number of individuals (hereafter MNI) per species were listed (Table 23.1) with the note that no human or fish remains were found. A description of the remains for each species was given and the discussion drew attention to the size of some species, notably red deer which were much larger than modern Scottish counterparts. In addition, Clark requested that the analysts should consider the season of occupation (Clark 1972, 22). This was determined, based on red deer, elk and roe deer antlers and when these are shed, with the conclusion that people must have inhabited the site during the winter until spring, notably April.

Common name	Scientific name	MNI
Common crane	*Grus grus* (Linnaeus, 1758)	1
? White Stork	*Ciconia ciconia* (Linnaeus, 1758)	1
Red-breasted merganser	*Mergus serrator* (Linnaeus, 1758)	1
Red-throated diver	*Colymbus stellatus* (Pontoppidan, 1763)	1
Great crested grebe	*Podiceps cristatus* (Linnaeus, 1758)	1
Little grebe	*Podiceps ruficollis* (Pallas, 1764)	1
Lapwing	*Vanellus vanellus* (Linnaeus, 1758)	1
Buzzard	*Buteo buteo* (Linnaeus, 1758)	1
Duck (size of pintail)	*Anas acuta* (Linnaeus, 1758)	1
Wolf	*Canis lupus* (Linnaeus, 1758)	2
Fox	*Vulpes vulpes* (Linnaeus, 1758)	2
Pine marten	*Martes martes* (Linnaeus, 1758)	2
Badger	*Meles meles* (Linnaeus, 1758)	1
Hedgehog	*Erinaceus europaeus* (Linnaeus, 1758)	1
Pig [sic]	*Sus scrofa* (Linnaeus, 1758)	5
Elk	*Alces alces* (Linnaeus, 1758)	11
Red deer	*Cervus elaphus* (Linnaeus, 1758)	80
Roe deer	*Capreolus capreolus* (Linnaeus, 1758)	33
Aurochs	*Bos primigenius* (Bojanus, 1827)	9
Hare	*Lepus* cf. *europaeus* (Pallas, 1778)	1
Beaver	*Castor fiber* (Linnaeus, 1758)	7

Table 23.1: Mammals and birds identified by Fraser and King (Clark 1954).

During Clark's original excavations, the finds were hand collected and there was no sieving protocol implemented. This methodology will have influenced the recovery rate of smaller species and more delicate elements, as acknowledged by Legge and Rowley-Conwy (1988, 12) in their reanalysis. Also, it is clear that Clark had a selection process for the finds although this is never outlined in his publications. Through the rediscovery of finds in the backfill during the most recent excavations (see also Chapter 7), it appears that Clark mainly kept elements that were complete or large fragments of bone and antler that were easily identified to species. Butchered fragments were kept, but only if they could be identified to species and element. Smaller fragments of bone and antler, or elements such as ribs that were difficult to identify to species, were not retained.

In the 1970s, a number of re-evaluations of the data were carried out. Because red deer antlers had been used for making artefacts such as barbed points, it was suggested that red deer antler should be discounted from analyses (Jacobi 1978; Caulfield 1978; Pitts 1979; Grigson 1981), which radically reduced the MNI of red deer. Pitts (1979) noted that the roe deer shed antler had not been used for making tools and so could be used for calculations of MNI. As noted in Chapter 2, this led to a study undertaken by Legge and Rowley-Conwy (1988) in which all of the faunal material from Clark's excavations, including material housed in various museums around the country, was re-assessed. This primarily set out to re-examine the bones from the large mammals: aurochs, elk, red deer, roe deer and wild pig [*sic*] (Legge and Rowley-Conwy 1988).

Their re-quantification of the bones changed the MNI for all of these species (Figure 23.1). Their work excluded red deer antler (shed and unshed), but also roe deer antler (38 left and 39 right) on the basis that virtually all have been broken out of the skull and if they are taken into account a very extreme and unlikely sex ratio is arrived at (Legge and Rowley-Conwy 1988, 10). It is suggested that the roe deer antler may have been collected for an unknown purpose. In addition, the representation of elk increased due to some bones having previously been identified as aurochs. There is no explanation as to why the MNI for aurochs increased, but this is perhaps a result of the corpus of Danish aurochs being published since the original faunal assessment, as noted by Legge and Rowley-Conwy (1988, 10). The wild pig [*sic*] decreased by an MNI of one because a mandible had been re-identified by Sebastian Payne as bear (Legge and Rowley-Conwy 1988, 10).

In addition, other important analyses were undertaken which changed the species list to some degree. Harrison (1987) re-examined the Star Carr birds. Nine bird species were identified in the original analysis by Platt, but Harrison states that of these nine, four 'appear to be invalid' (Harrison 1987, 141) (Table 23.2). Harrison disagreed with the identification of white stork (*Ciconia ciconia*) as this was based on a fragment of long
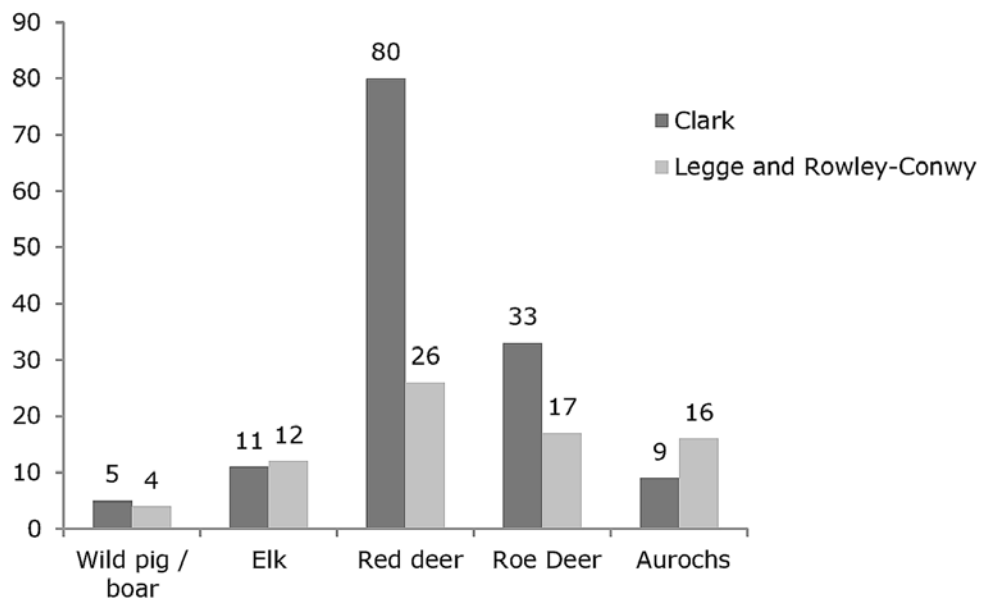
Figure 23.1: Differences in the MNI between the analyses presented in Clark (1954, 15) and Legge and Rowley-Conwy (1988, 9) (Copyright Star Carr Project, CC BY-NC 4.0).

Common name	Scientific name	Element	Side
Red-throated diver	*Colymbus stellatus*	Distal humerus	Right
		Ulna	Left
Great crested grebe	*Podiceps cristatus*	Tibiotarsus	Left
Little grebe	*Tachybaptus ruficollis*	Ulna	Right
Brent goose	*Branta bernicla*	Humerus shaft	Left
Red-breasted merganser	*Mergus serrator*	Tibiotarsus	Right
		Tibiotarsus	Left
		Carpometacarpus	Left
Common scoter	*Melanitta nigra*	Ulna	Left
Common crane	*Grus grus*	Humerus	Right
		Humerus	Left
		Ulna	Right
		Ulna	Left

Table 23.2: Birds reclassified by Harrison (1987).

bone midshaft only, and he revised this identification to 'indeterminate' (Harrison 1987, 141). There were several other identifications which Harrison changed: the common buzzard (*Buteo buteo*) humerus midshaft was re-identified as Brent goose (*Branta bernicla*); the pintail (*Anas acuta*) carpometacarpus was reassigned to red-breasted merganser (*Mergus serrator*) and the lapwing (*Vanellus vanellus*) ulna was re-assigned to common scoter (*Melanitta nigra*).

There has been much discussion about whether wolf or domesticated dog was found at Star Carr. Fraser and King (1954, 72) reported wolf; however, Degerbøl's (1961) and Benecke's (1987) analyses make it clear that they are domestic dogs, and a further dog right femur was found in the collection by Rick Schulting (Schulting and Richards 2009, 499).

A further notable addition to the record is brown bear (*Ursus arctos*). An upper left canine was found from this species by Tot Lord, who visited the excavations before Clark's trenches were backfilled (Dark et al. 2006, 191). In particular, he searched the deposits next to the birch trees in cutting II and found items by pushing his hands into the soft sediment at the base of the sections. In doing this he felt a skull but could not retrieve it; however, he was able to extract a tooth from it (Edwards et al. 2014). During our excavations we expected to find this skull; however, despite excavating all around cutting II there was no sign of it and the conclusion is that it has either demineralised (if it was on the east side—SC24 only contained two pieces of jellybone) or that it was retrieved by someone else. Two other brown bear bones have since been identified: as already noted, a broken mandible previously identified as wild boar (Legge and Rowley-Conwy 1988, 10) and an axis vertebra (Noe-Nygaard 1983). It has been suggested that the brown bear skull, mandible and axis vertebra possibly belong to the same animal (Dark et al. 2006).

Methods

Introduction

A number of traditional zooarchaeological methods were used to assess taphonomy, taxa, quantification, ageing, sexing, palaeopathology and seasonality. In addition, a range of biomolecular techniques were used: ZooMS to aid in the identification of taxa, and stable isotope analysis to assess diet for deer. In addition, aDNA was attempted on the bones of dog and wolf (by Greger Larson and team, University of Oxford) and beaver (by Melissa Marr, Danielle Schreve and Ian Barnes, Royal Holloway and the Natural History Museum); however, no positive results were produced, thought to be due to the poor preservation environment for aDNA at the site.

Taphonomy

The faunal remains excavated from the dryland areas of the site were found to be in a particularly poor condition: specimens were very desiccated, fragmentary and fragile and exhibited a high frequency of root damage. Due to these factors, almost half (49%) of the specimens could not be identified to species or element, although this is fairly typical for material found within these types of sediments and of this age. The bones from the wetland part of the site exhibited a range of problems including demineralisation, lamination and concretion of minerals as set out in Chapter 22 which also provides the methodology used in analysing the varying states of preservation.

All bones were analysed for evidence of natural taphonomic changes such as weathering and exposure, root or bioturbation damage and trampling, but also for evidence of modification: (1) anthropogenic modifications such as charring, cut marks or butchery evidence; (2) modifications made by animals such as uneven (ragged-edged) breakage, gnaw marks, crushing or cracking and tooth impressions (Lee Lyman 1994). The anatomical location of these modifications on each of the elements was described in detail and added to the faunal database. Elements with particularly clear or unusual evidence were then selected for photography. Identification of the causes of the modifications was also noted; for example, classic percussion damage for marrow extraction (Noe-Nygaard 1977) and longitudinal splitting for bone tool production (David 2005). In terms of the animal modification evidence, attempts were made, where possible, to identify the species responsible by examining any clear tooth impressions or gnawing patterns. Some species, such as canids and felines, tend to favour particular elements and the pattern of gnawing can be very distinctive (Haynes 1983): for example, dogs have a tendency to drag their teeth over the surface of a bone creating tooth scores and gouges and rodents leave parallel tooth scores (O'Connor 2000).

Taxa identification

The species or genus was assessed using the University of York zoological reference collection and the atlas of Quaternary mammals (Pales and Lambert 1971a; 1971b; Pales and Garcia 1981a; 1981b) by BK and TOC. In addition, measurements were taken where possible in order to try to differentiate between red deer and elk using von den Driesch (1976). However, this was sometimes problematic due to the large size of the red deer and the post-depositional changes that have occurred to a large quantity of the remains.

It was not possible to identify the species or genus of a large number of specimens, particularly those on the dryland because they were severely degraded. When species could not be determined, specimens were categorised to family level (e.g. *Cervid* sp., *Bovid* sp.), category (e.g. bird sp., ungulate sp.) and size (large, medium or small mammal). The composition of bird bones is very different to that of mammals as they are usually very gracile, lightweight and have a very different internal structure, making them much easier to identify as bird, though not necessarily to species.

It was possible in some cases to get to family level using size, robusticity and internal matrix detail of the bones. However, the majority of the material categorised to family level came from the application of ZooMS. A total of 280 bones were sampled and analysed by MB from the dryland excavations carried out in 2007 and 2008. In addition, a further 60 bones were analysed by PW and MC from the dryland excavations carried out in 2013 and 2014. Only specimens from the dryland were sampled for ZooMS because this is where identification using traditional methods was most challenging due to the deterioration of the bone.

Collagen, the dominant protein in mineralised tissues, is known to persist with extraordinary longevity and can be examined using ZooMS (Buckley et al. 2009), whereby peptides are fractionated using C18 ZipTip® pipette tips, and analysed by Matrix-Assisted Laser Desorption/Ionization Time-of-Flight Mass Spectrometry (MALDI-ToF MS). This method introduces the sample into the mass spectrometer as an air-dried co-crystallised acidic mixture of peptides and a coloured matrix. Under vacuum, the multiple samples spotted onto the plate are each in turn volatilized by a laser shot at the crystals. The energy is absorbed by the matrix within the crystals, causing it to partially decompose and volatilise. This pulse of energy also lifts the co-crystallised peptides off the plate and adds a proton, giving them a positive charge. These charged peptides are then accelerated by an electric field and guided down a flight tube, which assesses the mass of each peptide by its time of flight to reach a detector, peptides with lower mass arriving earlier than those with higher mass.

A small amount of each sample was removed and placed in an eppendorf micro-centrifuge tube. Then 200 μl of 0.1M sodium hydroxide (NaOH) was added to the sample to remove tannins and other chromophoric

compounds. The sample was then vortexed and centrifuged. The NaOH was removed, and 200 μl of 50mM ammonium bicarbonate solution (NH₄HCO₃) pH 8.0 (AmBic) was added in order to 'rinse' the sample. The eppendorfs were then vortexed briefly before being centrifuged again for one minute. This rinsing process was repeated twice more. 75 μl of AmBic was then added to the samples. Next, 1 μl of trypsin solution was added to each of the 'second' eppendorfs. These were then incubated for four hours at 37 °C. Following incubation, the samples were centrifuged, and 1 μl of 5% TFA solution was added to each to terminate trypsin activity. Peptides were then extracted from the sample solution using C18 ZipTip® pipette tips and eluted with 50 μl of conditioning solution. Then 1 μl of sample was spotted onto a Bruker ground steel target plate, following which 1 μl of matrix was added on top. Each sample was spotted in triplicate and the plate was then run on the Bruker Ultraflex.

Quantification

NISP and MNI were used in quantifying this material with the aim of calculating relative abundance of animals, or parts of animals, deposited at the site. Weights were not recorded because the deterioration of the deposits have affected the faunal remains so much that weight calculations would not be comparable across site, or with other sites, and would therefore be meaningless.

NISP is defined as the number of identified specimens. Usually the term 'specimens' refers to either a single bone, or a group of fragments originally derived from a single bone that could be refitted together. These calculations are used to illustrate the relative numbers of each element in order to assess which elements are abundant and which elements appear to be missing from the assemblage. For this analysis it was decided to include individual fragments in the NISP values; however, the potential bias of high fragmentation through working bone into tools was taken into account when discussing the dominance of different taxa within the assemblage.

MNI is defined as the minimum number of individuals. This was calculated using the most abundant skeletal element for each species within the assemblage, sorting into left and right specimens, and identifying repeating areas of the element. Age and size of the element were also taken into account in the calculations where possible.

As set out above, there has been much debate about whether to include antler in the quantification of deer from the site. In this study, the calculations of both NISP and MNI include unshed antler which still retained some attached crania, but do not include shed antler, as this material may have been collected from elsewhere and brought to the site for making artefacts. Similarly, bone and antler tools such as barbed points, bodkins and bone chisels are not included in these calculations because these artefacts might have been mobile within the landscape and may have been curated over significant periods of time. For convenience here, even though antler is of course a specialised form of bone, the terms 'bone' and 'antler' are used as separate categories.

Ageing, sexing and palaeopathology

In terms of age assessment, the two main methods used were epiphyseal fusion and tooth development. In general, as an animal ages the bone surfaces become more sculptured, muscle attachments become more pronounced and epiphyseal fusion occurs which obliterates the sutures. The presence of these characteristics can therefore add additional support for differentiation between adult and juvenile remains. Studies by Lesbre (1897–8), Grigson (1982), Purdue (1983) and Fanden (2005) investigated epiphyseal fusion in a number of different taxa, and these studies have been used to assess age for the Star Carr faunal remains. For tooth development, studies by Severinghaus (1949), Habermehl (1961), Briederman (1965), Matschke (1967), Silver (1969) and Hillson (2005) have been used for the different taxa. For some species it is also possible to use tooth wear data to aid with estimations of age (Severinghaus 1949; Aitken 1975; Brown and Chapman 1991a; Brown and Chapman 1991b; Hewison et al. 1999); where possible, these methods of analysis have been applied in this study.

Sex assessment is generally much more difficult to establish, especially in assemblages of archaeological animal bone of this age, due to deterioration and fragmentation. Sexing of the pelves could not be carried out because although some fairly complete specimens were found, the detail was obscured by concretions on the bone surfaces or exploded bone caused by salt crystals, or they had been compressed, warped or highly

demineralised (Chapter 22). The canine teeth of pigs and wild boars were assessed as these show marked sexual dimorphism, allowing the sex identification of mandibles and maxillae. Metric analysis of the bones for size comparisons to published datasets of comparable species is another way to aid sex identification; however, this is highly dependent on good preservation levels (Klein and Cruz-Uribe 1984). Legge and Rowley-Conwy (1988) made measurements of the astragalus, metacarpal, scapula and humerus, measuring the width of the distal end (Bd) and the thickness (Dd) after von den Driesch (1976). However, due to issues of compression, demineralisation and bloating this was not possible for the majority of bones recovered during the recent excavations. Only the astragalus of aurochs could be assessed in this way. In addition, calculations for age and sex were not possible for bones from the dryland due to poor preservation and high fragmentation of the material.

Palaeopathological changes can be assessed by looking for bone modification, either in terms of the bone structure or appearance of an element. There are many different ways in which pathologies can exhibit themselves on a skeleton. Arthropathies are pathologies of the joint, and this can encompass arthritic changes such as lesions on the articular surfaces or osteophyte formation (bony lipping or spurs occurring at the joints) and changes caused by rapid weight gain or uneven weight distribution across the limbs such as osteochondrosis (localised articular lesions caused by malformation of subchondral bone), for example. Various diseases can also exhibit themselves within the skeleton, such as periodontal disease which can affect the mandible and maxilla, causing a widening of the tooth sockets, and can result in the eventual loss of teeth. Trauma to the skeleton can also be exhibited and recorded, for example healed breaks, blunt force traumas or evidence of human damage such as projectile perforations. Very few specimens exhibit evidence of pathological alterations (n=7) and the evidence is often very subtle. The majority of instances are healed fractures on ribs (n=4) which are a result of wounding, possibly from red deer rutting, or possibly from a hunting incident. One of the large mammal ribs with a healed break just below the proximal head also exhibits an area of eburnation (polish) to the articular surface of the rib head. This is generally associated with bone rubbing on bone and is a diagnostic feature of osteoarthritis.

Seasonality assessments

The interpretation of seasonal occupation of the site is, for the most part, reliant on the ability to assess the age and development stage of the animal remains found there. By using information such as tooth development and epiphyseal fusion to age the faunal remains, it is often possible to estimate the age at death, and from this the time of year these animals died through an understanding of breeding and birthing patterns. For example, red deer in Britain tend to begin mating in September/October each year and their gestation period is typically around eight months. The young are therefore born in May/June (Dobronika 1988). Combining this information with the data gathered from age assessment at death, it should be possible to approximate the season of death. Other methods used to interpret seasonality information include the development and shedding of deer antler (which today in Britain occurs between March and April), and the combination of age data and seasonal migration patterns of certain species such as birds.

Stable isotope analysis

Carbon (δ^{13}C) and nitrogen (δ^{15}N) stable isotope analysis was undertaken on five faunal remains from the assemblage. One dog (*Canis familiaris*) and four red deer specimens were sampled; one of the latter was taken from a worked antler frontlet. Analysis followed a modified Longin collagen extraction protocol using ultra-filtration (30kDa MWCO) on c. 100–200 mg of bone (Brown et al. 1988; Richards and Hedges 1999; Colonese et al. 2015). The analysis was undertaken in order to contribute to the existing isotopic dataset for the site. Interest was particularly focused on comparison of the isotope values generated here with those previously obtained from the site (e.g. Schulting and Richards 2000; 2002a; 2002b; 2009), which have resulted in much debate surrounding potential movement of human populations between the coast and inland during the Early Mesolithic (Clutton-Brock and Noe-Nygaard 1990; Day 1996b; Schulting and Richards 2002a; Dark 2003; Schulting and Richards 2009). We also aimed to investigate the potential of any isotopic differences between the individual elements of red deer and the antler frontlet.

Samples were initially cleaned manually using a scalpel, and then were demineralised in 0.6 M aq. HCl solution at 4°C, and the resulting insoluble fraction was gelatinised in pH3 HCl for 48h at 80°C. The super-natant solution was then ultrafiltered (30kDa MWCO, Amicon) to isolate the high molecular weight fraction, which was then lyophilised. Purified collagen samples (1 mg) were analysed in duplicate by Elemental Analy-sis Isotope Ratio Mass Spectrometry (EA-IRMS) on a Sercon GSL analyser coupled to a Sercon 20-22 Mass Spectrometer at the University of York. Accuracy was determined by measurements of international standard reference materials within each analytical run. These were IAEA 600 $\delta^{13}C_{raw}$ = -27.9 ± 0.1, $\delta^{13}C_{true}$ = -27.8 ± 0.1, $\delta^{15}N_{raw}$ = 0.6 ± 0.1, $\delta^{15}N_{true}$ = 1.0 ± 0.2; IAEA N2 $\delta^{15}N_{raw}$ = 20.5 ± 0.1, $\delta^{15}N_{true}$ = 20.3 ± 0.2; IA Cane, $\delta^{13}C_{raw}$ = -11.8 ± 0.1; $\delta^{13}C_{true}$ = -11.6 ± 0.1. The overall uncertainties on the measurements of each sample were calculated based on the method of Kragten (1994) by combining uncertainties in the values of the international refer-ence materials and those determined from repeated measurements of samples and reference materials. These are expressed as one standard deviation (1σ). In addition, a homogenised bovine bone extracted and analysed within the same batch as the samples produced the following values; $\delta^{13}C$ = -22.9 ± 0.1; $\delta^{15}N$ = 7.0 ± 0.2. The overall mean value among 50 separate extracts of this bone sample produced values of $\delta^{13}C$ = -23.0 ± 0.7 and $\delta^{15}N$ = 6.7 ± 0.4. Stable isotope values are presented here relative to the internationally defined standards of VPDB for $\delta^{13}C$ and AIR for $\delta^{15}N$.

Collagen quality fell within reported ranges (DeNiro 1985; van Klinken 1999). Collagen yields were calcu-lated from retentate samples only, following ultrafiltration. Variability was seen in the yields obtained from the samples, from 22.5% in the one dog sample, but ranging from 2–12% for the deer samples; however, all samples exhibited acceptable atomic C:N ratios of between 3.3–3.4.

Taphonomic analysis

Introduction

Chapter 22 sets out the results of the bone degradation at Star Carr. In sum, the bone found on the dryland is very friable which has resulted in serious difficulties for the zooarchaeological assessment. It was possible to identify some specimens to taxa using ZooMS but other standard methods such as identification of elements, anatomical distributions, sexing and ageing proved problematic. Some of the bone that does survive appears to have been quickly buried within the sediment following deposition. Any bone which had not been immedi-ately buried is likely to have been subject to a variety of taphonomic factors such as clearing, dog-gnawing and trampling. It is impossible to quantify how much bone has completely deteriorated from this part of the site but it is highly likely that we are only seeing a very small percentage of what was originally there.

As seen in Chapter 22, the bone from the wetland has been subjected to high levels of acidity though this varies in strength across the site. The bone found in Clark's area was better preserved than elsewhere (the Clark backfill assemblage and the material obtained during the most recent excavations), perhaps because the bone was deposited as a dump, which might have helped buffer the acidity, and it was also surrounded by less acidic/near neutral backfill. In addition, these bones were probably deposited in shallow water, meaning they were less prone to other destructive factors such as dogs and trampling. Preservation in other areas of the wetland var-ies significantly and the presence of 'jellybone' (see Chapter 22) suggests much bone has probably disappeared completely due to the high levels of acidity. Even in the small pocket of less-acidic sediment to the south of the detrital wood scatter it is important to note that severely deteriorated bone has been found (Chapter 22).

The only evidence of natural taphonomic occurrences is the rounding and smoothing of the edges of bones. For the most part this is found within the waterlogged deposits of Clark's area (n=18) and Clark's backfill (n=8) and is likely the result of water flowing over the bones. There are also four specimens from the dryland which exhibit similar rounding, and this will occur when sediment moves over exposed bone, or bone is left lying exposed on the ground surface for a while (Klein and Cruz-Uribe 1984).

Anthropogenic factors

The different types of taphonomy related to anthropogenic factors were examined by area (Table 23.3). In Clark's area, most signs of modification are present, bar heating, and here percussion breaks are present on 39%

of the bone found. The prevalence of anthropogenic modification in this area is most likely due to the large numbers of bone found as opposed to a real pattern: loss of bone elsewhere on site means the areas are not directly comparable. Spiral fractures and percussion breaks are found in all areas of the site and are the result of people using heavy objects, such as stones or rocks, to break into the central cavity of the bones in order to retrieve the marrow (Figures 23.2 and 23.3). Although it should be possible to achieve this goal by producing

Figure 23.2: Photograph of an example of a percussion breakage, and clear percussion point, on the faunal remains from Star Carr (red deer radius <109242>) (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 23.3: An example of longitudinal splitting on a red deer tibia <110290> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

only one break, there are several examples of fractures occurring to both ends of a long bone, removing both the proximal and distal articular ends. For these specimens it appears likely that after the marrow was extracted, the long bone was prepared for tool production.

Marks created by cutting or scoring are rarely found, with the majority of examples coming from Clark's area, probably due to better conditions in this area. A large number were found on ribs (n=54): there was no clear patterning, with cut marks occurring along the full length of the rib, and they occur on the ventral and dorsal aspects, suggesting they represent a mixture of both skinning and dismembering activities. Cut marks have also been observed around the joints and along the midshaft of long bones, providing evidence of muscle and ligament removal during dismemberment, and on the cortical bone surfaces of crania and antler frontlets, providing evidence of skinning.

Bones which have been longitudinally split are found from most areas of the site, with the exception of the western platform and to the north of Clark's area, though due to small numbers of bone in these areas this is unlikely to be a significant pattern. The percentage of split bone is always under 10%. This type of modification was predominantly found on long bones (n=65; 90.3%), and is part of the process of bone tool manufacture.

In terms of human modification, Clark's area exhibits all of the different types of human interaction with the most common forms being for marrow extraction (percussion breaks and spiral fractures) (Table 23.3). Both of these techniques can also been seen in all areas across the site. Interestingly, both Clark's backfill and the detrital wood scatter assemblages exhibit a similar range of activities to Clark's area, but in smaller numbers.

Evidence of heating (in the form of blackening, charring or calcination) is lacking from large areas of the site (Figure 23.4). Due to the conditions of the bone and the staining from the peat it is very difficult to identify signs of heating; however, a total of 500 fragments of bone (43 hand collected bones and 447 from flotation) exhibit evidence of heat exposure. Of these remains, the majority were found on the dryland (n=486), 11 were found in Clark's area and three in Clark's backfill. Of the dryland heat affected specimens, the main concentration is from within and around the eastern structure (n=431).

The affected specimens were found to exhibit evidence of having been heated to varying degrees (Table 23.4): burnt/blackened (n=84), charred (n=170) and calcined (n=246), suggesting fires of varying different heat intensities and durations. The material from the dryland mainly consists of bone that was intensely heat exposed (calcined), but there is evidence of bone from the full range of heat exposures. In terms of the material from Clark's area, 11 fragments exhibit evidence of heating, and they also illustrate the full range of colour change.

		Clark's		Wetland							
	Detrital wood scatter (n=160)	Clark's area (n=560)	Clark's backfill (n=331)	Central platform (n=24)	Eastern platform (n=34)	Western platform (n=20)	Wood peat (n=157)	Marl (n=11)	Bead area (n=13)	Test pits (n=11)	Dryland (n=601)
Spiral fractures	13 (8.1)	99 (17.7)	36 (10.9)	3 (12.5)	6 (17.6)	3 (15)	11 (7)	3 (27.3)	3 (23.1)	6 (54.5)	33 (5.5)
Percussion breaks	18 (11.3)	219 (39.1)	66 (19.9)	6 (25)	9 (26.5)	3 (15)	14 (8.9)	2 (18.2)	5 (38.5)	2 (18.2)	12 (2)
Cut marks	1 (0.6)	93 (16.6)	18 (5.4)								2 (0.3)
Longitudinally split	2 (1.3)	23 (4.1)	15 (4.5)	1 (4.2)	3 (8.8)		8 (5.1)	1 (9.1)			17 (2.8)
Groove-and-splinter	5 (3.1)	3 (0.5)	3 (0.9)	4 (16.7)	3 (8.8)	3 (15)	4 (2.6)				2 (0.3)
Worked (antler)	5 (3.1)	2 (0.4)	5 (1.5)	1 (4.2)	2 (5.9)	1 (5)	1 (0.6)				

Table 23.3: Total number (and percentage) of the types of taphonomy exhibited for the excavated faunal remains within each area of the site.
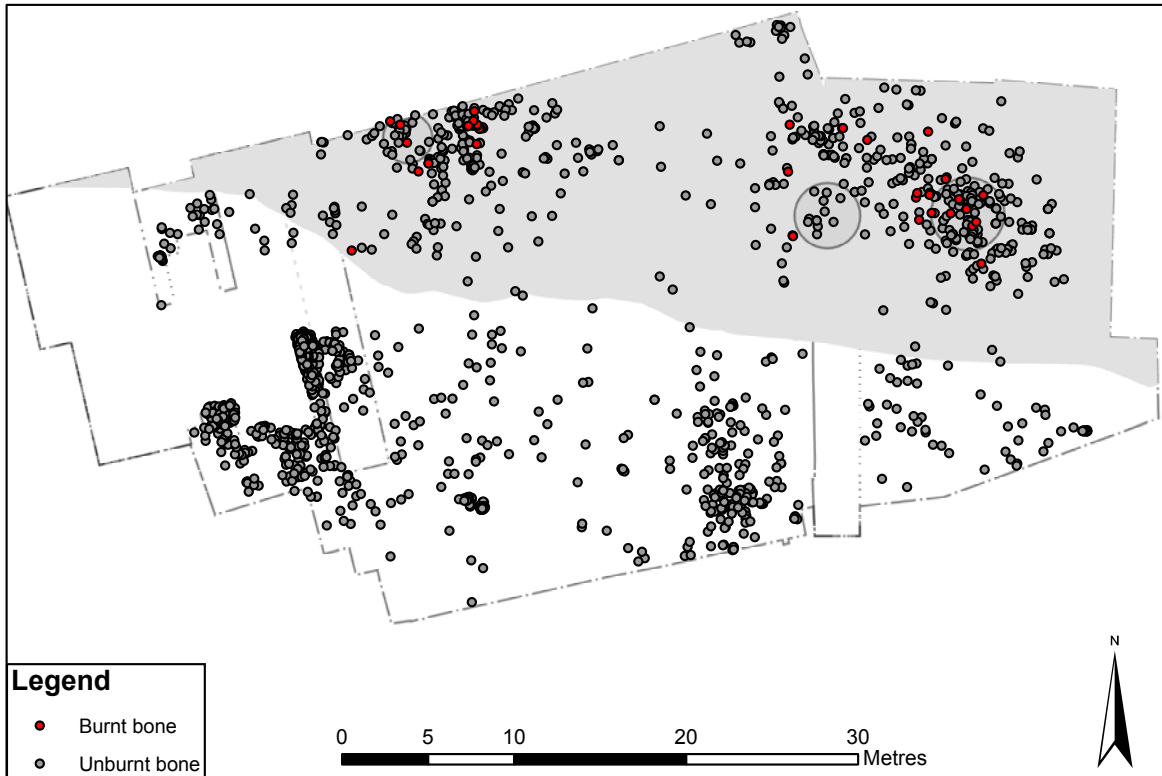
Figure 23.4: Plot showing the number and distribution of the hand-collected heat-affected bone compared to unburnt bone (Copyright Star Carr Project, CC BY-NC 4.0).

Area	Feature	Burnt (blackened)	Charred (black/grey)	Calcined (white)
Eastern structure	Central hollow	49	148	175
	Posthole [169]	1	15	28
	Posthole [185]			3
	Pit [177]			3
	Surrounding area	3	2	4
Central structure	Pit [336]	19		6
	Posthole [382]			
	Surrounding area			1
Northern structure	Posthole [358]			
	Posthole [459]			1
	Surrounding area	1		1
West of northern structure	Posthole [462]			9
Western structure	Central hollow	2		
	Surrounding area	1		14
Clark's area	Clark's baulk	7	3	1
Clark's backfill	Backfill	1	2	

Table 23.4: Number of fragments of bone exhibiting evidence of heat exposure (excavated and bone recovered from flotation).

		Clark's		Wetland							
	Detrital wood scatter (n=160)	Clark's area (n=560)	Clark's backfill (n=331)	Central platform (n=24)	Eastern platform (n=34)	Western platform (n=20)	Wood peat (n=157)	Marl (n=11)	Bead area (n=13)	Test pits (n=11)	Dryland (n=601)
Tooth impressions	1 (0.6)	14 (2.5)	7 (2.1)						1 (7.7)	1 (9.1)	
Tooth scores	3 (1.9)	12 (2.1)	4 (1.2)						1 (7.7)	1 (9.1)	
Uneven breakage	4 (2.5)	20 (3.6)	2 (0.6)	1 (4.2)					1 (7.7)	1 (9.1)	

Table 23.5: Total number (and percentage) of the animal modification exhibited for the excavated faunal remains within each area of the site.

The focus of these heat affected fragments of bone around the different structures on the dryland is very interesting. The eastern structure contains the most evidence, particularly within the central hollow, suggesting the presence of a hearth within the structure or possibly distribution of fire ash across the structure floor during hearth clearance. The other possibility is that the structure may have burnt down; however, this probably would have resulted in greater quantities of burnt material in this area. The heat-affected bone may also be the result of cooking, but gentle heating for marrow extraction purposes, bone waste disposal and accidental heating cannot be discounted.

Modifications by animals

Three types of modification by animals have been observed: tooth impressions, tooth scores and uneven breakage (which is often associated with one or both of the other two characteristics). A total of 50 specimens exhibit these modifications and they are found across the entire site (Table 23.5).

Long bones are the most common elements affected (n=19), along with ribs (n=9) and podial elements (n=8). The remainder are all represented by elements that could be considered to be waste products of butchery and are not meat-bearing (vertebrae, pelvis, scapula), so may be easily scavenged from a processed carcass. Interestingly, one red deer antler frontlet from Clark's area (<116888>; Chapter 26) also exhibits tooth impressions and score marks consistent with a small amount of carnivore activity.

The majority of modifications were consistent with wolf or dog gnawing: chewing concentrated on the ends of long bones (Figure 23.5) or the edges of fragments, and on elements at the joints such as the podial elements; and tooth impressions and tooth scores at the edges of elements (Figure 23.6) (Shipman 1981, in Lyman 1994). There is one exception: a wild cat humerus <116175> has tooth impressions around the edge of the proximal articular surface consistent with feline teeth, possibly another wild cat, or mustelid teeth.

The detrital wood scatter, Clark's area, north of cutting III (the bead manufacturing area), test pits and Clark's backfill all provide evidence for all three types of modification, with additional evidence of uneven breakage from the central platform. Given that dog bones have been found on site, it is not surprising that such evidence exists. The lack of evidence from other areas is more likely to be a factor of taphonomy due to deterioration than a real pattern: the numbers of bone found in the wetland is relatively small and the bone from the dryland is badly degraded and unlikely to show such modifications. The fact that this evidence does survive in some places suggests that bone was subject to animal gnawing, and there is a strong likelihood that much bone was destroyed during the occupation of the site through this process.

Discussion

A number of different factors have influenced the preservation of bone from Star Carr. The damage caused by the acidification of the deposits is impossible to quantify; however, because a number of 'jellybones' have been found and some areas have produced very small quantities of faunal remains (such as the western platform), the likelihood is that significant quantities may have been lost in some areas.

Figure 23.5: Photograph of the uneven (ragged-edge) breakage associated with carnivore gnawing on the proximal head of an ulna <109243> found in the area of the detrital wood scatter (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 23.6: Photograph of carnivore gnawing on a red deer navicular-cuboid <108662>, from the detrital wood scatter, with clear tooth impressions (on the articular surface) (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

On the dryland there is also evidence of severe deterioration of the bone because here the site is not water-logged; this is fairly normal for dryland sites of this period, and the level of degradation is likely to be more or less consistent across the area. However, other factors caused by both humans and animals, such as fragmentation through trampling, working bone for tools and processing it for food, and gnawing by dogs, all have further negative impacts on preservation. From the data it is not possible to assess how significant these actions were, but they are likely to have had an impact across the site.

In sum, as with most sites, we have to interpret the faunal remains data knowing that we are looking at a very partial record. Not only have we excavated less than 10% of the site (potentially missing material deposited in other areas), but the assemblage has been partially destroyed by acidity in the wetland, oxidation on the dryland, carnivores and a multitude of human actions in the Mesolithic period related to consumption practices, tool making and deposition of remains in various parts of the landscape. It is with these caveats in mind that the faunal remains analysis was undertaken.

Results

Overall quantification

NISP by taxa

A total of 2414 specimens of bone and antler were found from the site (Figure 23.7). Of these, 1925 archaeological bone and antler specimens were recovered through excavation on site (Figure 23.8), and 489 small fragments were recovered from flotation of soil samples. A further 12 have not been included in the analysis since they are undoubtedly intrusive (mole, rabbit, modern cattle, modern dog), or were found within re-deposited upcast from the nearby River Hertford.
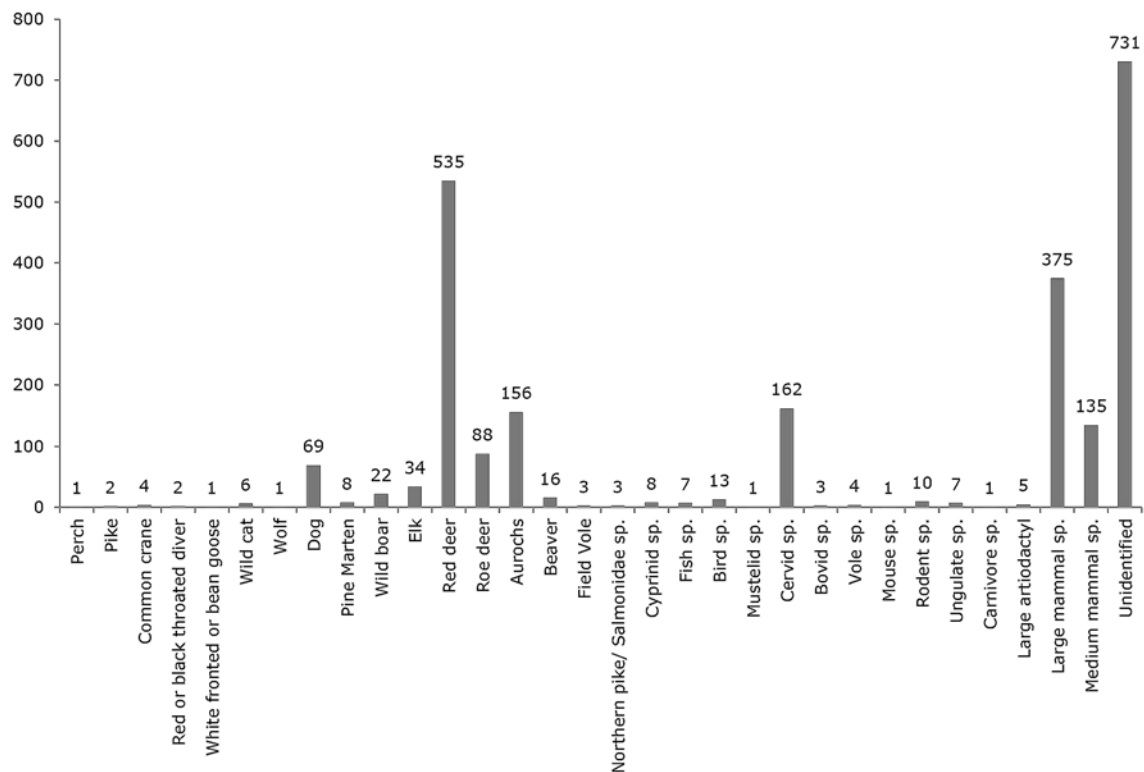
Figure 23.7: NISP of the taxa for the whole site (hand excavated and flotation) (Copyright Star Carr Project, CC BY-NC 4.0).
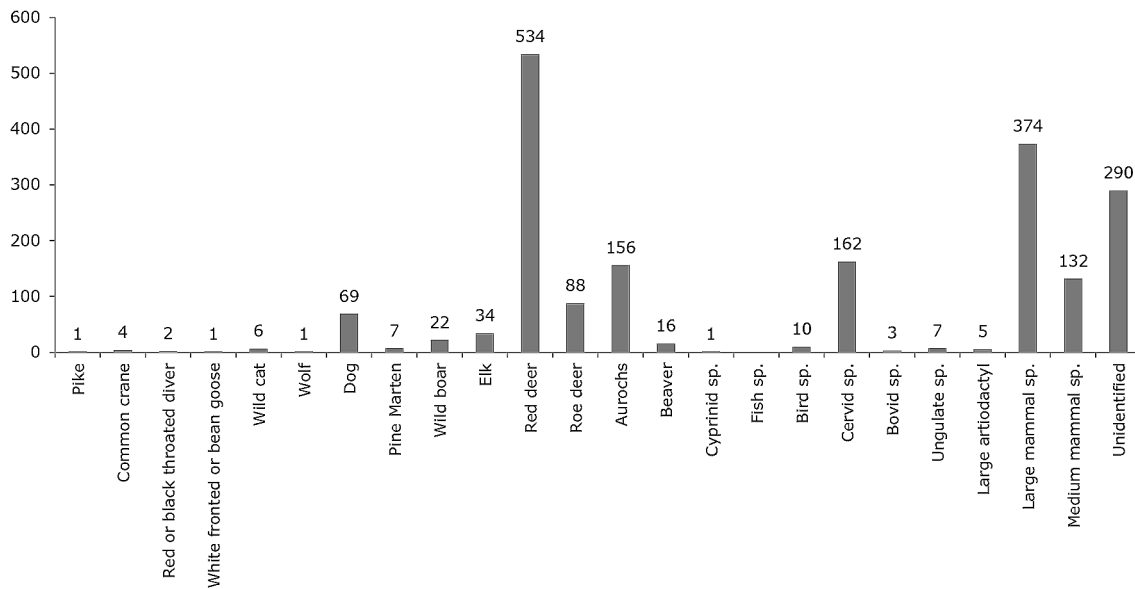
Figure 23.8: NISP for taxa from the hand-excavated faunal remains (not including flotation remains) (Copyright Star Carr Project, CC BY-NC 4.0).

A total of 16 species were identified, 12 of which had been found previously, and four of which were new: wild cat (*Felis silvestris*), field vole (*Microtus agrestis*), northern pike (*Esox lucius*) and European perch (*Perca fluviatilis*). The fish species are particularly significant because of the debate concerning the apparent lack of fish remains at Star Carr (Wheeler 1978). It is also noteworthy that microfaunal remains such as field vole, which have never been recovered before from Star Carr, have now been discovered through flotation.

The NISP values illustrate the dominance of red deer remains within this assemblage, followed by aurochs, and then roe deer (Figure 23.8). Dog is also dominant; however, this is represented by one almost complete skeleton which has the effect of skewing the results. In contrast, several species were represented by only a small number of remains: wolf, wild cat, pine marten, beaver, common crane, red- or black-throated diver and white-fronted or bean goose.

The NISP data also shows large numbers of cervid species, large mammals and unidentified bones (Figures 23.7 and 23.8). There were a total of 510 specimens that could only be categorised as medium or large mammals due to fragmentation and poor preservation: 506 excavated and four found during flotation. Of the 510 specimens, 375 were identified as belonging to large mammals (374 excavated and one from flotation) and 135 as medium mammals (132 excavated and three from flotation). There were also 162 specimens that could only be identified as cervid species (Figure 23.8). A further 731 could not be assigned to either species or general category and so were labelled 'unidentified' (290 from excavated deposits and 441 fragments from flotation) (Figure 23.7).

Of the 489 fragments of bone found through flotation, the majority of specimens were found from the eastern structure, the central structure, the possible northern structure and Clark's area. Seven fragments can be identified to species: perch, northern pike, pine marten, red deer and field vole (Figure 23.9). There are also a number of fragments that can only be identified to family, genus or medium/large mammal (n=41) and the majority (n=441) were unidentified, either due to the small size of the fragments or due to taphonomic processes affecting the preservation.

The category of 'cervid species' includes specimens that could be elk, red deer or roe deer. Of the elements identified only as cervid species, a large number were identified by ZooMS, mainly due to the bone fragments being either too poorly preserved or too small to identify macroscopically. This is reflected by the large number of specimens that were identified as 'cervid species' by ZooMS but could not be identified to element (n=78) (Figure 23.10).

Figure 23.9: Number of fragments recovered by flotation and sieving of soil samples and identified to taxa (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 23.10: NISP of the elements for the cervid species category (Copyright Star Carr Project, CC BY-NC 4.0).

The category of 'large mammal' includes specimens where it was not possible to distinguish between elk, red deer and aurochs. This category (Figure 23.11) was represented by a range of elements, with the majority identified as ribs (n=173) and long bone fragments (n=65).

A similar pattern can be seen for the elements that can only be identified as 'medium mammal species' (Figure 23.12). This category includes roe deer, wild boar, dog, wolf and wild cat. A range of elements can be identified for this category, the most dominant being ribs (n=83) followed by long bone fragments (n=18).

Although not much can be said about these three broad categories due to the large number of taxa they include, it is important to note the abundance of ribs and long bones, suggesting some of these elements will be missing from the taxa they represent: ignoring these elements when discussing the individual species creates a biased view of the assemblage. Unfortunately this is likely to have been the case in past analyses for this dataset (e.g. Clark 1954; Legge and Rowley-Conwy 1988), due to the large proportion of these types of elements that were found in Clark's backfill.

In terms of the flotation specimens, a range of different elements were represented with the majority being identified as fragments of loose teeth (Figure 23.13) from species of rodent (field vole: n=3, rodent species: n=5, vole species: n=3), fish species (cyprinid species: n=2, pike/salmon species: n=3), carnivore species (n=1) and red deer (n=1). In terms of the vertebrae fragments, most belong to cyprinid species (n=4) and fish species (n=3), with one identified as perch. The majority or ribs are identified as rodent species (n=3) but also fish species (n=2), cyprinid species (n=1), mustelid species (n=1) and medium mammal (n=1).

Figure 23.11: NISP of the elements for the large mammal category (excluding flotation data) (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 23.12: NISP of the elements for the medium mammal category (excluding flotation data) (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 23.13: Number of fragments of bone identified to element from the flotation samples (Copyright Star Carr Project, CC BY-NC 4.0).

Results by species

Fish

In total, 21 fish remains have been recovered from the site; however, it is likely that these represent only a fraction of the overall assemblage. In Clark's area, there was better preservation than elsewhere allowing for the recovery of six fish remains. Two of these were found by hand during the excavation of the reed peat (312) and were located approximately 5 m away from one another (Figure 23.14; Figure 23.15). The remainder were recovered through bucket flotation in the laboratory from basal deposits in Clark's area and from the fill of the hollow of the eastern dryland structure (context 149).

Of the 21 remains, 14 could be identified to family or species (Table 23.6). The assemblage was dominated by Cyprinidae (the majority of British freshwater fish species including carps and minnows), followed by northern pike/Salmonidae (*Esox lucius* L., 1758/salmons, trouts, chars and whitefishes), northern pike and European perch (*Perca fluviatilis* L., 1758). There were 12 postcranial elements and nine cranial elements.

Although identification was attempted to genus and species, 11 specimens from two families could not be further identified. Of these two families, two Salmonidae species and nine Cyprinidae species have been previously identified in contemporaneous faunal assemblages throughout Northern Europe (Aaris-Sørensen 1976; Richter 1982; Zabilska-Kunek 2014; Zabilska-Kunek et al. 2015): brown trout (*Salmo trutta* L., 1758), Atlantic salmon (*Salmo salar* L., 1758), white bream (*Blicca bjoerkna* L., 1758), common bream (*Abramis brama* L., 1758), Crucian carp (*Carassius carassius* L., 1758), common carp (*Cyprinus carpio* L., 1758), asp (*Aspius aspius* L., 1758),

Trench	Context	Skeletal element	Taxon
SC23	149	Unknown vertebra	cf. Cyprinidae
SC23	149	Pharyngeal tooth	Cyprinidae
SC23	149	Caudal vertebra	Cyprinidae
SC23	149	Rib	Cyprinidae
SC23	149	Caudal vertebra	Cyprinidae
SC23	149	Premaxilla	*Esox lucius*
SC23	149	Tooth	*Esox lucius*/Salmonidae
SC23	149	Tooth	*Esox lucius*/Salmonidae
SC23	149	Tooth	*Esox lucius*/Salmonidae
SC23	149	Vertebral fragment	*Perca fluviatilis*
SC23	149	Vertebral fragment	Unidentifiable
SC23	149	Vertebral fragment	Unidentifiable
SC23	149	Vertebral fragment	Unidentifiable
SC23	149	Rib/spine	Unidentifiable
SC23	149	Rib/spine	Unidentifiable
SC34	312	Pharyngeal bone with tooth	Cyprinidae
SC34	312	Pharyngeal tooth	Cyprinidae
SC34	312	Posterior abdominal vertebra	*Esox lucius*
SC34	Basal deposits	cf. posterior abdominal vertebra	Cyprinidae
SC34	Basal deposits	Unknown	Unidentifiable
SC34	Basal deposits	Unknown	Unidentifiable

Table 23.6: Contextual information and skeletal elements of the various fish identified in the assemblage.
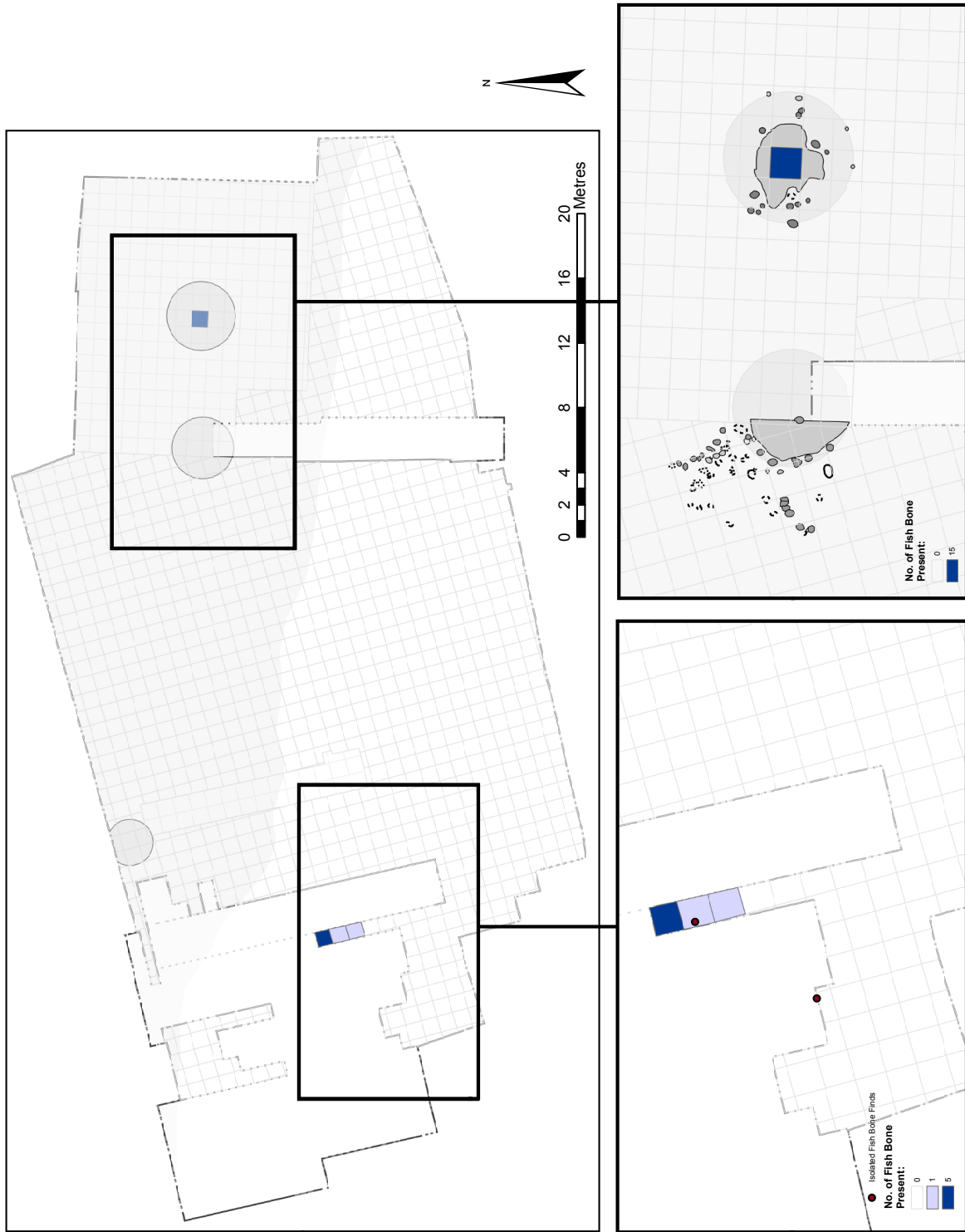
Figure 23.14: Location of the fish remains on site (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 23.15: Photograph of the northern pike posterior abdominal vertebra in situ. Scale: 9.1 mm across the greatest cranio-caudal length of the centrum (Copyright Harry Robson, CC BY-NC 4.0).

ide (*Leuciscus idus* L., 1758), roach (*Rutilus rutilus* L., 1758), common rudd (*Scardinius erythrophthalmus* L., 1758) and tench (*Tinca tinca* L., 1758).

The identified species spectrum consisted of freshwater fish. Northern pike and European perch are often termed stationary freshwater fish although they can also reside in weakly brackish waters. In general, they commonly occur in stagnant or gently flowing reaches of a river (Brinkhuizen 2006).

An estimation of total fish length (TL) was attempted for all specimens that were identified to the family or species. By estimating TL it is possible to determine whether or not the assemblage was anthropogenically or naturally derived. For example, if numerous species ranging in size are represented in a given assemblage, an argument in favour of a natural death assemblage can be put forward. However, if the assemblage is dominated by one species that are generally similar in size, the assemblage can be interpreted as anthropogenic, and the data probably represents the 'selective killing of fish of a certain size' (Noe-Nygaard 1995, 170). In addition, since TL is inter- and intra-species specific, size estimates can add weight to seasonality. For instance, the European eel (*Anguilla anguilla*) is sexually dimorphic; thus if a size frequency diagram demonstrates that the majority of eels were over 0.55 m in total length, then it can be argued that females were probably targeted during their autumnal migrational run (since males do not exceed 0.5 m) (Tersch 2003).

Given the incompleteness of the specimens it was only possible to estimate the TL for seven of the specimens. Based on comparison with modern skeletons of known taxa, one northern pike specimen was estimated to be <0.2 m in TL, whilst the posterior abdominal vertebra was estimated to have derived from an individual with a TL of c. 0.7 m (Robson et al. 2016). In addition, it was possible to estimate the TL for four of the Cyprinidae specimens. Based on comparison with modern skeletons of known taxa, these are estimated to have derived from specimens that were <0.2 m in TL. Furthermore, it was estimated that the one European perch specimen in the assemblage was derived from an individual that was <0.1 m in TL (Robson et al. 2016).

Whilst preservation on site was variable, it is unlikely to have impacted TL. The one pike posterior abdominal vertebra was in a very good state of preservation and had not been subjected to compression or warping.

On the other hand, the majority of the fish remains recovered from within the structure were calcined, which is likely to have affected their structure and size. For these reasons broad estimates (i.e. 0.1 m increments) were employed. Overall, the majority of the fish remains derived from small individuals, <0.2 m, with the exception of the pike posterior abdominal vertebra. Although the sample size is very small, the fish sizes coupled with the microwear analysis on the flint (Chapter 8; Robson et al. 2016) demonstrate that the assemblage was anthropogenically derived. Moreover, the data are comparable with the assemblage from the broadly contemporary Early Mesolithic site of Friesack IV (Robson 2016).

Birds

Overview

Fraser and King (1954) did not state the NISP values for birds present in the assemblage, though it was noted that not more than one individual of each species was represented. The current analysis found 20 bird specimens (2 from flotation): common crane (n=4), red-/black-throated diver (n=2), white-fronted/bean goose (n=1) and 13 specimens that can only be identified as belonging to bird species (n=7), large bird species (n=4), medium bird species (n=1) and small bird species (n=1). Of the 20 bird specimens, the majority were found within Clark's area (n=12), with the remainder being found within Clark's backfill (n=4), the dryland (n=3) and a 2005 test pit SC10 (n=1) (Figure 23.16).

It should be noted that during Clark's excavations, a section cut through a bird bone was found, thought to probably represent a bead (Clark 1954, 164). Of the 20 bird bones found here, seven demonstrate signs of human modification: six demonstrate evidence of percussion breaks or spiral fractures; the seventh was found on the dry land and was charred. One of the large bird bones has a cut mark. The breakage of these bones is

Legend

- ● Common crane
- ○ Red or black throated diver
- ● White fronted or bean goose
- ○ Tetraonidae sp.
- ● Large bird sp.
- ● Medium bird sp.
- ○ Birds sp.
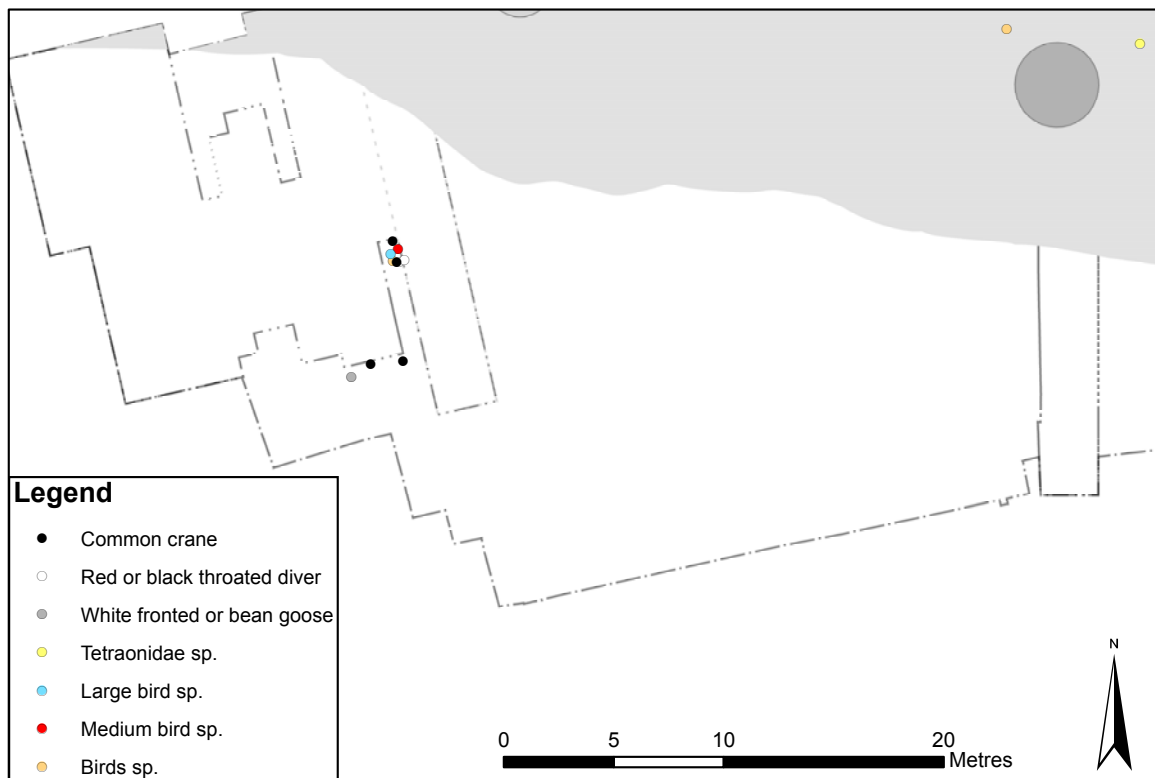
Figure 23.16: Spatial plot of the birds found at Star Carr within the main area of excavation (Copyright Star Carr Project, CC BY-NC 4.0).

unusual because there is no marrow in bird bones, so there is the possibility that they are being prepared for bead manufacture.

There is also evidence of what appears to be a healed break to the midshaft of a large bird humerus, which could have occurred in a number of ways; for example related to human action, carnivore action or as a natural accident.

White-fronted or bean goose

The one specimen of goose was found in Clark's area (Figure 23.16). It is identified as the midshaft of an ulna, but due to the partial nature of this element it is not possible to identify the species and it could derive from either a white-fronted or bean goose. The specimen was humanly modified: both the proximal and distal articular ends of the specimen are lacking and the breakage is very uneven and ragged, possibly suggesting a percussion and snapping action. It is not possible to age and sex this specimen. In terms of seasonality, both of these species of geese are migratory birds: today, these geese are only present in this country in the winter but Early Holocene distributions may have been markedly different given the climate data for this site (Chapter 18).

Red- or black-throated diver

Red-throated diver was found in the original assemblage (Clark 1954, 70). The current analysis produced two specimens of diver, consisting of a partial humerus and radius, from within Clark's area (Figure 23.16), but due to the partial nature of the elements it is not possible to identify to species. Both elements exhibit human modification: the humerus represents the proximal half of the element and the distal end has been removed by a percussion break (Figure 23.17); the radius represents the distal half and the proximal end has been removed by a spiral fracture. It is not possible to age or sex these remains. In terms of seasonality, both species of diver are migratory birds and today both species can be found in Scotland and Northern Ireland during the summer months for breeding and around the UK coastline in winter; however, again it is difficult to assess the Early Holocene distribution.

Common crane

Common crane was found in the original assemblage (Clark 1954, 70). A further four specimens were found within Clark's area (Figure 23.18): a partial radius, one complete and one partial carpometacarpus, and a frag-

Figure 23.17: Removal of the distal end of diver humerus <116486> by a percussion break (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 23.18: Spiral fracture to one end of a common crane tibiotarsus midshaft <115281> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

ment of tibiotarsus. The MNI is one. Two of the specimens appear to be humanly modified; one carpometacarpus is missing both its proximal and distal articular ends and the breakage appears to have been caused by percussion, and the fragment of tibiotarsus midshaft has spiral fracture breakage to one end. Unfortunately, due to the fragmentary nature of the elements represented, it is not possible to age or sex these remains. In terms of seasonality, common crane became extinct in the UK in the 1600s, but in recent decades European birds have begun to repopulate East Anglia (Brand, pers. comm. 2016). These populations are not migratory; however, cranes on the continent migrate and spend summer in the north and winter in the south (Svensson et al. 2008).

Carnivora

Wild cat

Given the chronological period in which these remains were associated, it was possible to discount domestic cat and therefore six specimens of wild cat were found. Four of these were recovered from Clark's area and two from the dryland (Figure 23.19). The two elements from the dryland are distal phalanges, both of which are burnt and calcined, and were found next to a spread of burnt flint on the peripheries of the western structure. The wild cat assemblage found in Clark's area consists of a right humerus and radius, a sacrum and a second metacarpal (Figure 23.19), which might even represent one leg, particularly as these remains were found no more than 1.5 m apart at the northern end of the baulk. It is not possible to ascertain whether the phalanges on the dryland are part of the same animal but given that the western structure may date to the same period as the deposition in Clark's area the MNI is one (Figure 23.20).

The wild cat remains from Clark's area are very well preserved. On the proximal head of the humerus, there are some very subtle tooth marks around the edge of the articular surface (Figure 23.21). The size and shape of these tooth marks seem to suggest that they may have been made by another wild cat or a mustelid. The partial radius appears to have suffered from a possible percussion break; however, modern damage has unfortunately obscured the clarity of this modification.
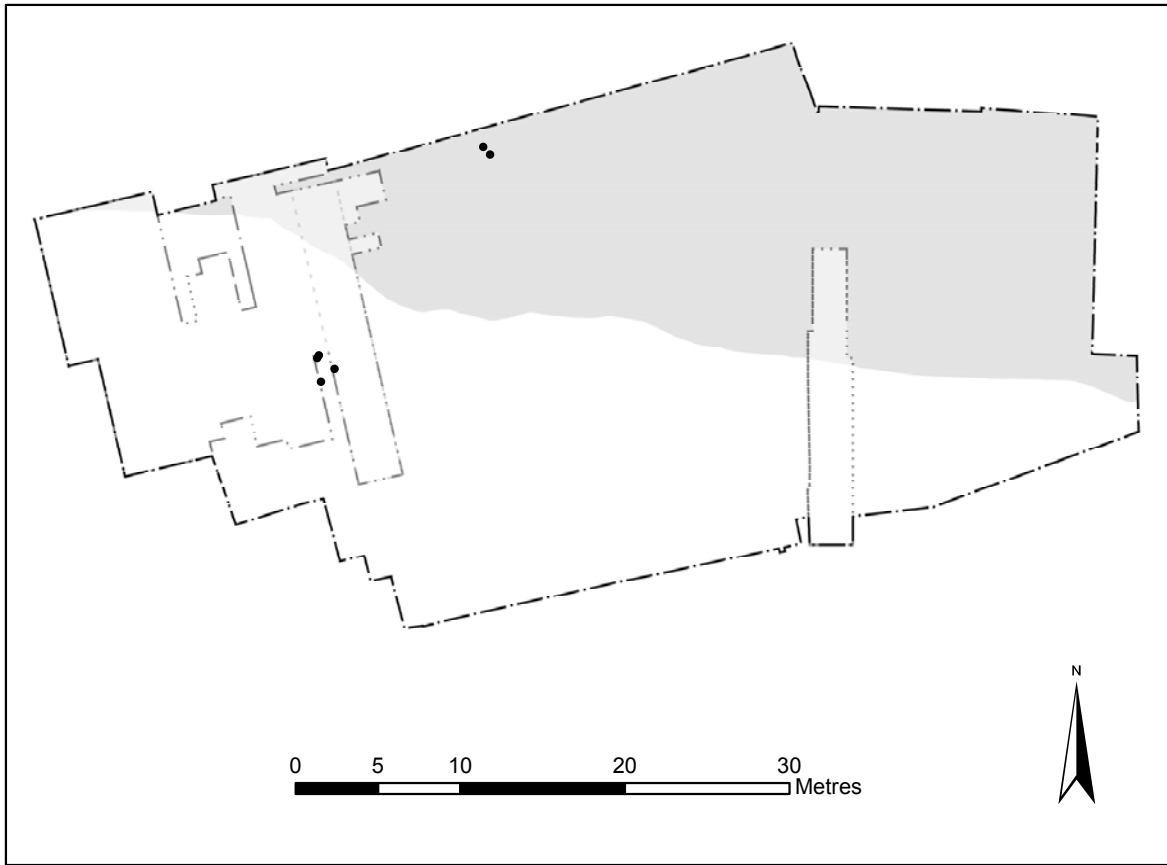
Figure 23.19: Spatial plot of wild cat (Copyright Star Carr Project, CC BY-NC 4.0).

Felis silvaticus
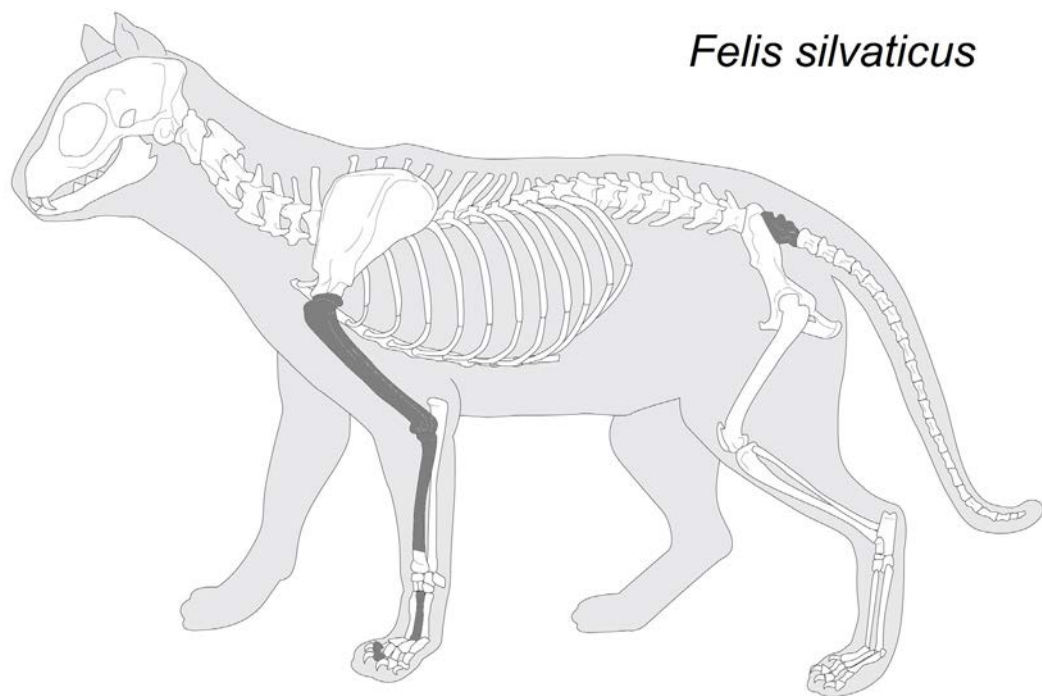
Figure 23.20: Element representation for wild cat (Copyright Archeozoo.org/M. Coutureau 1996. Adapted by Becky Knight).

Figure 23.21: Photograph of a tooth mark to the edge of the proximal head of the humerus <116175> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Wolf

One wolf specimen was found in Clark's area (Figure 23.22), and this was identified as a right second metatarsal from an adult animal. This specimen is attributed to wolf on the basis of its size and length-breadth proportions, considering the size and morphology of other canid remains from the site. The distal head is missing, and the breakage appears to have been caused by percussion damage; however, there is also a small amount of excavation damage to the anterior break edge. Not much can be inferred from this one element, though it is of interest because no other wolf remains have been found from the site: the remains identified as wolf from Clark's excavations were later reassigned to dog.

Dog

Overview

An almost complete skeleton of a dog was found within the peat above the marl (Figure 23.23). Although it was found at the base of the wood peat (310), the date obtained on the left canine (*OxA-33678;* Figure 17.16) dates it to the 90th century cal. BC (Chapter 17). Unfortunately the preservation of the remains is poor with demineralisation and compression of the bones and teeth; in particular, the teeth enamel was splitting and peeling away from the root.

Elements

The majority of the elements were represented (Figure 23.24; Figure 23.25); however, some of the elements from the extremities of the animal were missing, including the majority of the podial elements. Given that these are the smaller, more delicate elements, this may be as a result of the process of degradation. In addition, some elements may have been moved by water at the time of decomposition.

The skeleton was positioned in two separate groupings about 0.5 m apart. Some of the elements of the two groupings were still found to be semi-articulated: from group 1 the humerus, radius and ulna, and the vertebrae were semi-articulated; within group 2, the humerus, radius and ulna, and the femur and tibia were semi-articulated (Figure 23.26; Table 23.7).
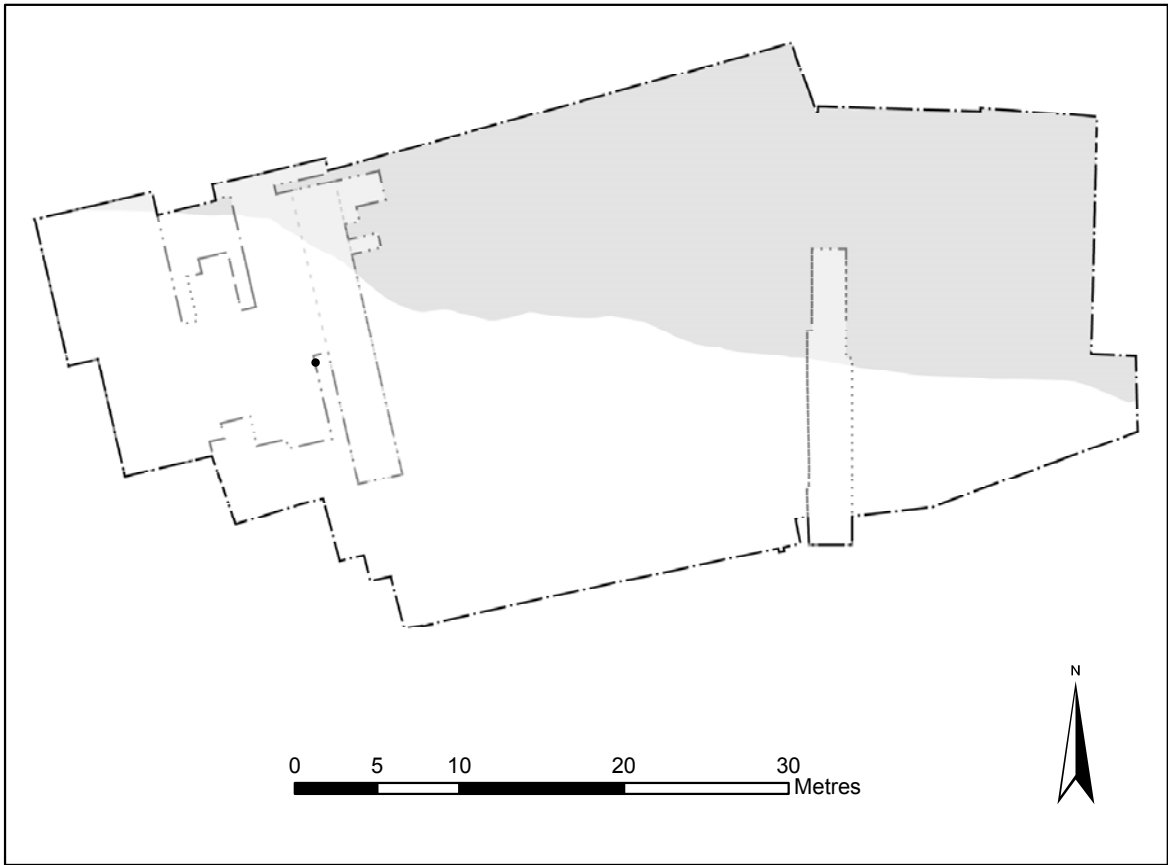
Figure 23.22: Spatial plot of wolf (Copyright Star Carr Project, CC BY-NC 4.0).
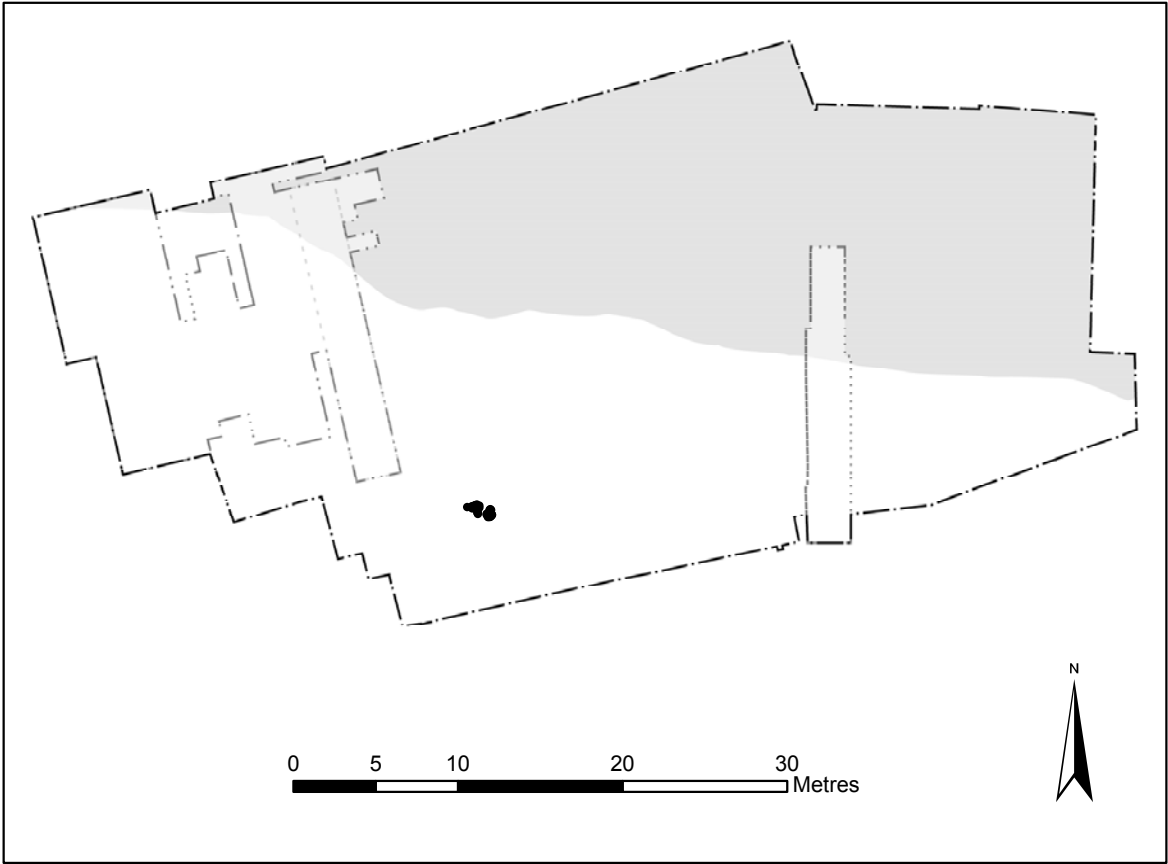
Figure 23.23: Spatial plot of dog (Copyright Star Carr Project, CC BY-NC 4.0).
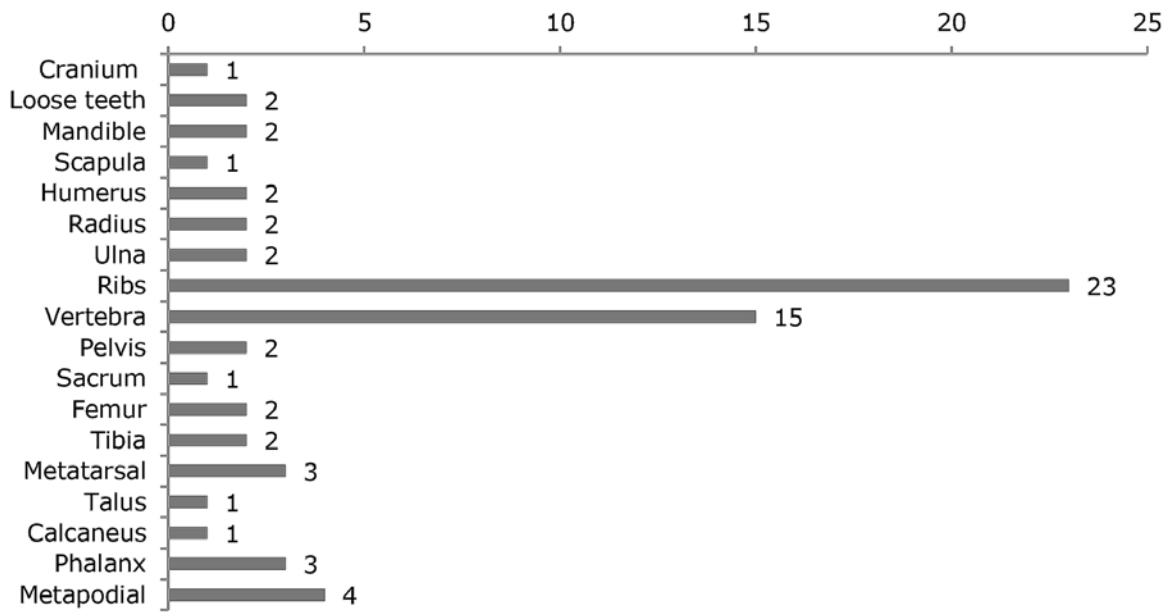
Figure 23.24: NISP of elements represented in the dog skeleton (Copyright Star Carr Project, CC BY-NC 4.0).
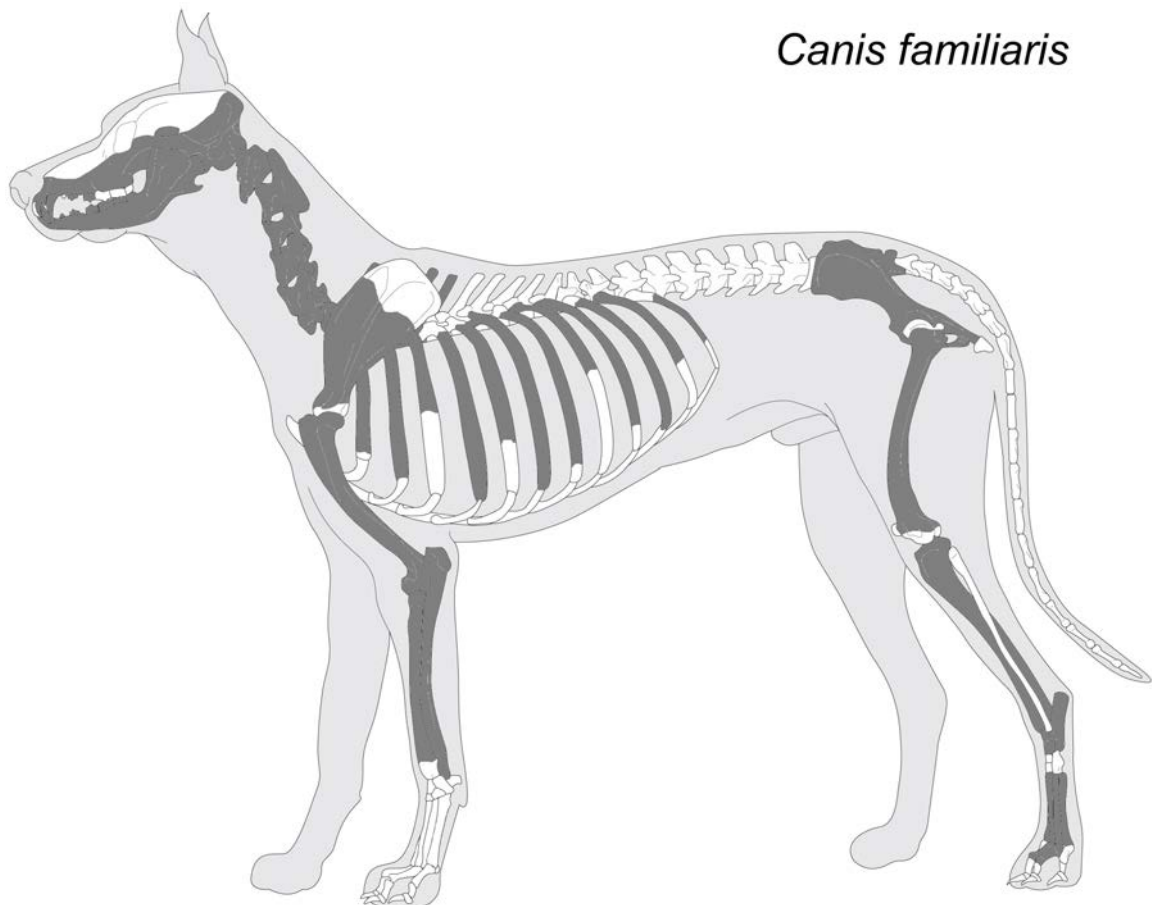
Figure 23.25: Element representation for dog (Copyright Archeozoo.org/M. Coutureau and V. Forest 1996. Adapted by Becky Knight).

Figure 23.26: Photograph of the in situ dog skeleton (group 1= left, group 2= right) (Copyright Star Carr Project, CC BY-NC 4.0).

	Mandible	2		Cranium	1
	Premolar	1		1st molar	1
	Humerus	1		Scapula	1
	Radius	1		Humerus	1
	Ulna	1		Radius	1
	Atlas	1		Ulna	1
	Axis	1		Pelvis	1
Group 1	Cervical vertebrae	9	Group 2	Femur	2
	Thoracic vertebrae	4		Tibia	2
	Ribs	22		Calcaneus	1
	Pelvis	1		Talus	1
	Sacrum	1		Metatarsal	5
				Phalanges	3
				Metapodials	4

Table 23.7: NISP and element distribution of the dog skeleton between the two separate groupings of bone.

This assemblage does not look as if the skeleton has split in half because each group of elements contains a mix of front and back parts of the dog. Given that group 1 is more tightly packed and in basic anatomical position, it seems likely that the bones in group 2 have moved to some degree: here the cranium and some forelimb bones are found with some hind limb bones. This is most likely to be water action: the water would have been flowing in that direction, out of the lake and towards the west. Given the context (shallow water reed swamp environment) and examination of the sediment on site, it is unlikely to have been a formal burial. The dog may have died a natural death in the lake or was placed within the water once it had died.

Age

Only the mandible is complete enough to aid with the age estimation: although the maxilla is present, a large number of teeth are either missing or are too degraded to be assigned. The left side of the mandible contains complete adult dentition. However, the right side contains only partial dentition: the incisors are missing and the third molar has not erupted. It is not possible to make any observations on the tooth wear due to the demineralisation and delamination of the enamel. Although the third molar from the left mandible is fully erupted, the third molar from the right side is still in the crypt. Therefore, based on the dentition, this animal would have been between six and seven months old at death (Silver (1969) and Habermehl (1961) in Hillson (2005)). Due to a combination of the individual being immature and the poor preservation of the bones, it was not possible to assess the size or robustness of the animal.

Isotope values

Due to the lack of human remains on British Mesolithic sites, dogs have previously been used as an analogue for both human diet and movement (e.g. Noe-Nygaard 1988; Fischer et al. 2007; Guiry 2012). This has extended to dog specimens from the Vale of Pickering both at Star Carr and Seamer Carr (e.g. Clutton-Brock and Noe-Nygaard 1990; Day 1996b; Schulting and Richards 2002a; Dark 2003; Schulting and Richards 2009). Both the initial $\delta^{13}C$ and subsequent $\delta^{13}C$ and $\delta^{15}N$ isotopic analysis of dog remains from Seamer Carr yielded values suggested to indicate some degree of marine resource consumption, and therefore potentially reflective of seasonal movements from the coast to the Vale of Pickering (Clutton-Brock and Noe-Nygaard 1990; Schulting and Richards 2002a), although this interpretation has resulted in significant debate (Day 1996b; Dark 2003; Schulting and Richards 2009). Conversely, isotopic analysis of dog remains from Star Carr have thus far indicated no evidence of the consumption of marine resources, and instead have been suggested to reflect a diet based upon terrestrial resources, with some possible freshwater protein input (Schulting and Richards 2002a; 2009).

One left rib sampled from the skeleton found during this excavation yielded sufficient amounts of collagen of suitable quality for $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis (Table 23.8) and exhibited isotopic values comparable to those previously reported for dog remains from Star Carr (Schulting and Richards 2002a; 2009). These results also indicate that this dog was unlikely to have consumed significant quantities of marine protein (Table 23.8; Figure 23.27).

The elevated $\delta^{15}N$ values of the dog remains from Star Carr have previously been interpreted as being indicative of a degree of freshwater resource and/or aquatic bird consumption, or possibly of low levels of marine protein (Schulting and Richards 2002a). The $\delta^{15}N$ value of 10.5‰ for the newly excavated Star Carr dog falls in line with these previous interpretations. In particular, when we consider the available isotope values for terrestrial herbivores from Star Carr (Table 23.11; Schulting and Richards 2009), it can be seen that the dog values fall more than a trophic level (3–5‰) above these, therefore indicating that there must be additional protein source(s) in the diets of the dogs. Given the isotopic data already available for the site, it seems most probable

Sample No.	Element	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C:N	Collagen yield
108261	Rib	−20.3 ± 0.1	10.6 ± 0.2	3.4	22.5%

Table 23.8: Carbon and nitrogen stable isotope data of the dog.
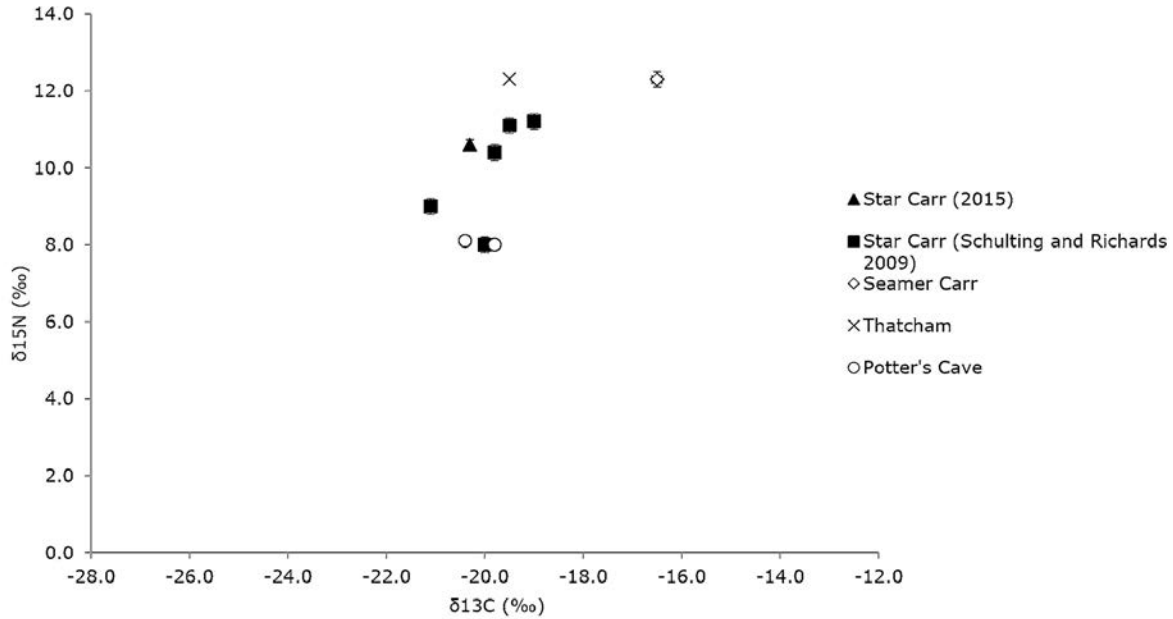
Figure 23.27: Dog isotope data from several British Mesolithic sites (data compiled from Schulting and Richards 2000; 2002a; 2002b; 2009; this study) (Copyright Star Carr Project, CC BY-NC 4.0).

that the Star Carr dog analysed here consumed a non-marine diet which comprised a degree of freshwater resource consumption. This therefore also lends weight to the hypothesis put forward by Schulting and Richards (2009) that movements to and from the Vale of Pickering and the coast were possibly not a particularly regular occurrence. Alternatively, perhaps, dogs did not often accompany people to the coast.

Pine marten

Pine marten was found in the original excavations (Fraser and King 1954, 71) and included cranial elements, long bones and ribs, with an estimation of at least two animals. A total of seven specimens of pine marten were recovered from the recent excavations: six from Clark's area and one from the detrital wood scatter (Figure 23.28). The element from the detrital wood scatter is the right side of a mandible, and from Clark's area there is a left radius and ulna, one lumbar vertebra and one caudal vertebra, the left half of a pelvis and a left tibia (Figure 23.29). Although all of the remains are well preserved, there is no clear evidence of human or animal modification.

It is not possible to combine the data from the original excavations with those from the recent excavations because not all the elements were sided in Fraser and King's report. In terms of the recent excavations, the MNI is one, as all the remains represent fully developed elements; however, as one specimen derives from the detrital wood scatter which is dated to much earlier than Clark's area (Figure 17.20), the MNI can be adjusted to two.

Artiodactyl

Wild boar

Overview

Wild boar was identified in the original assemblage (Clark 1954, 74) and re-examined by Legge and Rowley-Conwy (1988) who counted 22 fragments and estimated an MNI of four. In the recent excavations, a
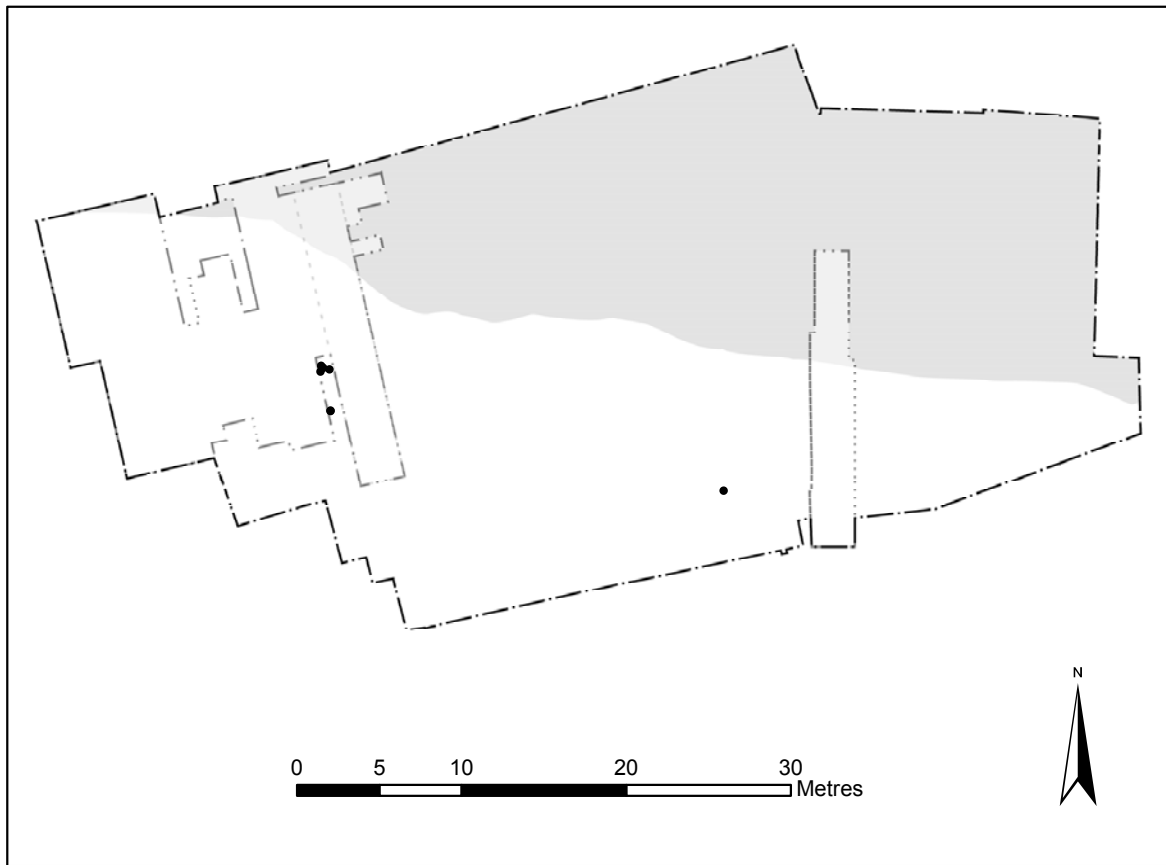
Figure 23.28: Spatial plot of pine marten (Copyright Star Carr Project, CC BY-NC 4.0).
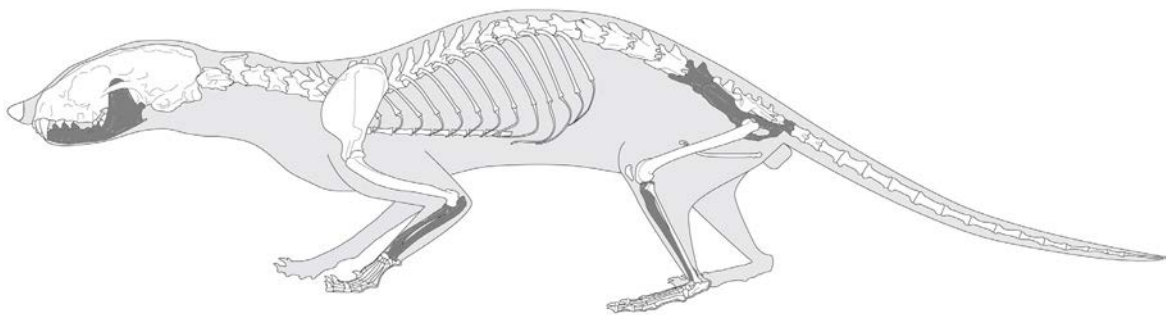
Figure 23.29: Element representation of pine marten (Copyright Archeozoo.org/M. Coutureau 2015. Adapted by Becky Knight).
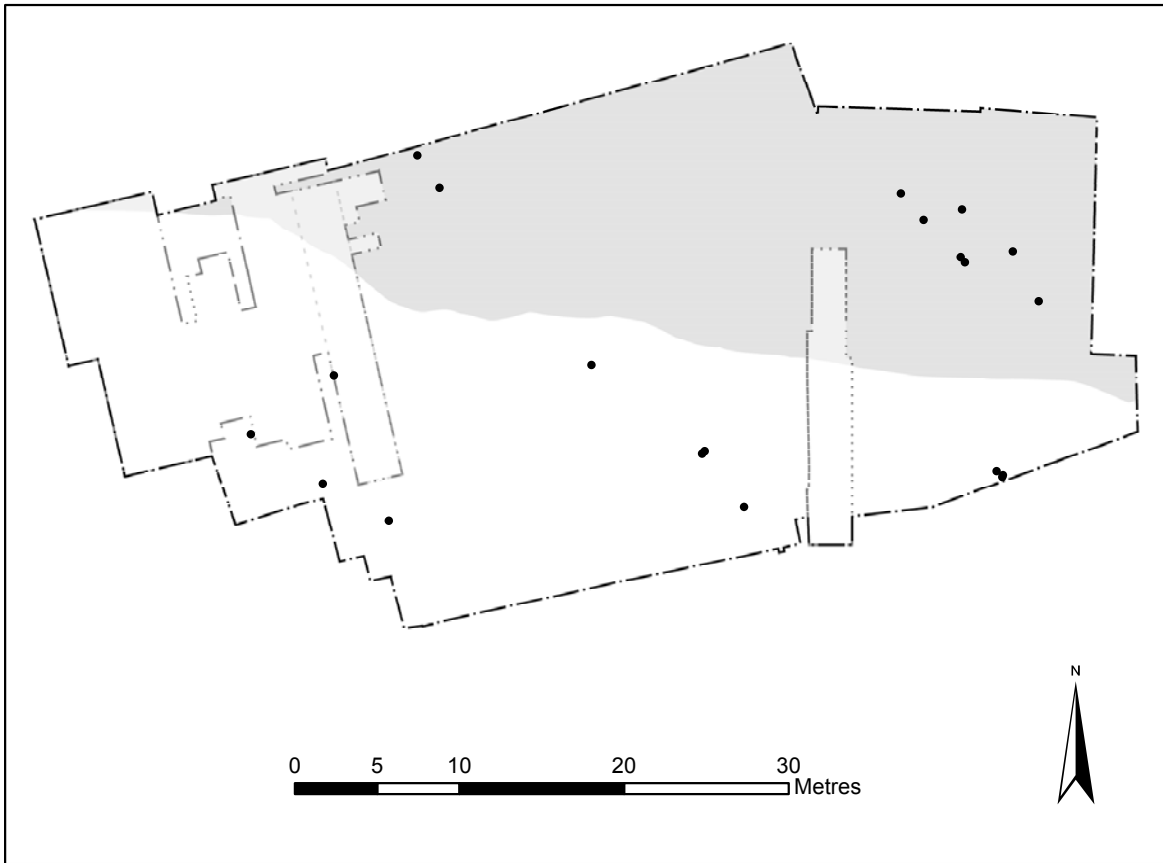
Figure 23.30: Spatial plot of wild boar (Copyright Star Carr Project, CC BY-NC 4.0).

further 22 specimens have been found across the site (Figure 23.30): three on the southern edge of the eastern platform, three in the detrital wood scatter, one above the western platform, four in Clark's area, a concentration of eight around the eastern dryland structure and two on the peripheries of the western dryland structure. Six specimens originating from the dryland have been identified to species through ZooMS but cannot be identified to element.

<div align="center">Elements</div>

Mandibles and loose teeth, scapulae and hind leg bones have been identified but the small number of specimens make it difficult to identify any significance in their spatial patterning (Figures 23.31 and 23.32). In terms of missing elements, the cranium, torso and front limbs were almost completely absent, apart from two scapulae (Figure 23.31). This is very similar to the results of Legge and Rowley-Conwy (1988, table 1E). However, it should be noted that there are a large number of rib elements that can only be identified as belonging to medium mammals, some of which may be wild boar, and therefore we cannot necessarily assume that torso elements are missing.

<div align="center">Age and sex</div>

Two specimens were used to aid in ageing the wild boar: an unerupted first incisor and an unfused femur (Table 23.9). The first incisor was a loose tooth find, it had no wear on the occlusal surface and it appears
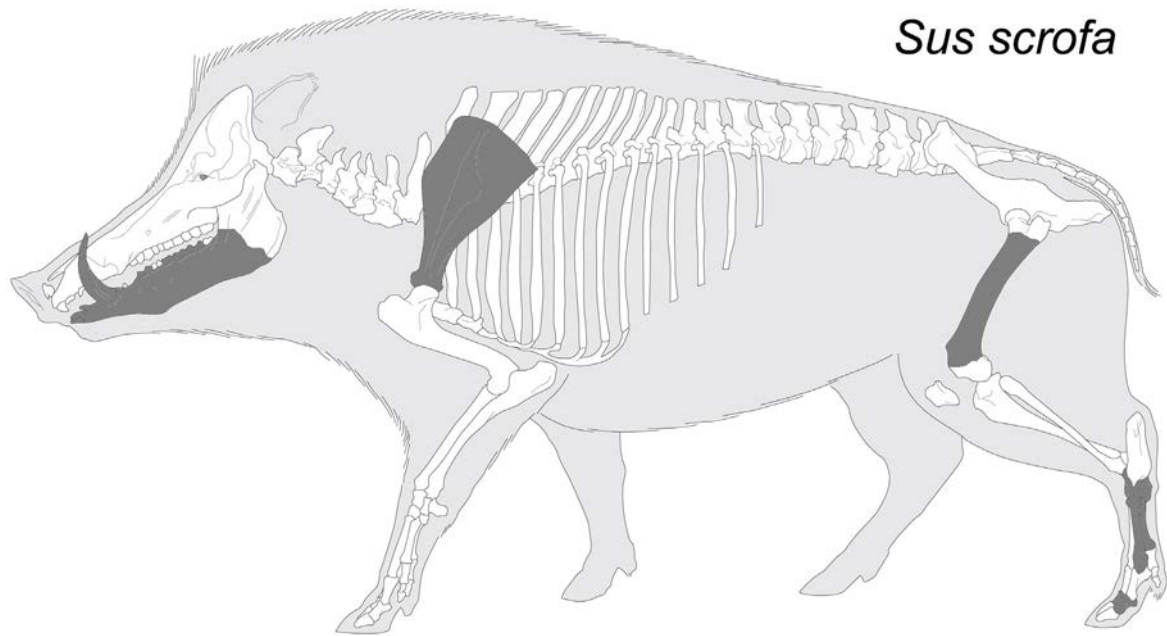
Figure 23.31: Element representation of wild boar (Copyright Archeozoo.org/M. Coutureau 2003. Adapted by Becky Knight).
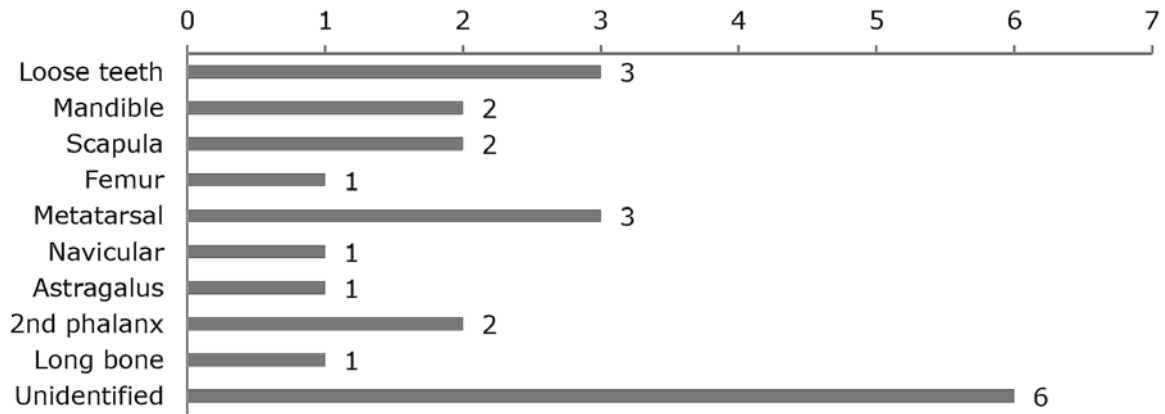
Figure 23.32: NISP values of wild boar (Copyright Star Carr Project, CC BY-NC 4.0).

Element	NISP	Age range
First incisor	1	14–16 months
Femur (prox.) / (dist) epiphyses	1	36–42 months

Table 23.9: Wild boar maximum age ranges when eruption and fusion are complete. Tooth development based on Briederman (1965) and Matschke (1967), and bone fusion based on Lesbre (1897–8).

to be only partially developed and is likely to have been an unerupted tooth. The femur is only represented by the midshaft, which is gracile and small and missing both the proximal and distal epiphyses. The lack of any evidence for fusion having begun on the femur suggests that this element belonged to an animal less than 3.5 years of age: the small size cannot be explained by sexual dimorphism as bone development is incomplete. However, it should be noted that due to the small amount of information available about the timings of epiphyseal fusion in pigs and wild boar, estimations of age from this method should be treated with caution.

The other wild boar remains all appear to be fully developed and the scapulae and metapodials fully fused (with the fusion lines obliterated). This corresponds to the two specimens which Legge and Rowley-Conwy (1988, 44) noted as being from dentally mature animals. Overall, there appears to be both young adult and adult wild boars in the assemblage. It was not possible to sex the majority of the remains; however, the presence of a partial mandible with large canines (which was found amongst the timbers of the western platform; Chapter 7) would suggest that the remains of at least one adult male are present at the site.

Modification

There is no evidence for modification by carnivores on these specimens. In Clark's area, of the four specimens found, three show evidence of human modification. The mandible has been broken using a percussion break, beneath the tooth row, for marrow extraction or to remove the canine. The distal end of the second phalanx has been removed by a percussion break for marrow extraction. The scapula exhibits ephemeral cut marks around the posterior aspect of the glenoid, which is likely to be the result of cutting through ligaments to separate the forelimb (a major meat-bearing limb) from the carcass. From around the eastern platform there are two third and one fourth metatarsal which exhibit percussion breaks at the distal ends; however, these are small elements with very little marrow.

MNI

The most dominant elements within the assemblage are metatarsals and loose teeth. Based on metatarsals an MNI of one is calculated; however, taking into account the age profiles provided by the incisor and femur, an MNI of two can be posited: a juvenile piglet of under a year and a fully developed adult. As the juvenile incisor was found on the dryland around the eastern structure, this is less likely to correspond with the juvenile femur from the detrital wood scatter, which could increase the MNI to three. However, as the dating of the dryland has a degree of uncertainty to it, the MNI should remain at two. If the MNI results are added to Legge and Rowley-Conwy's (1988, 9) MNI of four (from the left mandibles), the presence of a juvenile increases the overall MNI for the site to five.

Elk

Overview

Within the waterlogged areas, the elk remains were generally spread across most of the trench, with the majority located in Clark's area (Figure 23.33). Elk was identified in the original assemblage (Clark 1954, 76–79) and re-assigned by Legge and Rowley-Conwy (1988) who noted 247 fragments and an MNI of 12. In comparison, only 34 specimens have been identified from across the site during the recent excavations (including six from Clark's backfill).

Figure 23.33: Spatial plot of elk specimens (Copyright Star Carr Project, CC BY-NC 4.0).
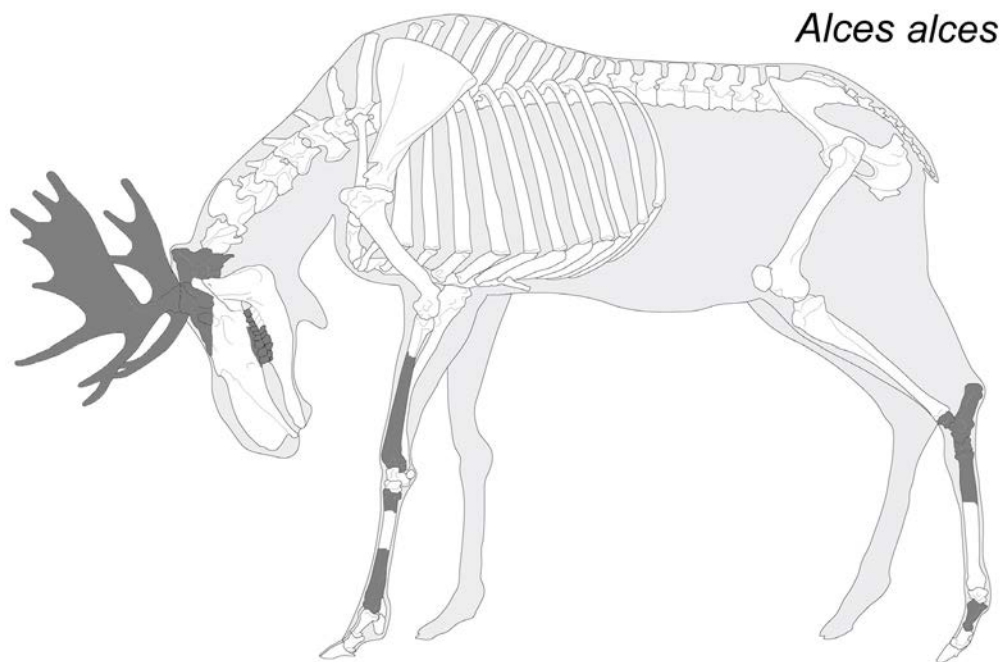
Figure 23.34: Element representation of elk (Copyright Archeozoo.org/M. Coutureau and J. Treuillot 2013. Adapted by Becky Knight).
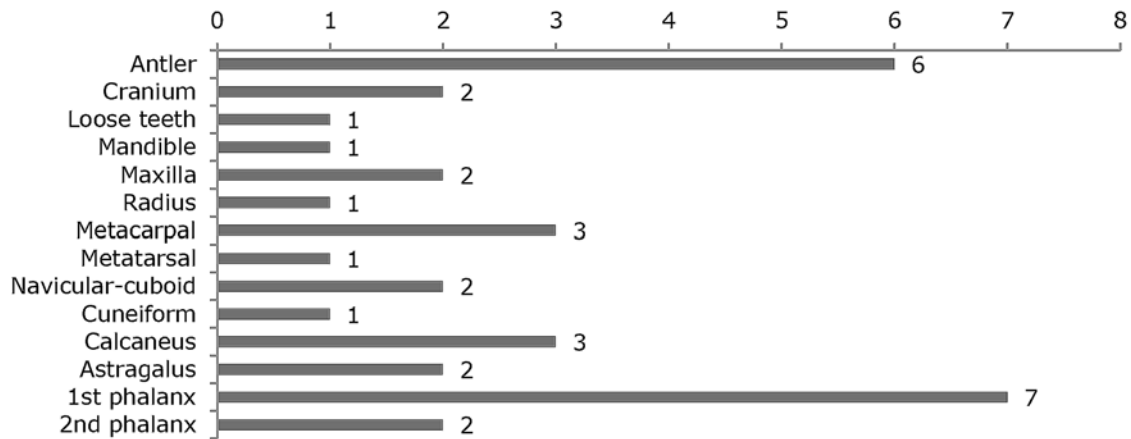
Figure 23.35: NISP for elk (Copyright Star Carr Project, CC BY-NC 4.0).

Elements

A range of elements are represented; however, the majority belong either to the skull or are leg bones (Figure 23.34; Figure 23.35). There is a distinct lack of long bones and also elements associated with the torso (such as vertebrae, ribs and pelvis), although as noted previously, most of the ribs found at the site have not been assigned to species. This pattern of element representation is different to the patterning observed by Legge and Rowley-Conwy (1988, table 1B) where most elements of the skeleton were found; however, their sample size was much larger.

Age and sex

In terms of the age profile for the elk remains, only one element possesses developmental information. The specimen, a calcaneal tuberosity epiphysis, is unfused and missing on the calcaneus of one elk specimen. According to Purdue (1983) this element fuses between the ages of 1.6–2.4 years, and so this gives a maximum age of 2.4 years for this animal. Legge and Rowley-Conwy (1988, 44) also noted that of the 10 elk jaws found, nine retained third molars, and in seven cases these were at a relatively early wear stage suggesting a high proportion of young adults in the cull.

It was not possible to sex the remains. Legge and Rowley-Conwy (1988, 63) also found this because the animals, in early dental maturity, exhibit little dimorphism. However, the inclusion of elk antler within this assemblage identifies that male animals are present.

Modifications

There are no signs of carnivore modification with these specimens. In total 16 specimens have evidence of human modification. Within the detrital wood scatter an astragalus exhibits a small round hole suggestive of a possible projectile puncture wound. In addition, a palmate portion, one antler fragment and metacarpal have been humanly modified but only the metacarpal is modified by both a percussion break and spiral fracture, likely for marrow extraction.

A piece of antler found by the western platform exhibits evidence of groove-and-splinter working. There was also one specimen of elk found above the eastern platform and this is a partial metatarsal; the distal half of the

element has been removed by a percussion break and there are clear radiating fractures from the percussion point. This would have been carried out for marrow extraction.

In Clark's area, the proximal end of a radius and the proximal end of a metacarpal have been removed by a mixture of percussion breaks and spiral fractures for marrow extraction. There are also four first phalanges, one second phalanx and a navicular-cuboid that have been broken open by spiral fractures and percussion breaks for marrow extraction: it is interesting to note that 'although there is relatively little marrow within these, what is present is tasty' (Speth 2010, 34). One of the first phalanges also has cut marks just above the break edge on the posterior aspect of the midshaft which probably occurred during skinning.

In Clark's backfill, the proximal end of a first phalanx and the proximal end of a second phalanx has been removed by percussion breaks and spiral fractures for marrow extraction. The first phalanx also exhibits cut marks just below the break edge which probably occurred during skinning.

Seasonality

A neonatal left maxilla of an elk was noted by Noe-Nygaard (1975), coming from an animal no more than a few weeks old and using modern analogy thought to represent a summer death. Legge and Rowley-Conwy (1988, 31–32) found that one mandible with tooth wear gave an indication of season and was probably killed later in the year, in September or October, though if the animal had been late born it would have been killed in November or December. An elk skull with shed antlers was originally taken to indicate midwinter occupation (Fraser and King 1954), but this was reinterpreted by Legge and Rowley-Conwy (1988, 31) who stated that the elk could have been killed anytime between December to late April/May. No seasonality of death could be ascertained from the faunal remains recovered from the recent excavations.

MNI

Although the most dominant element according to NISP was the first phalanx, it is very difficult to side these elements and so they cannot be used for calculations for MNI. Antler is also not used for calculations of MNI and so the calcanei have been used. Three specimens were found: two left and one right. Two specimens belong to adult animals, one left and one right element, and these were found in the detrital wood scatter. The final calcaneus (young adult) was found within Clark's area and is represented by a partial element with an unfused distal epiphysis. These data suggest two individuals. Legge and Rowley-Conwy (1988, 9) provided an MNI of 12 (left astragali); however, as elk has been found in the detrital wood scatter, which is dated much earlier compared to Clark's area (Figure 17.20), the MNI for the site can be raised to 13.

Red deer

Overview

Red deer was identified in the original assemblage (Clark 1954, 79-86) and re-examined by Legge and Rowley-Conwy (1988), who found 541 fragments and calculated an MNI of 26 (based on the left mandible). A total of 535 specimens of red deer were identified in the recent assemblage, including 73 specimens that were found within Clark's backfill. Red deer specimens were found across the entirety of the site (Figure 23.36). The largest concentrations are within the detrital wood scatter and within Clark's area. On the dryland there are several smaller concentrations of remains: around the eastern structure and around the western structure, and along the shore edge.

Elements

Red deer is the most dominant species from Star Carr and is represented by the most diverse range of elements (Figures 23.37 and 23.38), as was identified by Legge and Rowley-Conwy (1988, table 1A). Antler is the most
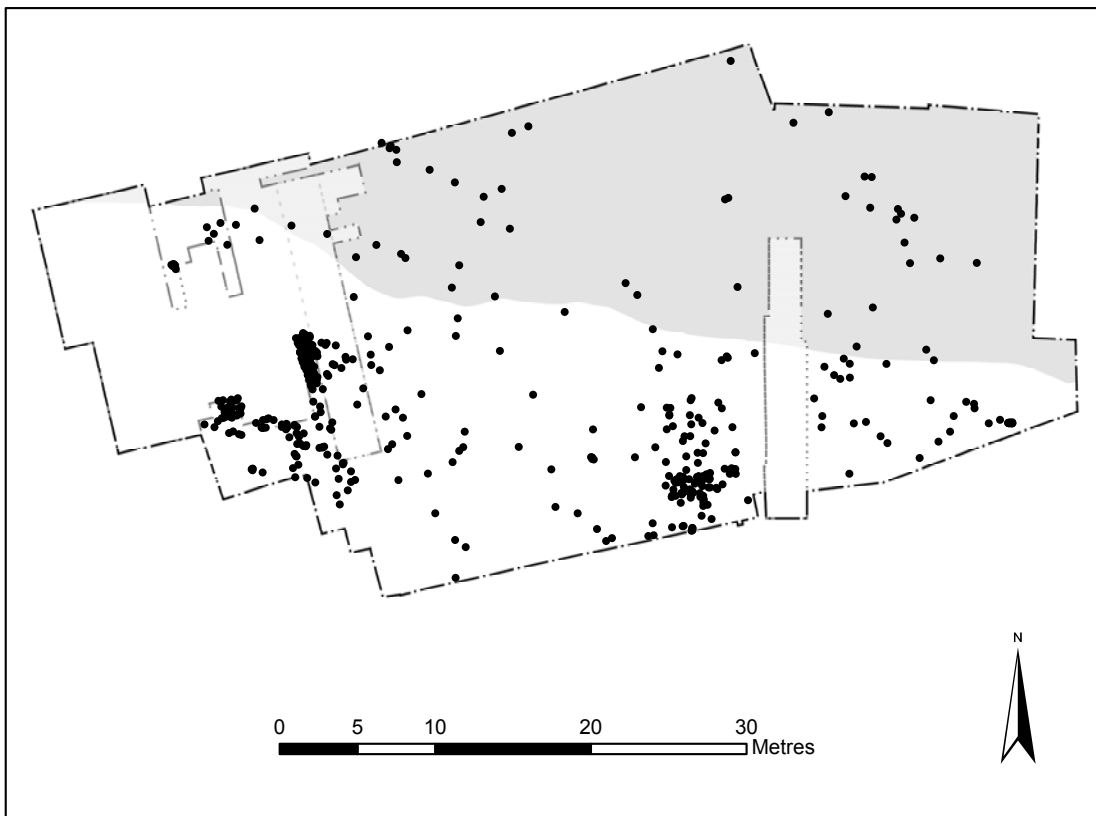
Figure 23.36: Spatial plot for red deer (Copyright Star Carr Project, CC BY-NC 4.0).
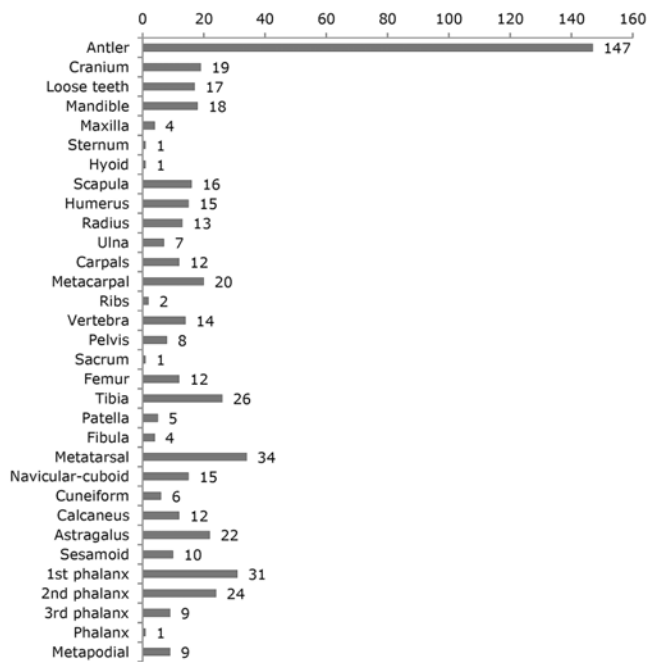
Figure 23.37: NISP values for red deer (including backfill and flotation finds) (Copyright Star Carr Project, CC BY-NC 4.0).
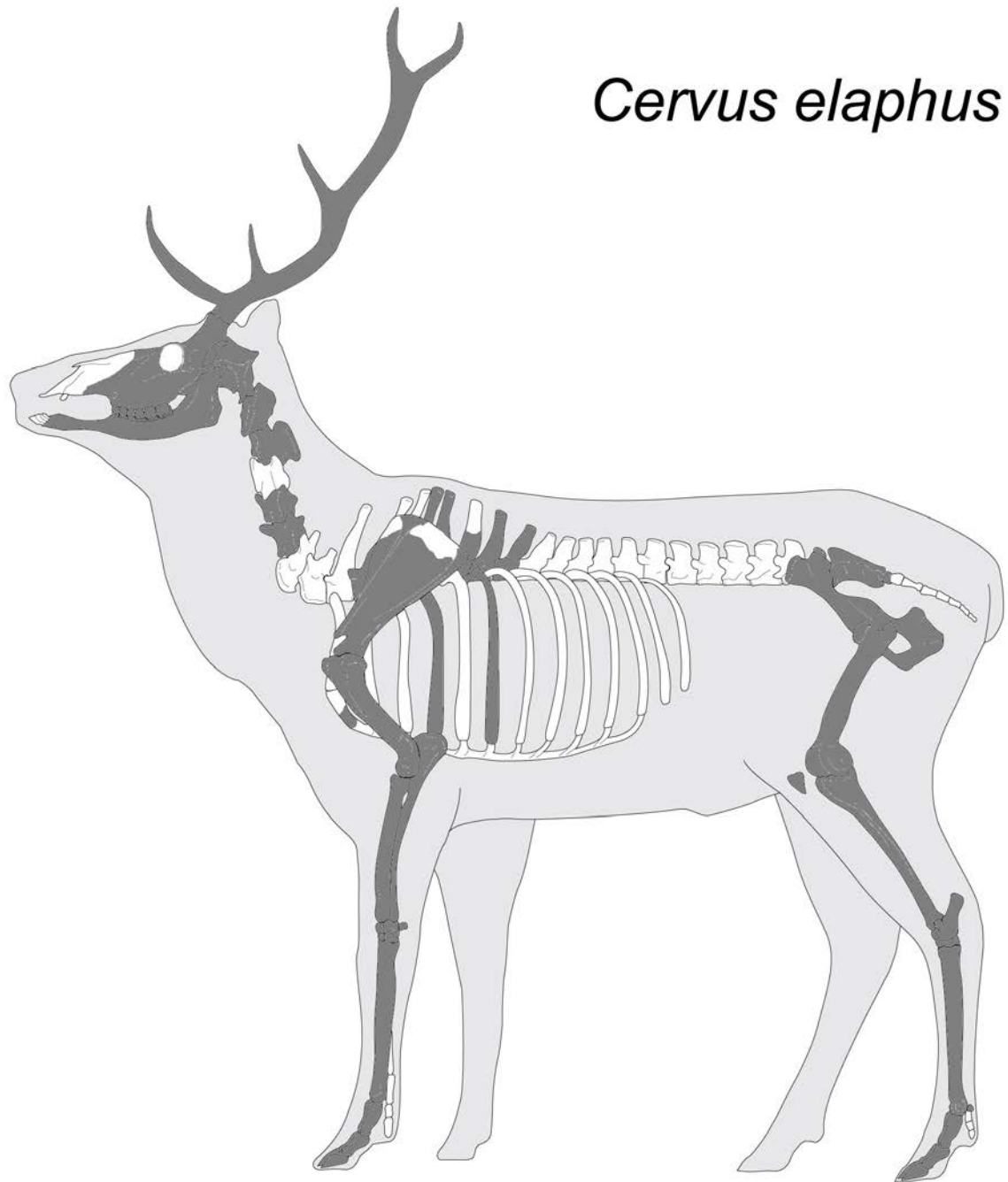
Cervus elaphus

Figure 23.38: Element representation of red deer (Copyright Archeozoo.org/J.-G. Ferrié 2004. Adapted by Becky Knight).

dominant element (NISP=147), with the most dominant skeletal element being metatarsals (NISP=34). Elements that are only represented by a small number of specimens (five or less) are the maxilla, sternum, hyoid, rib, sacrum, patella, fibula and cuneiform. Ribs appear to be lacking but they are difficult to identify to species, even when having been analysed using ZooMS, and so they may have ended up in categories such as 'cervid species' or 'large mammal species'.

Age and sex

Of the 22 mandibles that Legge and Rowley-Conwy (1988, 42–44) used for ageing, the age profile spanned 2–9 years with 15 (60%) falling into the three to five year classes. In terms of attempting to calculate the age profile for the recently excavated red deer remains, nine bone specimens were used. One of the mandibles and the ulna come from the detrital wood scatter, and the rest are from Clark's area. There are a range of ages represented suggesting there were at least five different individuals represented across the two areas.

In the detrital wood scatter, two specimens provide age data (Table 23.10). The first individual is represented by a partial mandible with mixed dentition: deciduous third and fourth premolars and a permanent adult first molar. Using data generated by Severinghaus (1949) for white-tailed deer, this mandible closely matches two mandibles that were aged between three to four months. In addition, a partial ulna with a missing and unfused proximal epiphysis was found 0.4 m from the mandible but has a different age: this is estimated to be no older than 26–42 months/2.2–3.5 years.

In Clark's area seven specimens exhibit age data (Table 23.10). Two mandibles show a similar age: a partial left mandible with a partially erupted permanent third molar which match mandibles of the age 11–12 months in Severinghaus' (1949) study, and a partial right mandible with deciduous second, third and fourth premolars and permanent adult first and second molars which match mandibles of the age 12–13 months. These were found c. 5 m apart and may or may not be from the same animal. A further partial mandible containing a deciduous fourth premolar with the permanent fourth premolar partially erupted out of the crypt, a permanent first and second molar and a partially erupted permanent third molar match mandibles of the age of 18–19 months (1.6–1.7 years of age). There are three specimens with an age maximum of 26–29 months/2.2–2.5 years: two metacarpals with unfused distal epiphyses and a partial calcaneus with an unfused proximal epiphysis. One further specimen, a distal tibia with a partially fused distal epiphysis, has a maximum age of 26–42 months/2.2–3.5 years.

In terms of sex assessment, Legge and Rowley-Conwy (1988, 58) used measurements from animals of known age and sex from the Isle of Rhum to establish sex assessment for the Star Carr red deer. They concluded that there was a roughly even sex ratio among the Star Carr red deer, contrary to previous interpretations that relied heavily on the antler data. They also noted that the common age class was three year olds (n=10); however, most of the antler has come from animals of four years old and above (Fraser and King 1954, 80) and so much of the antler must have been brought to site (Legge and Rowley-Conwy 1988, 58).

For the recently excavated assemblage it was not possible to measure the specimens with any accuracy due to the deterioration and warping and thus the datasets could not be compared. However, at least two females can be identified within the assemblage from the cranial remains. Both appear to be adult individuals in terms of size, robustness and development, and so it is unlikely they represent young male animals.

Element	NISP	Age range	Seasonality
Detrital wood scatter			
Mandible (dp3/4, M1)	1	3–4 months	Aug/Sept = **mid-late summer**
Ulna (proximal)	1	26–42 months (2.2–3.5yrs)	
Clark's area			
Mandible (partial eruption M3)	1	11–12 months	April/May = **mid-summer**
Mandible (dp2,3,4, M1, M2)	1	12–13 months (1–1.1yrs)	May/June/July = **mid-summer**
Mandible (dp4, partial eruption P4, M1, M2, partial eruption M3)	1	18–19 months (1.6–1.7yrs)	Nov/Dec = **mid-winter**
Metacarpal (distal)	2	26–29 months (2.2–2.5yrs)	-
Calcaneus (proximal)	1	26–29 months (2.2–2.5yrs)	-
Tibia (proximal—partial fusion)	1	26–42 months (2.2–3.5yrs)	-

Table 23.10: Age estimation of the Star Carr red deer remains using epiphyseal fusion after Purdue (1983) and tooth eruption after Severinghaus (1949).

Seasonality

The seasonality of the red deer has been much debated. It was originally proposed by Clark (1954, 1962) that people were based at Star Carr in the winter, following the red deer as they migrated to the North York Moors in the summer. It has since been suggested that red deer would not have migrated in this area (Legge and Rowley-Conwy 1988, 38). There is evidence from the work of Legge and Rowley-Conwy (1988, 38) that the young deer were killed in the late spring and summer and they state 'it is reasonable to assume that the adults were too'. More recently, Carter (1998) carried out analysis of the red deer mandibular ramus of red deer from the site and showed that one red deer younger sub-adult would have been killed in early winter, and another in the winter or spring. A further pairing of rami may be a late summer kill or an autumn/winter death.

From the recently excavated remains, using the age estimations of the younger individuals, it is possible to provide further seasonality data. This can only be based on the data gathered from dental development as this tends to be a more reliable age indicator (Purdue 1983). Red deer rut and begin mating around September/ October each year, and the gestation period typically has a duration of around eight months with animals being born in May/June (Dobronika 1988). From this, three mandibles suggest a summer death (one in the detrital wood scatter and two in Clark's area), but a fourth suggests that it was killed in the winter (from Clark's area) (Table 23.10).

Modifications

There are four red deer elements (scapula, ulna, navicular-cuboid and metatarsal) which come from within the detrital wood scatter which exhibit evidence of carnivore modification in the form of uneven breakage with associated tooth marks and tooth scores. From Clark's area, there are seven specimens with evidence of modi-fication by carnivores (a scapula, axis vertebra, tibia, astragalus, cuneiform, metatarsal and an antler frontlet), with uneven breakage associated with tooth impressions and tooth scores. In Clark's backfill three specimens (femur, calcaneus, metatarsal) exhibit uneven breakage, tooth scores and tooth impressions. Within test pit SC20 one tibia specimen has been broken, and exhibits tooth scores and tooth impressions.

Overall, 186 specimens (not including antler) from across the site have been modified by humans, in some cases exhibiting a number of different types of evidence. In terms of percussion breaks and spiral fractures, for the extraction of marrow, there are 10 specimens from the detrital scatter, 21 in the wetlands, 93 in Clark's area, eight on the dryland, 20 in the backfill and four in test-pits. This processing has been carried out mainly on long bones (98) but also on phalanges (37), mandibles (13), pelves (3) and cuneiform (1). Although most of this has probably been carried out for marrow, it is unlikely that the percussion breaks on the pelves would have been for this purpose. In terms of longitudinal split bone (n=24) for the production of tools, there is one from the detrital wood scatter, seven from the wetland, 10 from Clark's area; two from the dryland, and four from the backfill. Of these, 23 are long bones, of which 18 are metapodials, and one is a phalanx. Finally, cut marks are also evident: two from the detrital wood scatter, 27 from Clark's area, and three from the backfill. However, it should be noted that most of the cut mark evidence is exhibited on ribs categorised as cervids or large and medium mammals.

Palaeopathology

An interesting pathology was noted on a red deer skull with heavy remodelling to the cortical bone surface of the frontal and parietal bones (Figures 23.39 and 23.40). The cortical bone surface on the frontal bone undu-lates and clearly still had active bone remodelling occurring. It appears that the cause of this may have been the tearing of muscles that run across the surface of the cranium which help to support the weight of the head and antlers. The likelihood is this will have occurred during the rut. The porous nature of the bone surface suggests that there may have also been some infection associated with this damage. There is also some remodelling of the skull around the parietals with deep grooves in the skull, again associated with the muscles supporting the antlers, suggesting that this individual may have been an older individual with particularly large and heavy antlers, producing the need for highly developed muscles and anchor points on the cranium for these muscles.

Figure 23.39: Red deer cranium <116020> with active remodelling and infection of the cortical bone across the entirety of the frontal bone (Copyright Neil Gevaux, CC BY-NC 4.0).

Figure 23.40: Red deer cranium <116020> with remodelling of the skull and pronounced muscle attachments on the parietals (Copyright Neil Gevaux, CC BY-NC 4.0).

MNI

The element with the highest NISP value is antler; however, this is not used for calculations of MNI (Legge and Rowley-Conwy 1988, 9) and so the second most abundant element is the metatarsal, NISP=31 (not including examples in the backfill). Of these, nine were sided to the left and 13 to the right, whilst the other nine could not be sided. It should be noted that these are fragmentary remains and cannot be used directly for MNI counts: the specimens were examined to find repeating ends in order to calculate the MNI.

Nine specimens were found in the area of the detrital wood scatter, which has been dated as one of the earliest activity areas of the site and of these there are three repeating right distal ends of the metatarsal establishing an MNI of three. The final 22 specimens were found across both the dryland and within the waterlogged deposits. As there are six repeating proximal ends of the metatarsals, the MNI here is six individuals. Taking into consideration the distribution of these elements across the site, the total MNI for red deer is nine individuals.

Sample No.	Element	δ^{13}C (‰)	δ^{15}N (‰)	C:N	Collagen yield
108590	Thoracic vertebra	−22.3 ± 0.1	3.9 ± 0.2	3.3	4.0%
108594	Radius	−22.3 ± 0.1	3.8 ± 0.2	3.3	11.1%
108589	Second phalanx	−22.3 ± 0.1	4.3 ± 0.2	3.3	5.5%
103625	Skull (frontlet)	−21.4 ± 0.1	3.5 ± 0.2	3.3	2.5%

Table 23.11: Carbon and nitrogen stable isotope data for the red deer samples analysed in this study.
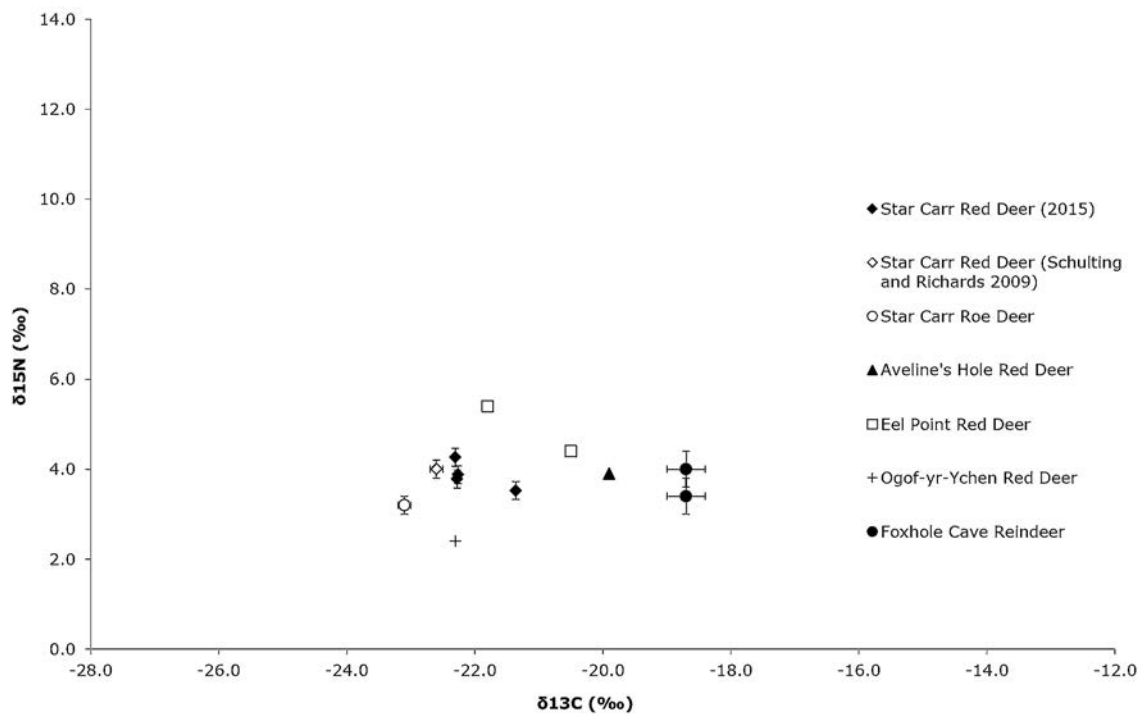
Figure 23.41: Red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and reindeer (*Rangifer tarandus*) isotope data from several British Mesolithic sites (data compiled from Bowen et al. 2000; Schulting 2005; Schulting and Richards 2002b; 2009; Schulting et al. 2013; this study) (Copyright Star Carr Project, CC BY-NC 4.0).

During their reanalysis, Legge and Rowley-Conwy used the mandible to calculate MNI, and identified 26 left specimens. During the most recent excavations within Clark's area, a total of four left mandibles were identified. By combining this data, the total MNI for red deer from this area of the site is 30 individuals.

Isotope data

The patterning of semi-articulated red deer bones in the detrital wood scatter, in close proximity to an antler frontlet (see Chapter 7), posed the question of whether these remains were derived from the same animal. As a way of addressing this question, isotopic analysis was undertaken on three of the bones and the frontlet. The four red deer samples yielded sufficient amounts of collagen of suitable quality for $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis (Table 23.11), and exhibit isotope values comparable to those previously reported from the site (Schulting and Richards 2009; Figure 23.41).

Interestingly, no significant difference was seen between the isotopic values of the disarticulated deer remains and antler frontlet sampled. This therefore suggests that the deer utilised for frontlets were not (isotopically) distinct from those utilised for other purposes (e.g. as a food or raw-material resource). Furthermore, the isotopic values obtained from the four skeletal elements fall within the error expected by replicate analysis of a single individual (Pestle et al. 2014).

The isotopic values generated from the newly excavated red deer remains are also directly comparable to previous deer values obtained from Star Carr, and can also be seen to be broadly comparable to data obtained from deer at other British Mesolithic sites (Figure 23.41). However, whilst similar in terms of $\delta^{15}N$ values, the Star Carr deer appear to be slightly more depleted in $\delta^{13}C$ than deer at other British Mesolithic sites (Figure 23.41).
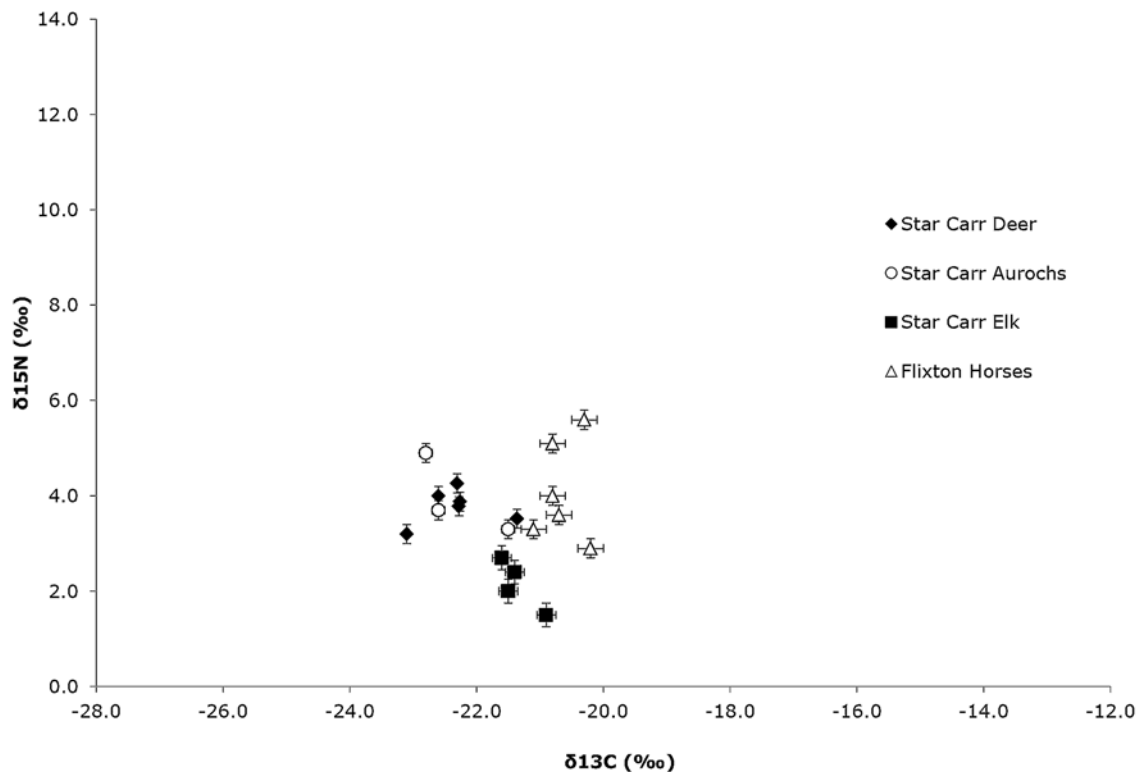
Figure 23.42: Red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), aurochs (*Bos primigenius*), elk (*Alces alces*) and wild horse (*Equus ferus*) isotope data from Star Carr and Flixton Island 2 (data compiled from Stevens and Hedges 2004; Schulting and Richards 2009; this study) (Copyright Star Carr Project, CC BY-NC 4.0).

More depleted δ¹³C values in fauna have previously been suggested to represent a diet derived from dense woodlands, rather than from more open habitats, representing a 'canopy effect' (Van der Merwe and Medina 1991; Noe-Nygaard et al. 2005; Drucker et al. 2008). The hypothesis that deer species at Star Carr may have favoured more closed, forested environments has also previously been proposed by Schulting and Richards (2009); however, a study by Stevens et al. (2006) on red deer has shown that a δ¹³C canopy effect is not always present in fauna inhabiting different environments, and as such should be treated with caution.

When we compare the Star Carr red deer with the other terrestrial herbivores from the site, and the horses sampled from the nearby Long Blade site at Flixton Island Site 2, there is somewhat of a division between the deer and the other terrestrial species, particularly elk and horses (Figure 23.42). The deer appear to be consistently more depleted in δ¹³C, which may indicate the consumption of different plant resources between the species, grazing in slightly different environments or occupying different ecological niches. This is not surprising given that site 2 on Flixton Island is earlier in date and would have had a different environment to that at Star Carr (Blockley et al. 2018).

Roe deer

Overview

Roe deer were identified in the original assemblage (Clark 1954, 79–86) and re-examined by Legge and Rowley-Conwy (1988, 9), who identified 103 fragments and estimated an MNI of 17, based on right mandibles. A total of 88 specimens were identified from the recent excavations, spread across the site, with a concentration
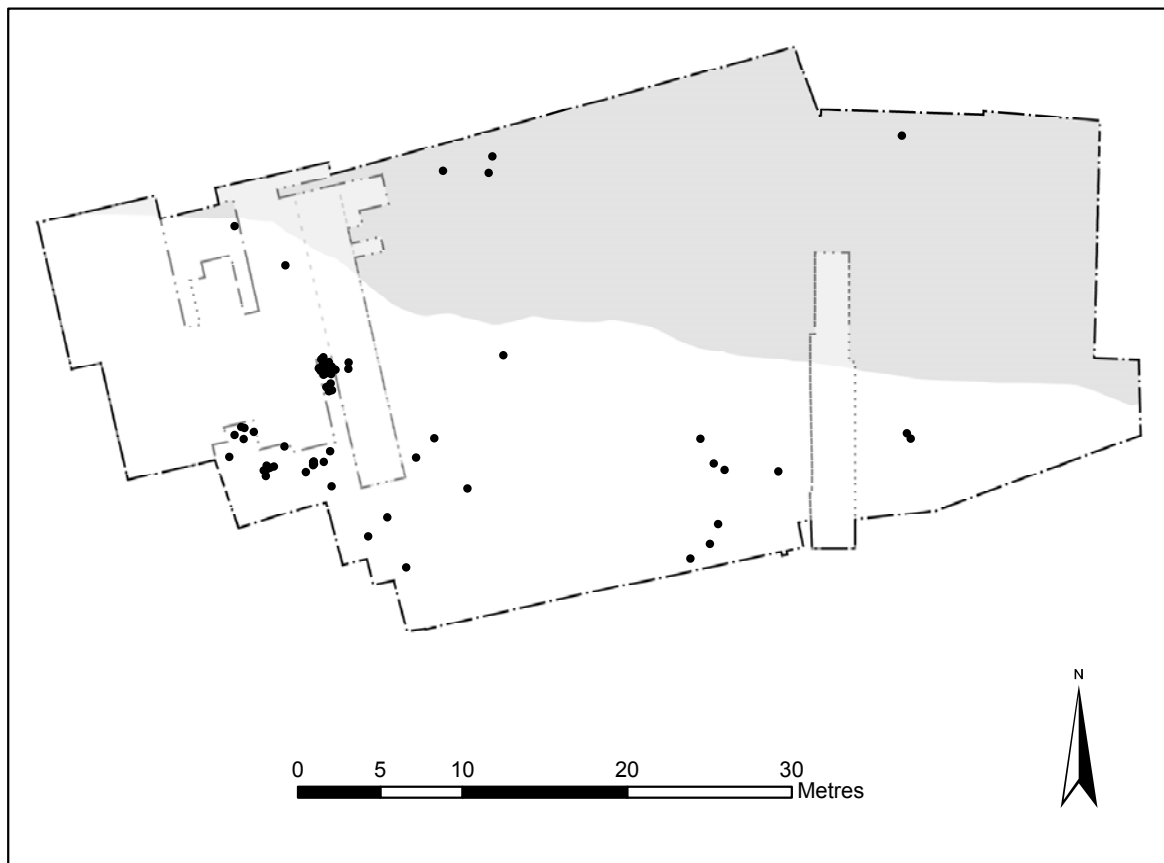
Figure 23.43: Spatial plot of roe deer (Copyright Star Carr Project, CC BY-NC 4.0).
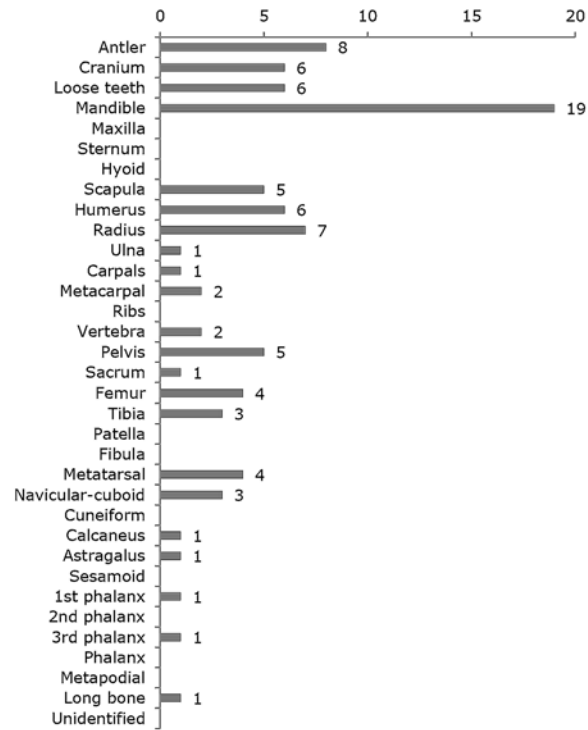
Figure 23.44: NISP for the roe deer in the assemblage (Copyright Star Carr Project, CC BY-NC 4.0).
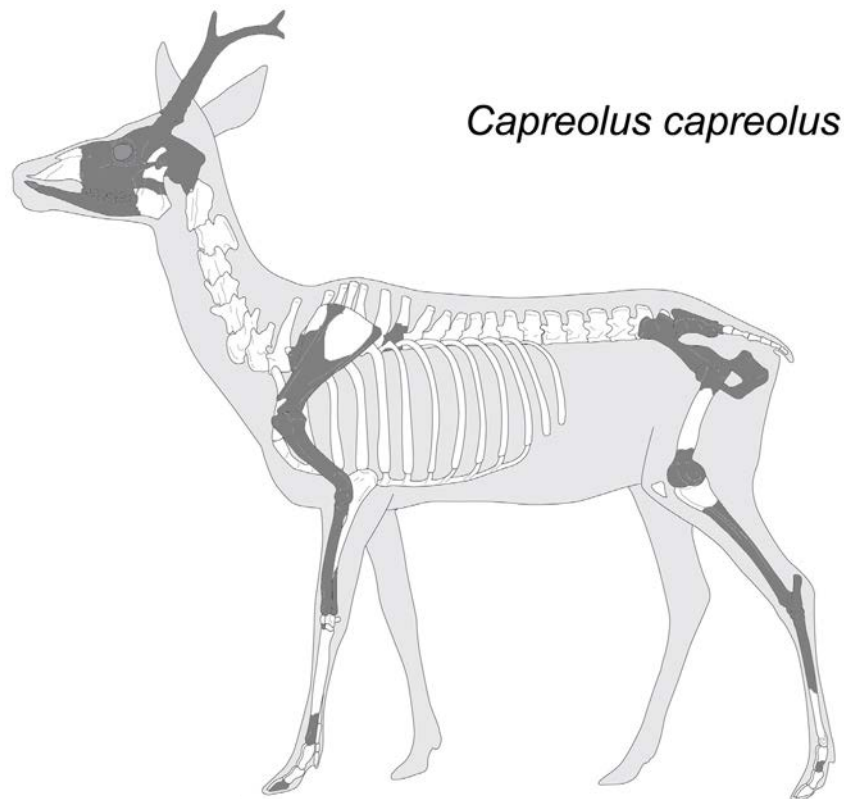
Figure 23.45: Element representation for roe deer (Copyright Archeozoo.org/J.-G. Ferrié 2005. Adapted by Becky Knight).

of 52 in Clark's area, eight in the detrital wood scatter, eight in the wetland, four in the dryland and 16 from Clark's backfill (Figure 23.43). A range of elements are represented, with the most common being mandibles.

Elements

Although the NISP of the roe deer from the site suggests there are no maxillae represented, one was still attached to a roe deer skull and represents the only example in the assemblage (Figures 23.44 and 23.45). Underrepresented areas of the body include elements from the torso (such as vertebrae and ribs) and also smaller elements such as carpals, tarsals, phalanges, patellae and fibulae. These elements are smaller in size and could have easily moved by taphonomic processes such as water, sediment movement or bioturbation. They are also less robust elements and so may degrade and disappear more quickly than some of the more robust elements. Equally, some of these elements such as the foot bones may have been left on hides. However, this patterning of element representation is similar to that found by Legge and Rowley-Conwy (1988, table 1D), particularly in terms of the dominance of mandibles and the lack of maxillae. Ribs may appear to be lacking, but they are difficult to identify to species and may have been assigned as medium mammals.

Age and sex

In this study, mandibles are used to calculate the age profiles of the roe deer. However, eruption is of very little use for aging older roe deer as all of the teeth tend to erupt within the first year (Aitken 1975); therefore, this method can only identify individuals less than a year in age. Also, all of the mandibles containing permanent dentition appear to have little to no occlusal wear. Only one specimen has the mixed dentition of part deciduous, part permanent teeth. The surviving teeth are deciduous third and fourth premolars and permanent first and second molars. This suggests that one individual was less than one year in age based on tooth development of roe deer by Severinghaus (1949).

Legge and Rowley-Conwy (1988, 40) identified a total of 21 roe deer mandibles that could be aged using tooth development criteria by Aitken (1975). They estimated that 45% of the animals (10 mandibles) represented animals aged approximately one year of age, whilst 19% were aged to two years. Using these methods it was not possible to identify, with any accuracy, animals from older age categories. Carter (1997), used radiographs to further investigate this question and found that seven mandibular rami from Star Carr roe deer could be aged to approximately 10–11 months. It was noted by Legge and Rowley-Conwy (1988, 42) that roe deer females tend to give birth from two years of age, and often have twins, meaning that the natural population has a high proportion of young.

In terms of sex assessment, Legge and Rowley-Conwy (1988, 59) collected measurements from the scapula and distal humerus, the two most dominant elements, in order to examine the extent of sexual dimorphism using carcass weights from Prior (1968). However, there was little division between the measurements and any differences emphasised by the measurements were coincidental and not related to sexual dimorphism. Due to the fragmentary or modified nature of the majority of the roe deer remains from the recent excavations, there were few complete elements from which measurements could be obtained. However, as Legge and Rowley-Conwy (1988) noted, the difference between the sexes for roe deer is minimal and so the lack of metrics is inconsequential.

Modification

Three specimens have evidence of carnivore modifications: a pelvis from the detrital wood scatter, a scapula from Clark's area and a femur from Clark's backfill. These show a mixture of uneven breakage associated with tooth impressions and tooth scores.

A total of 44 bone specimens exhibit evidence of human modification: two metatarsals and a mandible in the detrital wood scatter; 11 long bones, 10 mandibles, one scapula and one first phalanx in Clark's area; one humerus, one radius, one femur and one tibia in the wetland; and four mandibles, one humerus, one radius, one femur and one metatarsal in Clark's backfill. The evidence consists of a combination of percussion breaks and spiral fractures created during the process of marrow extraction. In terms of longitudinally split bones, thought to be created in the process of tool manufacture: one metacarpal and one metatarsal were found from

Clark's area, a tibia was found in the wetland and a metatarsal was recovered from Clark's backfill. Only three specimens, two crania and one mandible, exhibit cut marks from skinning, and they are all from Clark's area. In addition, a radius from the dryland was calcined. This specimen was found in the same area outside the western structure as the calcined wild cat phalanges.

Seasonality

The seasonality data from Legge and Rowley-Conwy (1988, 22–30) points to a late spring and summer kill from dental development of 13 roe deer mandibles. In addition, 63 unshed antlers were used with caution to suggest kills between April and November. However, Carter (1997) examined 12 mandibular rami using radiography and concluded that these animals were being killed in the late winter and early spring. No further analysis for seasonality has been undertaken from the recently excavated assemblage.

MNI

Mandibles are used in the calculations of MNI for roe deer. Seven specimens can be sided as right, five sided as left and one cannot be sided. Twelve of the mandibles contain teeth. The majority of the elements exhibit permanent adult dentition apart from one which has a mixture of deciduous and permanent teeth. Using these data, an MNI of six is established (five adults and one young adult) as it is possible to refit two of the right mandibles to one specimen. Two of the mandibles were found above the detrital wood scatter and the remaining four were found in Clark's area. Legge and Rowley-Conwy (1988, 9) had an MNI of 17, also based on right mandibles. By adding together our two groups of mandibles, the total roe deer MNI for the site is 23 individuals.
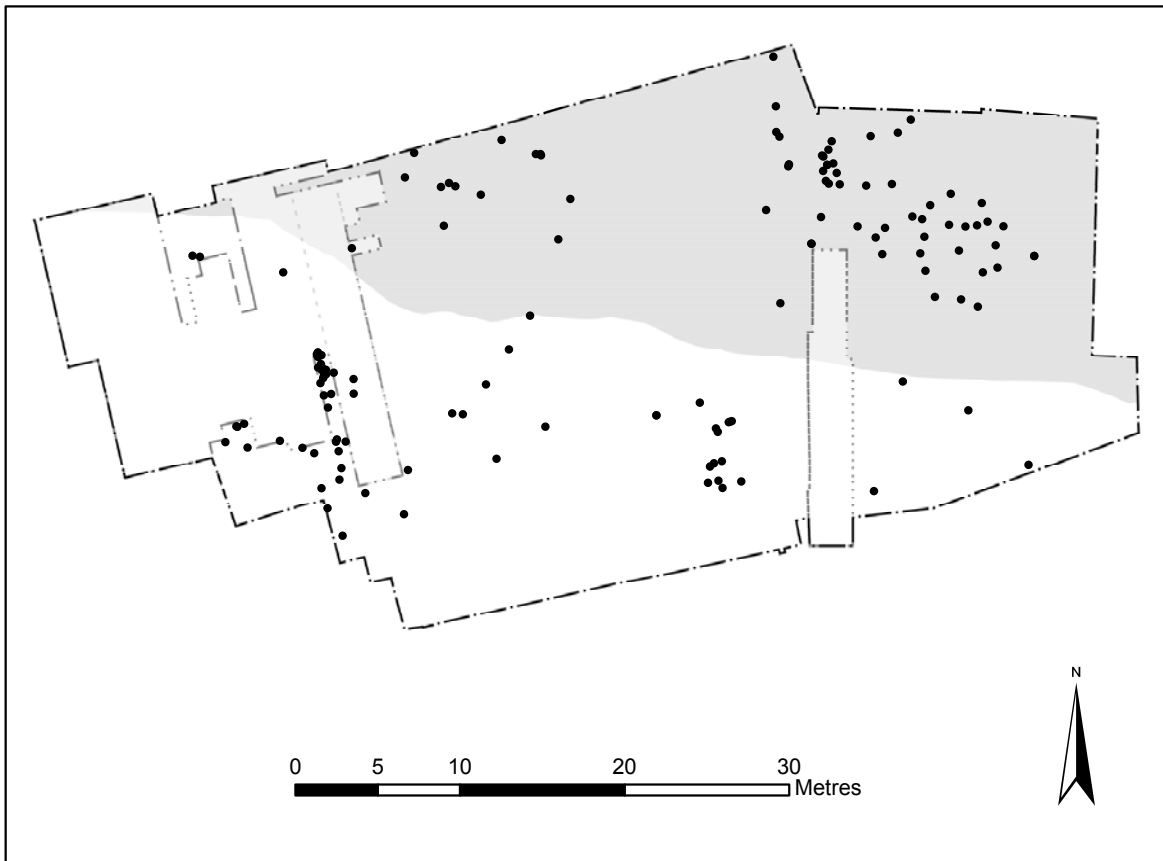
Figure 23.46: Spatial plot of aurochs.
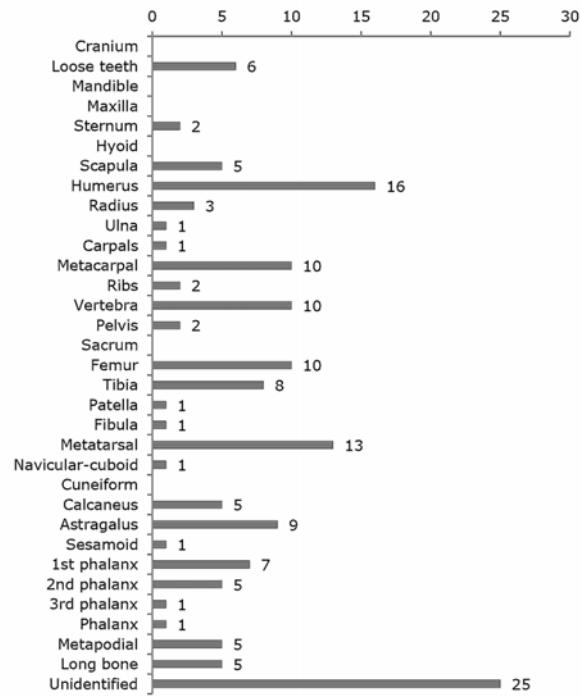
Figure 23.47: NISP for aurochs (Copyright Star Carr Project, CC BY-NC 4.0).
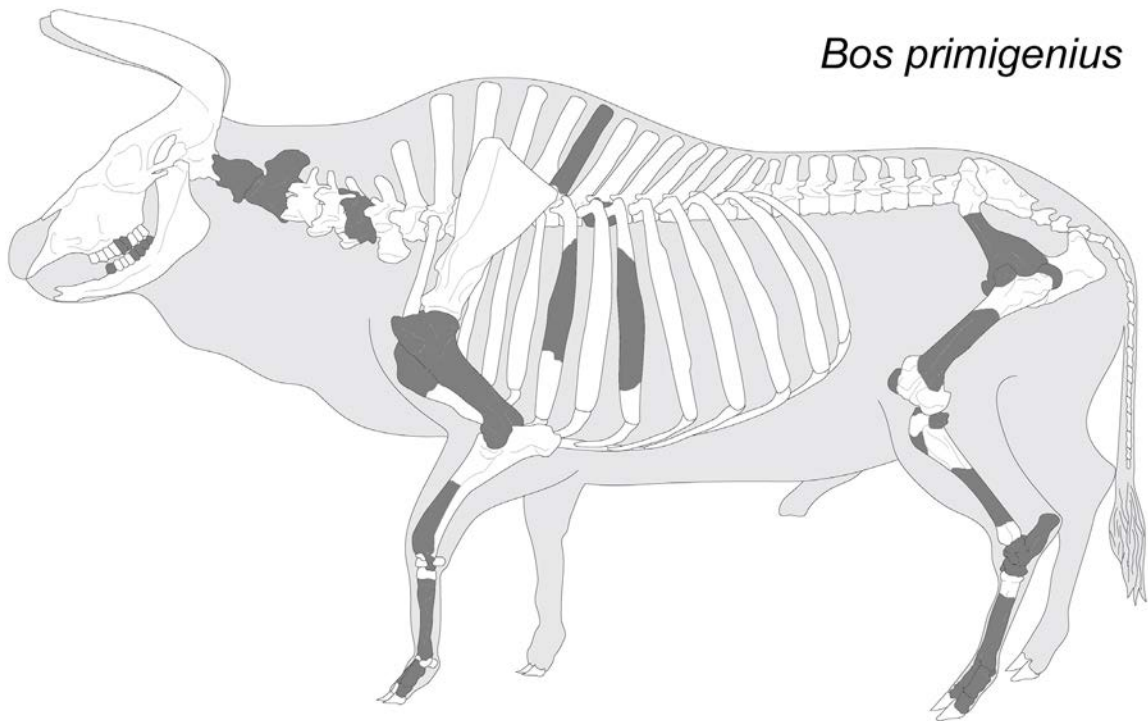
Figure 23.48: Element representation of aurochs (Copyright Archeozoo.org/M. Coutureau 2009. Adapted by Becky Knight).

Aurochs

Overview

Aurochs bones were identified in the original assemblage (Clark 1954, 79–86) and re-examined by Legge and Rowley-Conwy (1988, 9) who identified 174 fragments and provided an MNI of 16. A total of 156 aurochs specimens have been identified from the recent excavations (Figure 23.46) (Copyright Star Carr Project, CC BY-NC 4.0).

Elements

A wide range of elements are represented, with the most common being the humerus (Figures 23.47 and 23.48). Some elements are missing from the assemblage: cranial elements, hyoid, mandible, maxilla, ulna, sacrum and cuneiforms. However, these were found in the original excavations (Legge and Rowley-Conwy 1988, table 1C). There are also 25 fragments from the dryland that have been identified as aurochs using ZooMS but cannot be identified to element due to poor preservation or small size.

Age and sex

Legge and Rowley-Conwy (1988, 44) state that a single aurochs mandible with permanent teeth in wear suggest a relatively old individual. From the recently excavated assemblage, the majority of elements are too incomplete or too fragmentary to retain the developmental information required to gauge the age. However, age estimates have been made for a number of specimens using Grigson (1982), and although this is based on domesticated cattle, it is useful for a general guide to the development stages for this taxon.

The majority of the elements appear to be from large and robust adult animals; however, there are also nine elements that have unfused epiphyses, and one element that exhibits partially fused epiphyses (axis inferior vertebral body epiphysis) (Table 23.12) from which five separate individuals of different ages can be identified. The first is represented by an unfused distal end of a second phalanx. Fusion for this element occurs between 1.3–1.6 years of age, and therefore this specimen has a maximum age of 1.6 years. The second is represented by an unfused distal epiphysis of a metapodial. Fusion for this element occurs between 2–2.5 years of age, giving a maximum age of 2.5 years. The third individual has a maximum age of three years due to the unfused proximal calcaneal epiphysis. There are three specimens that are identified as having fusion between 3.5–4 years of age (a humerus with an unfused proximal epiphysis, a femur with an unfused proximal epiphysis and a tibia with an unfused proximal epiphysis), and so it is possible that all of these elements represent one individual; the fourth individual with a maximum age of four years. The fifth individual is

Element	NISP	Age range
Second phalanx (distal)	1	1.3–1.6 yrs
Metapodial (distal)	1	2–2.5 yrs
Calcaneus	1	3 yrs
Humerus (proximal)	2	3.5–4 yrs
Femur (proximal)	2	3.5–4 yrs
Tibia (proximal)	1	3.5–4 yrs
Axis vertebra (inferior vertebral body epiphysis)	1	4–5 yrs

Table 23.12: Summary of the age ranges associated with the unfused aurochs remains from Star Carr, using Grigson (1982).
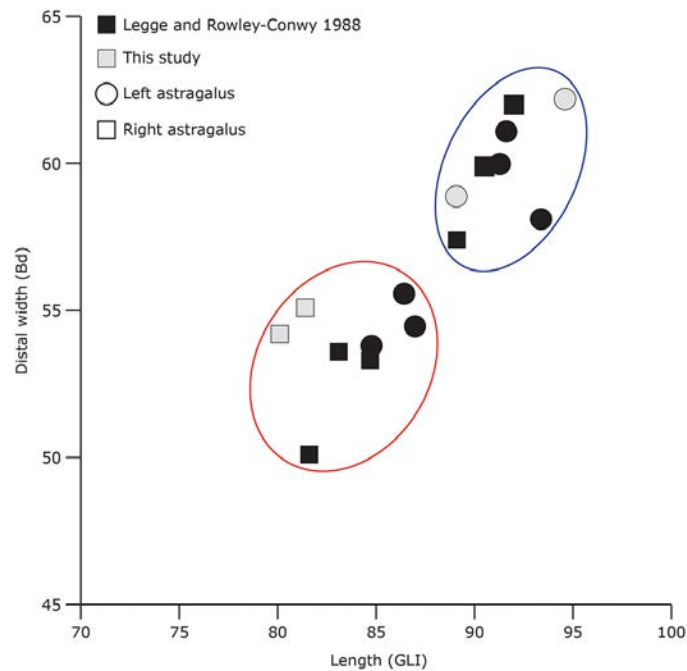
Figure 23.49: Metric comparison of the right (square) and left (circle) aurochs astragali data illustrating sexual dimorphism (males within the blue ellipse, females within the red ellipse) (Copyright Star Carr Project, CC BY-NC 4.0).

represented by an axis vertebra with a partially fused inferior vertebral body epiphysis, and a maximum age of five years.

Due to the fragmentary nature of the remains few specimens can be measured, except for four astragali, making it possible to do a comparative analysis with Legge and Rowley-Conwy's (1988, 46) data in order to establish evidence for sexual dimorphism. They found that from measurements on 13 astragali, seven were males, and among 15 metacarpals, 10 were males. In this study, plotting our astragali measurements against Legge and Rowley-Conwy's data, there are two more male specimens and two more female specimens (Figure 23.49).

Modifications

A total of 13 specimens exhibit evidence of carnivore modifications, 10 from Clark's area (six long bones, a cervical vertebra, a scapula, an astragalus and a first phalanx), one from the wetland (a calcaneus) and two from Clark's backfill (a radius and a femur). These all exhibit uneven breakage associated with tooth impressions and tooth scores.

A total of 65 specimens exhibit evidence of human modification. In terms of evidence of marrow extraction, there are 61 specimens, nine in the detrital wood scatter, 22 in Clark's area, 11 in the wetland, 10 in the dryland, eight in Clark's backfill and one in a test-pit. There are 13 specimens that are longitudinally split, likely for tool production: one in the detrital wood scatter (metatarsal), five in Clark's area (humerus, two metatarsals, a one first and one second phalange), two in the wetland (humerus and femur), four from the dryland (three humeri and one metatarsal) and one from Clark's backfill (metacarpal). Only five specimens exhibit cut marks: three from Clark's area (scapula, sternum and humerus), one from the dryland (thoracic vertebra) and one from the backfill (metatarsal), and these are likely to have been produced through skinning.

Palaeopathology

There is also one aurochs metatarsal with a healed lesion to the midshaft which appears to be spherical in shape. This is likely to be the result of a long-healed perforation or projectile wound. There is only a small amount of thickening to the outer surface of the affected area, and there is no associated deformity or excessive thickening, pitting or pock marking of the cortical bone surface to suggest disease or active healing. The internal surface of the medullary cavity also appears to be normal, further supporting that it is unlikely to be caused by disease. Due to the small size and shape of the affected area, it could be suggested that it is the result of a long-healed perforation, albeit caused by either human or natural causes such as trauma, or perhaps even the result of a possible projectile wound.

MNI

The humerus is the most dominant element. As there are four repeating fully developed distal articular ends, one right and three left, the MNI for aurochs is three. When looking at these remains spatially, two of the left distal humeri and the one right distal humerus were located above the central platform, and the third left distal humerus was found within Clark's area. As the peat above the central platform may be of a similar date to Clark's area, the MNI remains at three. Legge and Rowley-Conwy (1988, 9) provided an MNI of 16 based on metacarpals.

Figure 23.50: Spatial plot of beaver (Copyright Star Carr Project, CC BY-NC 4.0).
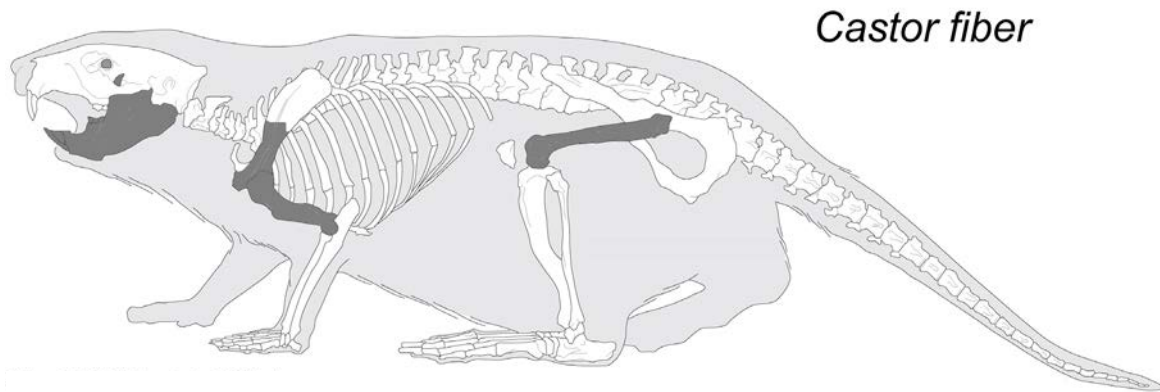
Figure 23.51: Element representation of beaver (Copyright Archeozoo.org/M. Coutureau 2003. Adapted by Becky Knight).
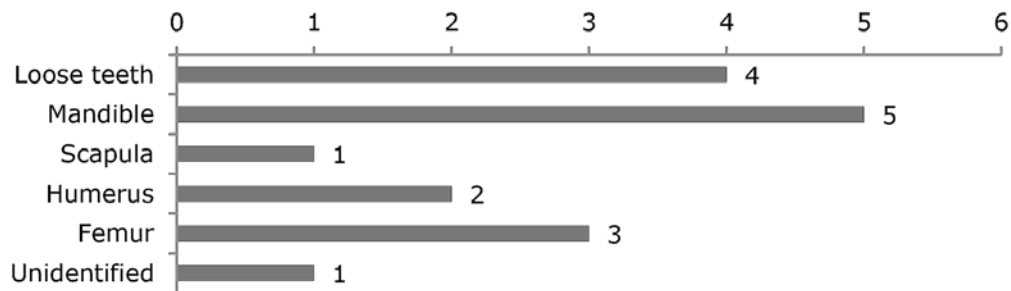
Figure 23.52: NISP of beaver in the assemblage (Copyright Star Carr Project, CC BY-NC 4.0).

Rodentia

Beaver

Overview

Fraser and King (1954, 73–74) noted that beaver is fairly well represented in the collection with an estimate of at least seven animals represented. In the recent excavations, 15 specimens have been identified, which mainly derive from Clark's area and the dryland (Figure 23.50). On the dryland, these remains are represented by one fragment that has been identified by ZooMS (but could not be identified to element), and teeth and mandibles.

Elements

Beaver is represented by four loose teeth and five mandibles, as well as a scapula, two humeri and two femora (Figures 23.51 and 23.52). This correlates with what was found in Clark's excavation, which includes jaw bones, two humeri, four radii, four ulnae, six pelvic bones, eight femora, 10 tibia, one sacrum and six lumbar vertebrae (Fraser and King 1954, 73–74). It is important to note that this pattern of element representation in terms of the presence of large and distinctive incisors is unlikely to be a result of excavation bias or sampling strategy, as

Figure 23.53: Two of the beaver mandibles (<116813> left and <115878> right) with similar modification to remove the ascending ramus, and fragmentary incisors (left to right: <117547>, <116164> and <115881>) (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

small and more gracile remains have been recovered for other species (for example roe deer loose teeth, wild cat phalanges, pine marten caudal vertebrae and small fragments of fish remains).

Age and sex

In terms of age assessment, one humerus has a proximal epiphyses which is unfused and missing. According to Fandén (2005) this element remains unfused between the ages of three months and 6.4 years. A complete femur is fully fused; fusion is complete in this element by eight years of age, therefore this individual could have been 8+ years old. It was not possible to sex these remains.

Figure 23.54: Polish just below the dental arcade on the mandible <115878> and on the buccal side of one of the molars, possibly suggesting the use of leather binding to create a tool from the mandible (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Modifications

There is only one specimen with evidence of animal modification: a beaver femur from Clark's backfill exhibits uneven breaks and associated tooth impressions and tooth scores. In terms of human modification evidence, six specimens exhibit percussion breaks, and they consist of four mandibles (two from Clark's area, one from the wetland and one from the dryland), an incisor (from Clark's area) and a humerus (from Clark's area). The breakage pattern to the mandible is similar for all four specimens, with percussion breakage to remove the ramus, and two exhibit breakage around the incisor tooth socket, possibly for the removal of the incisor itself (Figure 23.53). Although the removal of the ascending ramus is associated with marrow extraction in other similar elements of red deer, as there is no breakage along the jawline below the tooth row for the beaver mandibles, this breakage is unlikely for this purpose. This modification may therefore be related to the creation of beaver mandible tools, or for purposeful removal of the incisor from the mandible. Additionally, the presence of polish to the bone surface just below the dental arcade on mandible <115878> (Figure 23.54) on both the buccal and lingual sides suggests leather binding may have been applied to create a handle out of the mandible in order to use the incisor, possibly for woodworking. There are a number of archaeological examples, especially from Russia, of beaver incisors being utilised for decorative purposes or as a tool either whilst still within the mandible or loose and hafted into antler (Zhilin 1997; Lozovskaya and Lozovski 2015). All of the loose beaver teeth are incisors and all are fragmentary (Figure 23.53). There is no clear sign of hafting as seen in the Russian examples but dehafting may have taken place, or leather may have been used for holding them.

MNI

During their original analyses, Fraser and King (1954) identified 71 specimens of beaver; 15 loose teeth and 56 elements. The elements included one maxilla (with a complete set of teeth), 14 pieces of mandibles (eight right, six left rami of the lower jaw), 12 loose incisors, 3 loose molars, two humeri, four radii, four ulnae (two right, two left), six pelves (three right, three left), eight femora (one right, seven left), ten tibiae (three right, seven left), one complete sacrum and six lumbar vertebrae. Interestingly, the majority of the long bones (NISP=22) were found to derive from immature animals with one or more epiphyses unfused and missing. It is unclear which element was used to calculate the MNI, but they suggest that at least seven animals were represented, with the majority being immature individuals (Fraser and King 1954, 74). It is not clear why the rami were not used to give an MNI of 8, unless they were perhaps fragmentary.

For the assemblage described here, the most common element is the mandible, which consists of five specimens found in several locations: two on the dryland, one near the eastern platform and two within Clark's area. Four mandibles are sided as right and one as left, all of which contain permanent teeth in wear; this provides an MNI of four.

If the results from the most recent excavations are combined with Fraser and King (1954), based on the presence of mandibles, an MNI of 12 is estimated for the entire assemblage: four right mandibles from the recent excavations and eight right mandibles (rami) from those undertaken by Clark; however, without examining the original collection we cannot be sure that this does not double count some of Clark's specimens, if they were fragmentary.

Field vole

A total of three field vole specimens were found on the dryland, and they are all represented by fragments of loose teeth. The teeth are the easiest way to differentiate between the different species of vole, and they were found during the flotation of soil samples taken from the central hollow of the eastern structure during the 2008 excavations. All three teeth appear to have been charred. It is unlikely that these teeth were intentionally brought into the structure, and given that they are charred, it is likely that they occur here by accident; possibly a vole was caught in a fire. There is very little that can be said about this species due to the small number of remains found; however, they are of interest as microfaunal remains have not been found at the site previously.
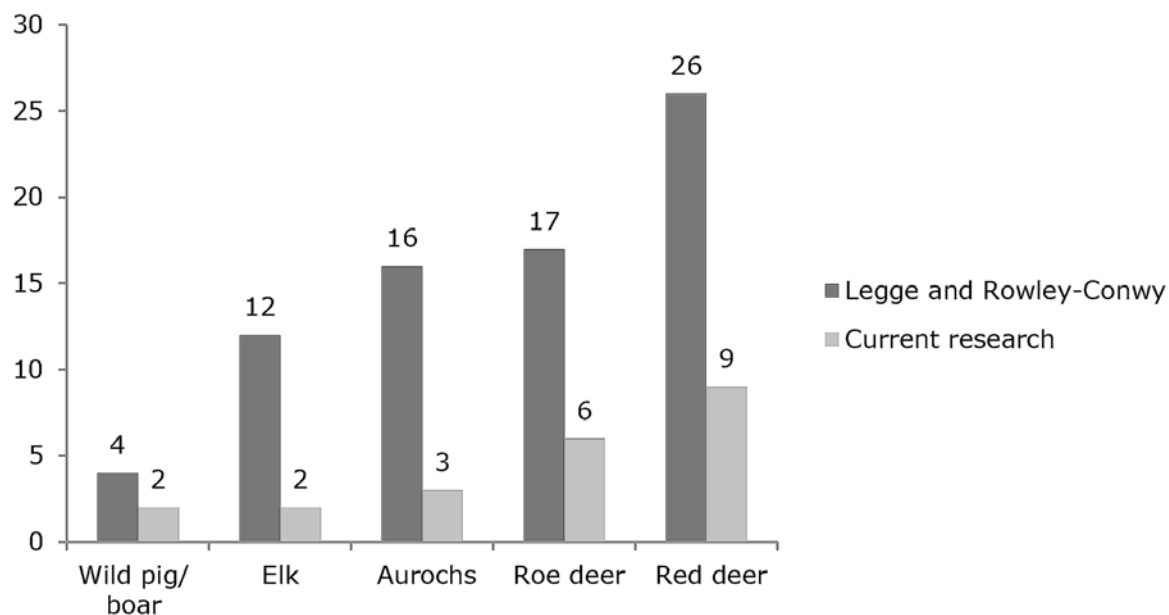
Figure 23.55: MNI comparison between Legge and Rowley-Conwy analysis and the current research (Copyright Star Carr Project, CC BY-NC 4.0).

Common name	Clark 1954	Degerbøl 1961	Harrison 1987	Legge and Rowley-Conwy 1988	Tot Lord	Present study	Overall
Northern pike						X	X
European perch						X	X
Common crane	X		X			X	X
White stork(?)	X		X̶				
Red-breasted merganser	X		X				X
Red-throated diver	X		X				X
Black-throated diver						?	?
Great crested grebe	X		X				X
Little grebe	X		X				X
Lapwing	X		X̶				
Buzzard	X		X̶				
Duck (size of pintail)	X		X̶				
Brent goose			X				X
Common scoter			X				X
White-fronted or bean goose						X	X
Bear					X		X
Wild cat						X	X
Pine marten	X						X
Fox	X						X
Wolf	X	X̶				X	X
Badger	X						X
Dog		X					X
Hedgehog	X						X
Roe deer	X						X
Red deer	X						X
Elk	X						X
Pig	X						X
Aurochs	X						X
Hare	X						X
Beaver	X						X
Field vole						X	X

Table 23.13: Revised list of taxa from Star Carr showing the presence (X) or absence of species. The names in red represent those species that are present in the amalgamated assemblages taking into account re-analyses of the material. ✗ denotes taxa that have been re-analysed and classified as something else.

Discussion

The data presented here provides some important new insights into the faunal assemblage at Star Carr. ZooMS as a complementary method has also provided additional information regarding species, allowing us to identify more of the dryland specimens, and although the cervids cannot be distinguished, the method identified significant quantities of aurochs within the assemblage. The recent excavations at the site have yielded four previously unidentified species: northern pike, European perch, wild cat and field vole. There may also be a black-throated diver (though it may be a red-throated diver) and there is a new species of goose (white-fronted or bean). There appears to be both a dog skeleton and a wolf bone, which brings wolf back into the list following previous re-evaluations of dog to wolf. There are also a number of rodent specimens from flotation samples which cannot be identified to the genus and species.

Overall, with all the corrections to the data over the years, there now appears to be 26 species identified from Star Carr (the potential black-throated diver has not been included in this total) (Table 23.13), as opposed to the 21 first identified (Fraser and King 1954). The fish bones are particularly noteworthy because there has been much debate as to why fish was not found previously at the site (Wheeler 1978): evidence has now been found both from the wetland (in Clark's area) and on the dryland as calcined bones demonstrating fish were being caught, processed and discarded on site (see also Robson et al. 2016).

It is interesting to note that of the MNI of the five most represented species (red deer, roe deer, aurochs, elk and wild boar) there is very similar pattern to Legge and Rowley-Conwy's (1988) data in terms of order of prevalence (Figure 23.55). This is probably due to the fact that a large proportion of the recent data also comes from Clark's area, although it should be noted that red deer appears to predominate in most areas of the site.

Legge and Rowley-Conwy (1988) hypothesised that the assemblage (as represented by Clark's excavation) was strikingly similar to that of a Nunamiut hunting camp. This pattern was based on the presence of mandibles, upper forelimbs and limb extremities, with the assumption that the upper rear limbs are transported back to a different residential base (Legge and Rowley-Conwy 1988). However, from our dataset we can see that femora are present. A number of them are classed as 'large mammal' because most are fragments due to breakage for marrow extraction, and many were found in the backfill. We now know that Clark did not collect many unidentifiable specimens and his assemblage had been handpicked, which skewed the dataset; this therefore throws doubt on the notion of this site being a hunting camp.

The seasonality assessment has also changed since the analysis of Legge and Rowley-Conwy (1988). It should be noted that all seasonality assessments are reliant on the use of modern analogues for the season of birth, the migration patterns of birds and the shedding of antler (Milner 1999; 2005). There is often some degree of variation in this data; for instance, some species can give birth over several months, which means the anchor point is moveable, and there is some variability in terms of the timing of tooth eruption and the development of wear patterns. However, what we do not know is how much further variability there might have been in the past, particularly for this site where we have clear evidence for significant fluctuations in climate (Chapters 4, 9 and 18). The changes in temperature inevitably would have affected the behaviour of animals, and we should be mindful that, for instance, bird migration patterns might have been significantly different.

What is clear is that there now appears to be evidence from Clark's area for animals that have been killed in all four seasons. Legge and Rowley-Conwy (1988, 38) made the point that game was probably accessible at all times of the year: none of the major species show a marked tendency to migrate. However, because at that stage no winter kill stages were present in their dataset, they suggested that a year-round settlement was unlikely. Red deer skulls with antler shed are likely to be spring (Legge and Rowley-Conwy 1998, figure 7), with a concentration of roe deer mandibles and maxilla argued to be indicative of May/June deaths. Further summer evidence comes in the form of neonatal red deer, red deer maxilla, red deer mandibles, a neonatal elk and summer migratory birds (Grigson 1981). An elk mandible suggests an autumn kill, possibly alongside some red deer mandibles. However, Carter (1997; 1998) has since demonstrated that both roe deer and red deer exhibit evidence for winter kills and one of the red deer mandibles assessed as part of this study also suggests a winter kill.

It is also important to consider the nature of the dataset. The seasonality data have always been based on the material from Clark's assemblage. We now know that this is part of a larger picture and this deposition may have taken place over a short period of time (Chapter 17). The only other seasonality data from the rest of the site is from the detrital wood scatter, where the evidence from one red deer mandible suggests a kill in the summer. This simply suggests that a deer was killed in the summer during the earliest occupation of the site but does not necessarily mean that occupation did not happen in other seasons.

Conclusions

This new data provides some important changes to our understanding of the faunal assemblage at Star Carr, with new species, as well as a re-evaluation of both the site type, as assessed by faunal remains, and seasonality. As Legge and Rowley-Conwy (1988, 7) state: 'no bone report is ever in a full sense a final report. Conclusions will always be subject to modification, and identifications to rechecking, as new methods and skills are developed.' They go on to say that having come to different conclusions to those of Fraser and King, they do so in the knowledge that their identifications and conclusions will also be subject to change, 'possibly in much less than the 30 years that have elapsed since the appearance of the original bone report.' It is now almost 30 years since their report, and in fact little has changed with the exception of Carter's (1997; 1998) work on age and seasonality. However, the recent excavations have thrown more light on Clark's area as well as new areas of the site: we also anticipate that this new dataset will generate further re-evaluations, new conclusions and new debate.

CHAPTER 24

Osseous Technology

Ben Elliott, Becky Knight and Aimée Little

Introduction

Clark's original excavations at Star Carr recovered extensive evidence for a rich and varied suite of osseous material culture. This included finished artefacts in the form of uniserial barbed points, modified red deer frontlets, elk antler mattocks, bone bodkins, aurochs bone scraping tools, worked red deer tines, a bird bone bead, an elk antler hammer, a spoon-like object made of elk antler and a possible red deer antler handle. In association with these finished forms, Clark also recovered a large quantity of red deer antler which had been worked to various extents: 'blank' splinters waiting to be worked into barbed points, the manufacturing waste from the production of the bone scraping tools and bodkins and fragments of elk antler left over after the production of mattocks. These finds were supplemented by a much smaller assemblage of worked red deer antler and a single barbed point during further excavation of the site in the 1985 and 1989 (Mellars and Dark 1998).

Our excavations have recovered evidence for bone and antler working from across the wetland areas of the site, with an overall assemblage which mirrors that of Clark in terms of the range of artefacts and debitage. This consists of modified red deer frontlets, barbed points, red deer antler debitage, bone working debitage, elk antler debitage, a bone bodkin, a bone scraping tool and an elk antler mattock. Finds were analysed, recorded and photographed at the University of York before being conserved by York Archaeological Trust. Selected artefacts were recorded using reflectance transformation imaging (RTI) prior to conservation.

Having outlined the methods used in analysis, this chapter will first deal with the working of bone at Star Carr and the production of aurochs bone scraping tools and bodkins, before moving on to discuss the working of red deer and elk antler, and the production of elk antler mattocks. A full description and analysis of the working of barbed points and red deer frontlets are provided within Chapters 25 and 26 respectively. These classes of artefact have been given their own chapters to allow for an independent discussion of their research history and their wider role within the European Early Mesolithic. However, discussion of the more general trends in osseous technological practice will draw from material across these three antler-based chapters, and involve various degrees of cross-referencing. A discussion of the significance of this assemblage within the wider context of Mesolithic Northern Europe will be provided within Chapter 27.

Methods

The use of traceological analysis in the study of osseous tools from Mesolithic contexts has been pioneered by the work of David (2005). Her method of analysis comprises four major stages of recording for each piece of osseous material recovered from an archaeological site. These consist of a hand survey to record the maximum length, width, thickness and weight of the piece, as well as any anatomical measurements that it is possible to record. Secondly, a technical description of the piece is carried out, using the methodology outlined by Voruz (1984). This method of shorthand description allows the occurrence of markings, their character, their location and their relationship to other markings and surfaces to be recorded quickly and consistently. Thirdly, the pieces are photographed to give an impression of the overall character, but also to illustrate working marks were present through the manipulation of raking light. Finally, drawing was undertaken for some of the material from Star Carr. This element of the methodology is modified slightly from that used by David. In this study, only finished artefacts were drawn and annotated in the style outlined by David (2005, 468–472). This decision was taken based on the advances in digital photography technology that have taken place since David's original development of the methodology, which allow high-quality images to be taken and disseminated with relative ease and which can illustrate the markings present on osseous material without the need to produce drawings.

From this recording process, several assertions can be made regarding the individual pieces of material. Firstly, the biological properties of the piece can be described. Through comparisons with reference material (both modern and archaeological), the species and element and anatomical region of origin can be determined. This is primarily based on the morphological form of the piece, the character of any intact compactor tissue and the consistency of spongy material. Events and processes which occur in the course of the biological history of the material are also possible to identify, based on an understanding of animal behaviour. For instance, the occurrence of polish on the tips of antler tines can be linked to the fraying of antlers, when deer rub themselves against the ground or trees, and need not be directly linked to anthropological action (Jin and Shipman 2010).

Secondly, the taphonomic factors to which the piece has been subjected can be discussed. Through an examination of the character of the material, the condition of the anatomical surfaces, instances of discolouration and the nature and orientation of striations and incisions, it can be possible to broadly identify processes such as gnawing (by rodents, ungulates or molluscs), demineralisation, exposure to weather or the action of water. This can also be greatly aided by the study of contextual information from the excavation archive, although in some cases this is not always possible.

Thirdly, once the biological and taphonomic processes have been identified and accounted for, the markings associated with specific working actions can be discussed. The form of these working marks can be related to specific techniques and actions, based on comparisons to both archaeological and experimentally produced reference material. The relationship between these markings can also be studied to gain an understanding of the sequence in which these were carried out. In a similar way to the principles of stratigraphy that are used to establish sequential relationships between depositional events on a site level, working marks which overlie or 'cut' other episodes of working or taphonomic processes can be said to occur later than the original actions. In this way, a sequence of actions, or chaîne opératoire, can be built up for each individual piece within the assemblage.

Microwear of some of the osseous artefacts was carried out by AL (see Chapter 15 for methods). During this work a limitation became apparent, in that published microwear reports detailing analysis of similar objects is severely lacking. This is perhaps not surprising considering the historical focus on flint followed by other stone types in microwear studies. Only more recently are we seeing attention turn to a more diverse range of materials such as shell, pottery, bone and antler.

Analysis and interpretation

Bone technology and debitage

Only three bone artefacts were found on the site during the 2004–2015 excavations: one barbed point (see Chapter 25), one scraping tool and one elk bone bodkin. However, there is further evidence for bone working in the form of debitage. Working traces beyond butchery marks and the spiral fractures associated with marrow extraction were detected on 47 animal bones.

David's (2005) analysis of Clark's material identified a châine opératoire for the production of rectangular bone blanks from large mammal metapodia (Figure 24.1). This was interpreted by David as evidence for the production of bone notched points; although bone notched points are not documented within the Clark assemblage, her analysis of the technological sequence in bone working stands as a good point of departure for considering the new evidence for bone technology. Her analysis showed a process which involved the initial enlargement of the proximal foramen (Figure 24.1, a) through the dotted perforation technique (Figure 24.1, b), the application of wedge-splinter technique to further modify the shape of the proximal epiphysis (Figure 24.1, c), the removal of the distal epiphysis through a sawing-prepared break (Figure 24.1, d) and the subsequent application of the wedge-splitter technique to divide the remaining bone along the natural grooving (Figure 24.1, f).

Of the material uncovered in the 2004–2015 excavations, 13 fragments of red deer and two fragments of roe deer metapodia, along with five red deer long bone fragments unidentified to element, show signs of having been split via the wedge-splitter technique (see Figure 24.2). However, the evidence for bone working contradicts the patterns identified by David to a certain extent. There is very little evidence of the use of dotted perforation (see Figure 24.2) to enlarge the nutrient foramen at the proximal ends of the pieces (with a single exception, <116893>), nor the use of wedge-splinter technique to shape the outer surface of the proximal end (again, with the single exception of <116463>).

There is also a consistent combination of both spiral percussion breaks and wedge-splitter evidence on the same bone, suggesting that bones were broken for marrow initially, and then the fragments were further split for other purposes. Perhaps related to this, there are numerous instances of splitting which ignore the natural grooving of the metapodia (a natural characteristic which can aid the production of sub-rectangular blank fragments), suggesting again that this splitting was carried out somewhat as an afterthought to butchery and marrow extraction. Furthermore, this splitting is not confined to metapodia: femora, ulnae, radii and tibiae
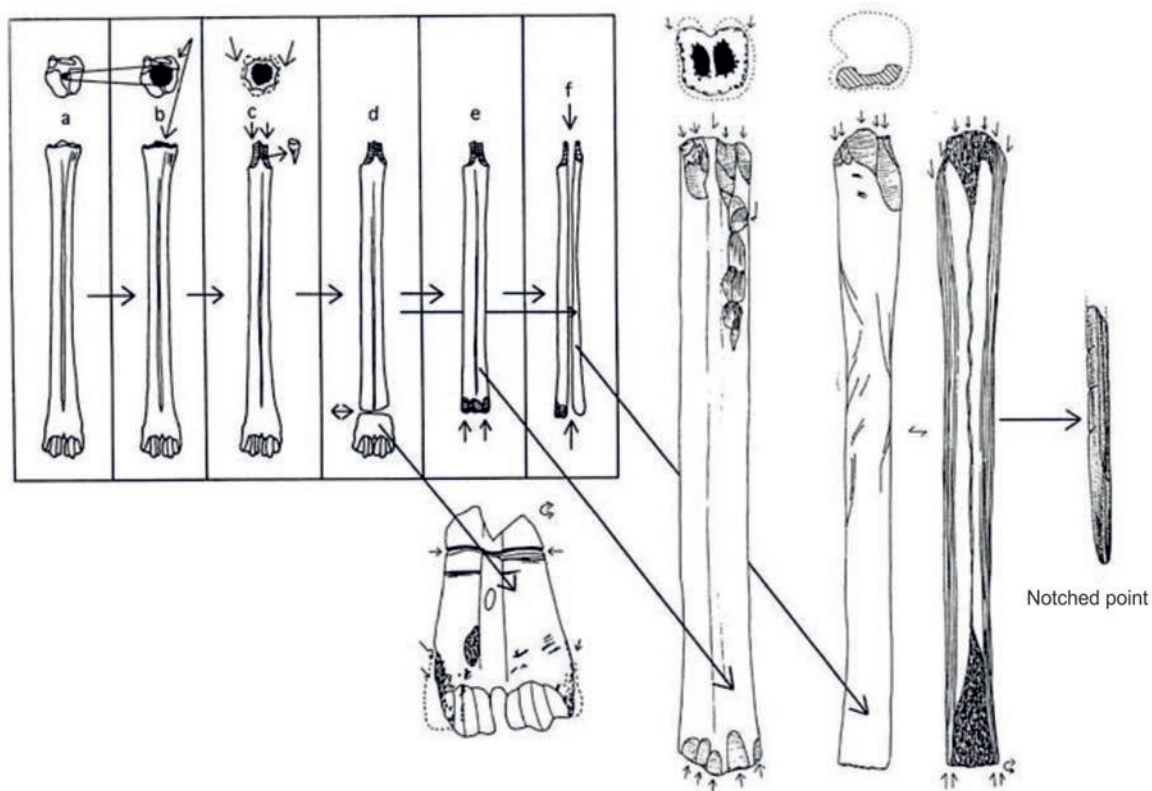
Figure 24.1: Châine opératoire for the production of bone notched points (David 2005, 326) (Copyright Eva David, CC BY-NC 4.0).
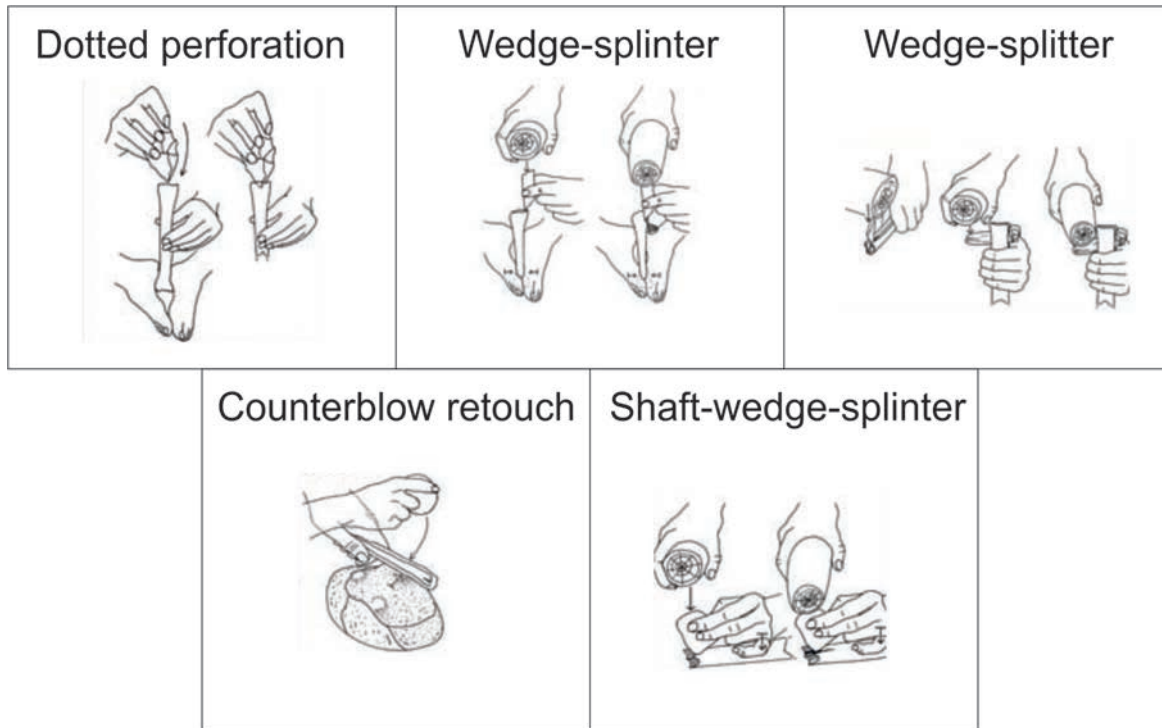
Figure 24.2: Distinct techniques used to work bone, as identified and defined by David (2007, 39) (Copyright Eva David, CC BY-NC 4.0).

have all been split using the wedge-splitter method. A single instance of the shaft-wedge-splinter technique was identified on a medium mammal rib bone. The bone material removed by this would have been too small to produce a barbed point, and so it must again be concluded that this technique was used to extract marrow from ribs.

As such, we have a complex combination of actions at play within this assemblage. On occasions, long bones are broken apart with no apparent concern for the form of the bone fragments left afterwards, producing spiral fractures. Given the disregard for the form of the bone fragments left, this was presumably undertaken for the extraction of marrow and grease, with long bones being particularly rich in both of these materials. In other instances, more controlled, wedge-splitter techniques are used to break bones apart, which help to produce regularly sized and dimensioned portions of metapodia; what would usually be considered as blanks for bone barbed point production. However, there are numerous instances which cloud this clear-cut distinction between bones fragmented to extract marrow and bones carefully split to make artefacts. These include fragments which have been carefully split via the wedge-splitter technique, but not in a way which produces blanks suitable for bone barbed point production, and fragments which have traces of both spiral fractures and wedge-splitting on them.

The intention here is unclear and may be a reflection of an occasional preference for the use of particular techniques in multiple tasks, even if they may not be the most efficient. Whilst many of the wedge-split bone would not be usable as material culture blanks due to their size and shape, the actions themselves may well have allowed marrow to be extracted. This suggests that the presence of the wedge-splitter technique in itself need not necessarily indicate an intention to produce material culture, and serves to highlight the complexity of the treatment of bone at the site.

However, these findings do demonstrate that, although not executed universally, cervid long bones were being occasionally split in a regularised manner to produce blanks which would be suitable for the manufacture of bone barbed points. The relatively small scale of these actions is notable in comparison to the abundant

evidence for the groove-and-splinter technique within red deer antler, and the almost total use of antler for the finished barbed points at the site (Chapter 25).

David's analysis also identified a distinct châine opératoire for the working of the more robust aurochs metapodia, specifically for the production of large scraping tools, (Figure 24.3), which involves the coin-éclat-fente (shaft-wedge-splinter) technique, alongside dotted perforation, wedge-splintering, and counter-blow retouch (Figure 24.3).

Two split aurochs metatarsals were recovered showing similar signs of working. One of these had been originally split using the wedge-splitter method, and showed signs of sawing and a prepared break at the distal end to remove the epiphysis. Following this, counter-blow retouch had been applied along one edge to further modify the shape of the piece. The second split metatarsal had been subject to the wedge-splitter technique and then abandoned. This appears to demonstrate the manufacture, use and deposition of a small number of these aurochs metatarsal scraping tools were being carried out at the site.

More unusual, aurochs bone working was apparent in the form of two phalanx fragments, which had been split longitudinally. Although the preservation of these pieces makes a full definition of their working methods problematic, the continuous and regular character of the split surfaces would suggest that this was achieved through wedge-splitting.

Aurochs bone tool

Clark's excavations at Star Carr recovered an assemblage of 11 finished aurochs bone scraping tools and nine pieces of debitage produced as by-products of their manufacture, made from metapodials, metacarpals and metatarsals. These were interpreted as hide-scraping tools through ethnoarchaeological analogies with Inuit groups in North America.
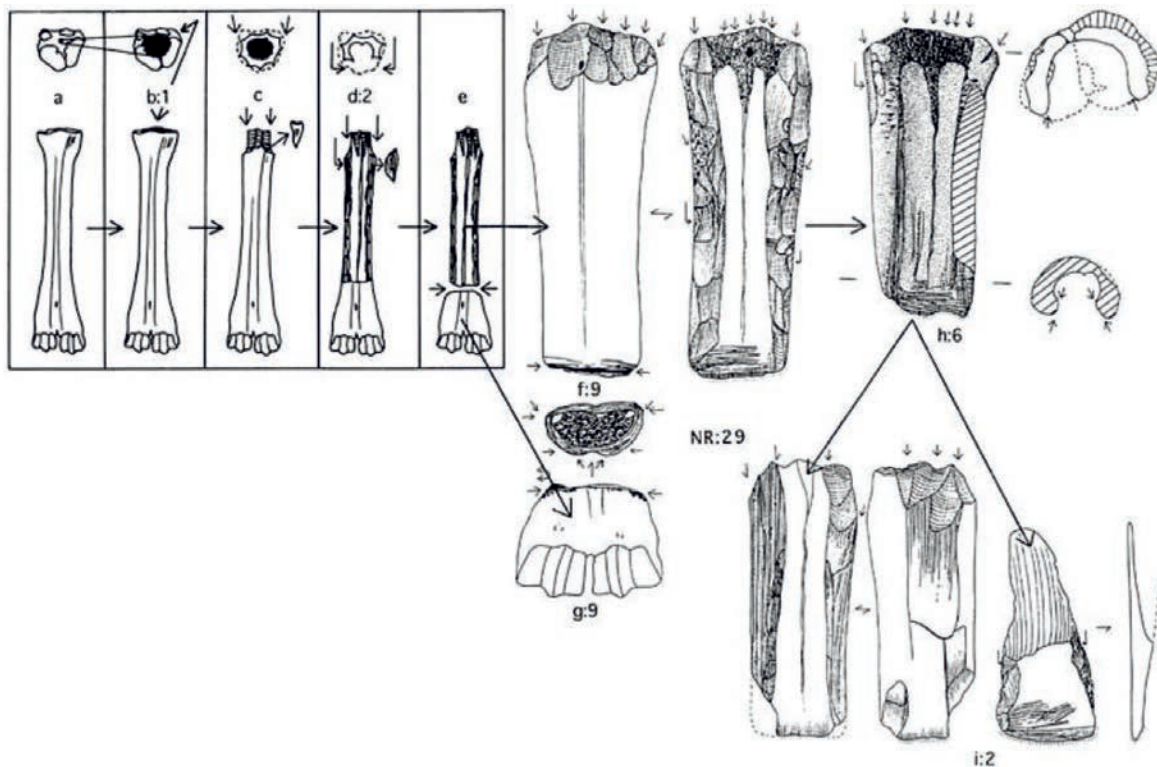
Figure 24.3: Châine opératoire for the production of aurochs bone scraping tools (David 2005, 331) (Copyright Eva David, CC BY-NC 4.0).
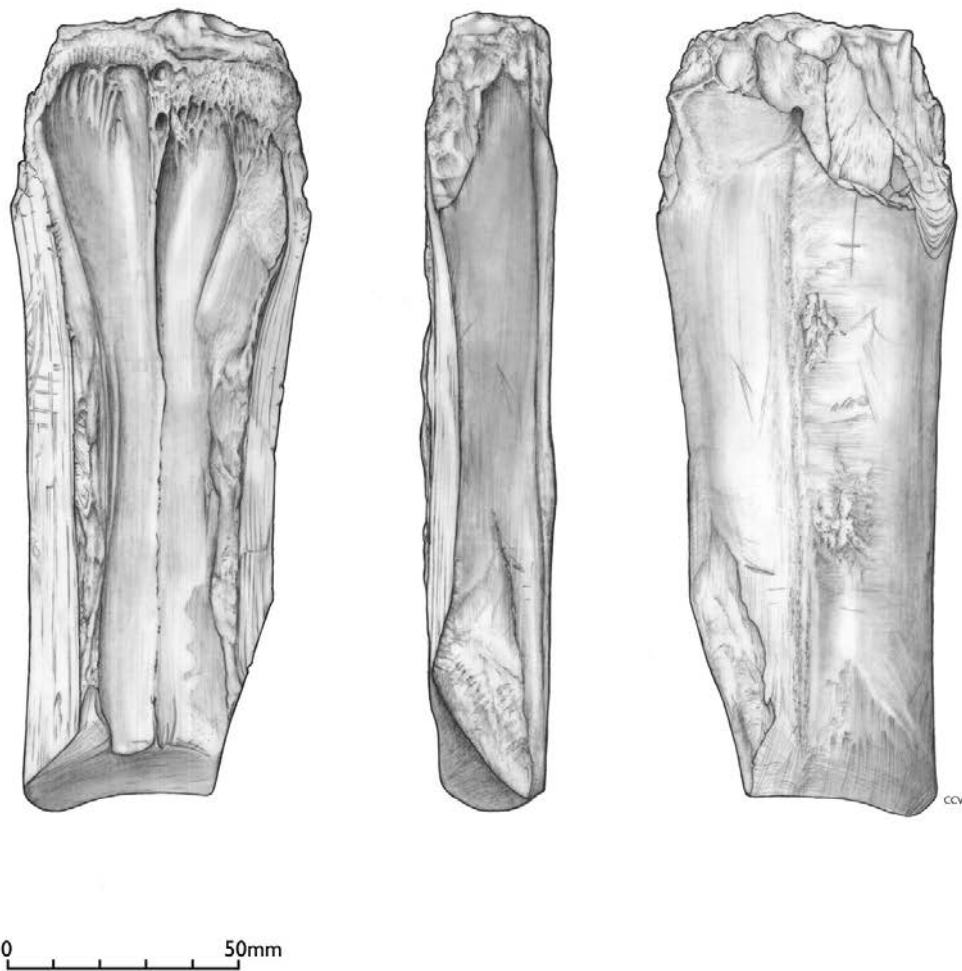
Figure 24.4: Aurochs bone chisel <117517> (Copyright Chloe Watson, CC BY-NC 4.0).

In 2015, a large, worked and utilised fragment of a split aurochs metatarsal midshaft <117517> was recovered from Clark's area of the site, within the reed peat (312) (Figure 24.4). The piece was well preserved and robust and there is the suggestion of a healed lesion on the cortical bone surface. The distal end has been modified through dotted perforation (opening up the medullary cavity) and then negative removal scars around the circumference of the bone suggest the use of the wedge-splinter technique to further shape the distal end.

The techniques used to achieve the splitting are unclear. Macroscopically, the highly lustrous and longitudinally striated edges suggest some form of secondary working or possible utilisation, whilst the angled, bulbous negatives on the inner aspects of the less-regular split edges suggests the shaft-wedge-splinter technique was employed. The angle of the proximal termination is consistent with those observed on spiral fractures throughout the Star Carr assemblage (Noe-Nygaard 1977), although it appears to be broken short to a certain extent. The surface of the proximal termination is highly lustrous and demonstrates multiple fine striations and has a similar character to that observed along the split edges.

The chisel was analysed for wear traces but none were identified. However, the lack of wear on the blade of the chisel may be a result of a later (post-use) rejuvenation of the edge, probably with a flint tool, which is visible macroscopically (Figure 24.5). It was possible to see that at high magnification this scraped area and an adjacent area which appears to have sheared off, possibly at the same time, lack the same shiny generic polish seen across the rest of the object, the cause of which is unclear. No use polish was identified on the ventral side of the chisel blade either. No hafting traces were identified. If this chisel was used and the wear traces were then removed through resharpening, it does not appear to have been used again after that resharpening event. The breakage that appears to have occurred at the same time may account for it not being re-used, although even with that damage, it remains a perfectly functional tool. The alternative possibility is that it was never used and may have been abandoned once the breakage occurred during the final stages of manufacture. In both scenarios, the question remains: why abandon a functional tool?

Figure 24.5: Close-up of the blade end of the chisel showing edge-sharpening traces, probably made with a flint blade (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Bone bodkin

Clark's excavations recovered a collection of eight elk lateral metacarpal bones which had been subtly modified to create tools, which he interpreted as bodkins (for making holes in leather) or fastening pins. These were shaped and either polished or worn smooth, with two displaying bands of fine, incised lines running perpendicular to the axis of the point. The 2004–2015 excavations recovered a further bodkin <116151> from Clark's area of the site, within context (312), made from a partial lateral metacarpal of an elk (Figure 24.6). The taphonomy of the piece limits the amount that can be said about the way in which has been made. However, it is formally consistent with the examples described and illustrated by Clark and as such adds to the scarce record for this particular type of artefact within Britain.

The distal epiphyseal end (see Figure 24.7) had broken away from the main body of the element post-deposition. The proximal end of the specimen has been humanly modified whilst maintaining the original shape of the bone. Identification of specific working marks is complicated by the post-depositional water-action, which has smoothed the surfaces of the artefact. However, some longitudinal striations are visible under raking light using RTI analysis. The very tip has broken off, possibly during use.

Use-wear analysis revealed a very bright shiny and smooth polish containing numerous micro-striations which was located towards the tip and in apparent association with the larger striations observed macroscopically. This polish is consistent with siliceous plant polish. On the ventral surface it has a very clear directionality, running perpendicular to the edge; whilst on the dorsal surface, the polish runs both longitudinally and perpendicular to the edge. Another occurrence of probable siliceous plant polish is associated with a second grouping of macroscopically visible striations located on the dorsal surface towards the epiphyseal distal end, which had broken off. Thus it appears that these striations are use related and have probably developed from regular contact with plant fibres. One possibility is that it was used in weaving (see Figure 24.8).
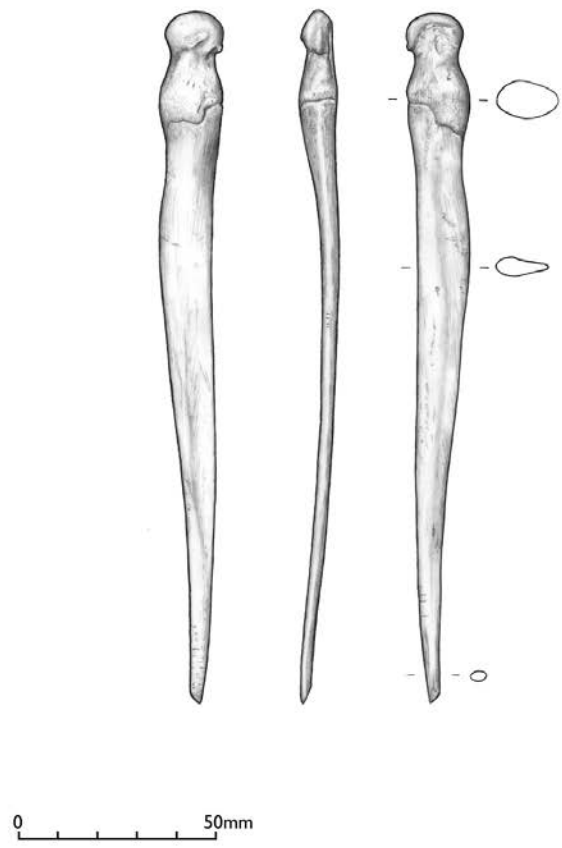
Figure 24.6: Elk bone bodkin <116151> (Copyright Chloe Watson, CC BY-NC 4.0).
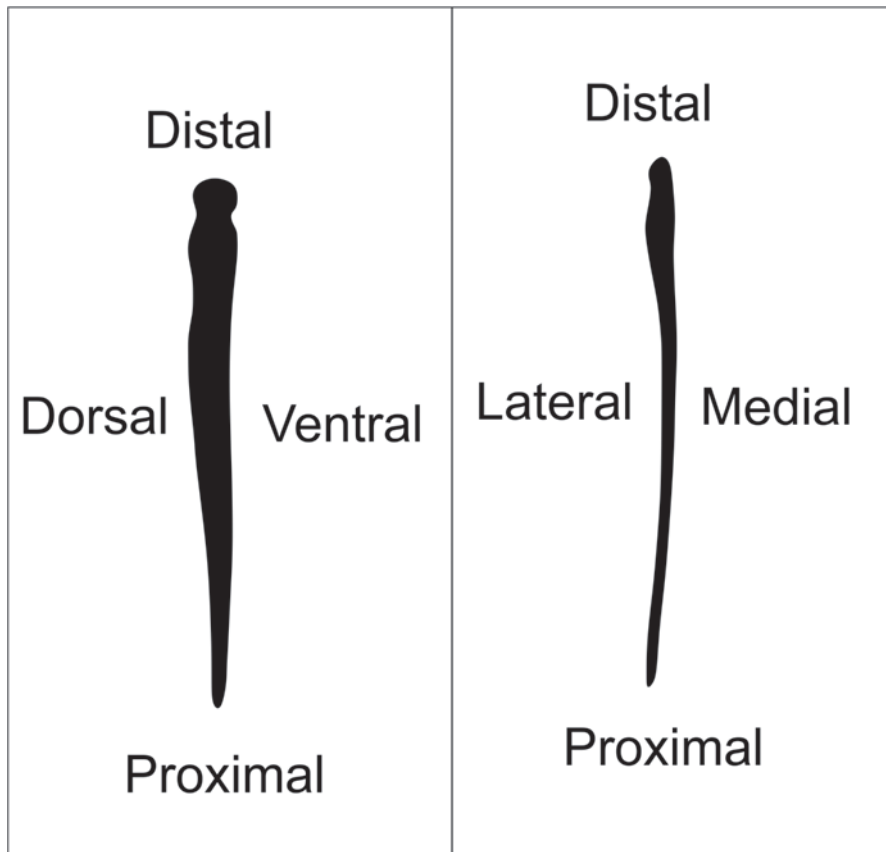
Figure 24.7: Schematic diagram of elk antler bodkin showing anatomical orientations (Copyright Ben Elliott, CC BY-NC 4.0).

Figure 24.8: Using a replica bone bodkin to make a coil basket (Copyright Aimée Little, CC BY-NC 4.0).

Antler technology

Elk antler technology and debitage

Six pieces of elk antler were recovered during the 2004–2015 excavations from a mixture of wetland and Clark's backfill contexts (Figure 24.9; Table 24.1). No elk antler was recovered from the dryland areas of the site, but given the small sample size and the reduced chances of survival for organic material within the dryland areas, it cannot be categorically argued that elk antler working was restricted to the wetlands. The assemblage includes a finished elk antler mattock, a possible mattock preform, two tines, a palmate portion and two unshed antlers attached to a skull. In terms of condition, this small assemblage is easily identifiable to species and region but lacks the preservation of fine surface detail to allow a more robust identification of working techniques. Whilst smaller than the original collection of elk antler finds recovered by Clark, these new finds confirm some of the patterns noted earlier at the site.

Elk antler mattock

Clark recovered six antler mattocks, which fell into two distinct types. Type 1 was made from the beam, pedicle and adhering frontal bones, whilst Type 2 was made using the beam and palmate portion of the elk antler. Further to this, Clark also recovered other types of elk antler artefact: a fragmented elk antler hammer and a spoon-like tool, as well as a small assemblage (n=13) of elk antler debitage.

<113836> is an intact, perforated elk antler mattock (Figures 24.10 and 24.11). Using Clark's typology, this is a Type 2 mattock utilising the distal portion of the beam (for the creation of the working edge) and the lower part of the palmate portion of the antler. The upper part of the palmate portion and tines have been removed,
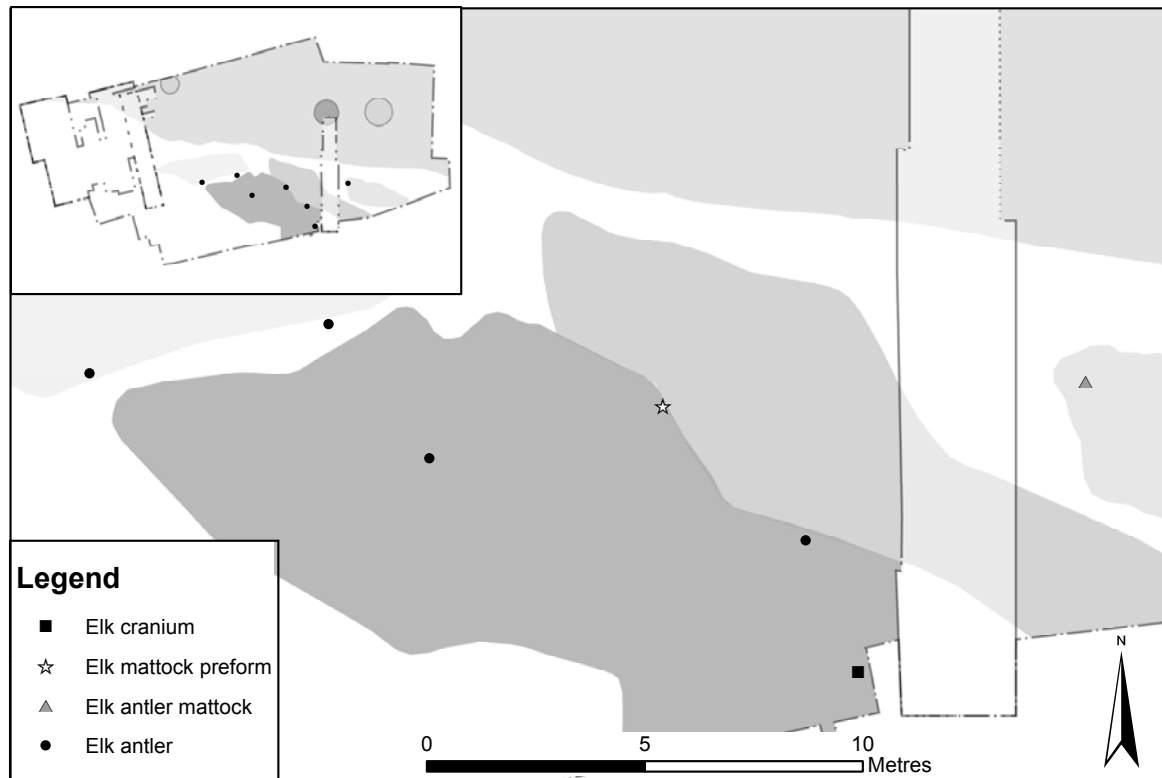
Figure 24.9: Distribution of elk antler across 2004–2015 excavations (Copyright Star Carr Project, CC BY-NC 4.0).

	Clark's backfill	Read peat (312)	Detrital mud (317)
Tine	1	1	0
Palmate portion	0	0	1
Skull with antler attached	0	0	1
Preform	0	1	0
Mattock	0	1	0
?Frontlet?	1	0	0

Table 24.1: Quantities, categories and contexts of elk antler from Star Carr 2004–2015.

although no indication of the methods used to achieve this survive due to localised demineralisation of the piece. The working marks associated with the creation of the working edge are also no longer intact. However, the angled break can be assumed to have been produced using a similar technique to that described by David et al. (2007, 40) for the creation of red deer antler axe and adze working edges. The perforation is larger on the internal aspect (ø32 mm) than on the external aspect (ø27 mm). It is set at an angle of c. 70 degrees to the axis of the piece and as such, when hafted, would have been set on a similar orientation to a modern day mattock (as opposed to an adze). No traces of a haft were found, despite meticulous excavation and the retention of all peat from within the perforation for post-excavation flotation.

In addition to the complete artefact, a possible antler mattock preform was also recovered. This represents a possible roughed out mattock, with the anatomical regions defined through primary working, but no further
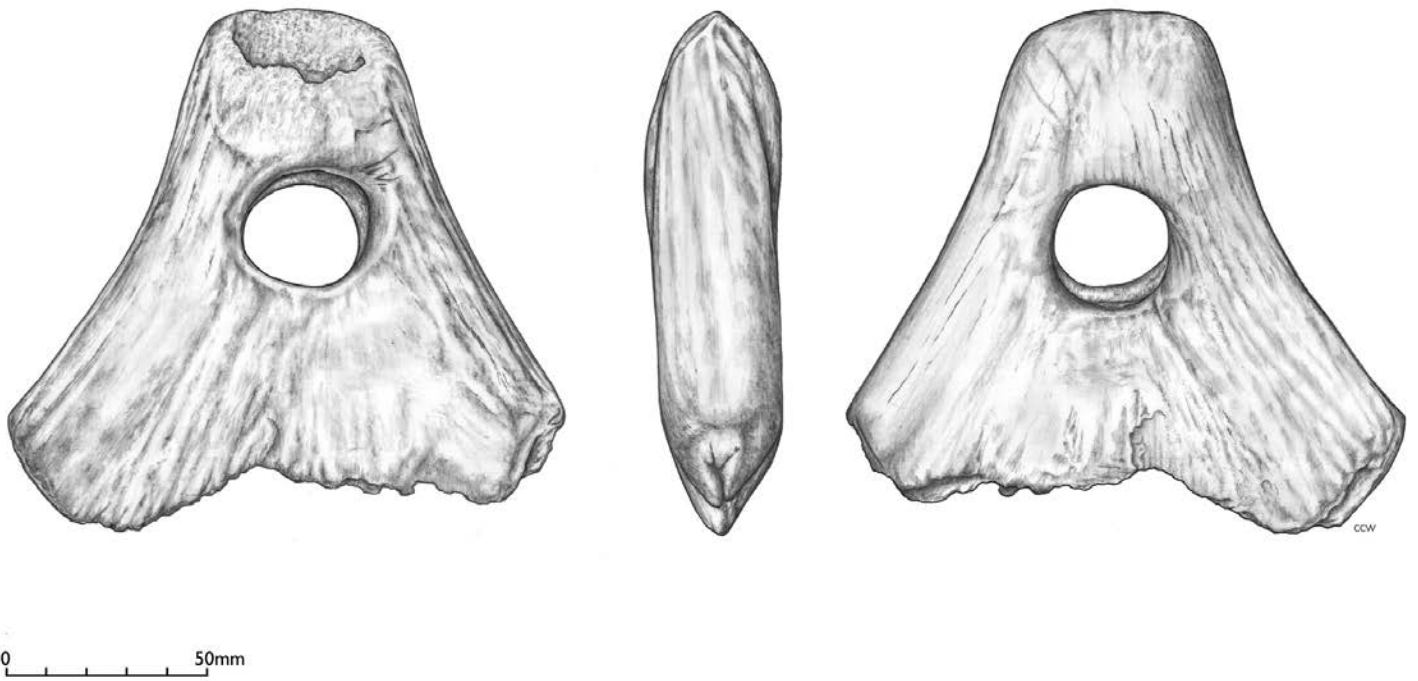
Figure 24.10: Elk antler mattock <113836> (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 24.11: Elk antler mattock <113836> in situ within reed peat deposits (Copyright Star Carr Project, CC BY-NC 4.0).

traces of finishing. This consists of the palmate portion and beam of an elk antler, with the tines removed. There is no trace of a perforation, or an attempt to create one. The preservation conditions of this piece appear to be particularly complex, with white leaching and demineralisation severely affecting the proximal termination of the beam. This is particularly unfortunate as it prevents an assessment of any modification in this area. As such, this piece remains a potential antler mattock preform, having been worked to isolate the portion of elk antler classically used to create Clark's Type 2 mattocks. As to whether or not a working edge had been created before the manufacture was abandoned, and if so how this had been attempted, it is now impossible to say. Unfortunately the condition of the mattock did not permit use-wear analysis.

Interpretation

Clark's original interpretation of the elk antler mattocks was as digging or grubbing tools for the extraction of roots and tubers. He dismissed the idea of them as woodworking tools based on the angle of the perforation which would have placed the haft at an acute angle to the working edge. However, experimental work challenges this. A replica elk antler mattock was manufactured, hafted (without binding) and used successfully in a series of woodworking activities (Figure 24.12). In this instance, the haft was formed of a trimmed piece of birch roundwood. Given their spatial association with the large quantities of worked wood within the wetland areas of the site, their suitability for woodworking should be considered.

The majority of the elk antler mattocks at Star Carr form part of a larger group of artefacts which were deposited into the wetland areas of the site having first been dehafted. <113836> falls into this category, alongside five of Clark's mattocks, the barbed points from the site and a range of flint tools which were hafted and dehafted prior to deposition within the wetlands. The quantities of wood recovered from context 312 demonstrate that wood was capable of preserving in this area of the site, and as such the lack of haft requires a more complex explanation than that originally offered by Clark.

The exception to this pattern of dehafting and disassembly is Clark's EM6—a single example of an elk antler mattock with the carbonised stump of a haft inserted within the perforation. EM6 is worth some further consideration here, as a well-recorded exception to this general rule. Analysis of the original specimen has identified the haft as a piece of unmodified roundwood: this would have been functionally viable as a haft but would not have allowed optimal performance of the tool in woodworking activities (see Chapter 29). The evidence for in situ reed burning across the site means that this burning could have occurred either before deposition or after, whilst the haft was still attached to the mattock head. However, the antler component of the mattock head

shows no sign of burning, even around the perforation itself. This may suggest that whatever the purpose of this particular piece of wood, it was burnt and then inserted into the perforation prior to deposition.

Red deer antler technology and debitage

Clark's analysis of the red deer antler working waste products recovered from Star Carr focussed around an assemblage of 104 loose antlers (that is, either shed or detached from the majority of the frontal bones of the skull and distinct from the frontlet artefacts described in Chapter 26), 94 of which had been modified in some manner. The basic sequence of working identified by Clark involved the initial removal of the crown and tines from a red deer beam, and then the subsequent light scoring of parallel grooves along the length of the beam, aligned with the natural guttering of the antler (Figure 24.13). These grooves cut into the hard outer compactor tissue of the antler. During our experiments it was observed that snapped flint blades became very useful for grooving. Using these tools, grooves are then progressively deepened until the compactor is fully penetrated, the underlying spongy core is exposed, and the intervening strip (or splinter) of antler removed. This rectangular splinter is then further worked into a finished barbed point using the methods discussed above. Experimental work has established that the detached tines played a key role as wedges for the removal of the splinter from the beam (Elliott and Milner 2010). The relative scarcity of removed splinters at the site has been commented on by several authors (Jacobi 1978; Warren 2006; Chatterton 2003), and in lieu of more direct evidence Clark relied on measurements of the removal scars left on the worked antlers to estimate the initial widths and lengths of splinters prior to further working. He noted that these splinters appeared to be much longer than the finished barbed points, and he suggested that individual splinters may have been divided up and used to produce multiple barbed points. This key point renders much of the subsequent discussion of the precise quantities of barbed points produced at Star Carr obsolete (Clark 1954; Mellars and Dark 1998; Price 1982; Mellars 2009), as even a speculative estimate of the numbers of splinters removed at the site does not equate directly to the number of barbed points that may have been produced.

Clark noted that the extent to which individual antlers were worked, in terms of the number of splinters being removed, varied considerably across the assemblage and that this bore no relationship to the mixture of shed (n=41) and unshed (n=65) antlers.

The 2004–2015 excavations recovered an assemblage of 158 pieces of worked red deer antler (Figure 24.14; Table 24.2). This is distributed across the excavated areas, with organic material being inevitably more likely to survive within wetland areas but with the occasional fragments of dryland antler providing evidence for antlerworking. Stratigraphically, the evidence for antlerworking is distributed throughout the sequence at Star Carr, indicating that this practice persisted throughout the site's occupational history and in a range of environments.

The evidence for the working of red deer antler is extensive, with similar patterns of tine and crown removal being observed, and both beams and tines being grooved and splintered for the removal of blanks for barbed points (Table 24.3). A mixture of prepared breakage and simple percussive breakage appear to have been used to achieve these initial steps, and in a small number of instances individual tines remained attached to the beam when groove-and-splintering began. There is also evidence for the application of the groove-and-splinter technique to tines which have been removed from the parent beam.

The preservation conditions of the assemblage need to be carefully considered when making comparisons between the absolute measurements of finished barbed points, removed splinters and the removal scars on worked antlers. Due to the range of factors affecting the Star Carr assemblage, some pieces of material will have been affected in different ways, with individual finds subjected to flattening, shrinkage and warping to varying degrees. As such, making definitive statements or analyses of the dimensions of these characteristics is problematic. However, the data available from the 2004–2015 assemblage supports Clark's initial observations on a relative basis, with the small number of removed splinters that have been recovered being longer than the intact barbed points and shorter than the length of splinter scars.

Figure 24.12 (page 266): Experimentally reproduced elk antler mattock being used to work wood (Copyright Aimée Little, CC BY-NC 4.0).

Figure 24.13: Stages in the groove-and-splinter process (Photographs taken by Ben Elliott. Sourced from Elliott and Milner 2010. Copyright Cambridge University Press. Reprinted with permission).

Clark's original discussion of Star Carr identified worked tines as a distinct class of artefact. This group included nine red deer tines which had been intentionally detached and further signs of modification towards the tip. These were originally interpreted as hide working tools and soft hammers for knapping. Subsequent discussions of woodworking at the site have cited these artefacts as potential wedges for the splitting of large timbers within the platform structures (Mellars and Dark 1998) and more recently, experimental investigations
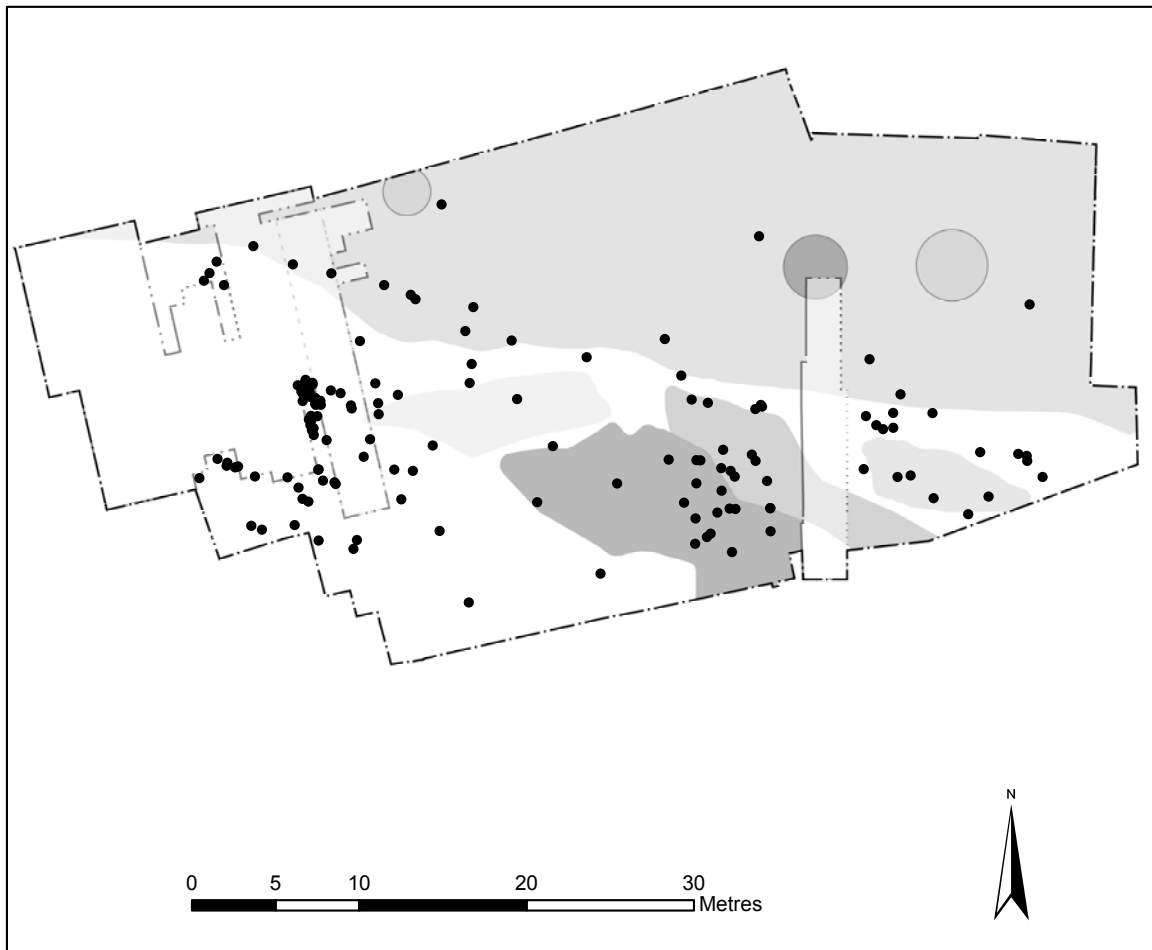
Figure 24.14: Distribution of red deer antler across 2004–2015 excavations (Copyright Star Carr Project, CC BY-NC 4.0).

have demonstrated the utility of removed tines for extracting splinters from a parent beam (Elliott and Milner 2010). As such, the current understanding of these objects is that they can be used in a range of tasks and are a simple but very flexible form of tool. However, Clark neglects to mention the 115 'broken-off tines' which Fraser and King describe within the faunal report. These have been intentionally modified, in their removal from the beam, and their natural form makes them perfectly suitable for use as soft hammers or wedges.

The 2004–2015 excavations recovered 46 removed red deer tines (Table 24.3). Some of these have been reduced via the groove-and-splinter technique (n=8), others show signs of modification at the tip in the form of longitudinal scraping (n=6, see Figure 24.15) and there are two instances of removed tines on which grooving has been attempted but not completed. Generally, tines were removed from the beams and then, if used, were not further modified. Only in a relatively small number of instances were the tips modified further, and the most substantial modifications were achieved through the original application of the groove-and-splinter technique (presumably whilst still attached to the parent beam), rather than scraping to achieve closer control over the final shape of the tip. Given the naturally high levels of variation which occur in the form of tines, this would tentatively suggest that they were involved in a range of different tasks rather than serving a single function throughout the site's occupation. However, if these are to be taken as a type of tool, their abundance at the site should be noted, with Clark's 124, Rowley-Conwy's three and the 47 recovered from 2004–2010, giving a total of 174 from the site to date.

Context	Deposit	Basal portion	Beam	Crown	Tine	Removed splinter	Compactor	Unidentifiable
35	Reed peat	1	1	2			1	
48	Dryland				1			
83	Wood peat						1	
84	Reed peat				1			
93	Reed peat				1		1	
240	Reed peat		1					
302	Dryland				1		1	
308	Dryland	1			1		7	2
310	Wood peat	3	6		9		11	2
310/312	Interface			1				
312	Reed peat	3	21	1	20	3	7	1
317	Detrital mud		6		5		5	
319/320	Interface							
320	Blue sand and cobbles		1					
Backfill	Backfill		6		7	1	14	1

Table 24.2: Categories, quantities and context of antler recovered from Star Carr 2004–2015.

Type	Quantity	Shed	Unshed	Non-diagnostic	Groove-and-splintered
Basal portion	8	4	4	0	2
Beam	42	10	11	21	29
Crown	4	0	0	4	0
Tine	46	0	0	46	8
Removed splinter	4	0	0	4	4
Compactor	48	0	0	48	4
Unidentifiable	6	0	0	0	0

Table 24.3: Working of red deer antler from Star Carr 2004–2015.

Spatially, the debitage assemblage shows an interesting degree of patterning. Beams (69% of which have had splinters removed) are deposited around the wetland areas of the site, and 64% of all of the beams are deposited into contexts which would have been at least partially submerged at the time of occupation. This may suggest a link between beams and standing water, which the experimental work into the importance of soaking antler during the application of the groove-and-splinter would support (Elliott and Milner 2010). As such, this suggests that antler was soaked for working in the wetland areas and that in the case of the beams this may represent in situ working of antler within the wetlands. The particular association between a concentration of beams amongst the central timber platform and detrital wood scatter, and another smaller scatter around the eastern timber platform, may also suggest use of the platforms to access these wetland areas, within which antlerworking was taking place.

Figure 24.15: Longitudinal striations at tip of removed tines. A) <103643> B) <103648> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

The presence of compactor fragments within the dryland areas of the site, in particular within the wood peat, may be more attributable to preservation bias, with these deposits being notably drier and so antler more likely to deteriorate into fragments of poorly-preserved compactor. Chronologically, this suggests that antler was still worked in substantial quantities at Star Carr, even after the areas of open water had been succeeded by fen.

In contrast to this, the deposition of removed tines appears focussed around the areas of good preservation such as Clark's area. As discussed in Chapter 26, it seems unlikely that this was an area of in situ frontlet manufacture as the high concentration of bone, antler, flint and wood in this area shows no signs of trampling or other taphonomic processes associated with the movement of people across this area after the deposition of the material. Therefore caution needs to be exerted when interpreting the distribution of the tines, as their presence may be more indicative of more formal, multi-material depositional practices than in situ discard or loss whilst removing and using the tines within the wetland areas of the site.

Conclusions

The analysis presented here reveals some key new findings concerning the ways in which osseous technologies at Star Carr were structured and practised. It has been shown that these excavations have yielded some evidence for the production of bone barbed points at Star Carr, through the identification of blanks made from deer metapodia. However, it has also been noted that the working techniques (originally defined by David and illustrated in Figure 24.1) used to create these blanks were also used alongside much less controlled methods in the general fragmentation of the faunal assemblage, thus suggesting that identifying the presence of these techniques in themselves is not enough to support the assumption that bone artefacts are being produced at a site. The products of this working are also required to confirm a site of production.

This fragmentation of bone often involved material which could have otherwise been used to produce bone barbed point blanks, and this, combined with the comparatively large numbers of antler barbed points in relation to bone (see Chapter 25) and the much higher rate at which red deer antlers were worked via the groove-and-splinter technique, suggests that antler was by far the more preferred material for the production of barbed points at Star Carr. Further to this, the analysis has shown that there is more variation in the ways that individual bone artefacts (both bone barbed points and aurochs chisel tools) were made than has previously been suggested for Star Carr.

The microwear analysis carried out on the elk bone bodkin also marks a major advancement in our understanding of this particular artefact type. Conventionally, bodkins are assumed to have been used in sewing or fastening hide and fabric. However, the analysis presented here suggests that they may have been used to work plant material, possibly in the making or maintaining of baskets. Experimental work carried out as part of this project has also prompted new questions concerning the function of elk antler mattocks, and suggested that they may have been used in woodworking tasks (Chapter 28). Red deer antler axes have long been associated

with woodworking (Jensen 1991; Van Gijn 2007; Van Gijn and Pomstra 2013), but this link for typologically defined elk antler mattocks is novel (Elliott 2014).

In regards to the working of red deer, the spatial data associated with the assemblage allows us to demonstrate that antlerworking was carried out throughout the occupational history of Star Carr and formed an important part of life at the site over multiple centuries. The focussed deposition of worked red deer beams within wetland areas of the site may well be linked to the soaking of antler. The data and analysis presented here confirms the sequence of groove-and-splinter working originally identified by Clark (1954) and further developed by Elliott and Milner (2010), and draws attention to the red deer tines which were removed from the beam as part of this process. These may have been used in a range of different tasks, without requiring further physical modification, and when considered as a group represent the second most numerous organic artefact from Star Carr, behind the barbed points (Chapter 25).

CHAPTER 25

Barbed Points

Ben Elliott and Aimée Little

Introduction

Barbed bone and antler projectile points are ubiquitous across Europe throughout the Mesolithic period, representing a 'type fossil' for Early Holocene hunter-gatherer groups (Chatterton 2003). Star Carr has produced 92% of the total number of bone and antler uniserial barbed points (projectile points with barbs along one side) attributed to the British Mesolithic (Elliott 2012). As such, discussions of uniserial barbed point manufacture and typology for both the British Late Upper Palaeolithic and Mesolithic have referred to this dataset (Table 25.1)(Clark 1954; Clark and Godwin 1956; Wymer et al. 1975; Jacobi 1978; Lord 1998; Griffitts and Bonsall 2001; David 2005; Elliott and Milner 2010).

Clark's excavations at Star Carr recovered an assemblage of 191 bone and antler uniserial barbed points. A barbed point was recovered from the site prior to backfilling by Tot Lord in 1950 (Dark et al. 2006), and another intact point was excavated in the 1980s (Mellars and Dark 1998). Of these, 58 were described as 'intact or nearly so', whilst the remaining 135 were broken fragments. Clark originally identified two of these as bone, two as undeterminable and the remaining 187 as being made from red deer antler, and thus linked to the evidence for the groove-and-splinter working of red deer antler at the site. More recent analysis of the assemblage has re-identified Clark's two bone points as red deer antler (Elliott and Milner 2010).

Clark's original discussion of the barbed points has proven somewhat contradictory: first highlighting the typological variation within the assemblage; before going on to define five distinct typological groups; and finally arguing that at least two of these groups are sufficiently stratigraphically discrete to support a two-phase occupation of the site. This latter suggestion has been adopted by subsequent authors and linked to peaks in the micro-charcoal profiles from the site (Mellars and Dark 1998; Dark 2000; Dark et al. 2006). Clark initially defined five typological units (see Table 25.2), allocating 44 barbed points to these groups before stating that 'a distinction may be drawn between those with fine closely-set barbs, those with medium-spaced barbs, and those with relatively coarse, widely spaced and often prominent ones [barbs]' suited the majority of the barbed points in the assemblage (Clark 1954, 125).

Site	Quantity	Reference
Star Carr	191	Clark 1954
	1	Mellars and Dark 1998
	1	Dark et al. 2006
	34	This volume
No Name Hill	1	Elliott and Milner 2010
Flixton Island 1	1	Clark 1954
Fosse Hill/Brandesburton	6	Clark and Godwin 1956
	1	Radley 1969
	3	Davis-King 1980
Skipsea	1	Armstrong 1922
Hornsea	1	Armstrong 1922
Royston	1	Clark and Godwin 1956
Waltham Abbey	1	Cook and Barton 1986
Earl's Barton	1	Tolan-Smith and Bonsall 1999
Battersea	1	Lacaille 1966
Wandsworth	1	Lacaille 1966
Wawcott XXX	1	Froom 2012
	246	

Table 25.1: All Mesolithic uniserial barbed points recovered from England.

A	B	C	D	E
Over 250 mm long	Short, broad points	275–363 mm long	Slender and smooth profile	Under 150 mm long
2–4 barbs Barbs project beyond the line of the stem and tang	2–5 barbs	8–18 barbs	medium-fine barbs	Fine barbs >28
Tang over 100 mm long		More pointed tangs Tangs 106–113 mm long	20 mm long tangs	Scored tangs
N=8	N=6	N=11	N=6	N=11

Table 25.2: Typology for the Star Carr barbed points outlined by Clark (1954, 125).

The 2004–2015 excavations at Star Car resulted in the recovery of 34 barbed points (or fragments). The contexts from which these finds originated are shown in Table 25.3 and the state of preservation set out in Table 25.4. This assemblage is similar to that of Clark's in that it consists of both intact barbed points (10) and broken fragments (23).

Of these finds, 11 fit Clark's (1954, 123) description of being in 'a blackened, shrivelled condition ... in a soft and decayed state', whilst 21 were sufficiently well preserved to allow a detailed discussion of their manufacturing methods. Following excavation, the barbed points were recorded, photographed and illustrated. In instances of suitably intact and well-preserved artefacts, microwear analysis and reflectance transformation imaging (RTI) were also undertaken.

Spatially, the barbed points recovered during the 2004–2015 excavations can be defined by two broad clusters (Figure 25.1). The larger of these groups encompasses Clark's finds focussed on cuttings I and III, and includes the 22 barbed point finds from Clark's area, the surrounding area and the single in situ find from the base of cutting II. The loci of the smaller cluster of eight falls in the detrital wood scatter in the central area of the wetland excavations. The terms used to refer to break patterns and the frequency of broken fragments are shown in Figure 25.2 and Table 25.5.

The spatial distribution of the intact and broken points requires further scrutiny. Within Clark's area, broken fragments make up 86% (n=19) of the 22 finds. Of the three intact points from this area, one is peripheral to the main focus of deposition. However, in the detrital wood scatter/central/eastern timber platform area there is only one broken fragment in the overall 8, and in this instance it is the single broken find which lies peripheral to the main focus of deposition.

Context	Description	Quantity of barbed points
310	Wood peat	2
312	Reed peat	17
317	Detrital mud	9
317/319	Interface of mud and gravel	1
319	Gravel	1
Clark's backfill	Backfill of Clark's cuttings	4

Table 25.3: Depositional contexts of barbed points from the 2004–2015 excavations.

IP Level	Condition	Quantity of barbed points
1	Tentatively identifiable as a barbed point	1
2	Artefact type identifiable, material unidentifiable	1
3	Artefact type and material identifiable, no surface detail surviving	10
4	Some surface detail surviving	10
5	All surface detail surviving	12

Table 25.4: State of preservation of the 2004–2015 barbed points.
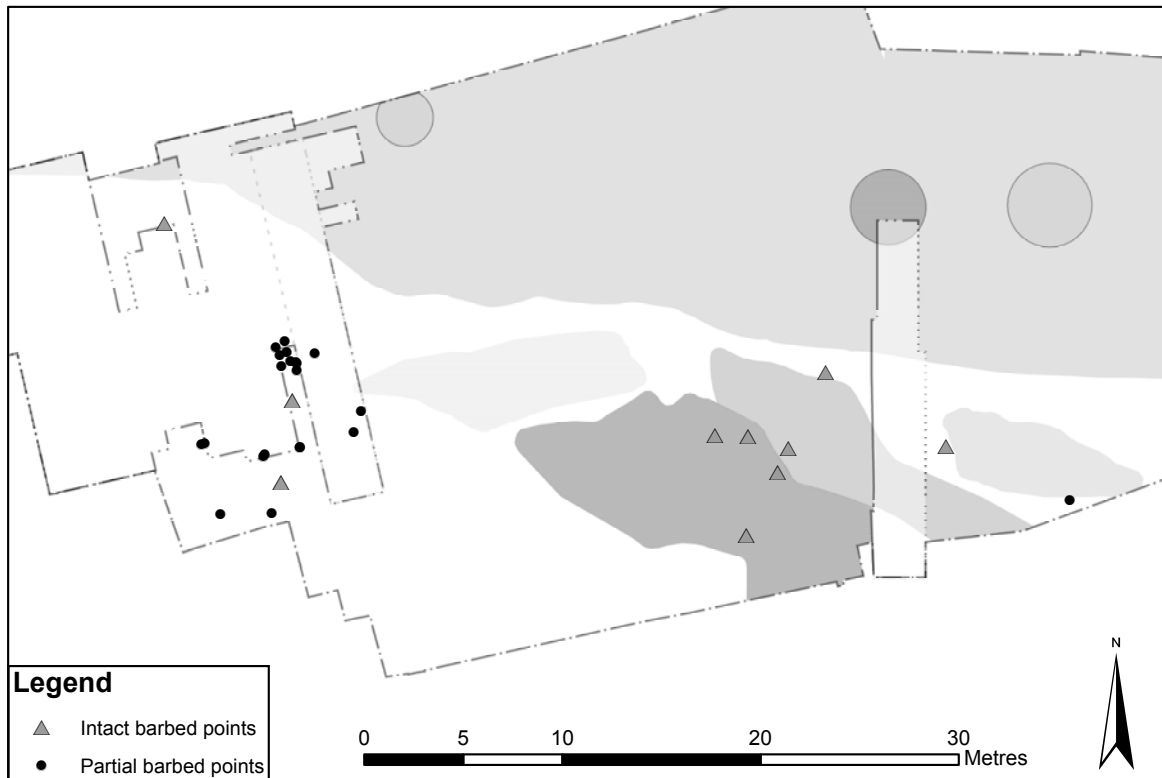
Figure 25.1: Spatial distribution of barbed points (Copyright Star Carr Project, CC BY-NC 4.0).
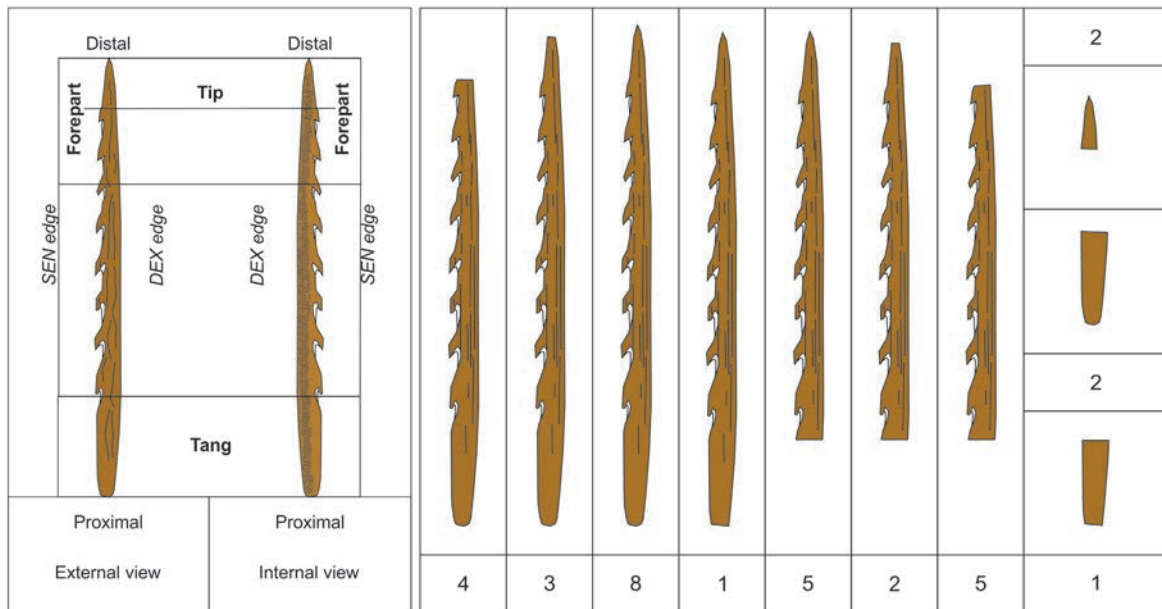
Figure 25.2: (left) schematic diagram of barbed point, with terminology used within the following analysis; (right) frequency of fragmentation patterns of the 2010–2015 Star Carr barbed points (Copyright Ben Elliott, CC BY-NC 4.0).

Find number	Phase	Context	Star Carr Type	Portion	Barbs
92370	Backfill	Backfill	D	Midshaft	3
92393	Backfill	Backfill	N/a	Tip, foreshaft and midshaft	3
92831	Cutting II	319	B	Tang and midshaft	3
99135	Central platform	310	N/a	Intact	8
99790	Central platform	312	N/a	Intact	12
99867	Detrital wood scatter	312	N/a	Intact	8
99886	Detrital wood scatter	312	N/a	Intact	10
103060	Detrital wood scatter	312	N/a	Intact	6
108789	Detrital wood scatter	319 / 320	N/a	Intact	2
113415	Eastern platform	312	N/a	Tang and midshaft	6
113733	Eastern platform	312	N/a	Intact	10
115238	Bead area	310	N/a	Intact	10
115976	Clark's area	312	N/a	Midshaft and tag	2
116025	Clark's area	312	N/a	Midshaft	6
116037	Clark's area	312	N/a	Forepart	7
116152	Clark's area	312	N/a	Tip	0
116464	Clark's area	312	N/a	Intact	15
116481	Clark's area	317	N/a	Tang	0
116482	Clark's area	317	N/a	Midshaft	7
116490	Clark's area	312	N/a	Tang and midshaft	2
116606	Clark's area	312	B	Forepart and tip	5
116706	Clark's area	312	B	Tang	0
116710	Clark's area	312	N/a	Tang and midshaft	2
116802	Clark's area	317	N/a	Tip and midshaft	12
116836	Clark's area	317	B	Forepart	2
116837	Clark's area	317	N/a	Midshaft	4
116870	Clark's area	317	N/a	Tip	1
117253	Clark's area	312	B	Intact	4
117421	Clark's area	312	N/a	Tang	0
117807	Clark's area	317	N/a	Forepart	7
117851	Clark's area	317	N/a	Forepart	7
117958	Clark's area	317	N/a	Midshaft	3
Backfill/71	Backfill	Backfill	N/a	Tang	0
Backfill/82	Backfill	Backfill	N/a	Midshaft	4

Table 25.5: Context of recovery, phase, fragmentation patterns, typological ascription and number of barbs for the 2010–2015 Star Carr barbed points.
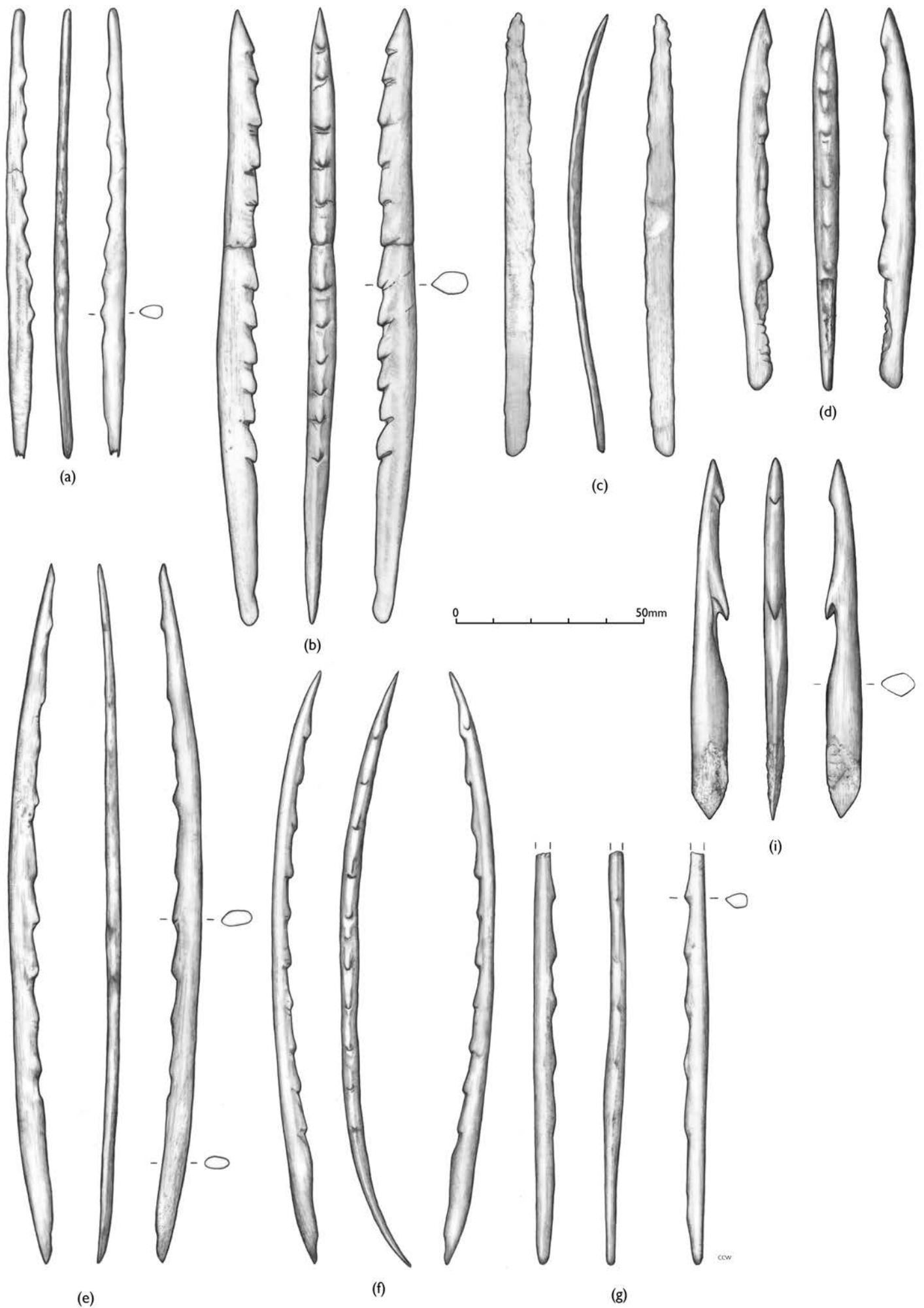
(a) 99135 (b) 99790 (c) 99867 (d)103060 (e) 99886 (f) 113733 (g) 113415 (i) 108789

Analysis

<99135> (Figure 25.3, a): An intact barbed point, with only the extreme tip missing. Although poorly preserved and lacking any surface detail, nine barbs are still visible. L=121 mm, W=7 mm, T=3 mm.

<99790> (Figure 25.3, b): A poorly preserved, complete point with 12 barbs visible in profile. Desiccation in situ has led to the discolouration, fragmentation, shrinkage and minor warping on the artefact, giving it a slight curve. L=170 mm, W=11 mm, T=4 mm.

<99867> (Figure 25.3, c): A complete barbed point, although poorly preserved and warped into a curve. Faint traces of eight barbs visible, although working marks do not survive. L=118 mm, W=7 mm, T=4 mm.

<99886> (Figure 25.3, e): A complete barbed point with ten barbs visible. The preservation is too poor to allow any surface detail or specific working marks to survive. L=184 mm, W=9 mm, T=4 mm.

<103060> (Figure 25.3, d): A complete barbed point with six barbs visible. It is poorly preserved and has sustained some damage in situ to the tang. No working marks survive. L=141 mm, W=8 mm, T=7 mm.

<108789> (Figure 25.3, i): An intact barbed point with two barbs and slight damage to the tip of the tang. The first barb shows signs of undercutting through sawing on the external aspect, whilst the second barb shows signs of sawing from the external and internal aspect. The second barb is well pronounced and with a rounded tip. There is a faint trace of the square-edged original grooved facet along the SEN edge at the tang. L=96 mm, W=8 mm, T=6 mm.

<113415> (Figure 25.3, g): The midshaft and tang with six barbs surviving, albeit in a poor state of preservation. The surface details of the piece do not survive, so no assessment of the techniques used to define the barbs and shape the overall point can be made. L=107 mm, W=5 mm, T=3 mm.

<113733> (Figure 25.3, f): An intact barbed point with ten barbs in a poor state of preservation. No spongy tissue survives, so the interior/exterior distinction is based on the curvature of the point itself. Due to the poor preservation of the piece, no surface details survive which might help to ascertain the techniques used to create the barbs or shape the point. L=163 mm, W=4 mm, T=3 mm.

Figure 25.3 (page 278): Barbed points from the detrital wood scatter and eastern timber platform areas (Copyright Chloe Watson, CC BY-NC 4.0).
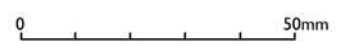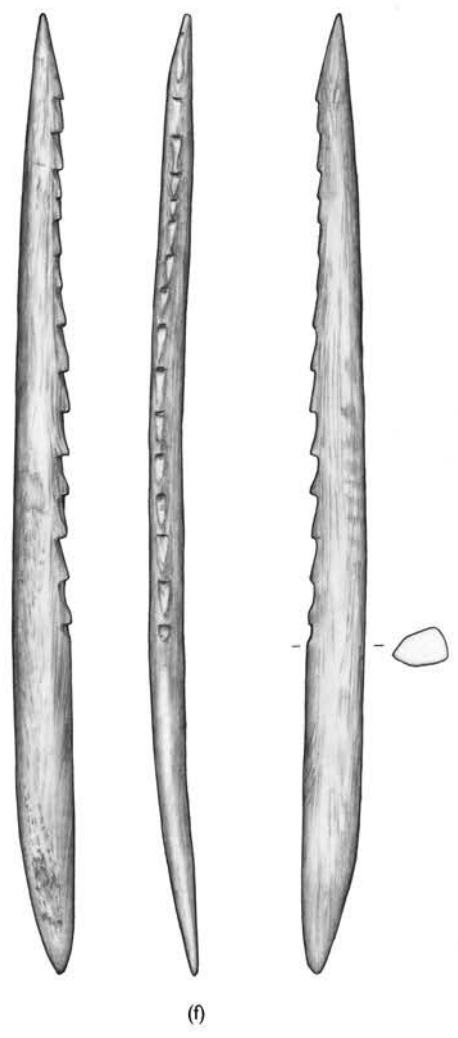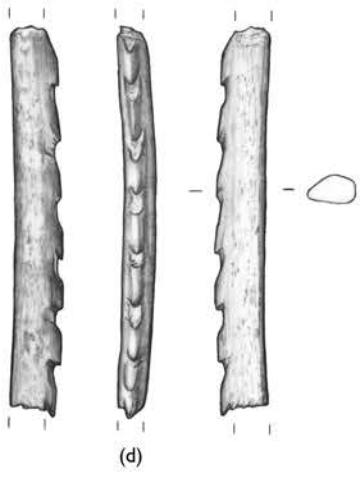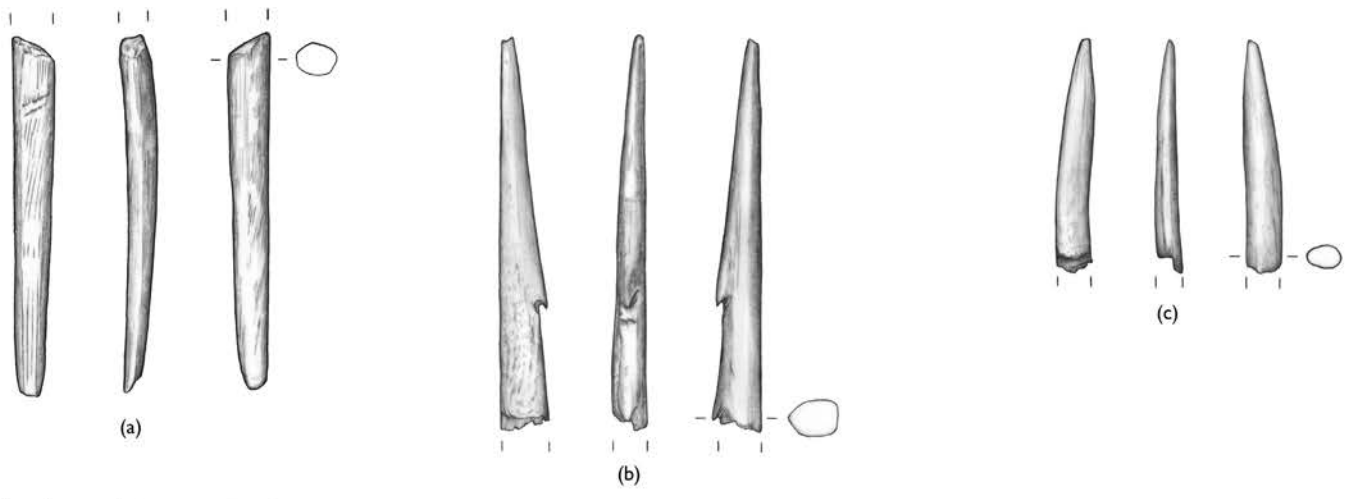
(a) 116152 (b) 116836 (c) 116481 (d) 116482 (e) 116802 (f) 116464 (g) 116490

<116152> (Figure 25.4, a): The tip of a barbed point. Oval shaped in section with longitudinal striations visible along the length, created through scraping along all edges and removing any trace of the original grooved facets of the splinter. L=65 mm, W=7 mm, T=5 mm.

<116464> (Figure 25.4, f): Intact barbed point with 15 barbs. Flat DEX edge with thick longitudinal striations showing signs of the original grooving of the splinter. The form of the original anatomical surface on the EXT aspect has been completely removed through scraping, leaving a series of longitudinal striations. The barbs are marked by long, continuous facets along the length of the point, characterised by well-defined longitudinal striations. The facets along the top and underlying the barbs themselves lack signs of sawing and feature a smooth surface and light polish, suggesting that they have been finished through filing.

Microwear analysis showed some crushing at the tip but no associated flake removals. Crushing may be a result of post-depositional processes or use. The tang has well-developed hafting traces—a polish that is smooth, bright, rounded and is only visible on the shaft, i.e. hafted zone. The very end of the tang has micro-flake removals which may relate to impact within the haft. From the degree of hafting wear it is likely that this barbed point was hafted and used. L=177 mm, W=6 mm, T=11 mm.

<116481> (Figure 25.4, c): Tip of a barbed point, broken at the foreshaft with longitudinal striations on all aspects.

Microwear analysis revealed a burin-like fracture at the tip. Micro longitudinal impact traces are visible at the tip, extending a short way down the foreshaft. Manufacturing traces, which are multidirectional, are visible across the surface. Microscopic evidence suggests that this barbed point was hafted and used. L=43 mm, W=7 mm, T=4 mm.

<116482> (Figure 25.4, d); A midshaft with seven barbs. SEN edge rounded with no traces of the original parent splinter surviving. The barbs undercut by sawing from the internal and external aspects, with smooth, lightly polished facets below each barb characterised by faint, diagonally orientated linear discolourations. These suggest filing has been used to further define the barbs after sawing. L=71 mm, W=9 mm, T=6 mm.

<116490> (Figure 25.4, g): The tang and midshaft with two barbs and scoring across the internal and external surface of the tang. The SEN edge is flat along the midshaft portion of the point with some longitudinal striations, suggesting the original traces of the grooved parent splinter. At the tang, both the SEN and DEX edges taper to a point. The barbs are undercut by sawing from both the internal and external aspects and feature a step immediately below the barbs, with a smooth, lightly polished facet below this step, displaying light, short and randomly oriented striations. This combination of both stepping and polish/randomly oriented striations is indicative of a phase of scraping followed by a phase of filing in the creation of these facets and the overall definition of the shape of the barbs. The tang is characterised by groups of well-defined striations running longitudinally towards the proximal edge of the piece. These are overlain by a series of shorter and lighter incised lines which create a pattern which falls into Clark's 'criss-cross group', where the lines overlap.

Microwear analysis revealed a discrete area of polish, which was orientated transverse to the end of tang. This may be the result of hafting but could also be manufacture related; as such it is not possible to determine whether this point was used. L=102, W=12, T=8.

<116802> (Figure 25.4, e): The tip, foreshaft and midshaft of a barbed point featuring 12 barbs. The proximal end of the piece is broken at the very start of the tang. The SEN edge is flat along the most proximal two-thirds of the point, with clear longitudinal striations suggesting the original grooving of the parent splinter. The SEN edge along the most distal third of the point is progressively more rounded towards the tip, which displays signs of macroscopic damage at the extreme tip. The barbs are undercut by sawing from the internal and external aspect, with short facets below the barbs devoid of any diagnostic working traces. The proximal end is characterised by diagonally aligned, fine incisions which are interrupted by a shelved break.

Microwear analysis revealed crushing and a burin-like fracture at the tip. Crushing was more evident on the internal surface. There is a clear distinction between polish that appears to be the result of hafting which is visible on the shaft only and the general manufacturing traces seen across the mid and foreshaft. The glossy polish from hafting extends to encompass the first (lowest) barb. It is unclear what this distribution means, or whether it could be a binding technique, using the lowest barb as a grip. In fact, the base of this barb displays the most developed polish, suggesting contact with either bindings or the haft itself. Given the brightness of the polish and its distribution it is probably the former, and probable that the bindings were made from plant materials. Within the hafted zone (the small part that remains) and beneath the hafting traces is a series of engraved lines running obliquely to the main axis. From the combination of impact damage and hafting traces it is likely that this barbed point was hafted and used. It is interesting to note that the breakage occurs at the base of the hafting zone, perhaps indicating an attempt to recover the tool from the animal carcass. L=113 mm, W=10 mm, T=6 mm.

<116836> (Figure 25.4, b): The tip, forepart and midshaft of a barbed point with two barbs. The tip shows signs of a jagged edged break with the extreme tip missing. The proximal end of the piece terminates immediately below the second barb in a jagged edged, shelved break. The first barb shows signs of sawing from the internal and external aspects, with a smooth, lightly polished facet below the barb which lacks any signs of striations. These facets may have been created through filing. L=72 mm, W=9 mm, T=6 mm.

Figure 25.4 (page 280): Barbed points from Clark's area (Copyright Chloe Watson, CC BY-NC 4.0).
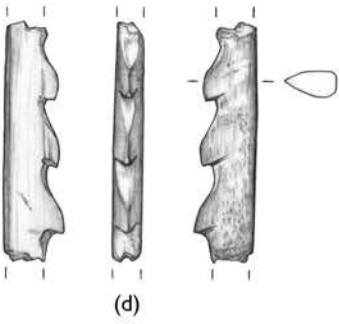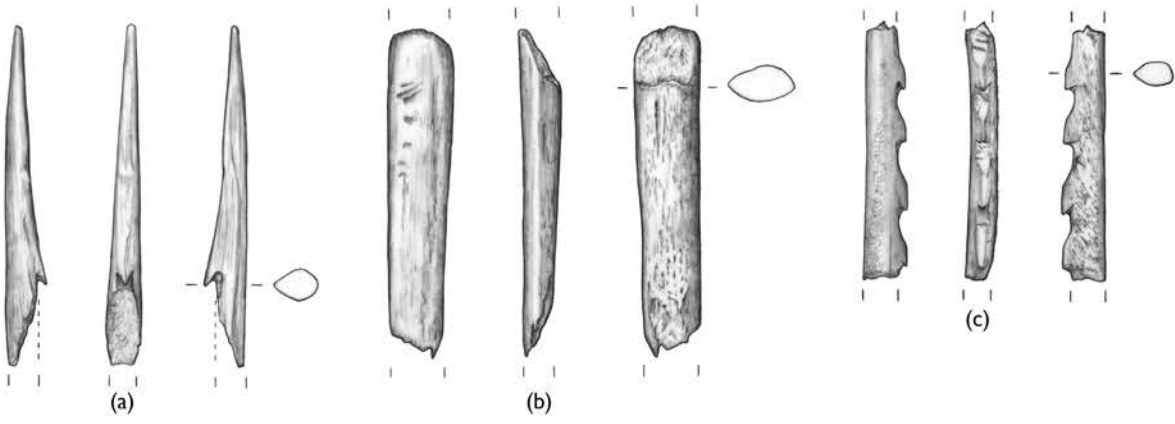
0   50mm
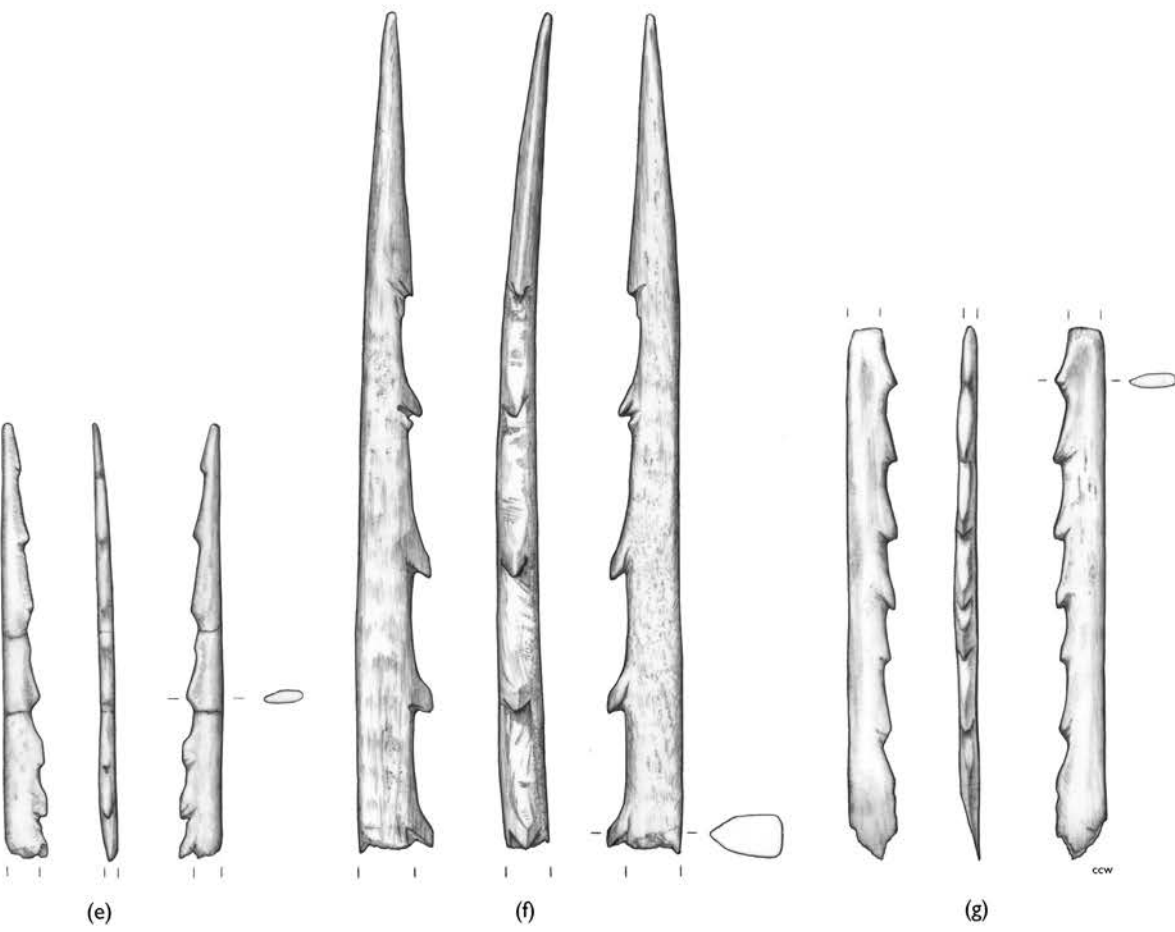
(a) 116870   (b) 116706   (c) 116837   (d) 117958   (e) 116037   (f) 116606   (g) 116025

<116025> (Figure 25.5, g): The midshaft of a barbed point with six barbs. The preservation of the point is poor, leading to a loss of surface detail and the distortion of its original shape. Due to these issues, the character of the proximal and distal breaks cannot be assessed and no clear conclusions can be drawn as to the techniques that have been used to create the barbs. However, based on the overall form of the barbs it would appear that they were undercut from both the internal and external aspect, with smooth facets being created below each barb to further define their shape in profile. L=104 mm, W=8 mm, T=5 mm.

<116037> (Figure 25.5, e): The forepart and midshaft with the tip absent. Seven barbs are visible, but the poor preservation of the piece prevents any working traces from surviving on either the barbs themselves or the proximal and distal breaks. L=83 mm, W=8 mm, T=5 mm.

<116606> (Figure 25.5, f): The tip, forepart and midshaft of a barbed point, with five barbs. The flat SEN edge with clear longitudinal striations towards the proximal end of the piece is consistent with the grooving of a parent splinter. Barbs are undercut by sawing from the internal and external aspects, with facets below the barbs which feature some longitudinally orientated groups of fine striations, and some diagonally orientated discolouration marks. This suggests a mixture of filing and scraping was used to define these facets and the finished profile of the barbs. The tip is characterised by small groups of short, longitudinally oriented striations on all aspects, suggesting intensive scraping being used to create the final form.

The tip displays possible impact traces in the form of crushing and flake removal. Indeterminate polish, probably use-related, is evident at the tip. The tang is missing, precluding the identification of hafting traces. L=156 mm, W=14 mm, T=8 mm.

<116706> (Figure 25.5, b): A portion of an elongated tang of a barbed point with an oval shape in profile. The distal end of the tang is characterised by a sloping, shelved break which may be indicative of flexion pressures. The proximal end of the piece is defined by a more ambiguous break, which is angled obliquely but which features a level edge. Three shallow chop-like marks on the external surface of the tang may relate to the dehafting of the tang prior to deposition. L=64 mm, W=12 mm, T=8 mm.

<116837> (Figure 25.5, c): A midshaft with four barbs. The distal and proximal breaks are characterised by uneven, jagged edges, the proximal break occurring directly below the fourth barb. The SEN edge is smooth and flat with a light polish, and may relate to the original edge of the parent splinter. The first and third barb are undercut through sawing from the internal and external aspect, whilst the second and fourth barb appear to be undercut by sawing from the external aspect only. A smooth, short facet below each barb helps to further define their shape, and the very faint, short, diagonally orientated discolourations suggest filing was used to create these facets. The external aspect of the barbs is also marked with a light polish. L=46 mm, W=8 mm, T=4 mm.

<116870> (Figure 25.5, a): The tip, forepart and fragment of midshaft, with one barb. The extreme tip is missing, with a diagonal sloping break defining the distal end of the point. The piece is circular in section, with longitudinal striations and multiple facets characterising all aspects. The single barb is undercut by a 'C'-shaped cavity, which appears to have been more likely to have been produced through a technique more akin to boring than sawing. A slightly raised area towards the tip may suggest an older or nascent barb which has been removed by scraping or was never fully defined. L=60 mm, W=5 mm, T=4 mm.

<117958> (Figure 25.5, d): A midshaft with three barbs. The SEN edge is flat and displays pronounced longitudinal striations, suggestive of the original grooved edge of the parent splinter. The barbs are undercut through sawing from the internal and external aspects, with polished facets immediately below the barbs created through either filing or scraping. Longitudinal striations on the external and internal aspects of the barbs also suggest longitudinal scraping of the DEX edge. The proximal and distal breaks are similar, with clearly defined, jagged but generally level edges. L=47 mm, W=8 mm, T=3 mm.

Figure 25.5 (page 282): Barbed points from Clark's area (Copyright Chloe Watson, CC BY-NC 4.0).
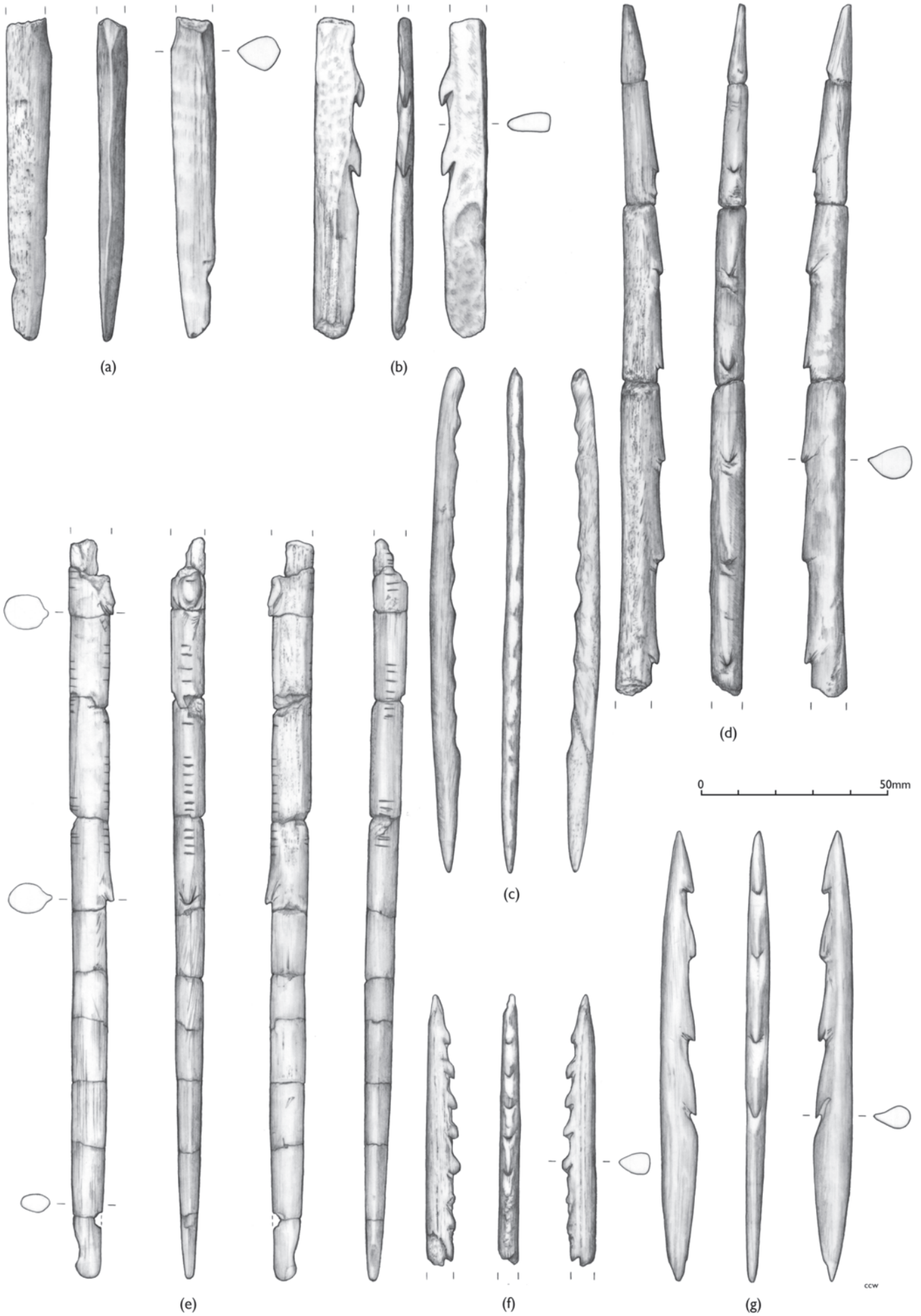
(a) 117421 (b) 116710 (c) 115238 (d) 117851 (e) 115976 (f) 117807 (g) 117253

<115238> (Figure 25.6, c): This is an intact barbed point with ten barbs. It is severely desiccated and shrunken, with no surface detail surviving. No macroscopic working traces visible.

During microwear analysis some crushing at the tip was identified. No clear signs of hafting were observed, but overall the surface is very degraded, limiting analysis. It is possible that this point was used; however, poor condition prohibits a more definitive interpretation. L=135 mm, W=7 mm, T=4 mm.

<115976> (Figure 25.6, e): A highly fragmented proximal portion of a barbed point with the tang and midshaft intact, and two barbs intact on the DEX side. The distal barb shows signs of damage and possible reworking and is slightly misshapen. Both barbs were created by sawing from the internal and external aspects and then subsequent scraping of the area below the barb to create a facet. The SEN edge is flat but shows no signs of the original grooving to remove the splinter. Longitudinal striations on the internal and external surfaces of the tang suggest that during the latter stages of production it was shaped with a flint tool.

<115976> is highly unusual in that it features a series of 37 1.5–3 mm long linear markings along the SEN and DEX edges, which have been created through transverse sawing. Along the DEX edge, there are three distinct groups of markings. At the distal break of the point, a single transverse line is situated on the barb itself. About 17 mm below this, another series of five transverse lines are apparent, spaced across a break in the artefact. 8 mm below this is a series of 11 transverse lines. Along the SEN side, there is a series of six lines, interrupted by the distal break. 20 mm below this is a series of eight transverse lines, and 23 mm below this is a group of six further lines. The location of these groups mirror each other on the SEN and DEX edges respectively. L=199 mm, W=12 mm, T=7 mm.

<116710> (Figure 25.6, b): The midshaft and tang with two barbs surviving. The cortical tissue is inconsistent with that of antler in its structure and extends over just the proximal 43 mm of the points' total length. As such, this barbed point is clearly made from bone rather than antler. Following ZooMS analysis (conducted by Krista McGrath) the bone was identified as either red deer or roe deer. The external surface features an unusual series of smooth, shallow depressions, and there is a generally unusual smooth character to the edges of all aspects of the piece. This may suggest exposure to water action at some point in its depositional history. The barbs are undercut by sawing from the internal and external aspects, with material then being removed from underneath the barbs to further pronounce their shape. These areas have no signs of working traces and may be linked to the water action mentioned above. L=82 mm, W=13 mm, T=7 mm.

<117253> (Figure 25.6, g): An intact point with four barbs. The tip features longitudinal striations on all aspects, suggesting shaping through scraping from all angles. The tang features similar groups of shorter, longitudinal striations on the external and internal aspects, particularly in association with the proximal extent of the piece. This again suggests the shaping of the tang was achieved through scraping. The barbs are undercut with sawing from the internal and external aspects, with a step directly below the barb, and short facets extending below the steps to further define the shape of the barbs. These facets, whilst in immediate association with the steps, lack any visible longitudinal striations. As such, it is suggested that the initial facet was created through scraping (creating the step), and subsequent filing (obscuring the striations of the scraping event).

The microwear analysis shows that the proximal tip displays crushing with a flake removal, initiated from impact. A smooth, bright, well-developed polish is visible at the end of tang (L1), which is comparable to the polish seen in the hafted zone of other barbed points similarly interpreted as being hafted. In sum, the impact fractures and hafting traces suggest this barbed point was hafted and shot. As the barbed point is complete, neither impact or detooling have resulted in breakage. L=123 mm, W=10 mm, T=6 mm.

<117421> (Figure 25.6, a): An elongated tang, with a jagged and level-edged break directly below the final barb at the distal end. The DEX edge is flat and features clearly defined longitudinal striations, suggesting the original grooved edge of the parent splinter. A semi-circular notch on the DEX edge may be indicative of the insertion of a wedge during the removal of the splinter. The SEN edge tapers to a delicate point, giving the tang a teardrop shape in profile. The external surface of the tang features a number of longitudinal striations, often aligned in small clusters, thus suggesting scraping was used to achieve the finished form. L=87 mm, W=11 mm, T=8 mm.

<117807> (Figure 25.6, f): The tip, forepart and midshaft with seven barbs. Damage at the extreme tip of the point is associated with a loss of surface detail, whilst the proximal break is sloped in profile. The DEX edge is flat, with some longitudinal striations visible towards the proximal end. However, these do appear to be pronounced enough to be linked to the original grooving of the splinter and probably related to secondary scraping. The barbs are undercut by sawing from the internal and external aspects, with

Figure 25.6 (page 284): Barbed points from north of cutting I and Clark's depositional area (Copyright Chloe Watson, CC BY-NC 4.0).

short smooth facets below featuring fine, multi-directional light striations. This suggests filing has been used to further define the shape of the barbs in profile. Longitudinal striations on the external and internal surfaces of the barbs suggest that longitudinal scraping has been used on the internal and external sides of the SEN edge to further shape the profile of the point. At the distal tip, longitudinal striations adjacent to the area of damage suggest shaping through scraping from all aspects.

Microwear revealed crushing at the tip, probably related to impact, which has also resulted in bifacial burin-like removals on opposing surfaces (L3: point of termination of flake removal). Micro longitudinal impact traces are also visible (L2 and L3). It is probable that this barbed point was used. L=73 mm, W=10 mm, T=4 mm.

<117851> (Figure 25.6, d): The forepart and midshaft with seven barbs, broken into four refitting fragments. The SEN edge is gently rounded and features faint longitudinal striations, suggesting shaping through scraping. The barbs are undercut by sawing from the internal and external aspects, with facets immediately below the barbs displaying longitudinal striations. This suggests scraping was used to create these facets and further define the shape of the barbs. Longitudinal striations on all aspects towards the broken tip suggest scraping to produce the finished shape.

Microwear analysis showed that, unlike other barbed points that display crushing and burin-like fractures at the tip, the tip of this point has a clear break. Micro longitudinal impact traces are visible from the point of breakage (L1–L3), suggesting that the tip snapped off with impact or perhaps during its recovery. No hafting traces could be identified as the tang has broken off. The wear traces suggest that this point was used. L=186 mm, W=11 mm, T=9 mm.
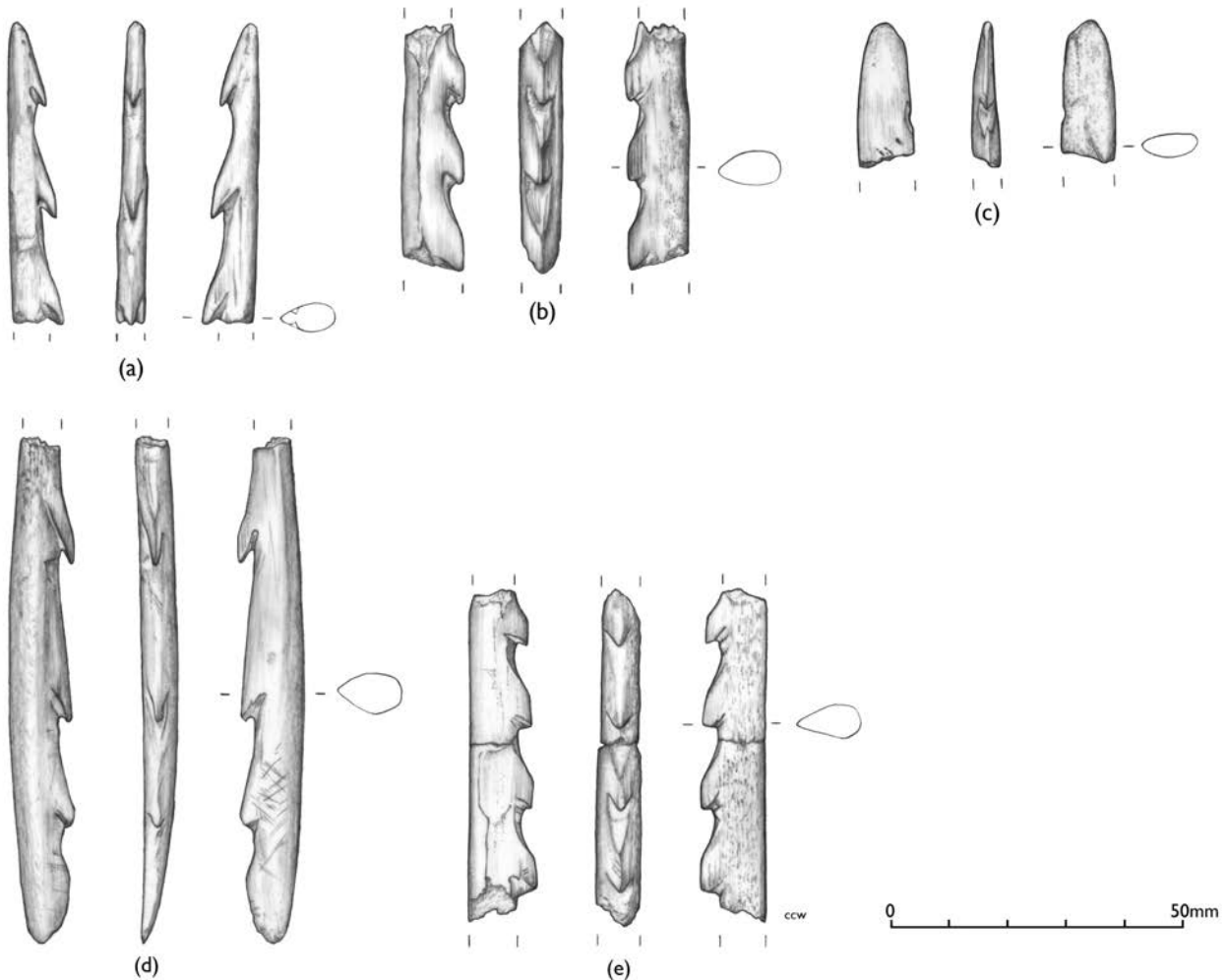
(a) 92393 (b) 92370 (c) Backfill/71 (d) 92831 (e) Backfill/82

<92370> (Figure 25.7, b): A fragment of midshaft with three barbs. The SEN edge is flat and features fine, longitudinal striations. These could be related to the original grooving of the parent splinter. There are signs of sawing to undercut the barbs from the internal aspect, with facets immediately below each barb featuring a smooth surface and diagonally orientated bands of discolouration. These therefore appear to have been reduced through filing. Both the proximal and distal breaks occur directly below barbs, and have uneven break edges. L=43 mm, W=11 mm, T=8 mm.

<92393> (Figure 25.7, a): The foreshaft and midshaft with three barbs and the tip missing. The DEX edge is gently rounded and shows no signs of the original parent splinter. Each barb is undercut with sawing from the internal and external aspect, and features a smooth facet directly below the barb itself. These feature a thin polish and very fine, longitudinal striations, typical of filing. The proximal break, below the third barb, is level and even. L=53 mm, W=10 mm, T=7 mm.

<92831> (Figure 25.7, d): The tang and midshaft with three barbs. The DEX edge is gently rounded and shows no signs of the original parent splinter. The barbs are undercut by sawing from the internal and external aspects. The internal and external surfaces of the barbs feature groups of fine, longitudinal striations running directly away from the edges of the barbs themselves, suggesting longitudinal scraping. The distal break is level, and may have occurred directly below another barb. L=87 mm, W=10 mm, T=7 mm.

Backfill 71 (Figure 25.7, c): The proximal tip of a tang, oval shaped in section. All of the interior spongy tissue has been removed and there are light longitudinal striations along the external face. There is some modern damage to the SEN edge, but all traces of the parent splinter have been removed through subsequent working. L=24 mm, W=9 mm, T=5 mm.

Backfill 82 (Figure 25.7, e): A midshaft with four barbs. The distal break is level edged, whilst the proximal break (directly below the fourth barb) is jagged, stepped and uneven. The barbs are undercut through sawing from the internal and external aspects, with facets immediately below the barbs. These facets feature stepping at the distal edge, which suggests scraping. However, no striations are visible on the surfaces of these facets, making it difficult to definitively determine the technique used to create these facets. L=11 mm, T=7 mm, W=5 mm.

Discussion

Technology

Analysis of the barbed points allows a more refined understanding of the châine operatoiré of their production. The identification of sawing from both the internal and external aspects to undercut the barbs, the presence of facets directly below the barbs and the identification of longitudinal scraping marks along the barbed edge affords some extra detail in this respect. The sequence proposed here begins with the removed splinter of red deer antler (Figure 25.8a). The selected edge is worked down from the internal and external aspect using longitudinal scraping (Figure 25.8b), leaving longitudinal striations and bringing the profile of the splinter in section to an apex (Figure 25.8c). The position of barbs is then marked out through sawing from both the internal and external aspect, creating a series of angled notches along the length of the point (Figure 25.8d). These notches are accentuated through either scraping or filing (or both), creating a facet below the barb which extends in a proximal direction, defining the finalised shape and style of the barb in profile (Figures 25.8e & f, 25.9). This interpretation of the barbed point finishing sequence is supported by the relationship between the longitudinal striations on the external and internal aspects of the barbs, which are often observed intersecting directly with the edges of the barbs. This would suggest that they are cut by the shaping of the barbs, and thus that these particular episodes of scraping predate the shaping of the barbs themselves (Figure 25.8).

This simple method for the definition of barbs allows considerable scope for simultaneous stylistic variability and technological homogeneity. The barbs of the Star Carr points vary considerably in terms of their size, prominence, spacing and shape in profile. This variation can be achieved through the methodology outlined

Figure 25.7 (page 286): Barbed points from Clark's backfill, the base of cutting II and the central platform area (Copyright Chloe Watson, CC BY-NC 4.0).
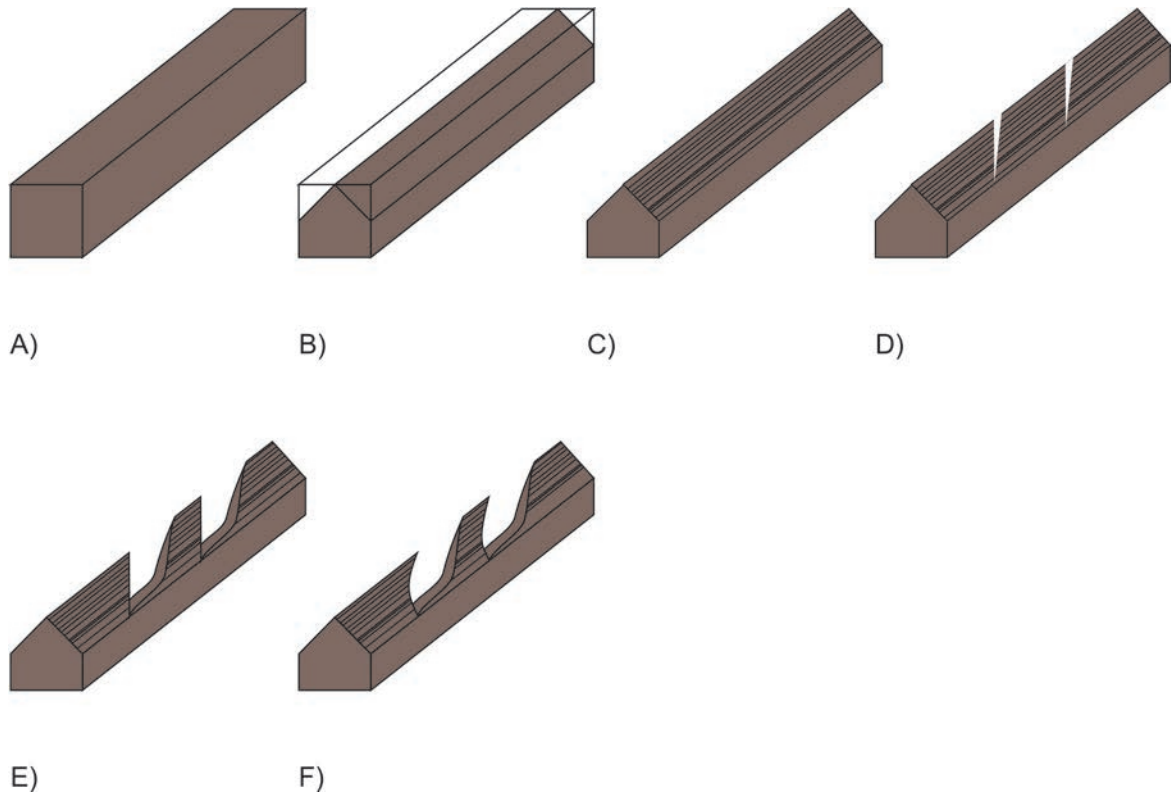
Figure 25.8: Schematic diagrams illustrating the stages of finishing a barbed point from the blank splinter:
a) removed splinter from beam; b) longitudinal scraping from INT and EXT to define an apex along one
edge; c) an apex is created with longitudinal striations running along both edges; d) sawing to create notches
where barbs are to be positioned; e) scraping/filing of apex to define facets below barb; f) further scraping/
filing below barb to fully define a hooked form to the barbs (Copyright Ben Elliott, CC BY-NC 4.0).

above, with decisions made at stage D affecting the spacing of the barb and the extent to which stage F is applied determining the morphological form of the finished barbs.

Typology

Clark's original typology for the Star Carr barbed points offers limited value for interpretation of the new finds. <92831>, <116606>, <116706>, <116836> and <117235> appear to be morphologically consistent with the points Clark places within Group B, whilst <92393> is slender and delicate enough to fit within Group D. Other typologies offer similarly limited use in defining the barbed points from Star Carr. Clark's (1936, 116) generalised Maglemosian typology of bone points from across Europe can be applied here (Table 25.6) and used to identify Kunda type 6 points (<99790>, <116025>, <116152>, <116481>, <116710>, <116836>, <117421>, <117851> and Backfill/71) and Mullerup type 7 points (<108789>, <116482>, <116490>, <116706> and <116870>), but it leaves a further 16 points unclassified. As such, both of these typologies leaves the majority of the finds unclassified, and attempting to impose a typological scheme onto this material may mask one of the key characteristics of the assemblage as a whole: its variability. Unifying typological characteristics for the Star Carr barbed points are difficult to define, with exceptions emerging to virtually every rule. This includes the perforated harpoon and two identical points found lying side by side originally noted by Clark (mooted as a leister), but it also extends now to include the bone point. Uniseriality remains the only common typological factor for the Star Carr assemblage.

The inability to ascribe the majority of Star Carr barbed points to a robust and consistent typology creates challenges for previous attempts to use the small number of previously identified typological groups as chronologically diagnostic. The absence of Type A and Type E points within the earlier and latter phases of the site's occupation, respectively, presents further problems for the typo-chronology suggested by Clark (1954; 1972) and echoed by Mellars and Dark (1998).

In lieu of this as an explanation for the variation in form of barbed point at Star Carr, it may well be worth considering the wider context of the occupation of the site. The large scales of consumption and construction observed at Star Carr, in comparison to the smaller scale of activity seen at other sites within the contemporary landscape, can be interpreted as evidence for aggregation events. If the production and deposition of barbed points is linked to these periods of aggregation, then this apparent variation in artefact form may be the product of a wider range of people coming together to visit the site at specific times. In this scenario, the formal/typological variation observed by previous authors would necessarily change through time, with each event aggregation being characterised by high levels of diversity in its own right.

Use

Although seldom explicitly stated, assumptions over the used/unused nature of the Star Carr barbed points have underlain much of their academic discussion. These assumptions have played a major role in understanding the context of deposition of barbed points at Star Carr, with some arguing for recovery of used points during butchery, others arguing for accidental loss during manufacture, and others discussing formal depositional practices, suggesting the ritualised production and breakage of barbed points prior to deposition. The microwear analysis of the barbed points from Star Carr demonstrates for the first time that some of these were likely to have been used prior to deposition (contra Mellars 2009). Three points show what are probably impact traces at the tip, indicating damage sustained during use as projectiles. There are three instances of micropolish associated with the tang region, indicative of binding and hafting; possibly with a plant material. In some instances, polishes also occur on the first barb directly above the tang, suggesting that binding may have extended over the first barb (Figure 25.10).

Figure 25.9 (page 288): A flint blade is used to shape the barbs of a replica barbed point (Copyright Aimée Little, CC BY-NC 4.0).

Clark's Star Carr Typology	Quantity	Clark's Maglemosian Typology		Quantity
A	0	Type 5		0
B	5	Type 6		9
C	0	Type 7		5
D	1	Type 8		0
E	0			
Unclassified	27			16

Table 25.6: Typological classification of 2004–2015 barbed points.

Figure 25.10: Plant binding materials extending over the first barb of replica barbed point: replicating hafting wear traces identified on artefact <116802> (Copyright Aimée Little, CC BY-NC 4.0).

Whilst the fragmentary nature of the points and poor surface condition prevent a full assessment of exactly how many were used, these results mark an important step in our understanding of the Star Carr barbed points. The evidence for hafting and use emphasises the fact that none of the barbed points excavated from Star Carr to date have been found in association with any form of haft. This is significant, given the quantities of worked wood recovered during the current excavations and the excellent preservation conditions noted in association with the locus of barbed point deposition. Equally, the suggestion that Star Carr was a hub for barbed point retooling and rehafting is compromised by the artefacts which are clearly broken beyond repair. This strongly suggests that some of the barbed points had been de-hafted post-use, elsewhere in the landscape, before being brought back to Star Carr for deposition, a practice which is mirrored in other forms of organic and inorganic material culture.

Beyond the evidence for hafting wear traces and impact fractures suggesting use as projectiles, a formal consideration of the entire Star Carr barbed point assemblage can offer further insight into their use. Hafted projectiles come in a variety of forms and can be used in a variety of ways, including being thrown as javelins, fired with a bow as arrows and held in the hand as thrusting spears (Clark 1954; Jacobi 1978; Elliott 2009). The wide range of bird, fish and mammal species represented within the faunal assemblage suggest that the inhabitants at Star Carr employed a variety of hunting and trapping techniques in order to successfully kill this behaviourally diverse group of animals (see Chapter 29 in terms of using a barbed point for fishing).

The intact points from Star Carr which offer measurements which can be approximated to their original length display a continuous distribution of lengths which cannot be easily divided into functional groups (Figure 25.11). On the one hand, given the context of their recovery alongside the aforementioned faunal assemblage, this range of lengths can be taken to indicate that barbed points were used to hunt a range of different species. It is difficult to envisage a species of animal for which both the largest and shortest of the Star Carr barbed points would be appropriate for hunting! On the other hand, trapping and flint-based hunting
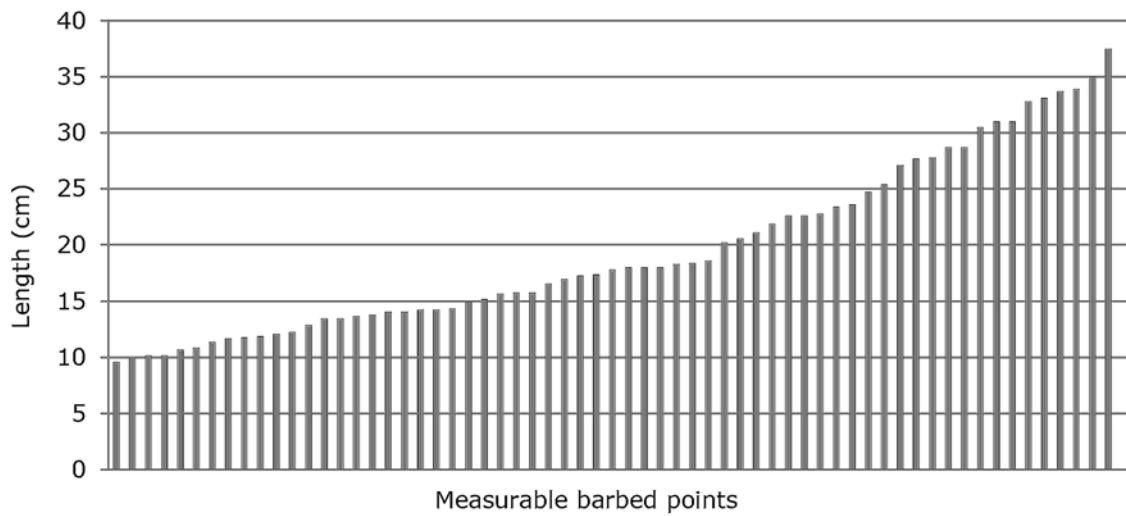
Figure 25.11: Lengths of 63 barbed points from Star Carr (all excavations) which are intact enough to give an indication of their original length (Copyright Star Carr Project, CC BY-NC 4.0).

technologies also undoubtedly played a role, and so assuming that barbed points were involved in the hunting of all of these species is unlikely. The continuous nature of the length distribution may also imply that some points may have had the potential to be hafted in several different ways and used as different hunting tools; being short enough to function as both arrow tips but long enough to also work in leisters or javelin tips. Alternatively, longer points may also have been suitable for use as both thrusting spears and robust javelin tips when hafted. This overlap emphasises the versatility of osseous barbed points as hunting tools and creating points which could be hafted in a range of hunting tools may have been a conscious choice made by the makers.

Decoration

Two barbed points show signs of incised lines on internal and external aspects of the tang region (Figure 25.12). This practice of incising tangs was noted by Clark (1954) and is attributed to the provision of roughage for hafting. However, given the presence of resin on two of Clark's barbed point tangs, and the substantial body of experimental and ethnographic literature concerning projectile hafting techniques, this functional interpretation is lacking in several respects. Firstly, the amount of extra friction which the marking of a tang surface might produce pales in comparison to the strength of resin and non-resin based hafting techniques which have been experimentally replicated. Secondly, both the form of the incised lines observed on the barbed points and the methods used in their creation (incision) have strong parallels with patterns observed on other portable objects at Star Carr and other European Mesolithic sites. The incised shale pendant (Chapter 34) and the possible incised piece of worked wood from Star Carr (Chapter 29) are good examples, as are the short, fine incisions which run across the surface of two of the elk bone bodkins excavated by Clark (EB1 and EB7), which also appear to be grouped into discrete sets (Clark 1954, 160). Yet in these instances a functional interpretation has not been proposed. There are also similarities between these overlapping criss-cross motifs and incised patterns documented in a range of Mesolithic contexts across Britain (Figure 25.13) and Southern Scandinavia (Milner et al. 2016). Some of these relate directly to portable material culture; others appear as examples of Mesolithic cave art (Mazel et al. 2007).

It may be argued that the position of the majority of these markings on the tang which would have presumably rendered them invisible once hafted would seem an unlikely place for decoration. However, there were presumably at least two moments when these markings became visible; after the point was made but prior to hafting, and after the haft had been removed prior to deposition. It may also be possible that barbed points were disassembled and reassembled between use and transported in their composite parts. If this was the case,

Figure 25.12: RTI images of <116490> (above) and <116802> (below) with illustrations of incisions to the right of each (Copyright Star Carr Project, CC BY-NC 4.0).
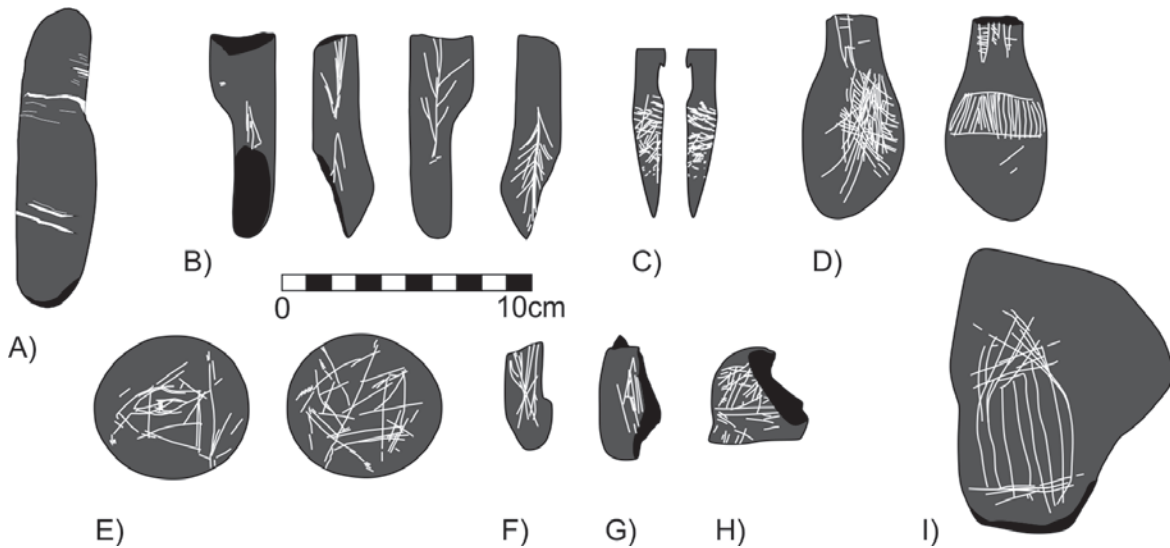
Figure 25.13: Examples of incised motifs from other British Mesolithic sites: a) Incised pebble, Camas Daraich;
b) Incised pebble SF1, Rhuddlan; c) Incised haft of barbed point <116490>, Star Carr; d) Incised pebble SF2,
Rhuddlan; e) Incised pebble B127, Llandegai; f) Incised pebble SF4, Rhuddlan; g) Incised pebble SF5, Rhud-
dlan; h) Incised pebble SF3, Rhuddlan; i) Incised pebble SF6, Rhuddlan (Drawn by Ben Elliott. Sourced from
Milner et al. 2016, *Internet Archaeology,* licenced under CC-BY 2.0).

it is possible that these markings remained visible throughout the object's active life. Discussions of artistic
expression and material culture aesthetics are notably absent within academic literature concerning the British
Mesolithic due to a perceived lack of data. A non-functional interpretation of behavioural practices such as the
incision of the Star Carr barbed point tangs may help to address this in the future.

Finally, the linear markings of <115796> (Figure 25.14) also need to be considered. These do not appear
on the tang region and cannot be functionally linked to hafting techniques. With this in mind, it may be
more appropriate to think of these incised patterns as decorative motifs forming part of a longer tradition of
linear-based designs which occur sporadically throughout the British Mesolithic. A notable parallel here is the
markings on an undated, uniserial antler barbed point from the Holderness region of East Yorkshire, curated at
the Kingston-Upon-Hull Museum (Accession no. KINCM 1973(a)). This also features a series of 49 transverse
markings created through sawing (Bartlett 1969).

Conclusions

When the finds of these excavations are considered, Star Carr can be seen to account for 227 of the 244 unise-
rial barbed points recovered from England to date. This constitutes 92% of the national record for this type
of artefact. Across the excavated areas, the deposition of barbed points appears to be focussed in two wetland
zones: the area of Clark's excavations, and across the detrital wood scatter/central/eastern timber platform
areas. Whilst deposition within Clark's area appears to be more intense, the detrital wood scatter area is notable
in being dominated by intact artefacts in contrast to the much higher rates of fragmentation within Clark's area.
Typological comparisons between these areas are hampered somewhat by the differential preservation levels,
which have left many of the detrital wood scatter points misshapen and distorted.

Analysis of the 34 new finds has revealed a shared chaîne opératoire in terms of finishing process, which
appears remarkably standardised across the assemblage. Yet beyond this, variation is plentiful. There is varia-
tion in the shape of barbs, in the spacing of barbs, in the length of intact points, in fragmentation patterns, in
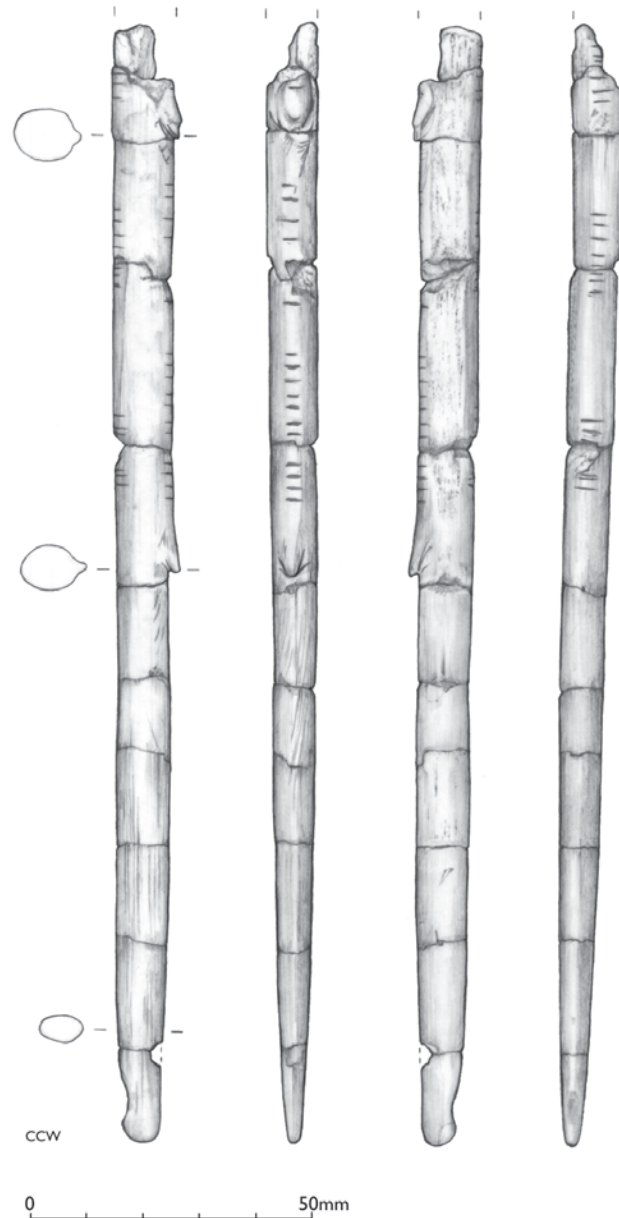
Figure 25.14: Barbed point <115976>, with groups of incisions between barbs and along unbarbed edge (Copyright Chloe Watson, CC BY-NC 4.0).

the form of the tang and in the position and presence of incised lines. This analysis has also identified the use of animal bone for the production of a very small minority of barbed points at Star Carr (see Chapter 24 for further evidence for this). As such, defining the Star Carr barbed points typologically is deeply problematic. The general Maglemosian and Star Carr specific typologies devised by Clark are of limited utility in understanding these artefacts, as the majority cannot be categorised under these schemes. Therefore, Star Carr barbed points demonstrate a high level of typological variation, but a low level of technological variation. In other words, the same production techniques and chaîne opératoire were being used to make similar artefacts in a wide range of different forms.

One area in which the Star Carr barbed points are united (as are the vast majority of similar barbed points from elsewhere in Europe) is their removal from any form of hafting prior to deposition. This echoes the removal of hafts from other forms of organic material culture such as elk antler mattocks, and flint artefacts such as axes and adzes. This, combined with the microwear evidence which suggests that barbed points were hafted and used prior to being deposited, indicates that these artefacts had complex, multi-stage biographies (Conneller 2004; Elliott and Milner 2010; Conneller 2011).

CHAPTER 26

Antler Frontlets

Ben Elliott, Becky Knight and Aimée Little

Introduction

The striking image of the Star Carr antler frontlets initially excavated by Clark (1954), and their implications for both Mesolithic cosmology and hunting practices, has fascinated archaeologists since their original discovery and led to their elevated status as iconic pieces of Early Mesolithic material culture (Lane and Schadla-Hall 2004). They feature in major narratives of World Prehistory (e.g. Mithen 2011; Scarre 2013) and, until recently, were considered a rare insight into Mesolithic ritual behaviour (Clark 1972). The 2004–2015 excavations at Star Carr recovered an assemblage of 12 humanly modified red deer frontlets. These include male and female animals, and also examples of modified crania with shed antlers. Seven (58%) are concentrated around Clark's area, whilst the rest are distributed across the wetland areas of the site.

This chapter will review Clark's original analysis of the Star Carr frontlets, before presenting the results of the zooarchaeological, traceological and microwear analysis undertaken on these new finds. This will be followed by a discussion of the technological implications that the findings of our analysis, in relation to recent experimental work carried out at the York Experimental Archaeology Research (YEAR) Centre and current understandings of this artefact type across Europe. Finally, our interpretation of these artefacts, based on the analysis presented, will be discussed.

Clark's analysis

Deemed some of his most spectacular finds, Clark (1954, 168) excavated 21 'stag frontlets having still in place portions of antler worked in a special manner', which he noted as sharing five key characteristics:

1. Beams reduced by removal of at least 75% of their circumference, and the spongy tissue removed to leave only the compactor.
2. The tines were similarly reduced, with 50% of the circumference being removed.
3. The interior aspect of the burr is removed.

4. The exterior aspect of the burr is retained.
5. When represented, the parietal bones are always perforated.

The technical terms used by Clark are illustrated within Figure 26.1. However, despite this seemingly clear definition within this group of artefacts, there existed significant variation relating to the levels to which the parietal and frontal bones had been reduced, the extent of the antler retained (including the number of tines still apparent), the area of burr removed, the reduction and smoothing of the rim and interior of the braincase, and the presence and quantity of perforations.

This variation led Clark to define three distinct groups: Class A frontlets (retaining the external aspect of the beam), Class B1 (retaining the posterior aspect of the beam) and Class B2 (retaining the postero-external aspect of the beam). Clark interpreted the worked stag frontlets as headdresses, based on the hypothesis that the perforations and supraorbital fossa (when present) could have been used to attach webbing or strapping, that the reduction of the antlers would have lightened the artefacts considerably, and that the attention paid to the regularisation and smoothing of the rim and interior of the brain case would have made them more suitable for wearing on the head.

He suggested two alternative hypotheses for wearing these red deer headdresses: either as part of a hunting disguise which allowed people to either attract deer or approach them at very close quarters, or as part of a ritualised costume for shamanic ceremonies. Both suggestions are supported by several ethnographic sources which feature hunter-gatherer groups from North America and Siberia who create deer headdresses for use in each context (Witsen and Boddaert 1705; Boas 1835; Birket-Smith 1929).
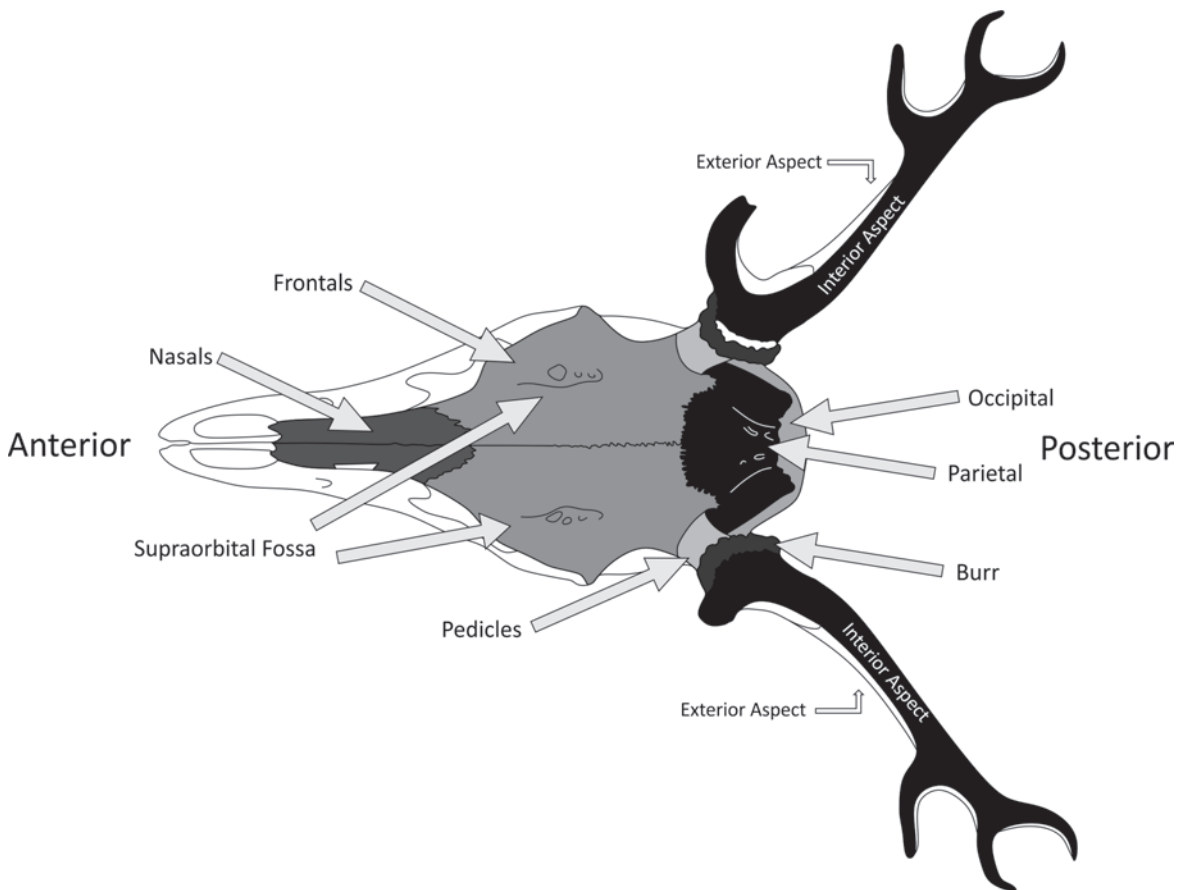
Figure 26.1: Schematic diagram of red deer cranium with key terms highlighted (Copyright Ben Elliott, CC BY-NC 4.0).

Methods

Following excavation, the frontlets were analysed from a zooarchaeological and traceological perspective, and the potential for microwear and residue analysis assessed (Chapter 15). They were then illustrated and conserved before being modelled through structure-from-motion techniques. The exceptions to this were frontlet <103625>, which was laser scanned prior to conservation, and <113901>, which was recorded in situ, illustrated and then immediately conserved due to its poor condition. At the time of writing <103625> was still in conservation and could not be photographed.

Spatial distribution

The deposition of worked red deer antler frontlets occurs across several different phases of the site's occupation, and varies in intensity and environmental context (Figure 26.2; Table 26.1). The earliest frontlets to be deposited at the site have been recovered from the detrital wood scatter. The Bayesian dating model suggests that the deposition of both <99528> and <103625> took place between *9315–9245 cal BC* (*start wood scatter*; Figure 17.20) and *9115–8915 cal BC* (*end wood scatter*; Figure 17.20) (95% probability) or probably between *9290–9255 cal BC* and *9095–9005 cal BC* (*68% probability*).

A much more intensive episode of frontlet deposition occurred between *8885–8775 cal BC* (*start Clark area*; Figure 17.20) and *8815–8715 cal BC* (*95% probability*) (*end Clark area*; Figure 17.20), probably between *8840–8790 cal BC* and *8800–8750 cal BC* (*68% probability*). This phase of occupation also encompassed the deposition of the assemblage excavated by Clark and as such includes the 21 complete or partial frontlets recorded in his excavations, along with the seven recovered from this area of the site more recently. This small cluster includes male and female frontlets, individuals with shed antlers, individuals with heavily reduced antlers,
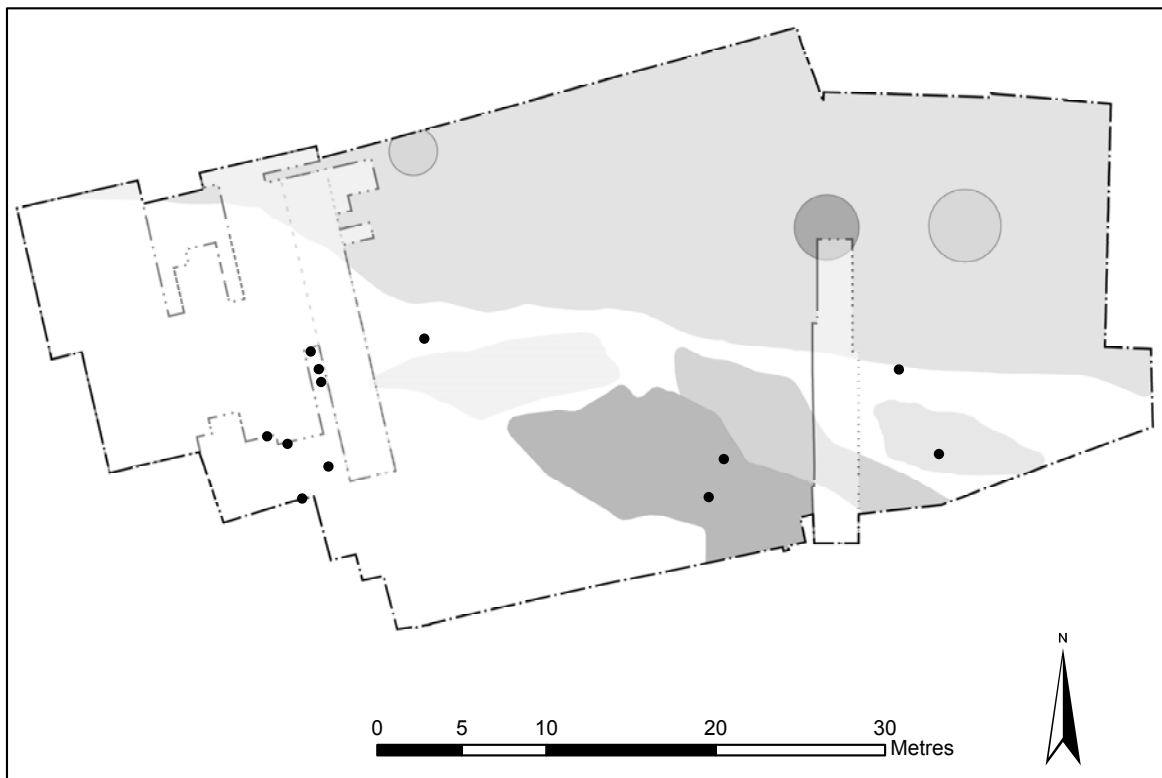
Figure 26.2: Spatial plot of the antler frontlets (Copyright Star Carr Project, CC BY-NC 4.0).

Finds number	Area	Context	Braincase reduced?	Sex	Shed?	Type
95870	Clark backfill	Clark backfill	Y	M	Unshed	B1
99528	Detrital wood scatter	312	Y	M	Unshed	A
103625	Detrital wood scatter	317	Y	M	Unshed	B2
113901	Woodpeat/ lake edge	310	Y	M	Unshed	A
113732	Eastern platform	312	Y	M	Unshed	A
114937	Clark's area	312	Y	M	Unshed	A
115876	Clark's area	312	Y	M	Unshed	B2
116020	Clark's area	312	N	M	Shed	N/a
116601	Clark's area	317	Y	M	Shed	N/a
116862	Clark's area	312	Y	M	Unshed	N/a
116888	Clark's area	317	Y	M	Shed	N/a
117803	Clark's area	312	N	F	N/a	N/a

Table 26.1: Details of the frontlets found during the 2004–2015 excavations.

individuals with significant portions of the beams and tines intact and (if Clark's data is considered) individual artefacts which had been perforated.

Frontlet <113732> was excavated from the area of the eastern platform, although directly relating the dates from the construction of this platform and the production and deposition of this particular artefact is difficult on stratigraphic grounds.

Finally the poorly preserved and heavily flattened frontlet <113901> was excavated upslope, within a peat-forming environment at the interface between reed swamp and wood fen environments (see Chapter 19). The drier, degraded nature of these deposits make them both difficult to date and also prevent the preservation of organic material necessary to accurately define the local environmental conditions. As such, it is difficult to place this particular artefact within the broader site sequence.

Analysis

<95870> (Figure 26.3): A very poorly preserved left-sided pedicle, burr region and c. 20% of the lower beam circumference. The spur of compactor situated at the posterior aspect, qualifies this as a Class B1 frontlet under Clark's original system, and it is the presence of this 20% of posterior compactor which led to this piece being identified as a fragmented frontlet and not a piece of groove-and-splinter debitage. The lack of any attached frontal or parietal bone make it impossible to ascertain if the original artefact was perforated. Although the surface detail is lacking, the longitudinally aligned edges of the remaining beam compactor tissue suggest grooving, and the lack of spongy tissue across the base of the antler is also indicative of the scooping which Clark notes for other frontlets from Star Carr. The interior burr is intact, although the poor preservation makes it impossible to assess the state of the exterior burr at the time of deposition. Although clearly not representing a full frontlet, this specimen has firm parallels with the fragmented finds that Clark notes and records as AF19-21.

Figure 26.3 (page 301): Frontlets <95870> and <113732> (Copyright Chloe Watson, CC BY-NC 4.0).
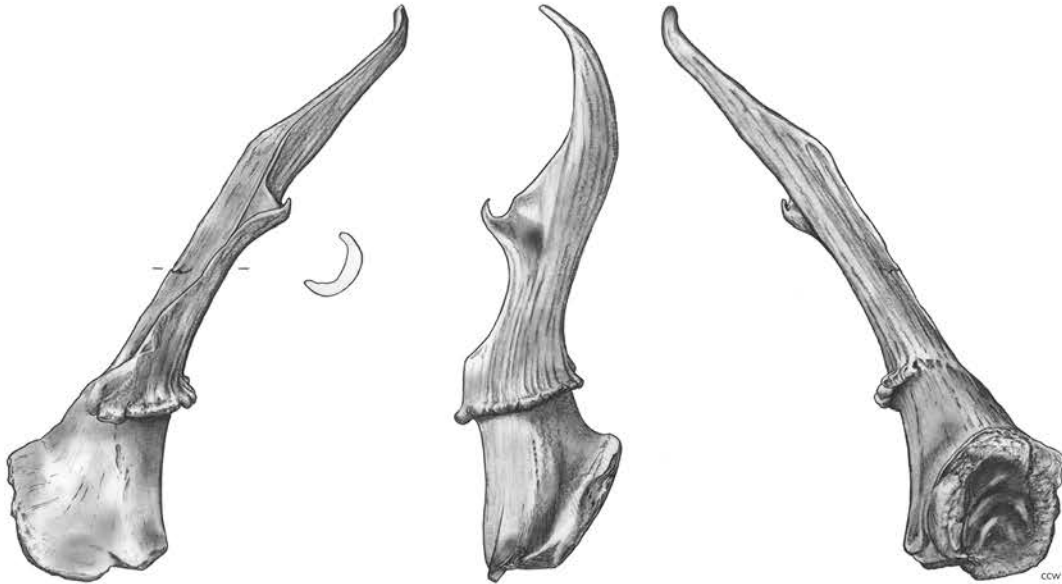
Red deer Frontlet
SC15 113732
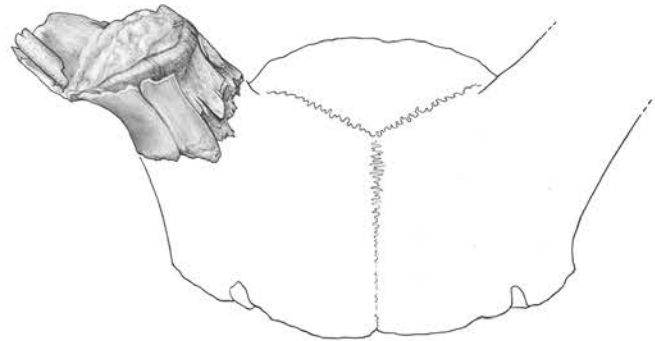
0 — 50mm

Red deer Frontlet
SC13 95870

0 — 50mm

Figure 26.4: Frontlet <99528> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<113732> (Figure 26.3): Left half of a red deer cranium which includes only a small amount of frontal bone, a pedicle and one trimmed antler. The beam is broken short of the trez tine junction and the bez and brow tine removed. 50% of the compactor circumference remains on the external aspect (Type A), with the spongy tissue removed. Although the details of the worked edges have not survived, the parallel nature of the cut edges suggests that the groove-and-splinter technique was used to remove the compactor. The methods used to remove the spongy tissue are unknown, but it has been applied extensively to the basal portion of the antler. The section of skull that remains appears to have been humanly modified. The pedicle and burr of the antler have also been modified so that there is a smoothed, possibly ground down, area on the medial aspect, possibly linked to the removal of the spongy tissue from the antler. The bone and antler are demineralised and also slightly compressed. Some of the surface detail on the antler has been lost due to a combination of the depositional and demineralisation processes.

<99528> (Figure 26.4): Partial cranium of a red deer that has been modified so that only a small amount of left and right frontal bones, complete pedicles and a small amount of antler remain. The modification of the skull has resulted in scalar flaking around the rim which has similarities with <103625>, in that the rim surface has an abraded appearance, and was probably ground with a coarse stone pebble, as our experiments have revealed comparable traces (Little et al. 2016). Although the levels of preservation recorded on <99528> appear to deteriorate towards the distal extents of the piece, several observations can be made as to the ways in which the antlers have been worked. The burrs have been removed on the anterior-external aspect, but remain intact on the internal aspect. The misshapen but intact lower beams demonstrate reduction in that they are missing c. 50% of their circumference, and the scooped shape of the basal junction implies that similar scraping has been carried out on both the left- and right-sided antlers as has been noted on other frontlets. The retention of the external aspect of the beam classifies this as a Type A frontlet. The pedicles appear to have been modified with a chopping action, probably with the use of a flint axe, to create a downward-sloping angle on their medial aspect. Both the bone and antler are demineralised and have a rubbery consistency. Due to the demineralisation process the bone has bloated and warped creating cracks and splits in the cortical bone. It is possible to see the white mineral gypsum within these splits.
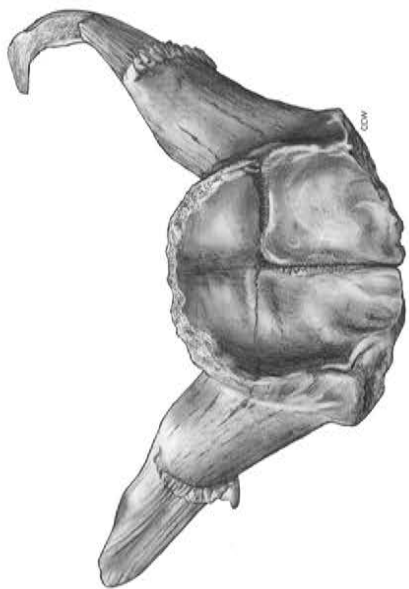
Red deer Frontlet
SCI3 99528
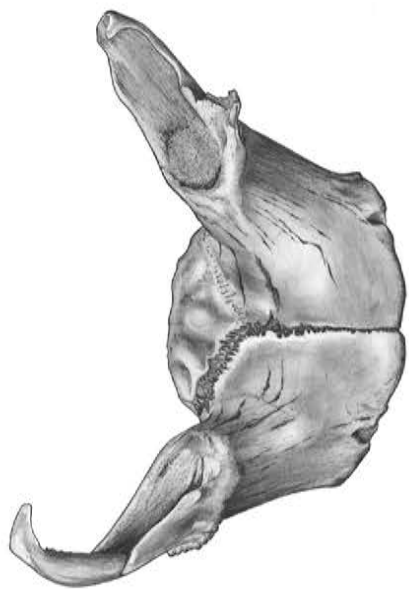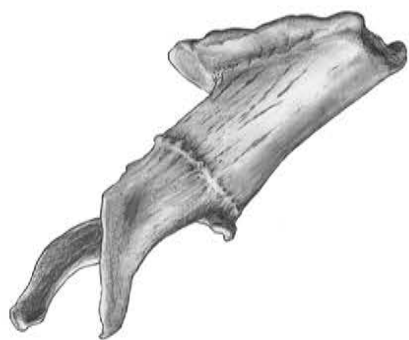
0 _____ 50mm

<103625> (Figures 26.6 and 26.7): Partial cranium of a red deer which includes partial frontal and parietal bones, with pedicles and associated antler beams and tines. Both the skull and antler have been humanly modified, trimmed and worked. The antler has been trimmed and also split in half by groove-and-splinter working. Portions of beam and brow tine of both the left- and right-sided antlers remained intact whilst the artefact was in situ, although these became fragmented during excavation. Evidence for the application of the groove-and-splinter technique is evident across both the beams and brow tines, with continuously smooth and longitudinal facets consistent with grooving. This has retained the postero-external portion of the beam, and the lower 50% of the brow tine's circumference. Although no working marks within the beams could be positively identified, the manner in which the spongy tissue has been so completely removed from the internal structure of the antler suggests strongly that scraping was employed, after grooving had removed the compactor tissue. Again, although no working marks survive, the smooth profile of the base of both the left and right antler suggest that scraping has been applied to create this hollowed out shape. The lack of visible scraping marks is curious, as substantial quantities of work would have been required to create this effect. The lack of scraping marks may be indicative of wear or abrasion in use, post-dating the manufacture of the artefact. However, this region does coincide with an area of highly localised poor preservation, and so the loss of surface detail is more likely to be associated with this phenomenon.

Two perforations have been created on the parietal bone, each in the region directly posterior to the orbital arches. These are surrounded on both the internal and external aspects by a large number of deeply etched gouge marks, radiating centrally from the perforation itself and extending onto the lower aspect of the adjacent pedicle. These are consistent with the perforation through the nicking technique being applied from both the internal and external aspects of the cranium. As such, they must have been carried out following the removal of the brain, in order to allow access to the internal aspect of the parietal bone. The right perforation also features a smoothed surface on its interior, extending around approximately 30% of the total circumference of the perforation itself. This smooth area has a light polish adhering to it and it appears to directly overlie the surrounding nicking marks, thus post-dating their creation.

This smooth surface appears unlikely to have been created during the manufacture of the frontlet. Although both drilling and boring are capable of producing similar polished surfaces, the uneven and jagged edge of the remaining 70% of the perforation circumference attests to the fact that the perforation had been completed prior to the creation of this smoothed surface. As such, it would seem strange that either technique would be applied after the perforation had been successfully created through nicking. This strongly suggests that this particular smoothed facet has been created during the use of the artefact, and may relate to materials being passed through the perforation itself.

The bone and antler is robust and shows no sign of demineralisation. However there are small patches of hard grey concretions and also iron staining on the cortical bone of the skull.

Figure 26.5 (page 303): Frontlet <99528> (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 26.6 (page 305): Frontlet <103625>, dorsal and ventral aspects (Copyright Chloe Watson, CC BY-NC 4.0).
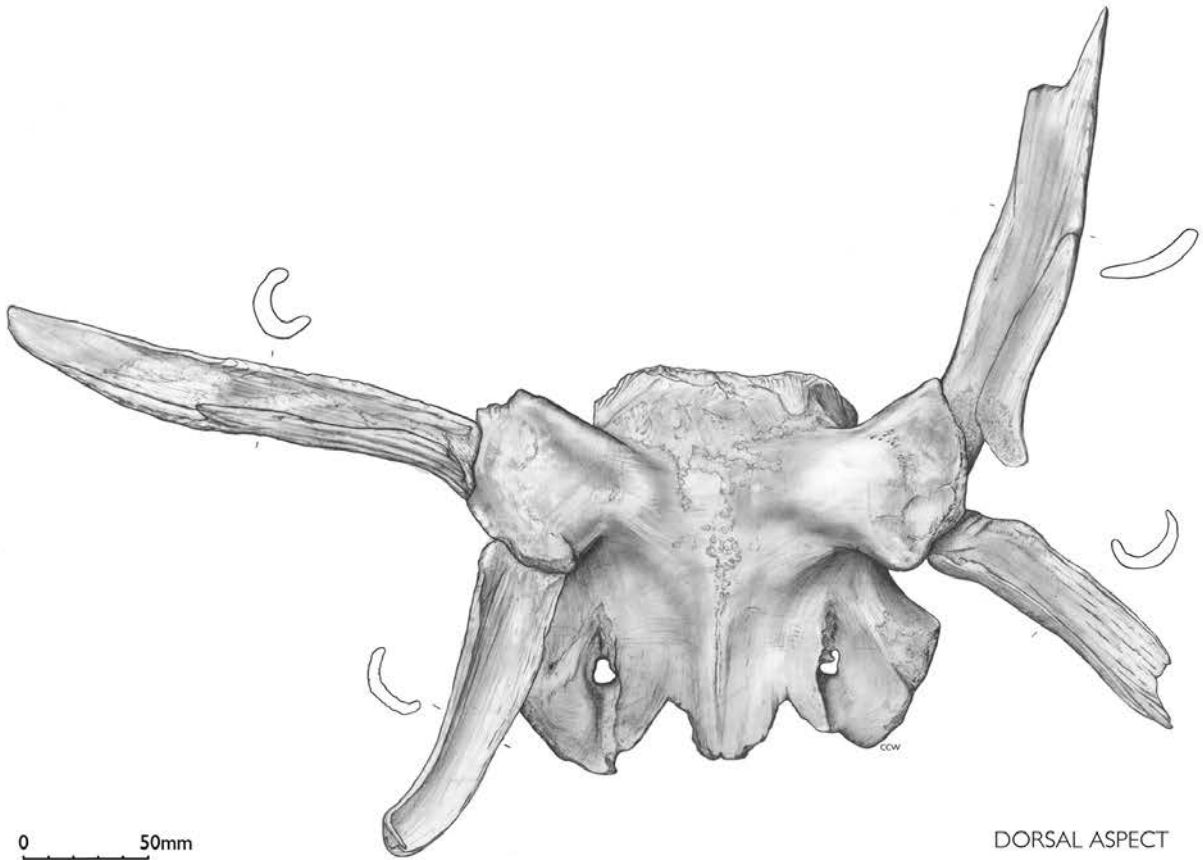
0   50mm

DORSAL ASPECT
Red deer frontlet
SC13 103625
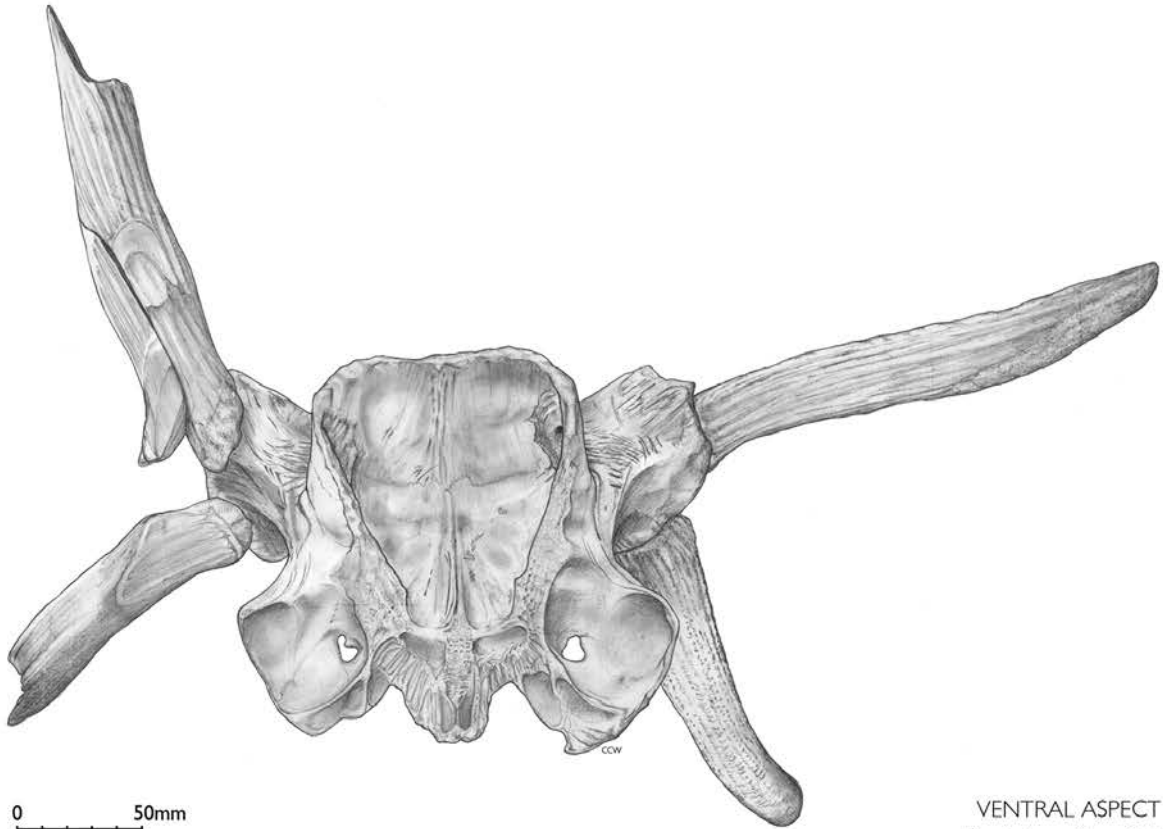
0   50mm

VENTRAL ASPECT
Red deer frontlet
SC13 103625
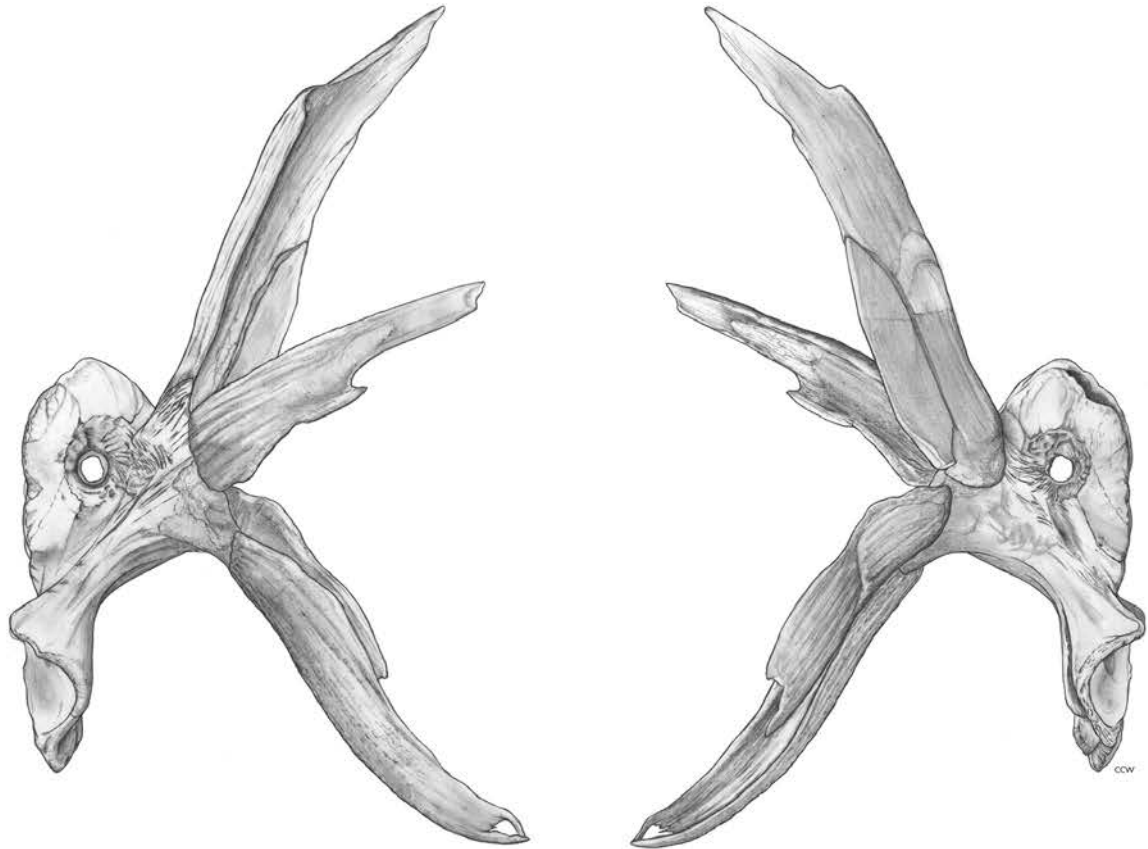
LEFT AND RIGHT SIDE ASPECTS
Red deer frontlet
SC13 103625

0 ____ 50mm

Figure 26.7: Frontlet <103625>, left- and right-side aspects (Copyright Chloe Watson, CC BY-NC 4.0).

<113901> (Figures 26.8 and 26.9): Partial cranium of a red deer that includes sections of both the left and right sides of the frontal bone, possibly a small section of parietal, pedicles and trimmed antlers. The preservation of this specimen is particularly poor as both the bone and antler are very desiccated and very compressed. The texture of both is comparable to leather. Due to the preservation issues it is difficult to comment on the modification of the skull but the antler appears to have been trimmed and the groove-and-splinter technique applied, retaining the external aspect of the beam (Type A).

Figure 26.8: Frontlet <113901> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).
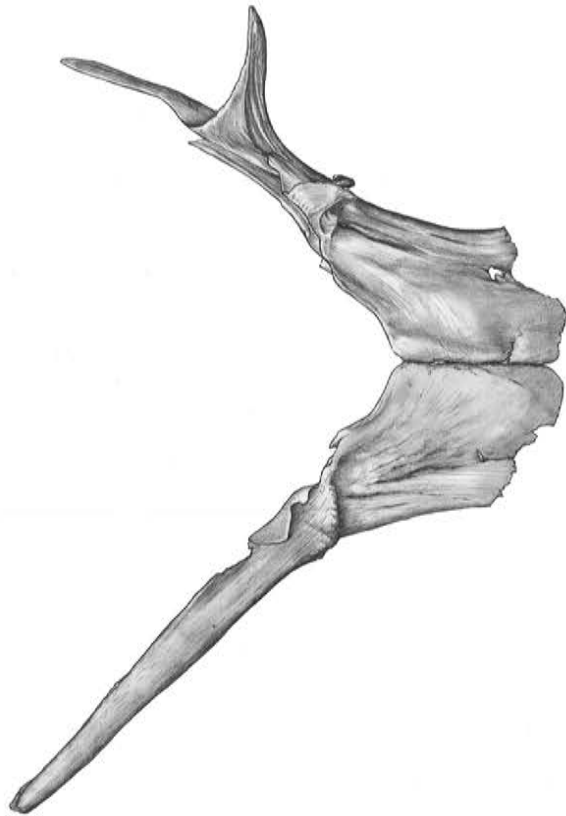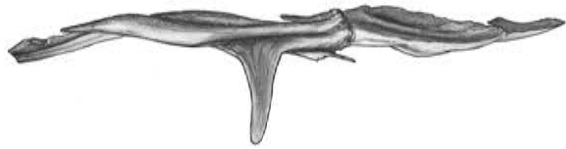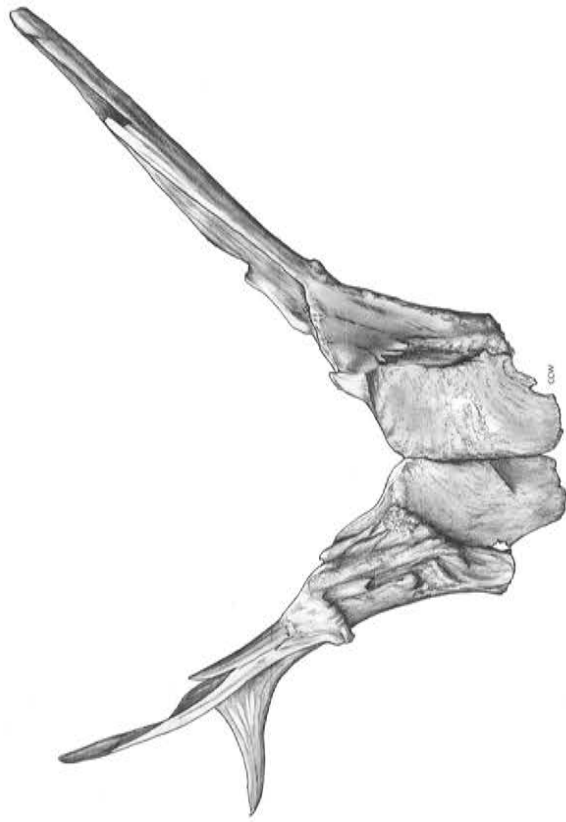
Red deer Frontlet
SC115 113901

50mm

Figure 26.10: Frontlet <114937> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<114937> (Figure 26.10 and 26.11): Partial cranium of a red deer which includes sections of frontal and parietal bones, complete pedicles, partial burrs and a small amount of attached antler on the right-side pedicle. This is too fragmentary to allow an assessment of the working techniques used in its reduction, but the small amount remaining intact is situated on the external aspect, classifying this as a Type A frontlet. The base of each burr has been hollowed out with all of the spongy tissue removed. The bone and antler is demineralised and has a rubbery consistency. Due to the demineralisation process the cortical bone of the skull has wrinkled, and splits and cracks have also occurred. Patches of hard grey concretions and fossilized roots were attached to the bone and antler surfaces. The cranium has separated along the suture line on lifting as it was only partially fused. The modification to the cranium has occurred just before the orbits on the frontal bone and just after the frontal parietal suture on the posterior aspect. Both of the pedicles and burrs have been ground and smoothed on a downward angle on the medial aspect.

Figure 26.9 (page 308): Frontlet <113901> (Copyright Chloe Watson, CC BY-NC 4.0).
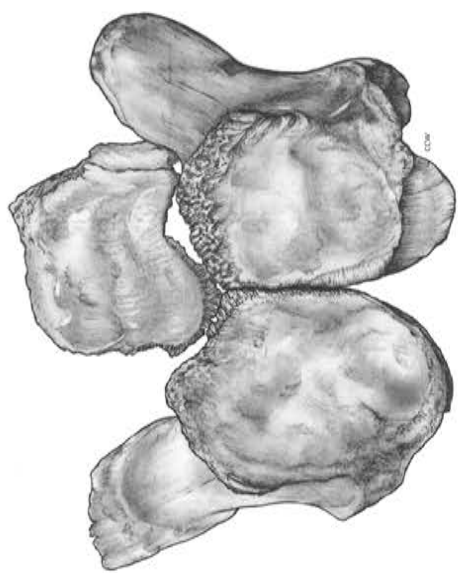
Red deer Frontlet
SCI3 114937
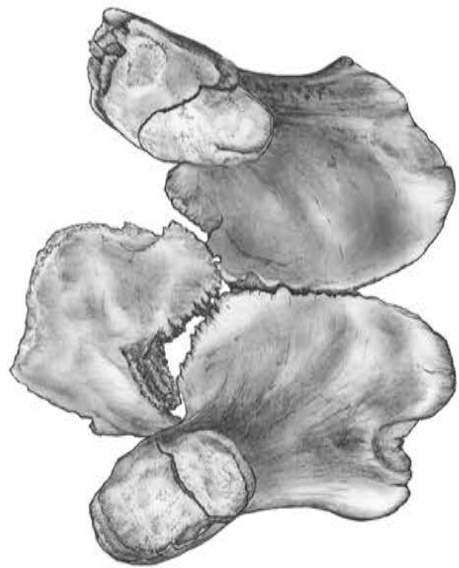
50mm
0

Figure 26.12: Frontlet <115876> (Copyright Neil Gevaux, CC BY-NC 4.0).

Figure 26.11 (page 310): Frontlet <114937> (Copyright Chloe Watson, CC BY-NC 4.0).

<115876> (Figure 26.12. 26.13 and 26.14): Modified cranium of a red deer represented by partial frontal bones, partial parietals, complete pedicles and partial antlers. The left antler is broken short below the trez tine junction but features the bez tine with the tip removed and the brow tine. The right antler is broken short below the bez tine junction and so consists of the basal portion and brow tine. A small piece of birch bark, c. 70 mm in length, was found adhering to the right antler and is included in the illustrations. However, under micro-excavation this was found to be underlain by 5–10 mm of sediment, meaning that it must have become entangled with the artefact post-deposition and afterwards sediment built up around the antlers. Each antler has had 50% of the compactor circumference removed and the spongy tissue extracted, leaving the posterior-external aspect of the antlers intact, classifying this as a B2 type frontlet under Clark's typology. Although the cut surfaces are not particularly well preserved, their continuous, parallel edges suggest the use of the groove-and-splinter technique in reducing the antlers. 80% of the right and left burr circumference is intact, with smoothing used to remove the interior 20% of each. The techniques used to achieve this smoothing are not apparent. The bone and antler are robust with no sign of demineralisation. More of the frontal bone is represented than is usually seen as the breakage is almost at the suture line of the nasal bones rather than horizontally across the supraorbital fossa like the majority of the other frontlets. The modification to the parietal is horizontally across the posterior aspect just behind the pedicles. The break edges around the circumference of the cranium appear as though they may have been ground or smoothed. There are also possible ephemeral cut marks on the frontal bone near to the central suture, but there is also a small amount of root etching to the cortical bone surfaces of the cranium.
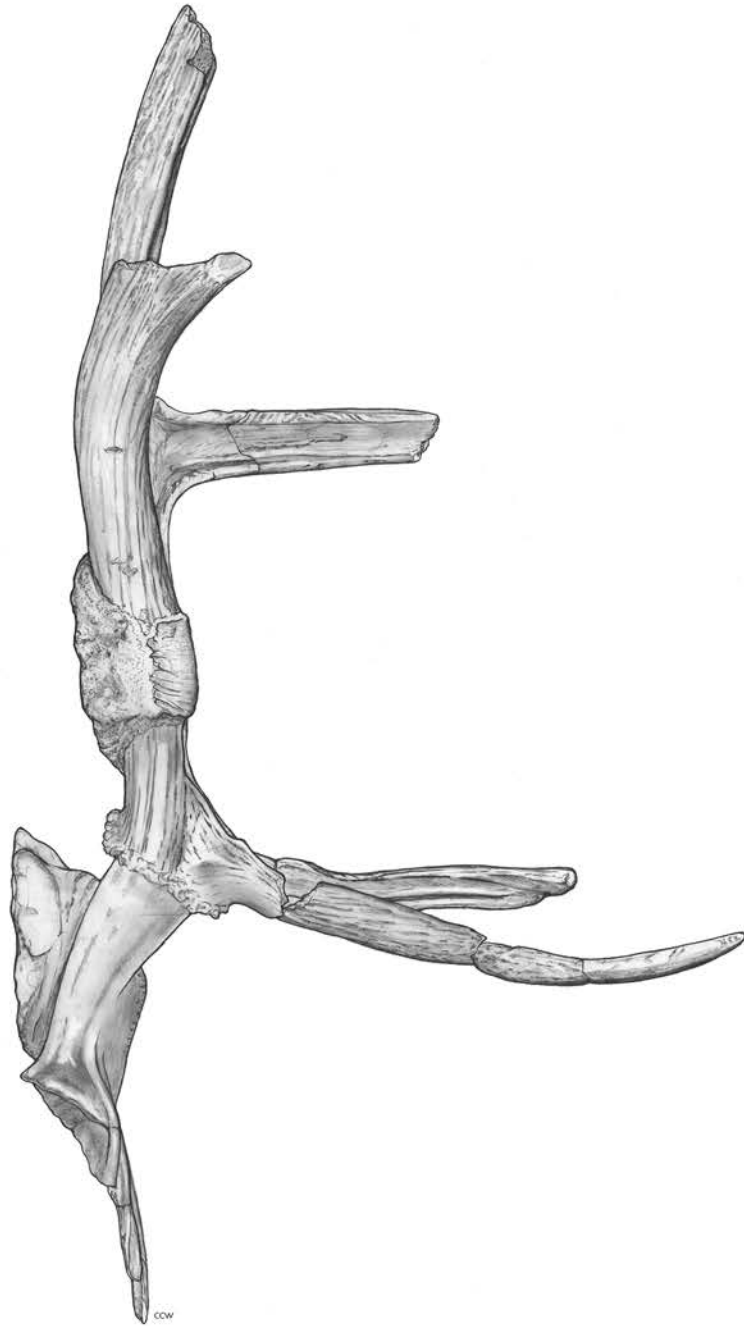
SIDE ASPECT
Red deer frontlet
SC15 115876

0   50mm

Figure 26.13: Frontlet <115876> side aspect (Copyright Chloe Watson, CC BY-NC 4.0).
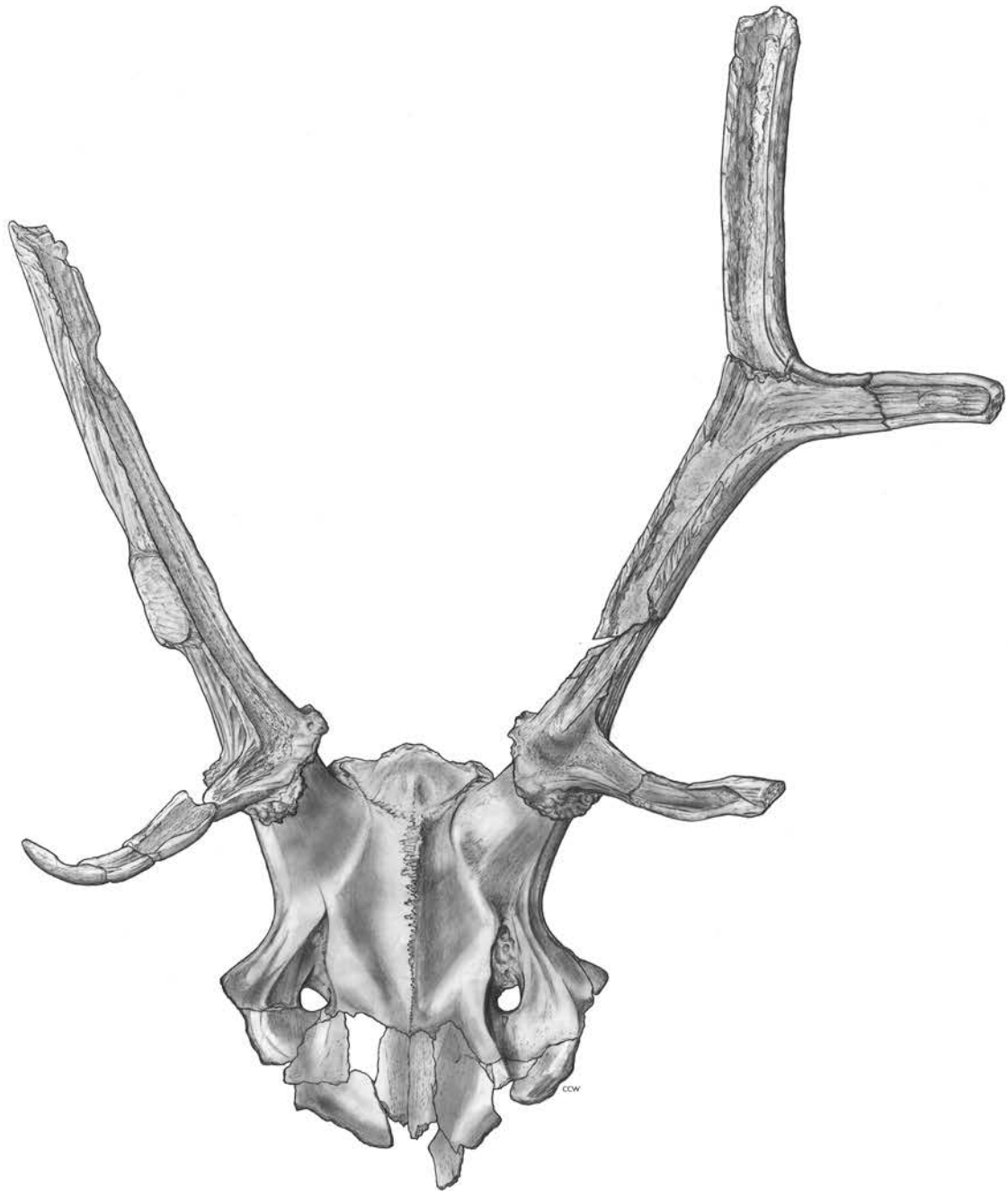
DORSAL ASPECT
Red deer frontlet
SC15 115876

0 _ _ _ _ _ 50mm

Figure 26.14: Frontlet <115876> dorsal aspect (Copyright Chloe Watson, CC BY-NC 4.0).
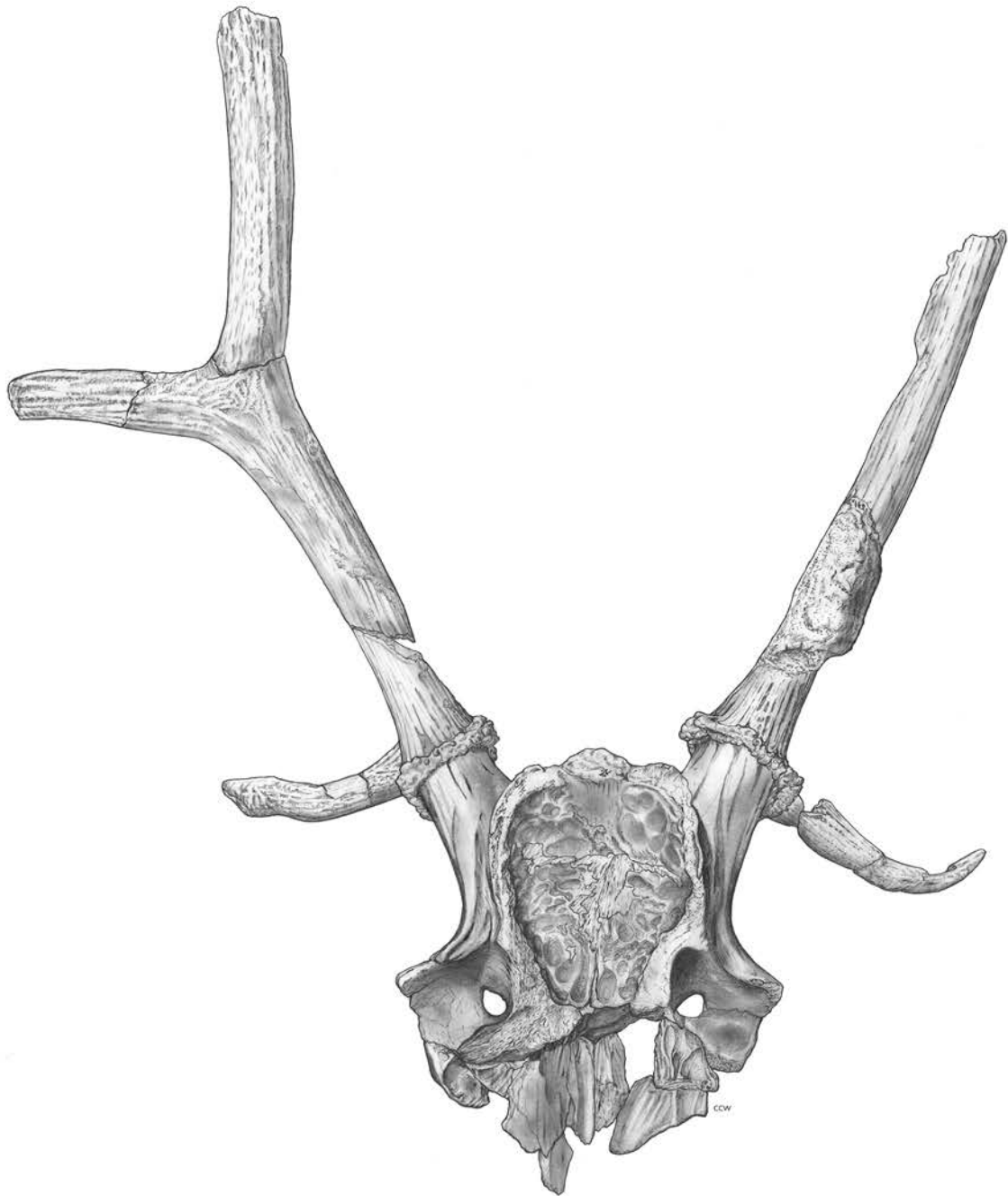
VENTRAL ASPECT
Red deer frontlet
SC15 115876

0 _ _ _ _ _ 50mm

Figure 26.15: Frontlet <115876> ventral aspect (Copyright Chloe Watson, CC BY-NC 4.0).

Red deer Frontlet
SC15 116020

50mm
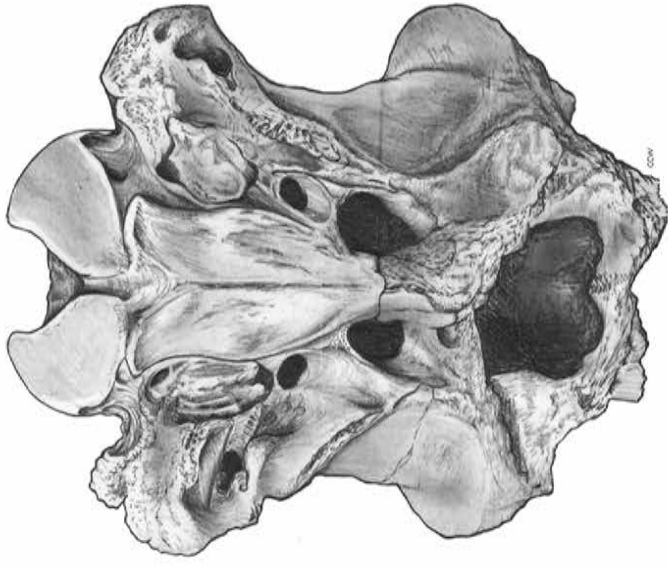
0
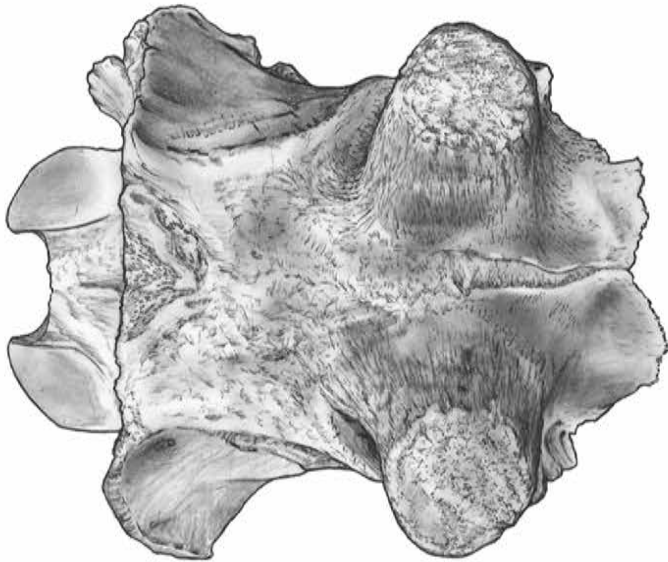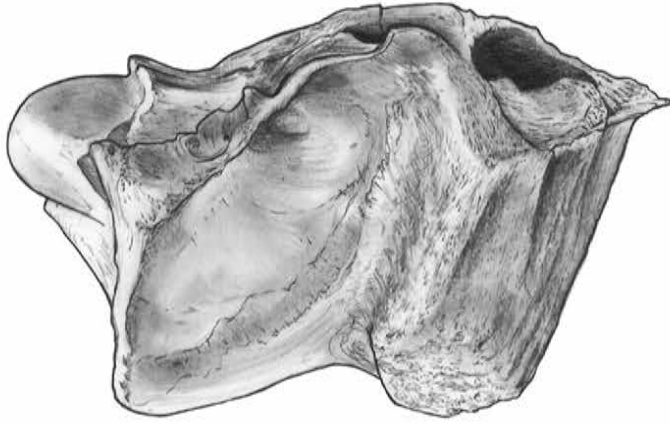
<116020> (Figures 26.16, and 23.39 and 23.40 in Chapter 23): A partially modified red deer cranium with breakage horizontally across the frontal, above the orbits, which is common in the majority of the other frontlets, but the majority of the brain case is still complete. There are also no antlers attached as they have been naturally shed. The bone is robust on this specimen and there is no sign of demineralisation. However, the surface of the cranium is uneven and there are very defined muscular grooves within the parietals (see Chapter 23). The breakage to the cranium is uneven and jagged, but it does appear some attempt has been made to grind or smooth the rougher, sharper areas of the sphenoid.

Figure 26.16 (page 316): Frontlet <116020> (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 26.17: Frontlet <116601> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<116601> (Figures 26.17 and 26.18): Partial cranium of a red deer. The pieces of the cranium that remain are the frontal, the parietal and the pedicles. The skull has been broken at the suture of the frontal and nasal, and at the suture of the parietal and occipital. There is evidence of pecking on the internal edge of the parietal, and some fragments of the parietal have become detached from the main body of the cranium during lifting, mostly along the suture line. The frontal suture is very visible and does not appear to have fused significantly. There is a small amount of flaking of the cortical bone on the left side of cranium on the anterior of the pedicle. There is a possible cut mark on the centre of the parietal and also on one of the detached parietal fragments. Also another ephemeral cut mark is present on the partial left orbit. The pedicles are smooth and rounded, though it is difficult to say whether it is from human modification or from post-depositional processes.

Figure 26.18 (page 319): Frontlet <116601> (Copyright Chloe Watson, CC BY-NC 4.0).

Red deer Frontlet
SC15 11601

ccw

50mm

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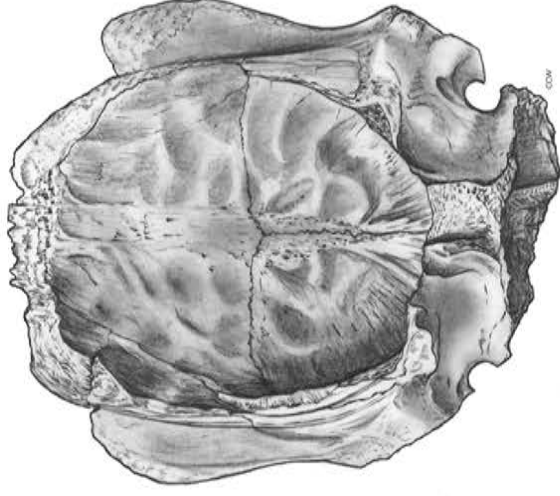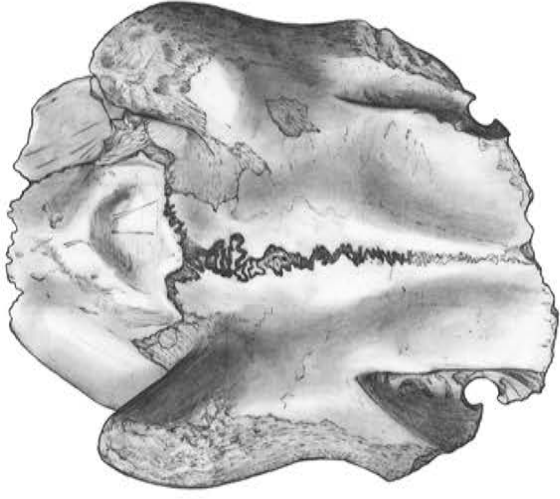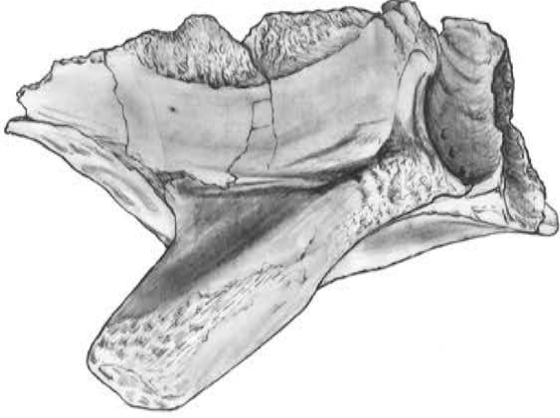
Figure 26.19: Frontlet <116862> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<116862> (Figures 26.19 and 26.20): Partial cranium of a red deer represented by partial frontal and parietal bones, pedicles and a small amount of attached antler. The breakage to the frontal bone is horizontally across the nutrient foramen and there appears to be some purposeful flaking around the break edge. There are a few possible ephemeral score marks on the centre of the parietal bone and also on the left side of the frontal bone close to the sagittal suture. The left-sided burr's circumference is 95% intact, whilst the right-sided burr has 50% of the original circumference intact, with the interior aspect having been removed. Both the bone and antler are robust with no sign of demineralisation. However, there was quite a bit of root adhering to the cortical bone surface and also some patches of iron staining.

Figure 26.20 (page 321): Frontlet <116862> (Copyright Chloe Watson, CC BY-NC 4.0).
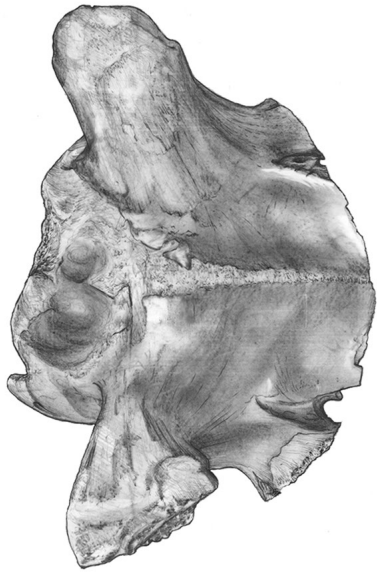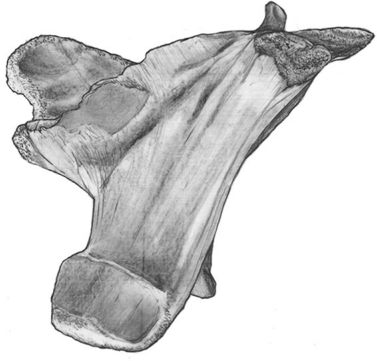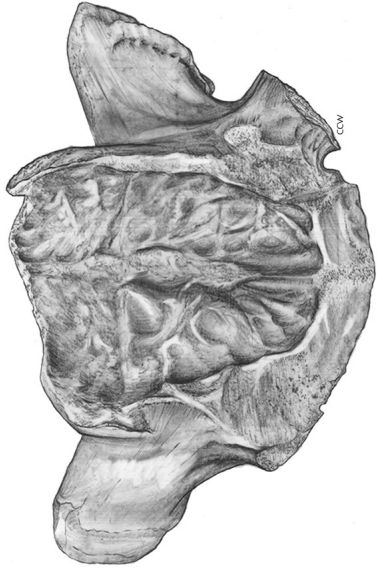
Red deer Frontlet
SC15 116862

0 �⌏ 50mm

Figure 26.21: Frontlet <116888> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<116888> (Figures 26.21 and 26.22): Partial cranium of a red deer with only a partial frontal and parietal bones present. There are no antlers attached to the pedicles as these appear to have been shed naturally. The breakage to the cranium is uneven and jagged and there is a clear percussion point at the base of the break edge on the parietal. The break to the frontal bone is just in front of the pedicle, before the nutrient foramen. The breakage to the parietal is approximately 10 mm after the pedicles and horizontally across. The sutures on the skull are still clearly visible. The area just underneath the pedicles at the very edge of the parietal (almost at the suture) features impressions and score marks suggestive of carnivore gnawing. There is a possible molar impression on the left side and tooth scores. The evidence is slightly more ephemeral on the right side yet still present. There are some possible ephemeral cut marks on the parietal with directionality anterior to posterior, located towards the right-hand side.

Figure 26.22 (page 323): Frontlet <116888> (Copyright Chloe Watson, CC BY-NC 4.0).
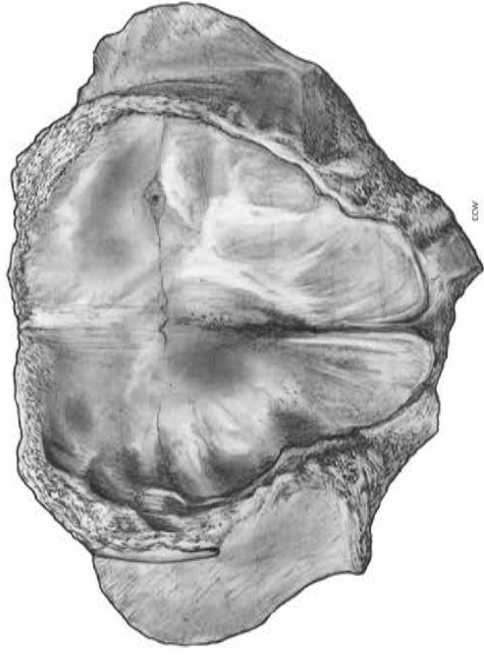
Red deer Frontlet
SCI5 116888

50mm
0
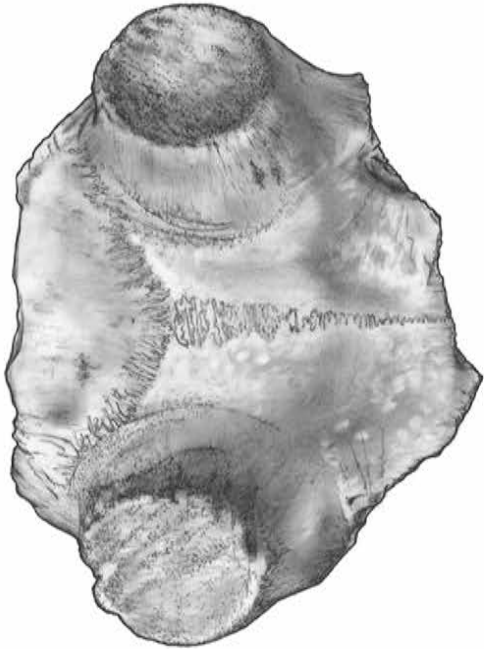
Figure 26.23: Frontlet <117803> exhibiting cut marks (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

<117803> (Figures 26.23 and 26.24): Partially modified cranium of a female red deer with only a section of frontal bone being retained but the majority of the braincase still intact. The frontal bone has been broken horizontally across, allowing approximately half of the orbits to remain attached. There was also a fragment of zygomatic associated but not attached to the main body of the cranium. It appears as though the sharper edges of the sphenoid have been ground or smoothed down. There are also three possible parallel cut marks to the edge of the left orbit but they are very ephemeral. The majority of the bone is robust but the right side of the cranium is partially demineralised. The cranium is very slightly warped and compressed due to this and is therefore leaning towards the right (softer) side. There is a small amount of excavation damage to the right parietal as a result of the demineralised bone.

Figure 26.24 (page 325): Frontlet <117803> (Copyright Chloe Watson, CC BY-NC 4.0).

Red deer Frontlet
SC15 117803

50mm
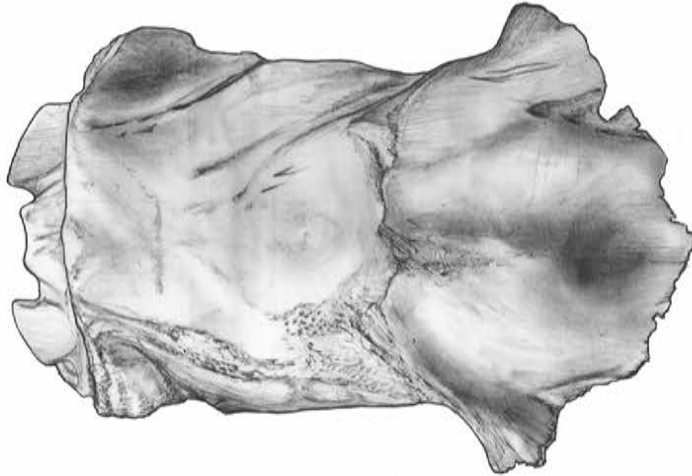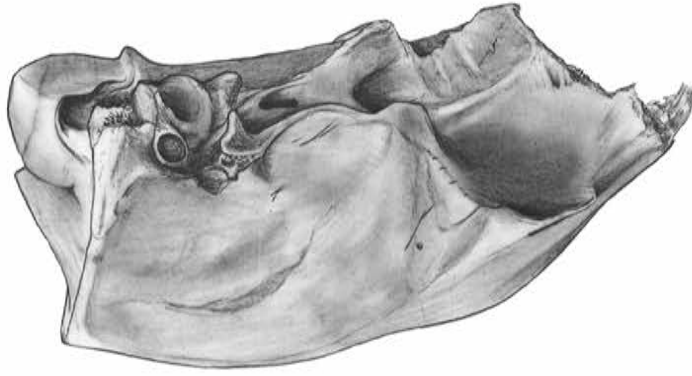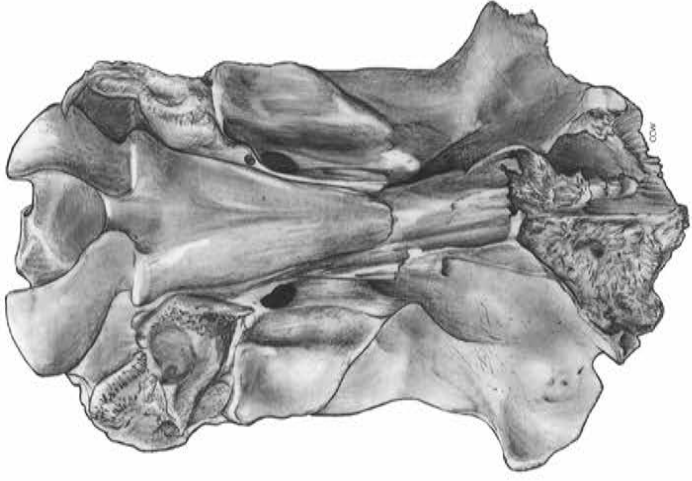
Experiments

The variation apparent within the 2004–2015 frontlet assemblage prompts a series of new questions concerning their methods of manufacture. Is this diversity representative of a châine opératoire sequence, with individual finds being abandoned at different stages of the production process, or typological variation within the form of the finished artefacts? To investigate these questions, a series of experiments were undertaken. These have helped to demonstrate the techniques used to reduce a fleshed deer head to the trimmed frontal portion seen at Star Carr. This work has also highlighted the extensive labour investment involved in the reduction of the antlers via the groove-and-splinter technique (Little et al. 2016).

In summary, these experiments found that the initial reduction of the skull was achieved by first skinning the head, using a tranchet adze to begin hide removal at the base of the antlers, and then covering the portion of skull which was intended to be retained with damp clay. The head was then placed within the hot embers of a small fire for several hours, after which point the exposed skull was removed through direct, repetitive percussion carried out with a small hammerstone (Figure 26.17). Using subtle variations of this technique, the lower part of the skull could be removed rapidly and then the edges of the braincase defined with a high degree of accuracy. This process left cut marks associated with de-skinning on the outer surfaces of the frontlet, cut marks within the braincase associated with the removal of the brain, and a series of shallow, scalar negatives of bone removal around the rim of the braincase. These experimentally recreated working marks were identified across all of the crania described here as frontlets.

As frontlet manufacture requires the use of clay and a hearth setting we can expect that the reduction of the skull would have been carried out on the dryland and not in the wetland. As such, a distinction needs to be drawn between the places where skulls were worked during frontlet production and the wetland contexts into which they were later deposited.

Figure 26.25: Experimental research into the manufacture of antler frontlets through the use of fire (Copyright Star Carr Project, CC BY-NC 4.0).

To watch this video, scan the QR code with your mobile device or visit DOI: https://doi.org/10.22599/book2.1

Discussion

A technological approach

These insights allow a more refined definition of red deer frontlets to be applied to the new material from Star Carr. A unifying factor within the assemblage is the evidence for the removal of the mandible, maxilla and nasal bones. The latter are notably absent from the wetland faunal assemblage, suggesting that this processing was carried out prior to deposition and are not attributable to taphonomic factors. When compared to the more-intact cranial fragments within the faunal assemblage, the frontlets again stand out. Generally, crania are surprisingly scarce at Star Carr, and the few which do survive include an articulated dog skull with no signs of modification, an elk skull with the maxilla and nasal bones intact, a female roe deer with the partial nasal bones and maxilla intact, and a female red deer skull which, whilst representative of similar elements to <117803>, lacks any clear working traces and retains substantial portions of the zygomatic arches. With this in mind, the consistency in the working of the cranial bones apparent in the frontlets is striking and suggests that these red deer crania were treated in a different manner to other examples.

Beyond this cranial reduction, the frontlets are worked to varying extents, with antlers (when present) being reduced through the groove-and-splinter technique to varying degrees, the parietal being trimmed to various extents, the lower braincase removed, and perforations being created. When antlers are present, an apparently key feature of the frontlets is the removal of the spongy tissue from the split beams and tines. This is in marked contrast to the red deer antlerworking debitage pieces within the assemblage, which often feature both shed and unshed beams which have considerable proportions of the beam circumference removed but which retain the spongy tissue. Whilst this cannot be considered a definitive feature of the frontlets (the specimens lacking antlers in the first instance clearly cannot be defined under this criteria), its consistency helps to mark out this type of artefact from barbed point debitage and strongly suggests an attention to the finished form of the artefacts.

This classification has some profound implications for the ways in which the frontlets can be understood. Firstly, it is noted that several of the 2013–2015 specimens do not feature antler. <116601> and <116888> have had their skulls treated in the same way as the other frontlets, but have used the heads of male red deer which have recently shed their antlers. <117803> is the skull of a female red deer, which lack antlers, and has been processed in the same way. The production of these artefacts would have involved the investment of a significantly smaller amount of time and effort, and also demonstrates that the extraction of antler for the production of barbed points was not always a key consideration in the creation of a frontlet. It has important implications for the meaning of the finished artefact, developing material connections between different animal gender identities, and at different times of the year, than has been previously assumed for the Star Carr frontlets (Conneller 2004; Conneller 2011).

Secondly, the extent to which the braincase is reduced is also a key consideration. The effect that this has on the finished form of the artefacts is pronounced, as is their suitability for use as a headdress. It would therefore be tempting to view the frontlets with substantial portions of the braincase still intact as unfinished objects, abandoned part-way through their manufacture. However, as noted above, the site of deposition for these artefacts could not have been that of manufacture, making the suggestion of accidental or casual discard during manufacture a poor fit for the contextual data available. These may well be unfinished artefacts, but their deposition appears just as considered and deliberate as that of the complete specimens.

Thirdly, it can be seen that the creation of perforations on the Star Carr frontlets is far from a definitive factor. Within Clark's assemblage, only eight of the 21 frontlets are listed as featuring perforations, whilst the 2013–2015 data brings the overall total to nine of 33. Recent work has drawn attention to the presence of perforations as a key way to define this particular type of artefact across Europe in the Early Holocene (Street and Wild 2015). However, the data from Star Carr suggests that within the assemblage, a technological approach may be more suited to classifying these artefacts rather than a typological one. It is the similarities in the chaîne opératoire of the artefacts at Star Carr which mark them out as a distinct group of artefacts, rather than a single typological feature.

Finally, if this technological definition is to be followed, it also worth considering its relevance to other species represented within the Star Carr fauna. In particular, of the six roe deer crania recovered during the current excavations, five show similar patterns of fragmentation with the maxilla, mandibular and nasal bones removed and the frontal and parietal bones retained. (Figure 26.18).

Roe deer

SC15 115870

SC15 115863

SC15 116483

SC15 115735

SC15 Backfil/30

50mm

0
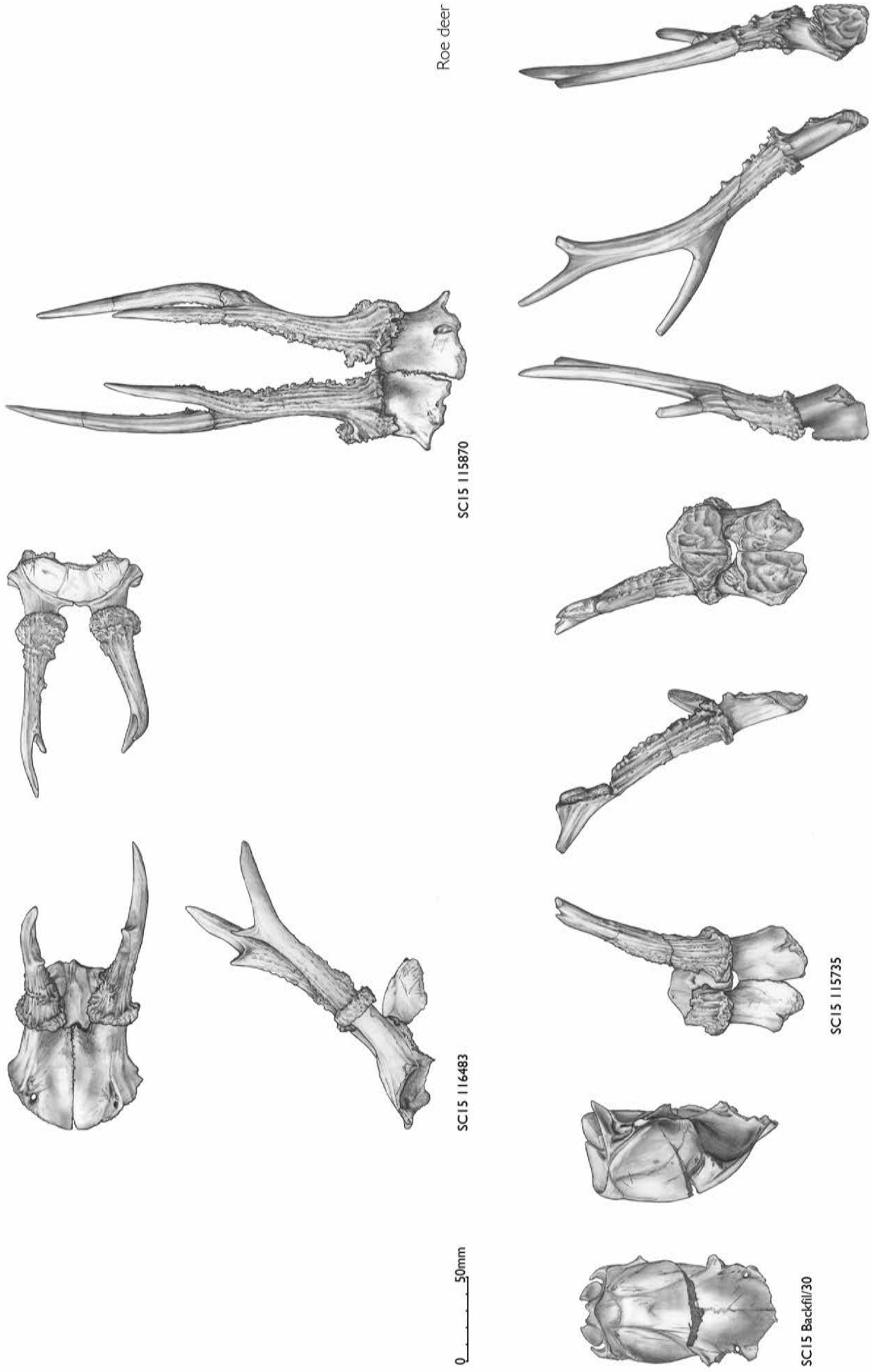
Figure 26.26: Modified roe deer skulls (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 26.27: Roe deer crania <116483> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0. Model created by Neil Gevaux. Copyright Star Carr Project CC BY-NC 4.0).

To view this interactive model, scan the QR code with your mobile device or visit DOI: https://doi.org/10.22599/book2.2

However, in comparison to the red deer crania the preservation of the roe deer crania is markedly poor, preventing the direct identification of working marks. As such, the evidence for human modification of these pieces is scarce, and there is also more variation within the portion of the braincase retained. There are differences in size between the red deer frontlets and roe deer crania which suggest that they could not have functioned in precisely the same ways, with the roe deer skull and braincase being considerably smaller and more curved than that of a red deer. So as these similarities cannot be positively demonstrated on typological or technological grounds, it remains a tentative link based on anatomical similarities. Yet their concentration around Clark's area and proximity to the locus of frontlet deposition, as well as the elements retained in their deposited form, suggest that there may be some links between these materials. As such, the roe deer crania may be considered to be associated with the same patterns of deposition as the red deer frontlets, and share some formal similarities which may suggest some overlap in meanings, without going so far as to say that they should be considered as the same type of artefact.

The European context

The similarities between the Star Carr frontlets and similar modified red deer crania from Northern Germany were noted by Clark (1954) in his original publication. Since then, further examples of mooted modified red deer crania have been added to this list of associated material (Wild 2014), notably including the discovery of two examples of similar artefacts at Bedburg-Königshoven (Street 1991) (see Chapter 12). In his comprehensive review of the wider body of data, Wild has provided a clear typological definition for these artefacts (termed *Hirschgeweihkappen,* or stag antler cap), which is reproduced here (Wild 2014, 158):

1. frontal, parietal and interparietal bones are always present,
2. antlers, frontal and parietal bones are only partially preserved,
3. a minimum of 75% of the different bones of the skull (including the antlers) show modifications by humans,
4. temporal, parietal and interparietal bones show two artificial perforations. In case one of these shows signs of breakage another perforation was usually nicked or cut into the bone,
5. antler beams and tines are longitudinally split and are often shortened.

The use of this definition helps to refine our understanding of these artefacts, restricting their chronological range to the Preboreal and eliminating much of the formal variation within this group to a small number of morphologically similar artefacts from Star Carr, Bedburg-Königshoven, Berlin-Biesdorf and Hohen Viecheln (Wild 2014). However, the specificity within this typological framework creates some problems when attempting to account for variation within the group. For instance, the Bedburg-Königshoven artefacts have little if any working of the antlers and feature much more of the nasal bones than are represented on any of the Star Carr frontlets (Chapter 12). The impact that this has on the form of the finished artefact has been noted by Conneller (2011), and there remains confusion over whether the Bedburg-Königshoven frontlets are 'finished' (Street and Wild 2015), and thus not technically *Hirschgeweihkappen,* or 'unfinished' *Hirschgeweihkappen* (Wild 2014). Further to this, the definition rules out many of the artefacts originally identified by Clark as frontlets, based on their lack of perforations or the fact that they are only represented by one side of the skull. In the case of our finds, despite the similarities in form, working methods, and distinction from the other cranial faunal remains excavated which are described above, only one artefact, <103695>, would be classed as a *Hirschgeweihkappen*, as all others lack perforations.

The data and analysis presented above allows for an alternative approach to this problem. With good contextual control, a robust chronological model, and a relatively large data set to work with, Star Carr allows for a technological approach to this group of artefacts (Little et al. 2016). Many of these factors are absent at other sites in Europe, and so shift analysis towards more typological approaches (e.g. Wild 2014). This is unavoidable, and indeed, where technological analysis is inhibited by preservation conditions and contextual data lacking, a typological approach remains an excellent way to interrogate this challenging dataset.

Taking a technological approach allows for artefacts which are formally varied (such as individuals which lacked antlers prior to working, lack perforations, or are unfinished) to be considered together in terms of the

similarities in their treatment and the specific working techniques that have been used in their production. From this perspective, parallels can be seen with the Bedburg-Königshoven examples, in the character and location of defleshing and deskinning marks, and use of pecking to create perforations for instance (Street and Wild 2015). This is despite the formal differences between the artefacts from these sites, and irrespective of their finished or unfinished nature.

Certain frontlets from the recent Star Carr finds show specific similarities with artefacts from within the *Hirschgeweihkappen* group. For instance, <115876> has very strong parallels in form to I/82/26 from Berlin-Biesdorf, in the form of the antlers retained and the bones of the skull represented. Beyond this, several other of the recent Star Carr finds have similarities with artefacts categorised within the *Schlachtausschuss* (butchery discard) typological group. These artefacts also feature modified crania but lack perforations, often have had the antlers heavily reduced or totally removed, and feature a much smaller portion of the frontal bone than is seen on the *Hirschgeweihkappen*. The heavily reduced nature of the antlers, and area of the frontal bones that has been broken away on <99528> and <114937> is similar to that observed on HV.3412 from Hohen Viecheln. The shed nature of the antlers and elements of cranial bones retained on <116020>, <116601> and <116888> is similar to K127 from Friesack 4 (Wild 2014).

Interpretation

The initial dichotomised interpretations offered by Clark as to the frontlets' purpose have characterised their discussion for the vast majority of the latter 20th century as either a shamanic headdress or a hunting disguise. More recently, however, Conneller has critiqued this dichotomy, noting that many hunter-gatherer world-views afford little meaningful distinction between functional and symbolic actions (Conneller 2004). It can be argued that as shamans are widely regarded as playing a key role in negotiating human/animal relations and hunting luck, an artefact which aids the corporeal transformation of a human body into that of a deer could be used in both capacities interchangeably. Certainly, the contexts into which the frontlets were being deposited at Star Carr suggests a complex set of meanings were attached to them, being deposited alongside a range of other unusual material cultures which had been prepared for deposition through dehafting, and forming part of such a persistent practice within a changing environment across the site. In particular, the concentration of frontlets in association with such an intense period of animal body processing and consumption within Clark's area may have imbued their production, use and deposition with an entangled set of meanings.

Zvelebil (1993) argues that the most robust ethnographic parallels for the hunter-gatherer groups of Northern Europe can be found in modern day Siberia, an area from which Clark drew his original analogies with the shamanic dress of the Evenki, documented by Witsen in the 17th century (Figure 26.18). Interestingly, the ethnographic examples of the use of deer heads in hunting disguises (Moyne de Morgues 1875; Gifford 1936; Du Bois 1936; Strachey 1953; Lawson 1967; Wetmore 1975) for stalking originate exclusively from North America, and this practice is not widely documented amongst the hunter-gatherers of Siberia. Following on from this, it may be tentatively suggested that the ethnographic data indicates that the Star Carr frontlets are more likely to have formed part of a shamanic costume, rather than to have been used as a hunting disguise.

A further point in relation to ethnographic and anthropological analogy concerns the terminology associated with the frontlets. Few of the writers who describe hunting disguises and shamanic dress use the term 'headdress' directly. Instead, 'mask' is often the term used to describe various forms of ceremonial dress and now has a considerable body of anthropological theory associated with it (Ray 1967; Lévi-Strauss 1982; Fienup-Riordan 1987; Oosten 1992; Pollock 1995; Humphrey and Onon 1996; Edson 2005; Vitebsky 2006; Pedersen 2011). Within an anthropological context, a mask can be taken to be any object which temporarily alters the identity of the wearer, and is not necessarily assumed to be worn directly over the face (Pernet 1992). Finger, knee, pocket, chest and crown masks are all documented within the First Nations cultures of Pacific Coast North America (Oosten 1992). There is ongoing uncertainty over precisely how the Star Carr frontlets may have been worn (Street and Wild 2015), with any attached hide or fur components (such as strapping, padding, insulation or decoration) either being removed prior to deposition, or failing to preserve within the peat deposits. As such, the ambiguity of the term 'mask' seems appropriate for the frontlets within this context.

Many anthropological studies of masks highlight the rich formal variation present within ethnographic collections, and the important role that form can play in the meaning and use of the masks themselves within

Figure 26.28: Depiction of a Tungus shaman wearing deer headdress (Witsen and Boddaert 1705).

communal ceremonies. Vitebsky cites an example of shamanic masks in Siberia. He describes Evenki shaman, who are known to adjust the form of antlers used within their costumes by sharpening their tips, in order to make them more 'spear-like'. This enhances their ability to negotiate and, if need be, fight with spirits encountered on different levels of the sky when in a trance state (Vitebsky 2006).

When considered in relation to the Star Carr frontlets, using the term 'mask' may be fruitful as a means to understanding the formal variation across the finished artefacts, with variations in the occurrence of perforations, the numbers of perforations on a single artefact, the presence of antlers, and the extent to which antlers were reduced, and the form of a female skull. It is possible that this formal variation may be associated with change through time, yet the range of frontlet forms represented within Clark's area, a single phase of the site's occupation, would suggest that these different styles of frontlet are contemporary. By considering the frontlets as masks, we could interpret this variation as attempts to evoke specific types of deer identity and facilitate specific kinds of negotiation.

As such, masks of male deer with shed antlers, male deer with severely reduced antlers, adult female deer and male deer with antlers which mimic the form of young stags would give the wearer the ability to create specific identities appropriate for negotiating with other beings. Whilst a direct analogy here should be avoided, due to the potential for masks as composite artefacts to incorporate the materials and forms which reference other types of being, this range of frontlet forms does suggest considerable diversity in the number of distinct identities, and potential forms of beings, within the cosmology of the inhabitants of Star Carr.

Considering the Star Carr frontlets as masks also helps to frame further questions concerning their broader social context. In his seminal essay on mask theory, Pizzorno (2010) defines a series of core philosophical concepts which are challenged by the physical form, display and wearing of masks. These include the materiality of masks as objects, which have been argued to be key vehicles of transformation and thus markers of liminality (Thomassen 2014). Pizzorno highlights the concept of *looking through* masks, across this liminal zone. Complex layers of meanings can be attached to masks through their material choices, which directly affect what a wearer might be *looking into*. This imbues masks with a social potentiality, and as such their display can be as powerful as their actual wearing.

The static facial expressions of masks have strong implications for death, mimicking the faces of the dead. This is brought into sharp focus when placed over the faces of the living. As such, masks have the potential to blur the distinctions between life and death. The unmoving and timeless character of expression, coupled with

these life/death connotations, can also evoke concepts of ancestry and myth, allowing a wearer to enact and engage with mythologies. This again is furthered by the way in which a mask wearer can become a 'monster'—a composite being in themselves, whose face does not match their body. As such, this manipulation of identity, and the construction of identities which would not have otherwise be possible, is a key element of mask wearing.

Conversely, Pizzorno also describes the strong association between mask wearing and dance and notes choreography, rhythm and lighting as a way of animating mask expressions beyond this stasis. This dynamism in mask wearing is furthered by the action of donning and removing masks. These acts allow the wearer to control the timings of shifts in identity within the context of a performance. These performances, again, can be linked to the narrative of mythology, but also have an effect on both the audience and performers. Pizzorno notes the inherent terror of watching masks being worn: the concealment of the face and the implications of transformation creating a fundamental tension over what is being revealed and what is concealed. In the words of Canetti (1984, 376), 'I am exactly what you see, and everything that you fear is behind me'. This element of fear and horror again imbues the performance and performer with further power over the audience.

In sum, the discussion provided here serves to highlight the diversity of new research avenues and lines of enquiry which the term 'mask' opens for considering the Star Carr modified deer crania. To engage further with the issues raised here, a contextual approach is necessary; one which considers the broader processes and characteristics of the social context of human life at Star Carr. This draws from multiple strands of the archaeological and palaeoenvironmental record and is provided within Chapter 10.

Conclusions

This chapter has presented the first analysis of 12 red deer frontlet artefacts from Star Carr, which supplements the 21 excavated by Clark and broaden this category of artefact considerably. These appear to have been deposited at various points within the site's occupational history, and into a range of different environments. The area excavated by Clark appears to be a particular focus for frontlet deposition, but smaller quantities were deposited within the detrital wood scatter, the eastern timber platform and higher up the slope of the lake edge within peat-forming environments. There appears to be no change in form across this period of time, either in terms of typology or technology, although the range of forms narrows as the quantity of artefacts deposited decreases. Away from Clark's area, the deposition of frontlets into other spatial and environmental contexts at the site suggests a dynamic persistence of depositional practices. Whilst the forms of the artefacts being deposited at the site, within the detrital wood scatter and higher peat forming environments are much less varied than those in Clark's area, they demonstrate a level of continuity (both before and after the deposition in Clark's area) in some underlying aspects of the cosmology of the inhabitants of Star Carr, throughout the duration of its occupation.

There is considerable formal variation within this material, which, as with the barbed points (see Chapter 25), creates problems for applying a rigorous and informative typological analysis. As an alternative, given the size of this dataset, we advocate a technological approach to their definition, which allows similarities in châine opératoire to be emphasized for an otherwise diverse group of artefacts.

In interpreting these artefacts we have noted the arguments of Zvelebil (1993) over the suitability of ethnographic analogies for the Mesolithic of Northern Europe. As such, it can be shown that the societies of circumpolar Eurasia are rarely (if ever) known to use deer skulls as disguises for hunting. In contrast, there are several accounts on the use of animal skulls in the creation of masks and costumes. The evidence for using deer heads as hunting disguises is plentiful amongst hunter-gatherer groups but appears to be heavily focussed in North America. In the absence of more direct evidence, we argue that the critical application of ethnographic analogy suggests that these artefacts were most likely used in dance and ceremonial contexts.

In a similar vein, it can also be seen that the terminology used to define these artefacts is problematic. The term frontlet draws heavily on the anatomical features of the artefact, and suggests confusion with elements of a faunal assemblage. Equally, the ongoing uncertainty over precisely how (and if) these artefacts might have been worn on the body presents problems for the term headdresses. As an alternative, the term 'mask' might be better applied within this context. This establishes links to the rich history of ethnographic and anthropological research into the use of masks in a range of cultural contexts. The broad definition of masks within this literature also leaves the question of precisely how they might have been worn open to debate.

CHAPTER 27

Animals in a Wider Context

Nick J. Overton and Ben Elliott

Introduction

The extensive assemblage of faunal remains preserved at Star Carr affords an excellent opportunity to explore the lifeways of the humans that lived in the local landscape: it indicates which species were hunted, how humans broke down animal bodies, how they moved parts across sites and landscapes and how they were deposited. It also offers a unique window into the techniques, processes and forms of the osseous technology that clearly made up a substantial element of the Early Mesolithic toolkit. However, this material and data not only reveals details of life at Star Carr; by comparing it to the other very Early Mesolithic assemblages in Britain and Europe, Star Carr can be placed within its wider context. How similar were lives across Early Mesolithic North-West Europe? Were humans engaged in the same practices across this area, or were their lives shaped by specific characteristics of their local environments? And if so, does a comparison of the Star Carr assemblage with the wider evidence highlight any particular affinities or differences between North-West European Early Mesolithic groups? In order to compare hunting practices and lifeways across North-West European sites, the frequencies of the five main ungulate species, namely aurochs, elk, red deer, roe deer and wild boar have been collated (see Table 27.1). These species have been selected as the quantification data for these species is readily available, and they are regularly recovered in good numbers, in part due to their size and robusticity. This is not to present an account that ignores the potentially significant role other resources, such as birds, smaller mammals and fish may have played in the Early Mesolithic diet; however, due to their small size, and associated problems with preservation and recovery, the remains of these species are much more infrequent and therefore not suitable for inter-site comparisons.

Faunal assemblage

Star Carr in the British context

Within the British context, the Star Carr assemblage stands out as by far the largest, in terms of the number of identified specimens (see Table 27.1) and the minimum number of individuals of each species, with all species except wild boar being represented by double Figures (Chapter 23). In contrast, the only other sites with any

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	Aurochs		Elk		Red deer		Roe deer		Wild boar		NISP Total
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	
Star Carr	315	17.47	275	15.25	995	55.19	175	9.71	4	2.38	1803
Britain											
Seamer C	22	64.71	2	5.88	8	23.53	2	5.88	0	0	34
Flixton School House Farm	17	100	0	0	0	0	0	0	0	0	17
Thatcham III	7	2.92	2	0.83	86	35.98	38	15.89	106	44.35	239
Faraday Road	16	2.18	0	0	56	7.62	26	3.54	637	86.67	735
Three Ways Wharf	0	0	0	0	671	81.43	153	18.56	0	0	824
Former Sanderson Site*	0	0	0	0	170	55.92	0	0	134	44.08	304
France											
Warluis IIIb	6	7.80	0	0	54	70.13	12	15.58	5	6.49	77
The Netherlands											
Zutphen-Ooijerhoek (site M)	0	0	0	0	7	35	5	25	8	40	20
Germany											
Friesack 4-complex I	16	2.55	57	9.09	221	35.25	242	38.60	91	14.51	627
Friesack 4-complex II	4	0.39	53	5.23	340	33.53	424	41.81	193	19.03	1014
Friesack 27 sk 1	10	7.75	23	17.83	49	37.98	38	29.46	9	6.98	129
Potsdam Schlaatz**	44	95.65		0	1	2.17		0	1	2.17	46
Bedburg-Königshoven	362	80.27	0	0	34	7.54	49	10.86	6	1.33	451
Mönchengladbach-Geneicken	n/a	100									n/a
Southern Scandinavia											
Lundby LM1			97	100							97
Lundby LM2			729	100							729
Lundby LM3			515	100							515
Lundby LM4			127	100							127
Lundby LM5***	Pres.			Dom.	Pres.		Pres.		Pres.		n/a
Skottemarke			n/a	100							n/a
Favrbo			n/a	100							n/a
Vig	n/a	100									n/a

Table 27.1: Species frequency of red deer, roe deer, aurochs, elk and wild boar at North-West European Early Mesolithic sites, based on number of identified specimen (NISP) data. Seamer C (Uchiyama et al. forthcoming), Flixton School House Farm (Overton and Taylor forthcoming), Thatcham III (Overton 2014), Faraday Road (Overton 2014), Three Ways Wharf (Overton 2014), Former Sanderson Site (Overton 2014), Warluis IIIb (Coutard et al. 2010), Zutphen-Ooijerhoek site M (Bos et al. 2005), Friesack 4-complex I (Schmölcke 2016), Friesack 4-complex II (Schmölcke 2016), Friesack 27 sk 1 (Groß 2014), Potsdam Schlaatz** (Gramsch 1987a; 1987b; Gustavs 1987), Bedburg-Königshoven (Street 1993), Mönchengladbach-Geneicken (Heinen 2014), Lundby LM1 (Leduc 2014), Lundby LM2 (Leduc 2014), Lundby LM3 (Leduc 2014), Lundby LM4 (Pedersen and Brinch Petersen in press), Lundby LM5 (Leduc 2014), Skottemarke (Pedersen and Brinch Petersen in press), Favrbo (Pedersen and Brinch Petersen in press), Vig (Noe-Nygaard 1973). For date ranges of European sites, see Chapter 12; for British sites, see Conneller et al. (2016). *NISP over inflates red deer (MNI Figures indicate wild boar more frequent). **NISP counts for Potsdam Schlaatz calculated from illustrations in Gustavs (1987). *** Dom. indicates dominant. Pres. indicates present in assemblage.

species represented by more than 10 individuals are Three Ways Wharf and Faraday Road, and in both cases, it is only the dominant species that are this frequent (cf. Overton 2014). The closest potential parallel to Star Carr in terms of size could be Thatcham, in the Kennet Valley; however, this assemblage originates from five separate 'sites' (trenches), and only some of the material is still in existence (see Chapter 11). As a result, only the assemblage from Thatcham III is deemed suitable for comparison and, as such, is much smaller than originally reported (cf. Wymer 1962). Therefore, the Star Carr assemblage offers a picture of Early Mesolithic hunting activity at a scale unlike any other site in Britain.

The presence and frequency of species highlights a clear difference between the sites in the Vale of Pickering, including Star Carr, and those in Southern Britain. At the northern sites, assemblages are dominated by the largest species, namely red deer, aurochs and elk; however, at the southern sites, whilst red deer remains prominent, both elk and aurochs are either extremely infrequent or entirely absent. It should be noted that elk and aurochs are also recorded at further southern sites, at Broxbourne, Eton Rowing Course and Wawcott XXX (Froom 2012; Allen et al. 2013; Chapter 11). However, whilst these indicate populations of these species were present within Southern Britain during the Early Mesolithic, they are clearly not represented in the quantity that we see within the assemblages of Star Carr and other northern sites. In stark contrast to this, the frequency of wild boar indicate the inverse pattern, being dominant on a number of southern sites, yet either very infrequent, such as at Star Carr, or absent within northern assemblages. If a single, homogenous mammal population inhabited Britain, it could be argued that the much larger size of the Star Carr assemblage presents a greater chance of including higher frequencies of a wider range of species. However, whilst that could explain the higher frequencies of elk and aurochs at Star Carr, it does not explain why wild boar are so infrequent. Furthermore, the other northern sites, which also present higher elk and aurochs frequencies, are much smaller, suggesting this pattern is not a function of assemblage size. Instead, the species frequency difference presented here suggest a clear difference in the species hunted at the broadly contemporary sites in the Star Carr environ, and in Southern Britain (Chapter 11).

The disparity in species frequencies is best explained as the result of environmental changes, in which denser forest and understorey vegetation colonised Southern Britain earlier, and pushed the majority of the open forest adapted elk and aurochs populations northwards (Overton forthcoming). However, this is not to say that human choice did not also play a role in shaping these patterns; rarer species may not have been regularly hunted, not only because of infrequent hunter-prey encounters, but also because humans chose not to, either out of a practical desire not to form a reliance on scarce species, or out of broader ontological understandings of rare species as distinctive or different (cf Overton 2016). Whether purely environmental, or mediated by human choice, this pattern highlights the fact that Mesolithic groups across Britain hunted different species. In turn, this would have significantly impacted their lifeways, shaping specific hunting techniques, affecting technology use, requiring movement through particular environments, at different times in the day, and across the year. Therefore, whilst Star Carr is the largest assemblage in Britain, it is not necessarily the most representative of Early Mesolithic life in Britain; indeed, differences in fauna and hunting practices between Northern and Southern Britain suggest no single site could offer a suitable picture for the whole of Britain. Instead, Star Carr is significant in providing us with an unparalleled picture of the lives and lifeways of the earliest Mesolithic hunter-gatherers in Northern Britain, whose hunting focused on the largest ungulate species.

Beyond the size of assemblage, the Star Carr material also indicates a wide hunting breadth (see Table 27.1), which is not evident to the same extent at a number of other British sites. The closest parallel from the southern sites would be Thatcham III, which evidences the hunting of all five main species, with relatively high levels of red deer, wild boar and, to a slightly lesser extent, roe deer. In contrast, sites such as Faraday Road and Three Ways Wharf demonstrate a much clearer focus on a single species (see Table 27.1). However, species breadth is likely to be shaped by the temporal span of a site; both Star Carr and Thatcham are palimpsests, made up of material derived from multiple occupations, in which different species were hunted in a series of hunting events. Conversely, sites such as Three Ways Wharf are potentially the result of a single occupation, and therefore reflect the specific nature of that single event. Although a number of the southern sites represent more temporally discrete events, taken as a whole, they indicate that, like Star Carr, a range of species were being hunted within the landscape (Chapter 11). This indicates a more broadly shared approach to hunting across the British Early Mesolithic, which is manifest within each assemblage in locally specific ways, based on the nature and length of occupation, and the broader environmental characteristics. However, whilst hunting a range of species does not highlight Star Carr as different to wider British practices, the sheer size of the assemblage,

the number of individuals within it and the overall intensity and scale of occupation does makes it distinctive within the British context.

Star Carr in the wider European context

Within the wider context of North-West Europe, Star Carr remains notable as the largest faunal assemblage (see Table 27.1), although the Early Mesolithic assemblages from Friesack 4 and 27 together contain a very similar amount of identified specimens. These are recovered from both temporally and spatially disparate sites, which present problems in trying to view them as a single amalgamated assemblage (Chapter 12).

Species presence and frequency

The presence and frequency of species across North-West European sites present a number of patterns which allow an exploration of both Star Carr and Britain within the wider European context (see Figure 27.1). Firstly, the high frequencies of red deer, roe deer and wild boar in Southern Britain is echoed in the more southerly and westerly European sites, such as Warluis IIIb in the Paris Basin (Coutard et al. 2010) and Zutphen-Ooijerhoek site M in eastern Netherlands (Bos et al. 2005). Across these sites, aurochs are equally infrequent or absent; however, they become more frequent moving eastwards and northwards into Germany and Denmark, with a particular dominance at Bedburg-Königshoven and Mönchengladbach-Geneicken in Western Germany (Street 1993; Heinen 2014). The most restricted range is exhibited by elk, which are only present at Friesack 4 and 27 in Northern Germany, and at Lundby, Skottemarke and Favrbo in Denmark (Groß 2014; Leduc 2014; Schmölcke 2016; Pedersen and Brinch Petersen in press). This pattern broadly reflects the species distributions within Britain, with the largest species more restricted to northerly areas, in particular elk, echoing previous suggestions that elk are a frequent and even dominant species within Scandinavian and Baltic Mesolithic assemblages (Bridault 1992).

These varying frequencies of species suggest a number of similarities and differences can be drawn between Star Carr and these other European sites. Firstly, the lack of aurochs and elk in France and the Netherlands may suggest lifeways in these areas were notably different to those at Star Carr, with hunting practices focusing on the more gregarious wild boar and red deer, and the small and secretive roe deer. In contrast, the more northerly sites in Germany and Denmark which show the presence of both aurochs and elk indicate hunting patterns that were more similar to those at Star Carr. The hunting of elk at Early Mesolithic Danish sites has previously been argued as being a significant act that was tightly bound into cultural aspects of life (Leduc 2014); it is interesting to consider the ways in which groups regularly hunting similar species, such as groups at Star Carr, Friesack, Bedburg-Königshoven and sites in Denmark, may have shared similar aspects of daily life as a result.

However, although these northern sites are tied together by the presence of elk and aurochs, they are not entirely comparable. In contrast to the broad range of species hunted at Star Carr, the Danish sites present a much narrower species range, heavily focused on elk, a pattern which supports previous suggestions that they represent the preferred game (Leduc 2014). This pattern may, in part, be the result of the clear difference between the Star Carr assemblage, being a palimpsest of repeated occupation, and the Danish sites, which are predominantly sites with a single phase of deposition, such as the discrete deposits of elk at Lundby 1–4, Skottemarke and Favrbo (Leduc 2014; Pedersen and Brinch Petersen in press). It is difficult to say whether larger, multi-phase faunal deposits in Denmark exist but have yet to be found, or the single discrete deposits mentioned here are characteristic of all Early Mesolithic activity in Denmark. However, the assemblage from Lundby 5 is reported as a more typical 'domestic' assemblage, with a mix of species, including red deer, roe deer, wild boar and aurochs (Pedersen and Brinch Petersen in press), and single bones of red deer, roe deer, wild boar and a possible elk from Flaadet (Møhl 1980) do at least suggest a wider hunting breadth than may initially be apparent. In the same vein, whilst the assemblages from Friesack 4 and 27 indicate a wide hunting breadth (Table 27.1), aurochs and elk are infrequent at Friesack 4 (complex I and II), and the assemblages overall are notable for the very high frequencies of roe deer, which provides a clear contrast to Star Carr. At Bedburg-Königshoven, the species ratio is heavily weighted to aurochs, and lacks elk altogether, which again contrasts the red deer, elk and aurochs dominated assemblage at Star Carr.
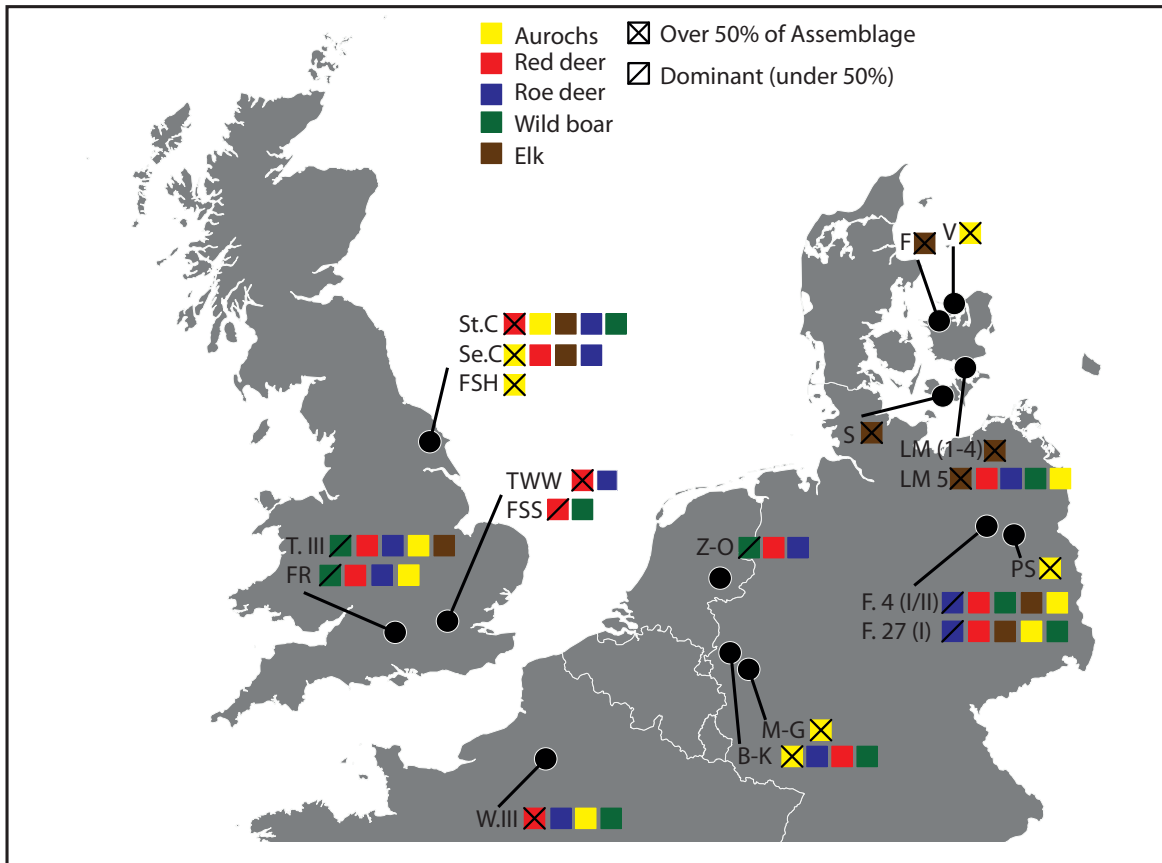
Figure 27.1: Presence and relative frequency of red deer, roe deer, aurochs, elk and wild boar in Early Mesolithic assemblages in North-West Europe. Order of species at each site indicates relative frequency, with most frequent on the left, and least frequent on the right. Based on the quantification of species by number of identified specimens (NISP) data, as presented in Table 27.1. Key: St.C: Star Carr. Se.C: Seamer Carr C. FSH: Flixton School House Farm. TWW: Three Ways Wharf. FSS: Former Sanderson Site. T.III: Thatcham III. FR: Faraday Road. W.III: Warluis IIIb. Z-O: Zutphen-Ooijerhoek site M. B-K: Bedburg-Königshoven M-G: Mönchengladbach-Geneicken. F.4 (I/II): Friesack 4 (complex I and II). F.27 (I): Friesack 27. PS: Potsdam Schlaatz. LM1–5: Lundby Mose 1–5. S: Skottemarke. F: Favrbo. V: Vig (Copyright Nick Overton, CC BY-NC 4.0).

Overall, whilst a number of the more northerly sites share a similar breadth of species as Star Carr, including elk and aurochs, they also exhibit more specific patterns. Star Carr, Friesack, Bedburg-Königshoven and possibly the sites in Denmark all existed within environments where elk, aurochs, red deer, roe deer and wild boar were present (except for elk at Bedburg-Königshoven). The faunal assemblages indicate the hunter-gatherers occupying these sites all engaged in hunting strategies that included all of these species; however, these manifested themselves in specific patterns, such as the dominance of roe deer at Friesack, or aurochs at Bedburg-Königshoven. Similarly, the sites in France and the Netherlands, whilst lacking the larger elk and aurochs, most probably due to changes in vegetation (cf. Overton forthcoming), also demonstrate hunting strategies that targeted a range of species. In this sense, all of the Early Mesolithic sites in Europe can be seen as adhering to a similar broad hunting strategy, in which humans predated on a broad range of ungulate species. However, this strategy manifests itself in specific ways in different areas and different sites, based on location, environment and local animal populations. It is important to remember that differences in species frequency within site assemblages may also be the result of hunting choices made by specific groups, but whether

dominance of particular species is the result of choice or abundance, the practice of hunting specific species would become bound into the local and perhaps regional identities of Early Mesolithic hunter-gatherers. Therefore, whilst groups across North-West Europe may have adhered to broadly similar hunting strategies, the specific practices associated with hunting particular species may have led to clearer similarities between areas; as a result, the occupants of Star Carr may have shared more aspects of their life with the groups hunting larger ungulate species in Northern Germany and Denmark.

Site use and deposition

Comparison of North-West European Early Mesolithic sites clearly demonstrate a range of different tasks and activities taking place, with a number of sites representing just a single or very discrete period of activity. In Germany, the aurochs at Potsdam-Schlaatz was represented by the skull, spine and ribs, indicating an individual that was killed and butchered before the limbs scapula and pelvic girdle were removed (Gramsch 1987a; Gramsch 1987b; Gustavs 1987). At Mönchengladbach-Geneicken, close to Bedburg-Königshoven, the majority of a single aurochs was recovered, which was killed and processed for meat and marrow on site, before the split long bones were deposited back with the carcass (Heinen 2014). Similarly in Denmark, discrete depositions of elk have been recovered at Lundby Mose, Skottemarke and Favrbo, in each case containing the partial remains of one or multiple individuals (Leduc 2014; Pedersen and Brinch Petersen in press). Also in Denmark, the Vig aurochs is also an example of a single individual (Noe-Nygaard 1973); however, it is difficult to assess whether this was a whole individual intentionally deposited or an individual that escaped hunters, only to later die of exhaustion and blood loss. These sites are in clear contrast to the Star Carr assemblage, which instead of a single event, represents material from protracted and repeated occupation. Unsurprisingly, it is the larger European assemblages, from Bedburg-Königshoven and Friesack 4 and 27, that offer a closer comparison to Star Carr. The material from Bedburg-Königshoven, recovered from Early Holocene sediments in a palaeo-channel in the Erft Valley within the Lower Rhine Basin, was heavily dominated by aurochs, and with the vast majority of skeletal element being present. However, this too is suggested to represent a single occupation, with whole aurochs being introduced from kill sites in the immediate area and processed, before being deposited in the palaeochannel (Street 1993). Therefore, the Star Carr assemblage, evidencing repeated occupation, including the introduction of animals as whole carcasses and as portions, the processing of meat, marrow and skins, and the deposition of faunal materials through multiple phases of activity presents a unique picture of Early Mesolithic life within North-West Europe.

One final theme that can be explored is the practice of deposition; across the North-West European sites, there appears to be a general concern for depositing animal remains in appropriate or meaningful ways. These can be broadly grouped together as practices of large-scale collation, discrete collections and the potential 'bundling' and deposition of remains. Large-scale collation can primarily be seen in the deposition of animal remains within watery context, which is documented at Friesack 4 and 27, Bedburg-Königshoven, Mönchengladbach-Geneicken and Zutphen-Ooijerhoek (Street 1993; Bos et al. 2005; Groß 2014; Heinen 2014; Schmölcke 2016) and at Star Carr.

Arguments for intentional deposition within water must be tempered by acknowledging the potential for differential preservation to only preserve the portion of a large scatter of bone that was placed within the water. However, deposition at sites such as Bedburg-Königshoven has been argued, through taphonomic analysis and spatial distributions, to represent intentional deposition in deep water (Street 1993). More specifically, large scale collation can also include acts of deposition where the remains of one or multiple phases of occupation or activity have been intentionally gathered together into a discrete deposit. This is evident in the 'midden' at Three Ways Wharf and the bone deposit at Faraday Road (Overton 2014; Chapter 11) and is also clearly present at Star Carr, within the exceptionally dense deposit of material, including faunal remains, flint, worked wood and stones in Clark's area. Here we see a clear concern for the aggregated deposition of materials, either in watery contexts, a pattern visible across many North-West European sites, or within dense collated deposits, a practice more visible within Britain.

Very similar to these, but on a smaller scale, are more discrete practices of collection; at Mönchengladbach-Geneicken, an aurochs was killed, butchered and processed for marrow, and the split long bones were returned back to the vicinity of the carcass, to create a single deposit (Heinen 2014). At Lundby Mose 1–4, Skottemarke and Favrbo in Denmark, the discrete deposits of elk remains, after processes of

butchery and marrow extraction had been undertaken, represents a very similar process. However, these regularly contain the remains of multiple individuals and never contain whole individuals; this commingling of partial individuals appears to be a specifically Danish elaboration and has previously been argued to be strongly tied to the importance of elk in the Danish Early Mesolithic hunting strategies (Leduc 2014). Furthermore, it has been suggested that some, or all of these deposits, may have been deposited as a 'bundle', within an elk skin. These processes of deposition can also be seen in Britain, at Flixton School House Farm, where a collection of aurochs ribs, vertebrae and a single pelvis fragment were deposited in a watery hollow (Overton and Taylor forthcoming). Furthermore, these practices can also be seen at Star Carr; the lake edge contains numerous tightly grouped elements which could be intentionally collected elements deposited into water, either as piles or within skins, whilst the numerous semi-articulated limbs recovered in the detrital wood scatter also represent an intentional act of collating and depositing bodies, or in this case, portions of bodies together.

Evidence for intentional deposition, on a broad scale, highlights these processes as both widely abundant in the archaeological record, and a clear concern of hunter-gatherer groups during the Early Mesolithic. The desire to collect, collate and deposit the remains of animals and their bodies points to a shared underlying motivation to 'take care' of animal remains; however, this motivation materialises in a variety of ways, some of which are more generally visible across Europe, such as deposition in water, whilst others are more specific, such as the bundling of multiple, partial elk remains in Denmark. The treatment of animal remains, whilst guided by broader understandings and worldviews, can also be understood as developing through the specific encounters, experiences and relationships between humans and animals at particular sites and landscapes (cf Overton and Hamilakis 2013), which accounts for the specific nature of depositional acts at particular sites. At Star Carr, the dense deposit of fauna, lithics and wood may be considered as tied into broader 'middening' practice, as seen on other British sites, and the discrete collections of skeletal elements share aspects of depositions in Denmark and Germany, whilst the deposition of whole articulated portions of bodies appear to be a manifestation of depositional practices unique to Star Carr.

Osseous technology

Comparing the working of osseous materials at Star Carr with other sites in Britain is an exercise which is, to a certain extent, constrained by the character of the dataset available. Occasional finds of antlerworking debitage and osseous artefacts elsewhere in the Vale of Pickering indicate that the use of the groove-and-splinter technique (Seamer K) was not restricted to Star Carr locally, and that broken antler barbed points (Flixton Island, No Name Hill) were also deposited into other areas of wetland around Lake Flixton during the Early Mesolithic (Chapter 25). However, the scale of these activities is much smaller, with a single piece of material culture being recovered from each site to demonstrate these practices.

Further afield, there are other echoes of the Star Carr osseous repertoire within Northern England. The wetlands of Holderness, East Yorkshire, have to date produced 12 barbed points from sites such as Brandesburton, Hornsea Mere and Skipsea Withow (Clark and Godwin 1956; Davis-King 1980). Whilst these remain undated, the formal and technological similarities between these and the Star Carr assemblage are notable. In particular, the incision of short lines along the length of <115796> has clear echoes within this assemblage. Landscape-level palaeoenvironmental studies have suggested that many of these artefacts were deposited into peat forming within a system of shallow lakes and meres, echoing the wetland context of Star Carr. However, there are also differences in material choices across Holderness, with bone making up eight of the 12 recovered to date, a ratio which contrasts sharply with those noted at Star Carr. Further work is needed to explore the relationship between these two landscapes fully, but at a very coarse level it appears to be another area into which bone and antler barbed points were being deposited during the Late Glacial/Early Holocene, with some formal similarities in material culture beginning to emerge.

The evidence for the working of bone and antler in Early Mesolithic Southern Britain stands in stark contrast to this. The sites noted above (Three Ways Wharf, Sanderson Site, Faraday Road and the Thatcham sites) have produced far fewer bone or antler artefacts, or osseous debitage. At sites with high levels of fragmentation (Three Ways Wharf), the apparent large quantities of long bone available for the production of bone artefacts were apparently sacrificed for marrow extraction. The small quantity of bone and antler artefacts from the Thatcham sites include an elk antler *lame de hauche* (Thatcham IV) and several unbarbed bone and antler

points, the working edge of an antler axe and a possible fragment of an antler sleeve. These artefact types are not found in the Star Carr assemblage. Furthermore, the Thatcham sites have produced an assemblage of 29 pieces of red deer antler which show no signs of the groove-and-splinter process and very little sign of working generally (Elliott 2012). As such, it appears that attitudes towards working antler and bone in Southern Britain were quite distinct from those seen at Star Carr. Here, the working of red deer antler was far less intense and when it did occur, was used to produce different forms of material culture. This implies a different outlook on material culture in Southern Britain, possibly a smaller role for osseous materials in everyday life and a different set of understandings concerning the bodies and anatomy of animals. What was appropriate and important in terms of how red deer and elk carcasses were butchered and used at Star Carr does not appear to have applied to Southern Britain at this time.

The structure and organisation of the osseous technologies demonstrates an enigmatic mixture of similarities and differences with other Early Mesolithic sites across Europe. This was originally commented upon by Clark, who noted that despite the production of typologically similar forms of barbed points, the overwhelming use of red deer antler and the groove-and-splinter technique at Star Carr is unique within contemporary North-West Europe. Clark linked the use of the groove-and-splinter technique to older technical traditions observed within the Hamburgian deposits at Stellmoor and Meiendorf and more widely, across the Late Magdalenian and Azillian in France and Spain. The form of the Star Carr barbed points falls well within the range observed at the classic Maglemosian sites, as does the form of the elk antler mattocks. The aurochs bone hide-working tools are not widely seen in the Early Mesolithic of Southern Scandinavia, but similar artefacts made using elk bone are known from sites in Eastern Europe. This combination of differences and similarities, alongside the pioneering use of pollen and radiocarbon dating, led Clark to assign Star Carr a 'Proto-Maglemosian' cultural identity—an intermediary form which succeeded the Ahrensburgian and Hamburgian groups and preceded the Maglemosian in North-West Europe.

David's technological approach to the Maglemosian further refined the affinities of Star Carr to the other key Early Mesolithic sites in the region. In terms of the form of the osseous artefacts at Star Carr, there are clear typological affinities with the assemblages of Hohen Viecheln, and Phases 1 and 2 of Friesack 4. These sites are linked through the common occurrence of worked red deer tines, aurochs bone scraping tools, elk antler mattocks and worked frontlets which are far from ubiquitous across other Early Holocene sites in Europe. The use of the groove-and-splinter technique in producing antler barbed points is also demonstrated at Hohen Viecheln (Horizon A) and Birsmatten-Basisgrotte (1955–56, Horizon 2), although in much smaller quantities than is evidenced at Star Carr. The method of producing aurochs bone scraping tools (the 'S' method) identified by David is unique to Star Carr, with the bone scraping tools of Zamostje being made from elk instead of aurochs and not utilising the dotted perforation technique in the early stages of the production sequence. David concludes that these technological and typological similarities allow Star Carr to be grouped with Early Mesolithic sites in Northern Germany. Further to this, Wild's work on the formal similarities between the *Hirschgeweihkappen* artefacts (see Chapter 26) from Northern Britain and Northern Germany creates a strong cultural link between Star Carr, Bedburg-Königshoven, Berlin-Biesdorf and Hohen Viecheln, which is described in terms of a cultural-evolutionary lineage (Wild 2014).

However, the analysis presented above demonstrates a substantial level of technological variability in the ways in which people worked bone and antler at Star Carr. This variation, with people finding different ways of solving technological problems when working bone and antler, and seldom following a strict set of rules throughout the production of osseous material culture, makes these comparisons harder to draw. Variations in the extent to which splinters were extracted from red deer antlers, the methods used to extract splinters, the use of scraping and filing to define barbs, and the methods used to extract marrow and create bone blanks demonstrate this apparent technical flexibility. Similarly, the typological variation apparent in the Star Carr barbed points makes it difficult to fit this assemblage into the more robust typological frameworks of Maglemosian Europe without overlooking significant portions of the dataset. Whilst the analysis presented here suggests that red deer metapodia were being split to produce blanks for barbed points, and a single bone barbed point has now been identified within the assemblage, the heavy bias towards the use of red deer antler, and the universal use of the groove-and-splinter process to produce blanks for antler barbed point manufacture, is unique within Preboreal and Maglemosian sites. This suggests a very different attitude to the use of animal materials, and the processing of animal carcasses, to similar sites from North-West Europe, despite the apparent similarities in the finished forms of osseous material culture.

When attempting to interpret these links, the scale of analysis is important to bear in mind. On a macro-scale, the commonalities between the ways bone and antler were worked at Star Carr and other sites in Northern Germany are evident, whilst on the micro-scale, that of individual actors and technical decisions appear far less robust and much more variable. The relationship here appears much less consistent than, for instance, the Maglemosian sites which David (2005) identifies as *Maglemosian stricto-sensu*. So rather than a cultural consistency between these sites, it is perhaps better to suggest that the inhabitants of these places shared some common conceptual ground in terms of the forms of material culture and the techniques and traditions that can be used to work osseous materials. However, big differences still existed in the ways osseous material culture repertoires were produced, moved across landscapes and deposited. This might suggest communication, movement of people and a sharing of technological know-how around this region during the Early Mesolithic, but without the formal and repeated consistencies in material culture and technology that the term 'cultural group' has come to imply within Mesolithic studies. Ideas concerning the use of animal bodies to create material culture may have been shared between these people living around the region, but rules concerning the ways in which these should be made seem to have been more localised.

PART II
Vegetable

'Although wood must have been extensively used for handles, shafts, bows and other purposes, disappointingly little was found in the way of finished objects, owing no doubt in part to the soft condition in which it survived.'

<div align="right">(Clark 1954, 178)</div>

CHAPTER 28

Woodworking Technology

Michael Bamforth, Maisie Taylor, Diederik Pomstra, Aimée Little and Anita Radini

Introduction

There are 1602 pieces of worked wood recorded from Star Carr that have been split, trimmed or hewn and this forms both the earliest and largest Mesolithic woodworking assemblage in the UK. The assemblage is varied and contains finished artefacts, large split and unsplit timbers, entire trees and roundwood stems, rods and poles. However, woodworking is a reductive technology and there is also a significant quantity of woodworking debris of various sizes from large off-cuts (timber debris) to small woodchips, detached by a single blow of an axe. Traces recorded from the wood assemblage provide evidence for the Mesolithic woodworking tool kit and the material itself provides a glimpse of the types of woodland that were being exploited, and possibly even managed. Overall, the wood assemblage and the evidence of woodworking it contains is relatively uniform across the site and across the centuries of occupation and appears to represent a single, distinct, woodworking tradition.

This chapter sets out how the raw material itself may have been selected and the potential relationship between people and the landscape around them. It examines the possible evidence for coppicing as well as the evidence for beaver-gnawed wood, before examining in detail the tools, technology and skills required to work the wood. This chapter should be read in conjunction with the research on wooden structures (Chapter 6), wooden artefacts (Chapter 29) and the use of bark (Chapter 30).

Evidence for beaver activity

European beavers (*Castor fiber*) are present in the faunal assemblage at Star Carr, with some evidence that the mandibles may have been utilised as tools (Chapter 23). There is also evidence for their activity within the wood assemblage, in terms of distinct and unique gnawing marks. These gnaw marks have been identified on the basis of modern reference material, published literature (Coles 2006) and the authors' previous experience (MT and MB).

Figure 28 (page 345): Diederik Pomstra shooting a replica bow and arrow (Copyright Aimée Little, CC BY-NC 4.0).

The beaver is a large rodent (c. 20–25 kg) that generally lives near water including rivers, streams and lakes (Coles 2006). The lake edge setting at Star Carr combined with the wooded landscape would have provided an ideal habitat. Beavers will generally build a burrow dug into banks at the edge of the water, with ingress from a sub-aqua entrance. In environments where it is not possible to dig a burrow, beavers will construct a lodge from a heap of wood and gnaw out a burrow within it (Coles 2006). Beavers are vegetarians with a broad diet that can include leaves, twigs and bark. In the search for food or material for a lodge, beavers are capable of felling saplings and even substantial trees (Coles 2006).

Following the identification of beaver-gnawed wood from the brushwood 'platform' Coles (2006, 78) suggested that the accumulation of wood recorded by Clark may have been partially, or wholly, the result of beaver activity. However, although there is some beaver-modified material present within this area, only two items displaying these traces were recovered from Clark's area during the recent excavations, suggesting the role of beavers in the accumulation of this material is minimal at best (see Chapter 6).

Overall, 24 items show evidence of beaver modification: 22 pieces of roundwood, one piece of roundwood debris and a timber classed as a tree (a side branch has been beaver gnawed). These were recovered from the brushwood (n=6), detrital wood scatter (n=11), central platform (n=1), Clark's area (n=2) and the western platform (n=4). The majority of the material has been gnawed through at one or both ends or a small side branch. A single item showed the classic 'melon slice' that can be caused by a beaver gnawing through one face (Figure 28.1). These types of modification, i.e. gnawing along the shaft to consume bark for food and gnawing of ends to acquire building material or for food, are all within the range of normal beaver behaviour.

Although much of this material was recovered towards the base of the sequence, often below culturally modified material, some of the items have also been anthropogenically modified. Of key interest to this study are three items which show possible evidence of both human and beaver modification: <116509> is half split roundwood debris that may represent cultural or natural modification and that has also been beaver gnawed at one end; <109099> appears to have been trimmed with an axe or adze and beaver gnawed at the same end; <103190> has been beaver gnawed at the proximal end and one side branch whilst the distal end has been trimmed with an axe or adze and torn in a chop and tear (see below). Coles (2010) has suggested that during later prehistory, people may have been drawn to beaver-modified landscapes, either to hunt the beavers or to take advantage of areas cleared of tree cover by the animals, an assertion that may have some relevance at Star Carr.

Raw material

Selecting the right tree is essential to successful woodworking. Choosing a tree with the required characteristics, be it straightness or curve of the grain, the presence/absence of side branches and knots, or size and form is the first step to successfully manufacturing the wooden objects required. The people living at Star Carr would have had a close relationship with their surrounding landscape, spending time hunting large and small prey and gathering food and other materials from the surrounding woodland. These forays into the woodland would have drawn their attention to a wide range of woodland resources. Warren (2003, 22) reminds us that Mesolithic gatherer-hunter communities would have had personal relationships with the woodlands they lived alongside and within, and that the woodlands themselves were not the pristine, wild spaces sometimes invoked

Figure 28.1: Roundwood <99927>. Both ends are beaver gnawed and there is a distinct 'melon slice' beaver gnaw along the stem (Copyright Michael Bamforth, CC BY-NC 4.0).

in archaeological narrative, but living spaces criss-crossed by paths and route ways (produced by humans and animals) and with locations imbued with memories and meaning.

From the material evidence for specific woodworking practices at Star Carr it is clear that people were knowledgeable and selective regarding the type and quality of wood they utilised, and by extension, aware of the location of suitable trees in the surrounding landscape. As Taylor (2010) points out, trees are the largest living things encountered by the majority of human beings. They exist on a timescale that is often longer than that of a human and as a result might have appeared 'other worldly'. Wood can be harvested without killing the tree, as is the case with coppiced or pollarded rods and perhaps, as discussed below, planks cleft from the outer surface of a standing tree. Alternatively, a tree can be felled, making all of its wood available, though bringing the life of the tree to an end.

The majority of the larger-diameter pieces of wood encountered at Star Carr are derived from the trunks of trees as opposed to the limbs, as inferred from the centrally located piths. This is based on the propensity for hardwood trees (dicotyledons) to support branch wood in tension, leading to an eccentrically located pith (Jane 1970, figure 108). As such, the larger diameters are describing the trunk sizes of trees felled from the surrounding landscape. The largest piece on site has a diameter of 350 mm; however, a large proportion is below 180 mm (Figure 28.2). The pieces with the largest diameters are generally complete trees which have either been utilised within the lake edge timber platforms or have been growing at the lake edge and have fallen into the upper lacustrine deposits. The longest is a tree which is 10.3 m long (Figure 28.2). The trees that have been used for the wooden platforms have straighter grains and fewer side branches, suggesting that these have been growing in denser woodland cover than those growing along the edge of the lake (Figure 28.3 and Figure 28.4).

A significant part of the assemblage is formed of rods, poles and other small diameter roundwood. The larger items are likely to be the trunks of smaller trees and saplings whilst some of the smaller material has morphological traits suggestive of coppicing (Figure 28.3 and 28.4). Whether derived from coppiced woodland or not, the presence of so many straight-stemmed roundwood rods and poles points to strong selection criteria for this trait.

There is widely accepted evidence from historic periods in the UK for extensive woodland management in the form of large standards interspersed with understorey coppice. The resulting rods were utilised for basketry, construction (wattle) and charcoal production. During later periods, coppicing was often carried out on a rotation cycle of several years (Rackham 2006). Evidence for possible managed coppice from Britain and Ireland dates back to the Late Mesolithic in the Liffey estuary, Dublin, Ireland (McQuade and O'Donnell 2007).

The problems inherent in attempting to identify possible woodland management or forestry in assemblages of roundwood stems has been discussed in detail elsewhere (Out et al. 2013; Warren et al. 2014). Warren (2014) rehearses a series of debates around the nature of any possible resource management in terms of both purposive versus opportunistic resource exploitation (Brown 1997) or the visibility of less-defined practices such as adventitious coppice (Crone 1987) or draw felling (selecting stems for the required diameter) (Rackham 2006). Caution in inferring management practices is advised.
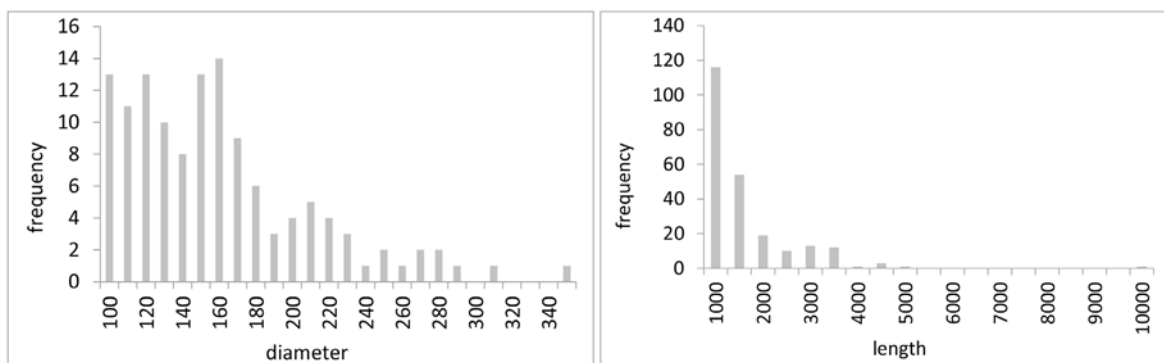
Figure 28.2: (left) frequency of diameters and reconstructed diameters over 100 mm (n=127). Reconstructed diameters have been inferred where a complete radius from pith to bark edge is present; (right) lengths greater than 1000 mm (n=250) (Copyright Star Carr Project, CC BY-NC 4.0).
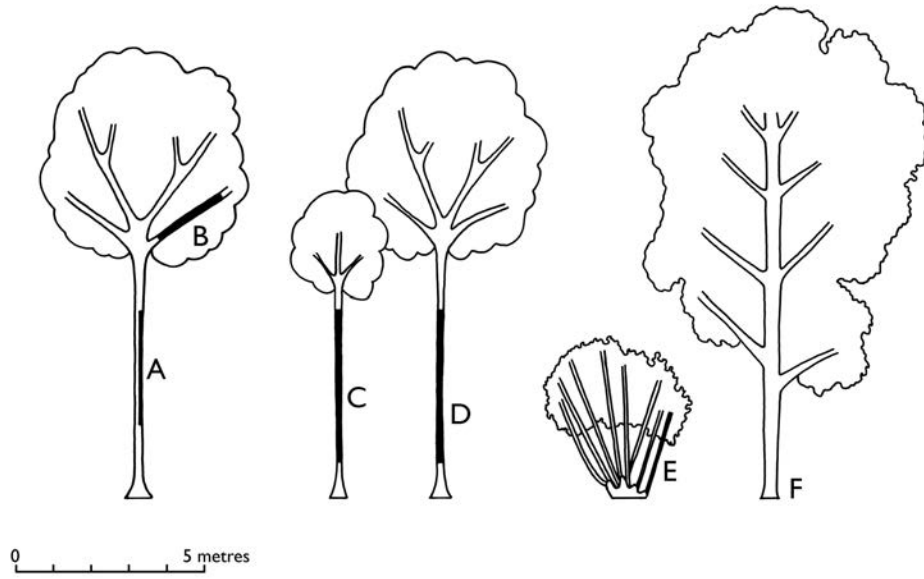
Figure 28.3: Woodscape Model: a) tangential outer split from knot free trunk; b) tree limbs; c) trunks of young trees; d) entire straight-grained tree trunks; e) 'coppiced' rods; f) lake edge trees with frequent low side branches (Copyright Chloe Watson, CC BY-NC 4.0).
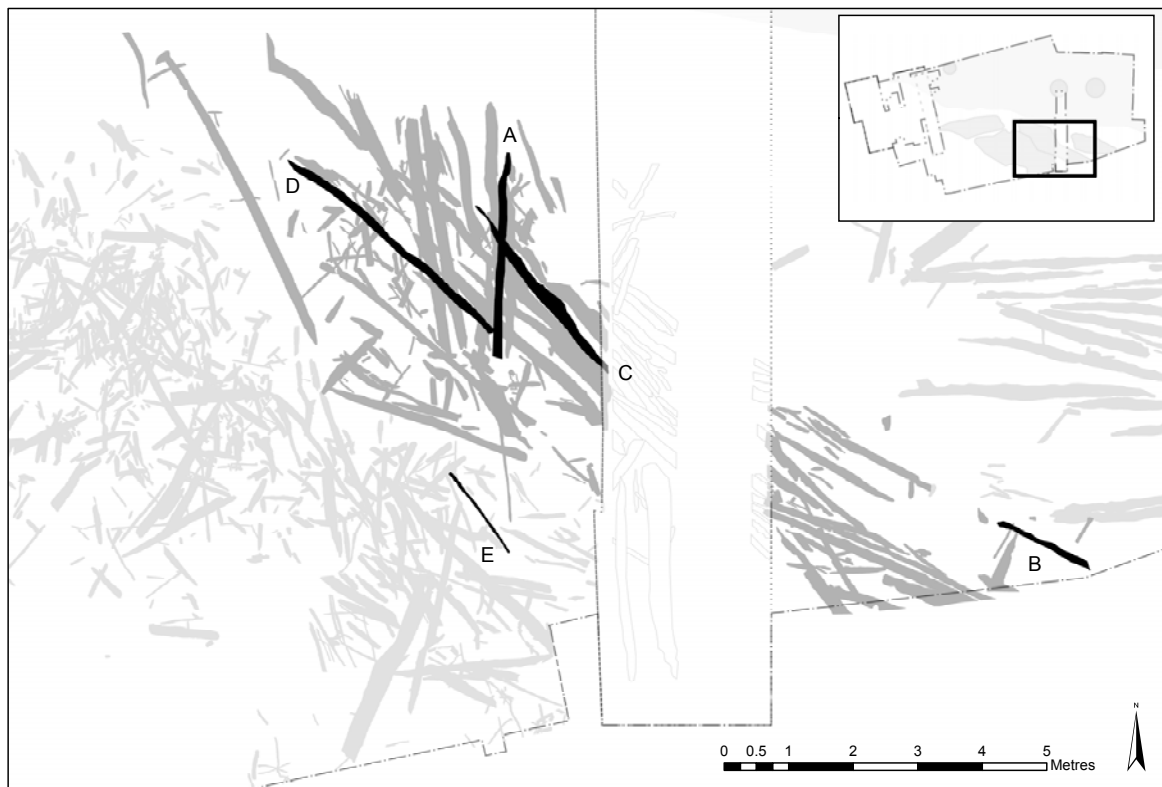
Figure 28.4: Elements used to construct woodscape model seen within the central platform (see Figure 28.3) (Copyright Star Carr Project, CC BY-NC 4.0).

Throughout this volume, reference is made to pieces of roundwood that appear to be coppiced. There is no assertion that these are the result of planned or deliberate coppicing or pollarding, although this is a possibility. There is clear evidence of both beaver and human populations felling trees, and many of these would have regenerated, producing coppice stems or rods. Whether coppicing was carried out as a deliberate act or the stems resulted from felling, such stems would almost certainly have been available within the local landscape and people presumably would have harvested them for use. The presence of a large number of long straight stems and poles recovered from the site shows a strong selection criteria for the harvesting of this type of material, which would have been useful for building structures, such as those seen on the dryland (Chapter 5), or perhaps for weaving wattle.

In the analysis of the wood from Star Carr, roundwood was noted as having possible morphological evidence for coppicing when a straight stem with a relatively uniform diameter and a central pith was present (Figure 28.5). Additional morphological characteristics that may be indicative of coppicing as identified by Rackham (1977) were also noted, such as a curved and/or flared butt/proximal end, or stems with evidence of topping. In terms of the prevalence of possibly coppiced roundwood across the different spatial analytical areas, there is a tendency for the two scatters of wood (detrital wood scatter and Clark's area) to have a higher incidence than the three lake edge platforms (Table 28.1).

Growth ring count studies are often carried out on archaeological assemblages of roundwood that appear to be the result of coppicing, with the intent of identifying rotational cycles. However, coppicing can also be carried out on an ad hoc basis and even if a rotational cycle is in place, practices such as draw felling can negate the evidence of any possible rotational cycle. Although recent research (Out et al. 2013) highlights the potential difficulties of identifying deliberate coppicing through growth ring count analysis, it seems pertinent to consider this data.

Growth ring count and seasonality of felling analysis was attempted from the Star Carr assemblage for items identified as having morphological traits associated with coppicing and a control group that did not. Unfortunately, the relatively poor condition of the material at a cellular level, combined with the high rates of

Area	Roundwood with morphological evidence suggestive of coppicing
Brushwood	1%
Detrital wood scatter	17%
Central platform	8%
Eastern platform	0%
Western platform	10%
Clark's area	44%

Table 28.1: Percentage of roundwood assemblage by area, which displays morphological traits associated with coppicing.

Figure 28.5: Long, straight stem <103437> (Copyright Michael Bamforth, CC BY-NC 4.0).

compression, severely hampered data collection and it was not possible to acquire a large enough dataset to be statistically viable for meaningful analysis. However, the data that were acquired are considered below.

A total of 78 growth ring counts were recorded (76 of these were from roundwood and two from roundwood debris with a complete radius from pith to bark edge present), 48 of which showed morphological evidence for possible coppicing (Table 28.2). The growth ring counts derived from all the spatial analytical groups and across species are considered together (Tables 28.2 and 28.3) (for further information regarding species identification, see Chapter 15).

It is often possible to record the season in which an item has been felled, via microscopic examination, from the presence of early or late wood at the bark edge (Jane 1970: 68). However, due to the poor condition of the wood, this deduction was only possible for ten items, all of which have approximately two growth rings, the results of which provide no discernible patterning regarding seasonality of felling/harvesting (Table 28.4).

Due to the poor condition, many of the ring counts were given as an estimated range which for the purposes of this study have been assigned a median value (e.g. 3–4 years = 3.5 years). Out et al. (2013) have shown that stems in the 20–60 mm range will often have an older age for a given diameter when derived from unmanaged as opposed to managed woodland resources. The age distribution for managed assemblages has also been shown to generally have a sharper cut-off in comparison to unmanaged stems (Out et al. 2013). When plotting growth ring count against diameter, no clustering is noted for either roundwood with or without morphological evidence suggestive of coppicing (Figure 28.6). The roundwood with morphological evidence for possible coppicing does show this trend for slightly higher age for a given diameter but there is no sharp cut off of growth rings (Figure 28.6). However, there is a marked tendency for the stems showing possible morphological coppicing evidence to cluster strongly in the 2–3 years of growth range, despite no such clustering being noted amongst the horizontal diameters, a trait that may be suggestive of some form of woodland management (Figure 28.7).

Morphological evidence for possible coppicing?	Brushwood	Detrital wood scatter	Western platform	Central platform	Other	Total
Yes	3	36	1	4	4	48
No	1	27	1	0	1	30
Total	4	63	2	4	5	78

Table 28.2: Roundwood and roundwood debris growth ring counts assigned to area.

Morphological evidence for possible coppicing?	willow	willow/aspen	aspen	birch	birch/ alder/ hazel	Total
Yes	12	1	5	9	3	30
No	39	0	6	3	0	48
Total	51	1	11	12	3	78

Table 28.3: Roundwood and roundwood debris growth ring counts assigned to taxa.

Morphological evidence for possible coppicing?	c. 2 years growth, early wood	c. 2 years growth, late wood	Total
Yes	3	3	6
No	2	2	4
Total	5	5	10

Table 28.4: Early and late felled/harvested material.
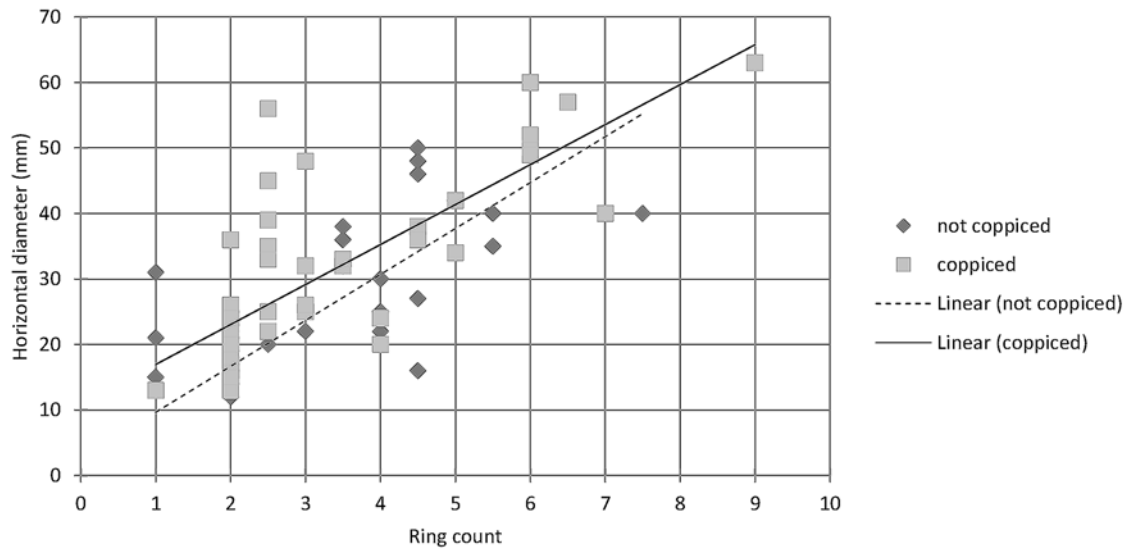
Figure 28.6: Growth ring count plotted against diameter for material with morphological traits indicative of coppicing and material without morphological traits indicative of coppicing (Copyright Star Carr Project, CC BY-NC 4.0).
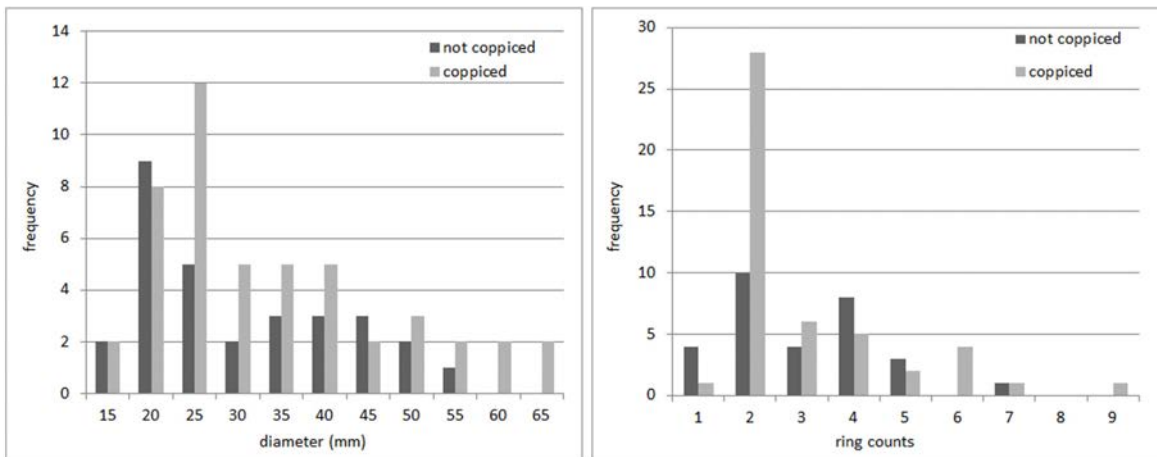
Figure 28.7: (left) frequency of horizontal diameters for material showing morphological signs of coppicing and material without morphological traits indicative of coppicing; (right) frequency of years of growth for material showing morphological signs of coppicing and material without morphological traits indicative of coppicing (Copyright Star Carr Project, CC BY-NC 4.0).

In sum, although no conclusive evidence for coppicing or pollarding has been found, there is certainly a strong selection bias for straight, even stems, rods and poles amongst the wood encountered at Star Carr, and deliberate woodland management strategies remain a strong possibility.

Technology

The majority of prehistoric woodworking is based on two core principles:

1. Use of edged tools such as axes and adzes to fell trees and trim and hew timbers into shape by reducing the items down blow by blow, chip by chip.
2. Use of wedges and hammers to split or cleave logs longitudinally in the tangential and radial planes into the shapes required.

The woodworkers at Star Carr were prolific wood splitters, working in the tangential and radial planes and producing split timbers up to 3.6 m in length (Figure 28.8). Some of the split material is unusually long for any prehistoric woodworking assemblage (Bamforth 2010; Taylor 2001; Taylor 1998b) and shows a very high level of competence in this particular technique.

   Tool facets provide us with evidence for hewing and trimming and many of the well-finished wooden artefacts illustrate the woodworker's depth of understanding of dowel technology. The presence of a two-stem twisted willow withy similarly displays an understanding of plying and cord production (Chapter 29).

   It is reasonable to assume that the majority of the pieces of wood displaying traces of working at Star Carr will have been trimmed to length with an axe or adze. However, there is a low prevalence of tool facets or stop marks; it seems that the ends of the majority of the wood assemblage, where the longitudinal cellular structure of the wood is truncated and exposed, have degraded to such an extent that few tool facets remain. Where they are visible, the facets tend to be short, narrow and concave, as would be expected from the relatively obtuse cutting edge of stone tools (Coles and Orme 1978; Coles and Orme 1984; Sands 1997). A single stop mark was recorded from debris <103726> and measured 40:4 mm (Figure 28.9).
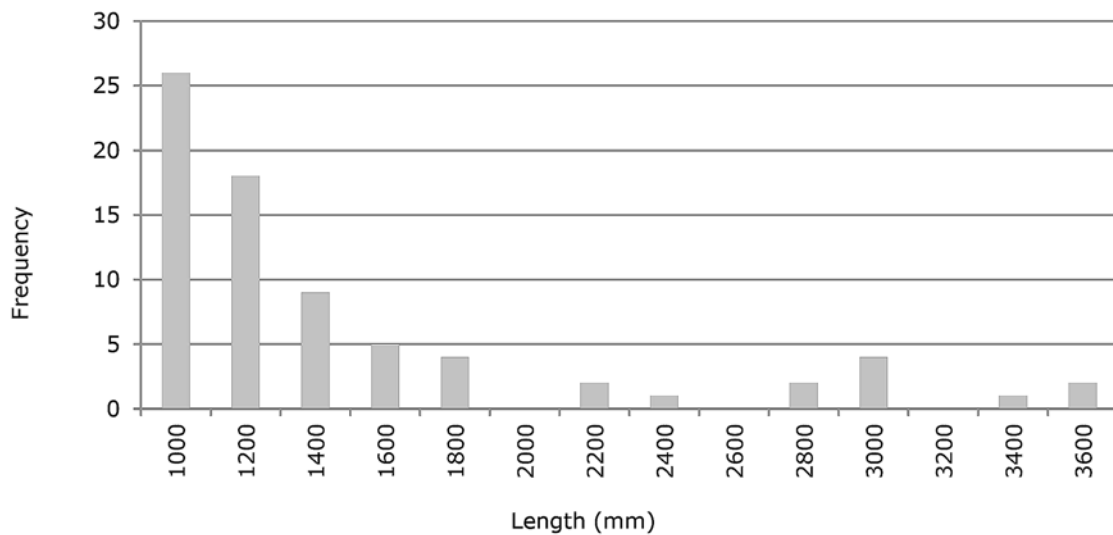
Figure 28.8: Lengths of split items greater than 1000 mm (n=74) (Copyright Star Carr Project, CC BY-NC 4.0).
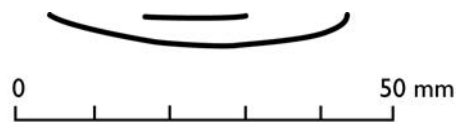
Figure 28.9: Tracing of stop mark left by the cutting edge of a flint axe or adze on the face of debris <103726> (Copyright Chloe Watson, CC BY-NC 4.0).

There are several woodworking features that stand out amongst the Star Carr assemblage as being unique or very unusual. These include the high prevalence of tangential outer splits, the high prevalence of parallel sided split items, the high prevalence of split timbers with the split fading/feathering out at one or both ends, the presence of longitudinal grooves on split faces, the presence of long, thin strips of woodworking debris and the presence of diagonal groove/gouge marks on split faces. The presence of these traces has led to the formulation of various hypotheses to explain the techniques that may have produced them, some of which have been tested through experimentation.
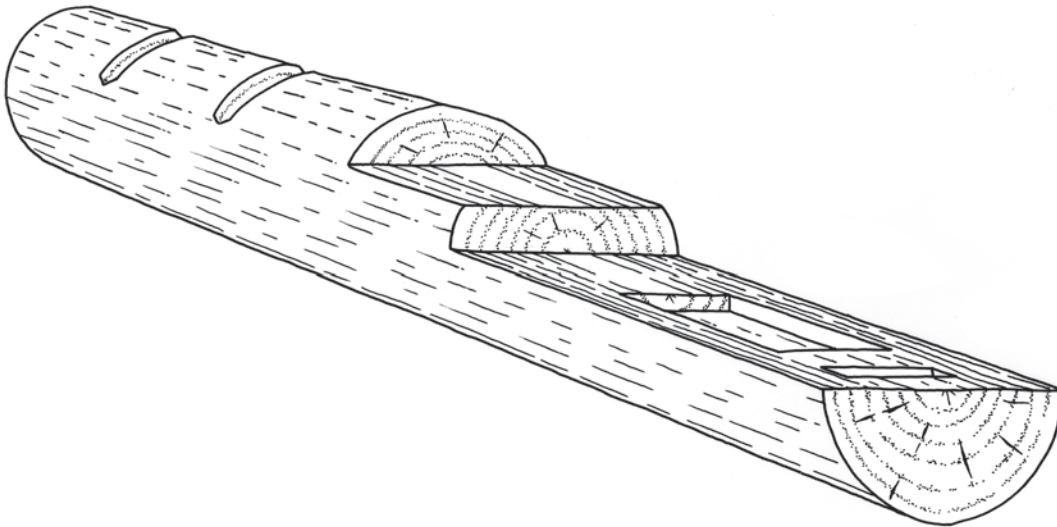
Figure 28.10: Notch-and-split technique (Copyright Chloe Watson, CC BY-NC 4.0).
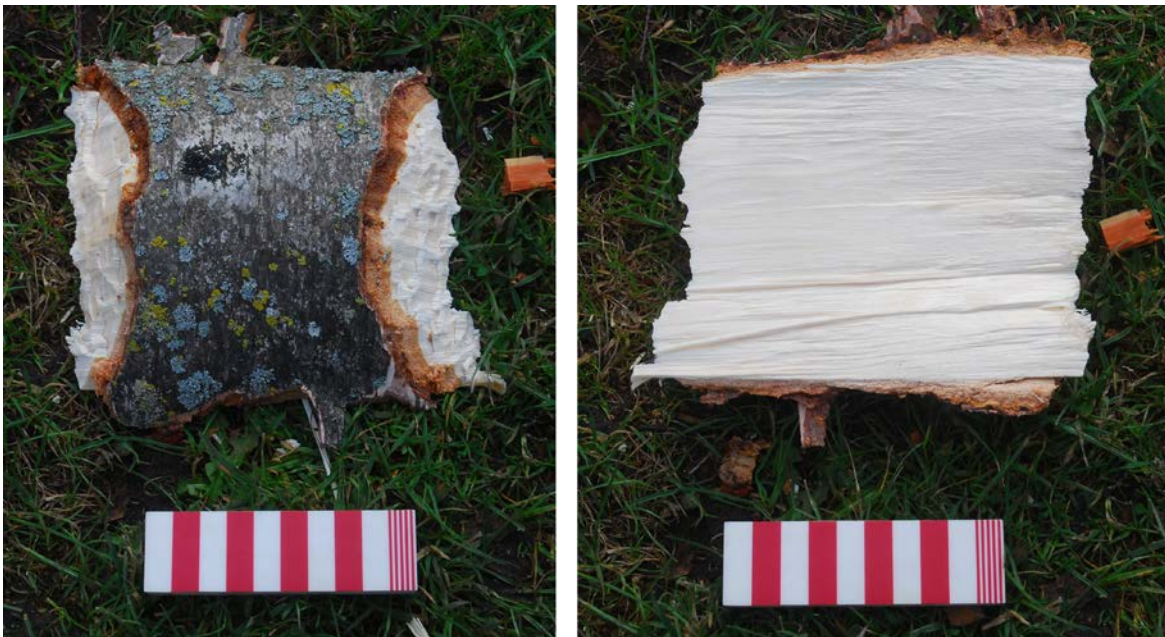
Figure 28.11: Notch-and-split debris produced during experimental work (Copyright Michael Bamforth, CC BY-NC 4.0).

Notch-and-split woodworking techniques can be used for felling trees (Jørgenson 1985; Stewart 1984, 38), facing up logs (Stewart 1984, 42) and hollowing out log boats (Stewart 1984, 54; Christensen 1999, figure 9.2). The authors are aware of this technique and the distinct 'blocks' of debris it produces (Figures 28.10 and 28.11). Three pieces of debris that may have been produced by this technique were identified during the excavation:

- <99215>, 205 × 82 × 7 mm, tangentially split.
- <103715>, 160 × 74 × 10 mm, tangential outer split.
- <103805>, 418 × 115 × 65 mm, tangential outer split, torn down both sides; appears to be from base of small tree.

As has been discussed elsewhere in the volume (Chapter 29) there is no extant evidence for the use of fire either to shape wood through charring and scraping or to harden wood. In addition, with the exception of a small hole drilled through wooden artefact <115952>, probably with a flint awl, there is no evidence from Star Carr for any other joints or fixings of any type. There is also no evidence for boat building though it is likely that people at Star Carr had watercraft of some kind to navigate the lake and visit the islands, and a possible paddle was found by Clark (see Chapter 29 for full discussion). Although unlikely, there are three pieces of debris that may be derived from notch-and-split woodworking (Stewart 1984, 54; Christensen 1999, Fig. 9.2) that could conceivably be the by-product of log boat building.

The low prevalence of vertical elements in the forms of stakes, posts or piles is very unusual and worthy of note. This is limited to five stakes: three roundwood and two utilised pieces of debris (Chapter 29) and to the indirect evidence provided by the stakeholes and postholes of the dryland structures (Chapter 5).

Tools

The wood assemblage provides us with indirect evidence of the tools used in the form of the traces they have left on the wood. At Star Carr, a strong case can be made for woodworking activities being undertaken with bone, antler and flint tools. Microwear traces of woodworking on flint has been identified on a number of flint tools, initially by Dumont (1983, 1988), and more recently, as part of this project (Chapter 35). Although it was not possible to identify wood traces on osseous tools due to the poor condition and, in the case of the bone chisel, a re-sharpening event, experimental research demonstrated the high likelihood of their employment in woodworking tasks. Wood hafting traces on flint tools provides further indirect evidence of the diversity of uses wood as a raw material had at Star Carr

Flint tranchet axes are well represented in the flint assemblage and may have been hafted as either axes or adzes, most probably in a haft constructed from a willow heartwood dowel (Figure 28.12). Microwear traces of wood polish suggestive of these tools being used for trimming and chopping wood have been recovered from tranchet flake <98825> (refit group 89, Chapter 8), axe <92077>, recovered from the eastern structure and two further small axes (<99469> and <94367>, refit group 88, Chapter 8). Dumont (1983) also identified a core resharpening flake with woodworking traces.

Woodworking microwear traces have been recovered from several other flints. A Type E disc core (part of scatter AC8, Dumont 1983) is identified as a woodworking tool. Five burins with microwear traces of wood polish show evidence of scraping, grooving and whittling. Five blades show microwear traces resulting from use as woodworking tools: two utilised as borers and three as scrapers. Just one scraper displays woodworking traces, though it is possible that re-sharpening events removed evidence of use on wood and other contact materials from these tools. Notched/denticulate tools with transverse woodworking traces within the retouched zone indicate the use of these tools to scrape and/or burnish wood, possibly shafts. The circular, waisted, hourglass-shaped hole worked through wooden artefact <115952> provides indirect evidence for the possible use of flint awls on wood (Chapter 29). This is further supported by Dumont's (1983) microwear work

Figure 28.12 (page 357): Flint tranchet adze in use to prepare a tree trunk for splitting a tangential outer timber from a standing tree (Copyright Don Henson, CC BY-NC 4.0).

Figure 28.13: (left) Flint flake being utilised to produce longitudinal grooves as part of groove-and-split woodworking; (right) bone chisel used as splitting wedge as part of groove-and-split technique (Copyright left photograph Don Henson, CC BY-NC 4.0. Copyright right photograph Michael Bamforth, CC BY-NC 4.0).

which identified two awls with traces of plant polish that may possibly indicate woodworking. Flint flakes were successfully used as part of groove-and-split woodworking during experimental work (Figure 28.13).

Elk antler mattocks were formed from either the beam, pedicle and adhering frontal bones or the beam and palmate portion. These tools would have been hafted with either a roundwood stem or heartwood dowel (Chapter 29). Clark recovered six antler mattocks and the recent excavations uncovered a further finished example <113836> and an item interpreted as a possible roughout (Chapter 24). Experimental work showed this type of tool to be effective as a woodworking tool; unfortunately the condition of the artefact did not allow for microwear analysis (Chapters 24 and 29).

A single large bone chisel fashioned from a split aurochs metatarsal was recovered <117517> (Chapter 24). Although analysed for use wear traces, any evidence of function had been obliterated by a sharpening event. The chisel does not seem to have been hafted and is of a sufficient size to be held in the hand. There was clear bruising and percussion damage to the butt end of the tool to suggest that it was repeatedly hit with a heavy object; however, there was no breakage associated with this to suggest long-term or heavy usage. This item is of a suitable size and form to be used as a woodworking tool or a splitting wedge. Experimental work proved slightly smaller bone chisels to be very efficient and useful woodworking tools as well as splitting wedges (Figure 28.13).

It has been suggested that the numerous worked antler tines (n=175), originally identified by Clark, may have been utilised as wedges for splitting wood (Mellars and Dark 1998) and experimental work carried out in October 2014 proved them to be very effective for this undertaking. However, it is cautioned that these items are extremely numerous and would have been suitable for a number of different tasks (Chapter 24). Two pieces of split willow, <116520> and <103149>, may have been wooden splitting wedges (Chapter 29). In addition, there are several longitudinally split pieces of animal long bone that have been interpreted as the discards from which blanks have been split from to fabricate barbed points (Chapter 24); however, these could conceivably have been used as splitting wedges, though preservation of these items was too poor to allow microwear analysis.

Finally, stone <96759> has a series of parallel grooves that contain traces of microwear revealing wood and or antler polish, raising the possibility that the item was used perhaps to sharpen barbed points or as an arrow straightener (Chapter 34).

Felling and trimming

There are several different felling techniques that the woodworkers of Star Carr may have used. It is possible that the tree may have been ringed 'beaver style'. Alternatively, a 'cut to fall' technique familiar to modern woodsman with a front cut and back cut may have been used. Either of these techniques can be achieved through axing/adzing or by using a notch-and-split technique (Figure 28.14). Three pieces of possible notch-and-split debris that may be indirect evidence of felling have been described above.

There are 94 items identified as entire trunks of large trees. Seven of these were growing on the lake edge and are lying in situ where they have fallen into the waterlogged deposits and <109924>, which formed part of the western lake edge platform, has a root bole present at the proximal end showing the use of a naturally fallen tree. However, only two trees display working at the proximal/butt end possibly related to felling. Both are from the detrital wood scatter: tree <109557> has been tangentially split at one end and possibly trimmed at the other. It is unclear which end is proximal and which distal; tree <110365> has been reduced to a half split
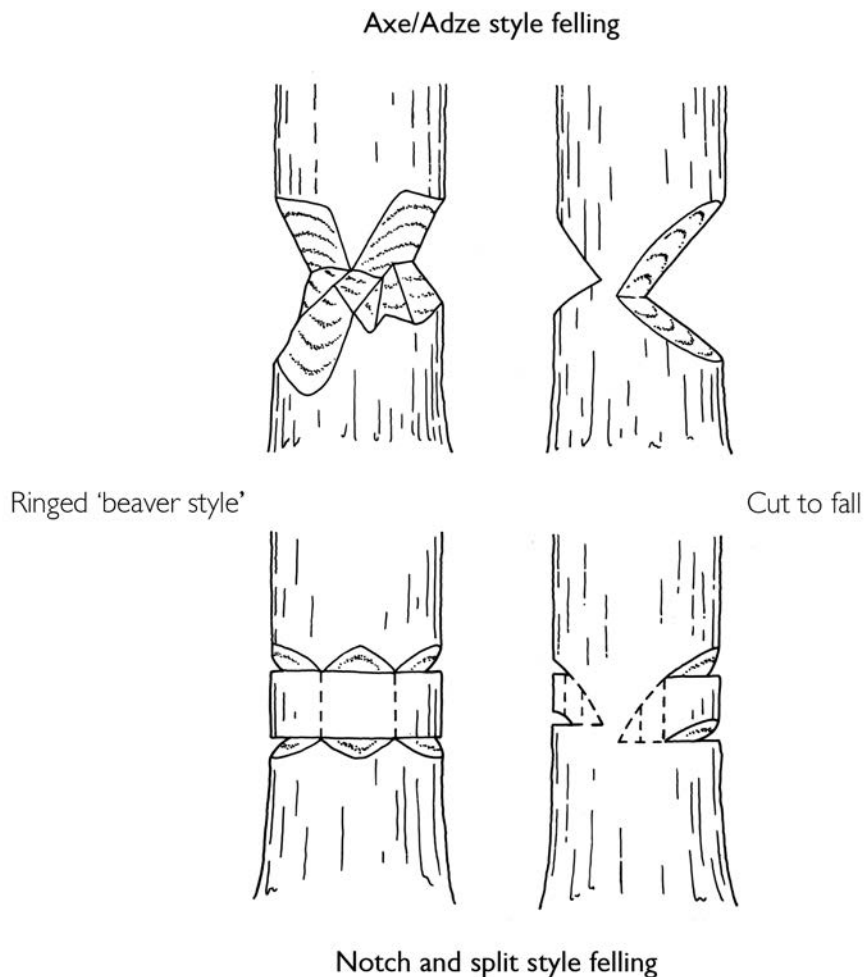
Figure 28.14: Possible felling techniques (Copyright Chloe Watson, CC BY-NC 4.0).

at the proximal end—the split face appeared torn and parallel lines of chop marks were present, cutting across the grain. These may represent faint traces of notch-and-split felling. It is also possible that fire may have been used to assist in the felling of trees. Two trees show evidence of charring: <99893> is lightly charred on one face at the proximal end. However, this charring does not seem extensive or intense enough to be associated with felling. The proximal end of fallen tree <109922> has been completely charred through and it seems likely that this tree was felled by fire. However, there is no way to know if this was a deliberate cultural action designed to fell the tree or merely a by-product of a fire on the lake edge.

Generally limited to stone tool woodworking assemblages, the chop and tear technique of trimming small diameter roundwood stems (c. 20–50 mm) involves bending the stem and chopping it, allowing it to tear, and then chopping again to sever the stem, leaving a distinctive stepped edge. It is known from other UK stone tool woodworking assemblages such as Etton Neolithic causewayed enclosure (Taylor 1998, Figures 169 and 170) and has been proved effective through experiment (Jørgensen 1985, 35–37 and figure 41). Similar evidence was also recorded from the Danish Ertebølle site of Tybrind Vig (Johansen 2013, figure 7). Twenty-four examples of chop and tear have been recorded from the Star Carr assemblage. This includes a particularly interesting example <103190> that shows evidence of both chop and tear and beaver gnawing (Figure 28.15).

The presence of cross-grain woodchips is of particular interest. When comparing the bronze tool-derived Bronze Age woodchip assemblage recorded at Flag Fen to the stone tool-derived Neolithic woodchip assemblage recorded at Etton, Taylor (2001, 182–3) points to the lack of cross-grained woodchips in the latter assemblage and suggests that it may be particularly hard to detach a cross-grained wood chip with a stone axe without suffering some damage to the tool. As such it is interesting to note their presence in this, the earliest woodworking assemblage currently known from Europe. Further experimental work may help to elucidate the efficacy of stone axes when used to work across the grain.

Figure 28.15: <103190> showing chop and tear at distal end and beaver gnawing at the proximal end and side branch (Copyright Michael Bamforth, CC BY-NC 4.0).

Conversion	Frequency	%
Radial	151	11.6
Radial 1/2	79	6.1
Radial 1/3	20	1.5
Radial 1/4	20	1.5
Radial 1/6	1	0.1
Radial 1/8	5	0.4
Tangential	729	56.2
Tangential, outer surface split away	6	0.5
Tangential outer	194	14.9
Tangential and radial	15	1.2
Cross grain	8	0.6
Unknown	70	5.4
Total	1298	100.0

Table 28.5: Conversions recorded from the Star Carr wood assemblage (excluding woodchips).

Conversion	Frequency	%
Off roundwood	9	4.9
Radial	40	22.0
Tangential	113	62.1
Cross grain	2	1.1
Unknown	18	9.9
Total	182	100.0

Table 28.6: Conversions of the Star Carr woodchip assemblage.

Splitting

Overview

The assemblage at Star Carr has a large quantity of split material in a variety of conversions. Tangential material dominates (73%), with moderate quantities of radially cleft material (21.3%) and occasional cross grained items (1%) also present (Table 28.5). Interestingly, this closely matches the alignments of the recorded woodchip assemblage (Table 28.6). During the recording of the wood assemblage, it was noted that many of the split surfaces appeared rougher than would be expected, or perhaps torn. The cause of this is unknown.

Tangential outer splits

A striking feature of the worked wood assemblage recorded from Star Carr is the strong bias towards tangential outer splits, with bark edge still present (Figure 28.16). The split tends to fade out at either end of these timbers, which can range in length from 1.0–3.6 m. The presence of so many tangential outer split timbers within this assemblage is extremely unusual. In a later assemblage such material would often be generated as waste material from squaring up timbers into boxed heart or half splits. However, there is no evidence from the
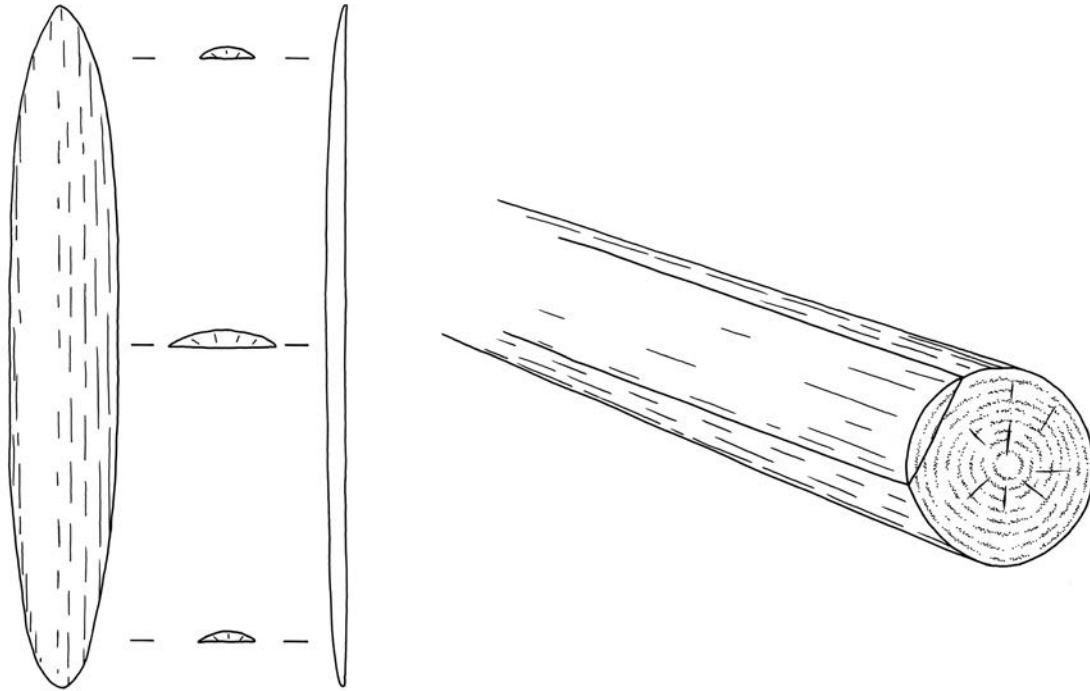
Figure 28.16: Tangential outer splits, often fading / feathering out at both ends (Copyright Chloe Watson, CC BY-NC 4.0).

wood assemblage at Star Carr of such boxed-up material to suggest that this is the case here. There are several items which have had a single outer surface tangentially cleft away, which would produce an offcut that was a tangential outer cleft. However, there are only six of these items (Table 28.5) which cannot account for the large number of tangential outer splits. Instead, the tangential outer splits seem to be, for the most part, finished products rather than waste material. This leads to the possibility that some of these timbers were being harvested from living, standing trees. This practice is known ethnographically. Indigenous peoples of the Pacific North-West Coast split huge structural timbers from living cedar trees (Stewart 1984, 42), and the Bindibu people of Central Western Australia cut parallel sided planks from standing Mulga trees from which to produce spear throwers (Thompson 1964) using a technique similar to the groove-and-split technique discussed below.

Experimental work carried out during October 2014 showed it to be surprisingly easy to cleave planks from a standing tree. A notch was cut out at the top of the desired split to allow the insertion of splitting wedges. Wood, bone and antler wedges were used to chase the split down the trunk (Figure 28.17). This resulted in a stepped, almost cross cut distal/top end to the timber and a feathered out lower/proximal end. The tree used had a diameter of 165 mm. It took 20 minutes to make the top cut and a further 30 minutes to split away a 1.6 m long timber. DP and MB felt that this could be achieved in perhaps half the time with practice. It was noted that to split a longer timber from a standing tree, one would need to be at height having either climbed the tree or used a ladder or similar. However, it was not possible to replicate the feature noted on several split archaeological timbers where the split fades or feathers out at both ends. It is still unclear which technique produced this result.

Groove-and-split

Previous investigations at Star Carr identified the presence of longitudinal parallel grooves on the faces of timbers and a tendency for both parallel sided timbers and long, thin, parallel sided woodworking debris (Mellars et al. 1998).

Figure 28.17: Tangential outer timber being split from a standing tree using wood and antler wedges (Copyright Don Henson, CC BY-NC 4.0).
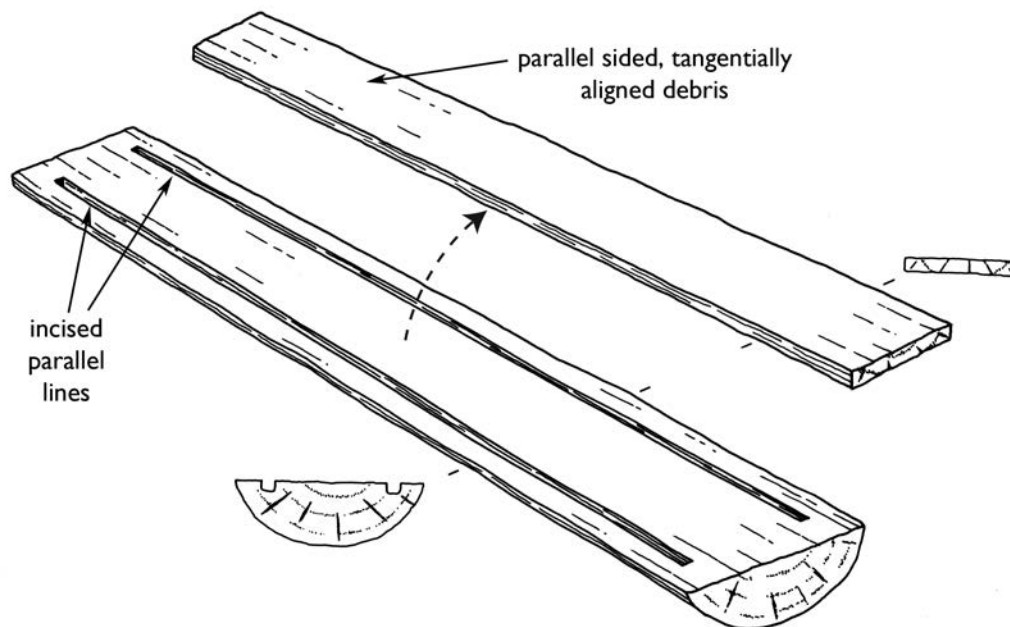
Figure 28.18: Schematic representation of groove-and-split (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 28.19: Groove-and-split debris <103676> (top) and debris produced during experimental work (bottom) (Copyright Michael Bamforth, CC BY-NC 4.0).

Similar traces have been recorded at Etton Neolithic causewayed enclosure (Taylor 1998a), the Raunds Neolithic Long barrow (Taylor and Bradley 2007) and the Late Mesolithic Carlisle Northern Development Route (Taylor and Bamforth 2013). These traces, distinct to stone-tool woodworking assemblages, may have been produced by a previously unrecognised woodworking technique: groove-and-split. It seems that parallel grooves have been used to control the edges of splits and that the debris has been split or gouged from between the parallel grooves (Figures 28.18 and 28.19). This hypothesised technique is somewhat similar to the groove-and-splinter technique applied to antler (Chapter 24) or to the notch-and-split technique used for tree felling and boat building discussed above.

This technique was tested on a small scale during experimental work. Parallel grooves were incised into the surfaces of split birch timbers with both flint flakes and bone chisels. The section of wood between the grooves

Figure 28.20: Diagonal groove feature on <99211> (Copyright Michael Bamforth, CC BY-NC 4.0).

was then split away using antler tines and a bone chisel. Although the experimental work did produce the woodworking traces recorded from Star Carr in the form of parallel grooves and long, parallel sided pieces of woodworking debris, it was noted as being quite a slow technique and it was unclear why it would have been necessary to split thin pieces away from the surfaces of timbers.

There are 12 items from the recent excavations, generally of medium to large size, that show removal scars from hewing or splitting several large pieces away in the tangential plane.

Diagonal groove/gouge mark

A small group of split timbers recorded during the recent investigations at Star Carr also have an unusual diagonal groove or gouge mark present on the split surface (Figure 28.20). Previous experimental work carried out at Flag Fen had shown that using seasoned oak wedges to split wood does not leave any traces on the split timber. Furthermore, traces of splitting wedges on the split surfaces of timbers are not seen from prehistoric woodworking assemblages. Therefore, it was hypothesized that the diagonal features may have been produced by the use of antler tines as splitting wedges. However, experimental work using antler tines to split birch timbers showed this not to be the case and the cause of these groove features is still not understood.

Wider context

Star Carr currently sits alone in the UK as the only large assemblage of Early Mesolithic worked wood. However, there are comparable assemblages in Europe. Investigations at the submerged Danish site of Tybrind Vig have provided evidence for Mesolithic carpentry and woodworking practices relating to the Ertbølle period (Anderson 2013), including radial and tangential splitting, trimming of roundwood stems and the remains of felling scars, carried out with both core (generally larger items) and flake (generally smaller roundwood poles) flint axes. Dowel technology and species selection is also well represented in a series of hafts, digging sticks and bows. These tended to be extremely well finished, obliterating any evidence of initial production. A small number of woodchips (n=13) were also present that provide evidence for possible 'char and scrape' woodworking at the site. Like at Star Carr, the propensity for straight hazel rods has also led to the suggestion of coppicing at Tybrind Vig, in this case to produce stems for the construction of fish weirs.

In the UK, investigations at the submerged landscape of Bouldnor Cliff (Isle of Wight), have also provided evidence for Late Mesolithic woodworking in terms of tangentially split timber and a possible log boat fragment (Rich et al. 2016). The assemblage recovered from Bouldnor Cliff is relatively small (although large in terms of Mesolithic worked wood in the UK) and, coupled with taphonomic issues resulting from the burial environment, this has led to some difficulties differentiating anthropogenic from natural material. To this end, a

programme of experimental work has been undertaken to better understand Mesolithic woodworking practices, focusing particularly on the use of non-stone tools, including bone chisels and wooden wedges (Rich et al. 2016).

Conclusions

Although there is evidence for beaver activity, both predating the human activity at Star Carr and continuing throughout the phases of deposition, the volumes of beaver-modified wood (n=24) are small in comparison to the quantity of split, trimmed and hewn pieces made by Mesolithic woodworkers (n=1602).

The appearance of many of the roundwood stems suggests that they may be derived from coppice. This is represented by a spike in growth rings of 2–3 years seen amongst the roundwood with morphological evidence of coppicing, and also a slightly elevated diameter-to-age ratio for the roundwood possibly derived from coppicing compared to the control group. This may be an indicator of woodland management in the form of intentional coppicing: however, this may simply be a result of natural re-growth of material from trees felled either by humans or beavers.

However, there is much evidence that the woodworkers at Star Carr showed a high level of competence and although complex carpentry in the form of joints or fixings does not seem to have been used, the woodworkers had an excellent understanding of both splitting and dowel technology. There is also evidence for the use of multiple twisted stems of willow plied together to produce an early form of rope. Entire trees were felled and then utilised whole or split down into large timbers, several of which were impressively long in a prehistoric context. It also seems likely that as well as harvesting regrowth 'coppice' stems, the woodworkers at Star Carr were also harvesting planks from living trees, demonstrating a husbandry of available woodland resources.

From traces on the wood, items in the finds assemblage and the use of microwear analysis and experimental archaeology, it has been possible to identify a suite of tools that formed part of the Mesolithic woodworking toolkit, which appears to have consisted of flint axes/adzes, blades, burins, denticulates/notched pieces, scrapers, flakes, fragments, chunks, nodules and coarse stone burnishing tools. In addition, results from our experimental research suggests the use of splitting wedges made of wood, bone and antler, and the probable use of antler mattocks and bone chisels, which proved to be highly functional tools for working wood.

As is often the case when carrying out experiments which rely on skill, knowledge and crafts that are no longer commonplace, a real difference was observed in the speed and quality of work that could be achieved by skilled versus unskilled labour. It was also interesting to note that during the initial manufacture phase, which in these experiments was generally carried out with a flint tranchet axe, the more experienced woodworker produced relatively larger woodchips and debris than the less experienced woodworker; the former worked more efficiently to detach larger pieces of debitage for each strike of the tool.

Although the wood assemblage and experimental work have provided a wealth of evidence for woodworking and basic carpentry practices at Star Carr, many questions still remain. For instance, the efficacy of groove-and-split, the performance of flint axes when working across the grain and the creation of split timbers that fade out at both ends are still poorly understood. It is through further experimental work, alongside the analysis of excavated remains, that we will further our understanding of Mesolithic woodworking practices.

Overall, it should not be surprising that Mesolithic woodworkers had a firm understanding of the use and selection of available resources and had perfected many basic carpentry techniques, particularly when considered in conjunction with the fine and precise microlith technology in use at the time, and in light of the extreme antiquity of the utilisation of wood for artefacts (Chapter 29). When excavating and analysing worked Mesolithic wood, it seems prudent to start from a perspective that expects relatively advanced woodworking technology, carried out with great sympathy to the naturally available resources, in order to fully understand what would have been a critical and versatile technology of the period.

CHAPTER 29

The Wooden Artefacts

Maisie Taylor, Michael Bamforth, Harry K. Robson, Chloe Watson, Aimée Little, Diederik Pomstra, Nicky Milner, Julian C. Carty, André C. Colonese, Alexandre Lucquin and Steve Allen

Introduction

Clark (1954, 178) stated that although wood must have been used for a variety of implements in the Mesolithic, including handles, shafts and bows, 'disappointingly little was found in the way of finished objects'. The two artefacts that were found were part of a wooden paddle which lay horizontally in the mud, identified by Donald Walker as birch (Clark 1954, figure 77, plate xxi), and the carbonised head of a handle found in the hole of an antler mattock (Clark 1954, 158, figure 69, plate xv). In addition, the trimmed end of a birch branch is illustrated (Clark 1954, plate xx g).

During the 1980s excavations, further wooden remains were encountered in the form of a platform (Chapter 2), but no artefacts were identified (Mellars and Dark 1998). The lack of wooden artefacts is perhaps not surprising because although they are known from other Early Mesolithic sites, particularly in Southern Scandinavia (Chapter 12), they are rare when compared to artefacts made of stone, bone and antler.

There are many difficulties when studying wooden artefacts. Larger artefacts are more likely to survive and be recognised than smaller or broken items. However, artefacts with direct modern parallels and those with distinctive shapes, such as an axe haft, are bound to be over-represented, although there is so little data about different kinds of hafts and handles that they may not be recognized, even when complete. Context may make the function of some artefacts clear or there may be recent parallels which make identification more straightforward. However, there is also the danger that although an artefact may have modern parallels which look similar, such as the paddle, these are objects which may have had many functions. To say that an artefact is a 'paddle', therefore, prioritises its form rather than identifying its function. Finally, any work on Mesolithic artefacts is further complicated because the wood, even where it is relatively well preserved, can still be extremely degraded, fragile and difficult to handle. As a result, virtually nothing is known about which tools were used for specific tasks, methods of hafting and techniques of working and shaping wood.

The study of ancient wood working, a reductive industry, has many of the same problems as the study of flint. For example, it is only recently that excavators have realised that the debris and detritus from the working of wood is as important, if not more important than the finished artefacts. This leads on to the difficulty of differentiating artefacts from waste material and specifically artefacts formed from utilised waste. As a response

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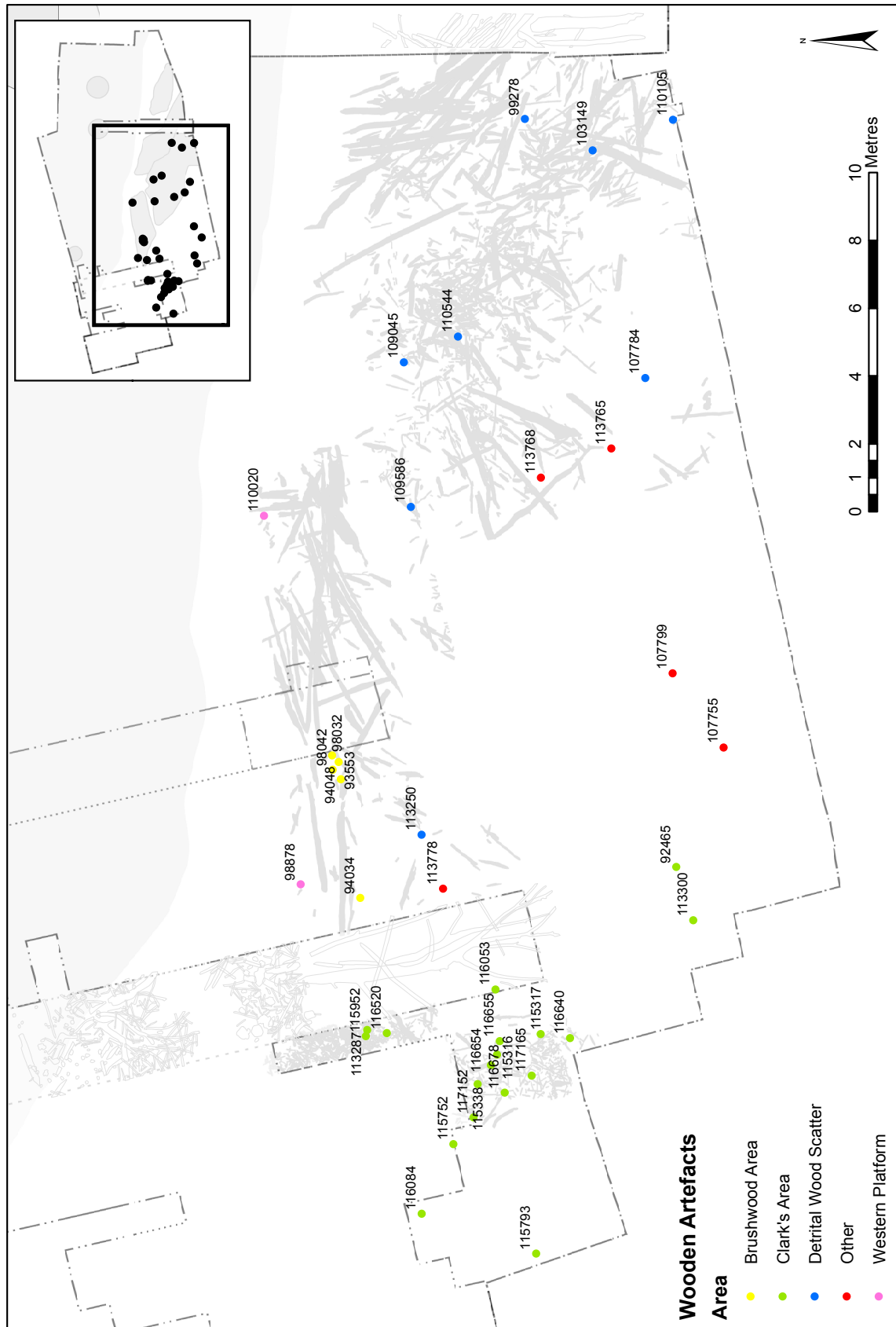
Figure 29.1: Wooden artefacts by analytical area (Copyright Star Carr Project, CC BY-NC 4.0).

to this, for the material from the recent excavations, we have taken the approach of examining all wood, rather than hunting for artefacts, and all worked wood was recorded in detail. This revealed that the woodworking technology was simple but effective and that the bulk of the worked material from the site was produced by splitting wood and trimming. However, these two simple techniques can be used in sophisticated ways that can produce, for example, dowels.

When wood is trimmed using a stone tool, the detritus produced tends to be small because the tool does not slice through the wood as cleanly as a metal blade. This also means that there is very little detritus from the site which might be derived from hewing, although there are a number of pieces from Star Carr which were probably finished by hewing. However, splitting wood produces by-products which come in shapes and sizes that can be modified to form useful objects.

The detailed recording during excavation allowed the identification of items which were 'different' from the general woodworking assemblage, pieces which did not fit neatly into the categories defined during the general analysis. Some of these items were identified as artefacts on site, whilst others were set aside for further study due to the possibility that they could represent artefactual material. Items were identified as possible artefacts if they were heavily worked and finished, or due to the presence of unexplained features, such as the appearance of polish at an end. Finally, some items were included due to their setting or context, including the few vertically set items and items of interest due to their close association with other artefacts. Gradually it emerged that there were certain technological categories of material that the artefacts and possible artefacts could be divided into.

This analysis has resulted in a total of 38 pieces which have been classified as wooden artefacts, recovered from five spatial analytical areas (Figure 29.1). The chapter sets out the analysis, considered first by technology and then the artefacts as they have been categorised. This incorporates microwear analysis and experimental work. The results are discussed in terms of spatial patterning and taphonomy and then in the context of the European evidence.

Analysis

Once identified as artefactual or potentially artefactual material, the 38 items were initially categorised by technology as opposed to form. This produced four distinct categories: 15 utilised roundwood, 14 dowels, six utilised debris, and three other. These can be seen to be spread across the site with no clear patterning (Figure 29.2).

Once these categories had been established it was possible in many cases, although not all, to suggest an interpretation regarding the original use of the artefact, based on its appearance, form and context (Table 29.1). As all the material was classified by technology first, it could be assigned or removed from interpretive categories as work progressed and could even appear under more than one label: for example, there are possible digging stick fragments which are roundwood and some which are dowels.

A programme of identifications were carried out by Steve Allen with six different taxa of wood identified (see Chapter 15 for methods):

- *Alnus* spp.—alders (exact species not determinable)
- *Betula* spp.—birch (exact species not determinable)
- *Frangula alnus* Mill.—alder buckthorn
- *Populus* spp.—aspen, white or black poplar (exact species not determinable)
- *Salix spp.*—willows (exact species not determinable)
- *Sambucus nigra* L.—elder

Note that *Populus* spp. are interpreted as aspen (*Populus tremula*) based on the presence of its distinctive catkin scales at the site (Chapter 15).

A programme of microscopic microwear analysis was carried out by Aimée Little on artefacts that were identified as having potential for displaying wear and/or manufacture traces based on their morphology as well as macroscopically visible traces of working (see Chapter 15 for methods). Where possible, items identified in the field thought to have potential for microwear analysis were subsequently not cleaned or handled unnecessarily.
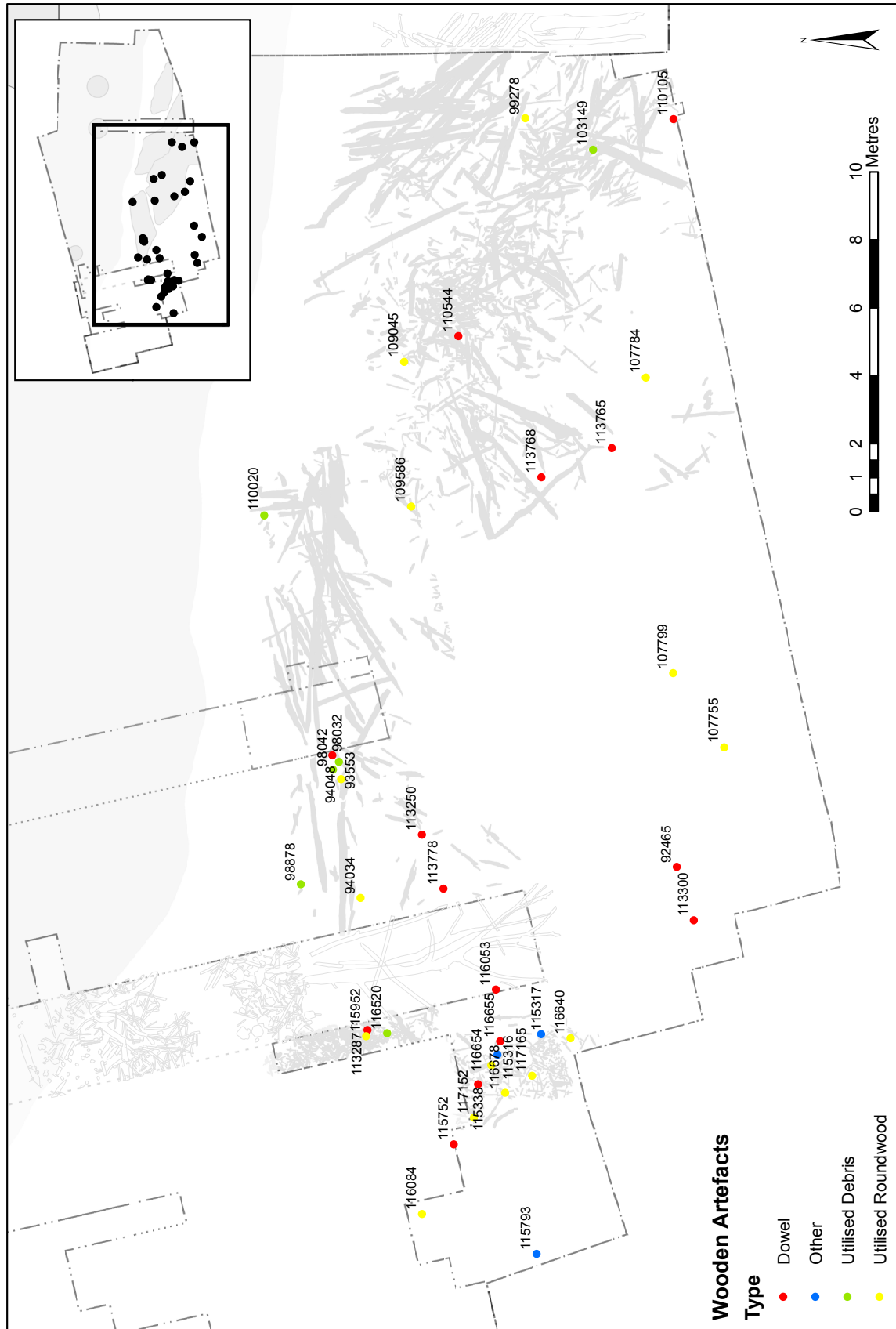
Figure 29.2: Wooden artefacts by technological type (Copyright Star Carr Project, CC BY-NC 4.0).

	Utilised Roundwood	Dowels	Utilised Debris	Other	Total
Ad-hoc tool	5		1		6
Board				1	1
Bow		1			1
Decorated item			1		1
Digging stick	4	3			7
Digging stick / haft or handle		1			1
Haft or handle		3			3
Other dowels		6			6
Peg			1		1
Roundwood with holes	2				2
Stake	3		2		5
Vessel or container				2	2
Wedge			1		1
Withy	1				1
Total	15	14	6	3	38

Table 29.1: Technological groupings by possible function.

Ten items were selected for analysis, including six dowels and four pieces of utilised roundwood with a range of different suggested original functions. The results of this analysis are set out in the section on the artefacts.

Molecular analyses were performed on extracted lipids by André Colonese and Alexandre Lucquin from two of the wooden artefacts from Star Carr, bow <113300> and radial dowel <113778>, in the hope of identifying residual traces of plant resins and tar that may have been used as an adhesive. Samples were collected from the extremities and the middle of these artefacts and lipids were extracted using established protocols in archaeology (Craig et al. 2013; Little et al. 2016; Regert et al. 2003). Lipids were also extracted from soil samples recovered from the artefacts for comparison. Analyses by Gas Chromatography (GC) and Gas Chromatography Mass Spectrometry (GC-MS) demonstrated the presence of lipids; however, those that were present were consistent with the local soil chemistry (e.g. alkanes, long-chain fatty acids). No evidence for plant resins or other adhesives, for example birch bark tar, were identified.

Technology

Introduction

The simplest form of a wooden tool is the unmodified stick and it can be argued that items like this were the earliest tools, probably pre-dating the emergence of humans (Sanz et. al. 2004). The next stage would be to find a piece of wood which naturally had a good shape for the task to be performed: a stick with a side branch which could be used as a hook, for example. A short step from this would be to modify the natural shape to be even more efficient, with the use of hafted flint axes and adzes for felling, trimming and shaping and wooden or antler wedges for splitting (Chapter 28). This third stage is more or less where woodworking remained until the invention of efficient saws enabled the wood worker to cut wood, to any shape, ignoring its natural shape and grain (Taylor 2010).

It would gradually become apparent that finding the best raw materials is important. Relying on chance to find an appropriate piece of wood was not always satisfactory and experience would show that the properties of wood as a raw material vary. Wood which is freshly cut is easier to work than older material which had seasoned and become harder (and more brittle). Other differences would also emerge. Living wood has different

qualities to dead but there are also differences between the species: differences of flexibility, durability, ease of working, growth patterns and exudates. There are differences in the properties of wood taken from the different parts of the tree: between trunk, branch and root as well as at different seasons of the year. Living wood is easier to work than dead but at certain times of the year, particularly in the spring, some species (including willow, birch and poplar) 'bleed' copious amounts of sap when cut. This may lead to fungal attack of standing trees but the more immediate problem for the wood worker comes because the wood is wet and sticky and therefore harder to work. The activities of beavers illustrate the fact that some trees regenerate when felled and some die. Regenerating trees, such as willow, produces stems of a predictable shape and size. It is a short step from observing beavers and exploiting the raw materials produced by them, to controlling quality and supply by coppicing (Chapter 28).

Roundwood

The simplest tool is the utilised or modified stick (Sanz et al. 2004). A roundwood stick is flexible as the high level of cellulose in the young wood (sapwood) makes it more likely to bend than break. One disadvantage of this is that with many species once the stick is cut, the sapwood begins to dry, shrink, crack, break down and rapidly (this normally happens within a year) become brittle. However, as it is a stick, it is quick and easy to replace.

Not surprisingly, the 15 modified and/or utilised pieces of roundwood found at Star Carr are the most frequent type of material recognized as possible artefacts. Fourteen pieces (all the items in this category with the exception of the withy <94048>) were formed from small or medium diameter roundwood and were identified as having one or both ends worked and/or utilised (Table 29.2). A broad range of possible functions has been suggested for the utilised roundwood assemblage consisting of: five ad-hoc tools, four possible partial or complete digging sticks, two pieces of roundwood with holes including <115952> that may have been part of a frame-built object, three stakes and one withy (Table 29.2). These were recovered from four of the analytical areas: two from the brushwood, four from the detrital wood scatter, seven from Clark's area and two from 'other' (parts of the site outside the key areas).

Four of these were simple pieces of roundwood where one end had broken either in antiquity or during excavation and the other end had been trimmed or utilised: <107755>; <107799>; <109045>; <116084>; <116654>. Three were simple roundwood with both ends worked: <107784>; <109586>; <116678>. Others showed evidence

Number	Context	Area	Conversion	Identification	Interpretation
094034	312	brushwood	none	willow	digging stick
094048	312	brushwood	none	willow	withy
099278	312	detrital wood scatter	rad 1/2	not identified	ad-hoc tool, ?antler working
107755	310	other	none	willow? Very decayed	ad-hoc tool, ?spindle / toggle
107784	317	detrital wood scatter	none	willow	stake
107799	312	other	none	elder	ad-hoc tool
109045	319	detrital wood scatter	none	willow	ad-hoc tool
109586	317	detrital wood scatter	none	aspen	roundwood with holes
115952	312	Clark's area	none	willow	roundwood with holes
116084	312	Clark's area	none	willow	ad-hoc tool
116640	312	Clark's area	none	alder buckthorn	digging stick
116654	312	Clark's area	none	aspen	stake
116678	312	Clark's area	none	willow	stake
117152	312	Clark's area	none	alder buckthorn	digging stick
117165	312	Clark's area	none	willow	digging stick

Table 29.2: Items categorised as utilised roundwood (rad = radial).

for coppicing and more complex modification: <94034>; <115952>; <116640>; <117152>; <117165>. A single item, <99278>, had been half split and charred. It is difficult to discern whether the material from Star Carr was modified or utilised, or both, as utilisation may have removed manufacture marks and shaping might be due to wear alone. The poor preservation of the ends of many pieces of roundwood made it difficult to detect polish or gloss from use on the points or clear tool facets from shaping.

Dowels

Radically altering larger timbers or roundwood poles to produce dowels appears to have been a woodworking technique that was very important by this time. Dowels are larger items that have been reduced down and shaped longitudinally by splitting, trimming and hewing whilst generally avoiding the pith, until close to the dimensions required for the finished dowel. More surplus wood was then removed to finish the dowel probably by hewing, whittling, charring, abrasion or a combination of these techniques.

Dowels can be any shape in section, including round, square or oval. Roundwood and dowels have different properties: roundwood is very flexible, dowels less so; roundwood can be very perishable, dowels less so and in some contexts these were obviously properties which were valued. The dowels at Star Carr are usually well finished and it is difficult to be precise about methods of manufacture: digging stick <92465> is a good example of this.

There is very little evidence that charring was used to shape the wood from Star Carr, although there is clear evidence dating from the Neolithic for this technique (Taylor 1998a, 154). Shaping with light charring is not to be confused with 'fire hardening' which is a persistent myth in discussions of prehistoric wooden artefacts. Charring *may* harden wood, but at the expense of flexibility. If charring is used as an aid to shaping, it must be very light to avoid heat penetrating the wood. Charred material can be cleanly scraped off, leaving little or no trace.

Fifteen dowels were identified for detailed analysis (Table 29.3). A broad range of functions have been suggested for the dowels including: one bow, three digging sticks or parts of digging sticks, one possible digging stick or haft/handle, three hafts or handles and six dowels of unknown function, including two items which are very tentatively identified as possible piercers. These were recovered from four of the analytical areas: one from the brushwood, three from the detrital wood scatter, seven from Clark's area and three from other.

Most of these were generally well finished but one, <110544>, is quite rough and others, such as <113250> and <115752>, were not particularly well finished or had been damaged during finishing. With the exception of the bow <113300>, all the dowels were either radially aligned or had a sub-square cross section with radially

Number	Context	Area	Conversion	Identification	Interpretation
092465	312	Clark's area	rad	willow	digging stick
098032	317	brushwood	rad	aspen	digging stick
110105	317	detrital wood scatter	rad	aspen	haft or handle
110544	320	detrital wood scatter	rad / tan	aspen	other dowel
113250	317	detrital wood scatter	rad 1/4	willow	other dowel
113287	312	Clark's area	rad 1/4	willow	other dowel, ?piercer
113300	312	Clark's area	tan	willow	bow
113765	312	other	rad	willow	digging stick / haft or handle
113768	317	other	rad	willow	other dowel, ?piercer
113778	312	other	rad	alder	other dowel
115338	312	Clark's area	rad	alder	haft or handle
115752	312	Clark's area	rad	willow	haft or handle
116053	312	Clark's area	rad / tan	alder	digging stick
116655	312	Clark's area	rad	aspen	other dowel

Table 29.3: Items categorised as dowels (rad = radial, tan = tangential).

and tangentially aligned faces. It would seem that radially aligned dowels were strongly preferred, suggesting superior performance of this conversion for many tasks. In terms of the tangentially aligned stave for the bow, this alignment is a prerequisite to take advantage of increased performance of this form under the flexing stress of a bow in use (Bamforth et al. forthcoming).

It is apparent that the techniques and skills existed to produce dowels in a wide variety of shapes and sizes. A clue to how they were used could have lain in the modification and wear on the ends but here there were similar problems to those encountered with the roundwood. Ten pieces, <92465>, <098032>, <113287>, <113300>, <113765>, <113768>, <113778>, <115338>, <116053> and <116655> have ends with indications of tooling or wear. Of these, several different end shapes were observed, including those shaped to a point (<113287>, <113300> (at both ends), <113765>, <113768>, <113778>, <115338> and <116053>) or wedge <116655> or in the case of <92465> and <098032>, shaped like a digging stick tip with a rounded, somewhat flattened end. Three of the dowels had broken at one end in antiquity: <115338>, <115752> and <116053>.

Utilised debris

Six items are classed as utilised debris (Table 29.4). These items are all formed from woodworking debris that has been modified or utilised at one or both ends. A single item was interpreted as an ad-hoc tool, one item is possibly decorated, one is a possible peg and one is a wedge. These were recovered from four analytical areas: two from the brushwood, one from the detrital wood scatter, two from the western platform and one from Clark's area.

The utilised debris items are generally relatively small and there are radial, tangential and cross-grain aligned items. They are relatively intact and ancient damage is limited to that from possible use: the top of stake <98878> seems to have been damaged by hammering during insertion, possible peg or wedge <103149> has buckled at the tip, perhaps during use, and possible splitting wedge <116520> has possible 'bruising' from hammering at the thick end of the wedge.

Other

Three items were assigned to the category 'other' (Table 29.5). Two of the pieces are highly likely to form part of the same artefact, a vessel or container in the shape of a platter <115316-7>. An item interpreted as a board <115793> is also included in this category. All these items were recovered from Clark's area.

Number	Context	Area	Conversion	Identification	Interpretation
093553	312	brushwood	tan	aspen	ad-hoc tool, ?burnishing
098042	312	brushwood	rad?	willow	decorated item
098878	317	western platform	rad 1/4 / tan outer	willow	stake
103149	312	detrital wood scatter	cross grain	willow	peg or wedge
110020	312	western platform	rad	aspen	stake
116520	312	Clark's area	tan	willow	wedge

Table 29.4: Items categorised as utilised debris (rad = radial, tan = tangential).

Number	Context	Area	Conversion	Identification	Interpretation
115316	312	Clark's area	tan	willow	vessel or container
115317	312	Clark's area	rad 1/4 and tan	willow	vessel or container
115793	312	Clark's area	tan?	willow? Very decayed	board

Table 29.5: Items categorised as other (rad = radial, tan = tangential).

Artefact interpretation

Ad-hoc tools

Six items have been identified as possible 'ad-hoc tools': five pieces of utilised roundwood and a single piece of utilised debris (Table 29.6; Figure 29.3). These items all display evidence of possible use or utilisation whilst not having the level of finish or design seen with other more formalised artefacts considered in this chapter. They are pieces of woodworking debris or roundwood that appear to have been 'to hand' and pressed into action as an ad-hoc tool. Several of these items have suggested functions whilst others do not. They were found across the site: brushwood, detrital wood scatter, Clark's area and other.

<93553> (Figure 29.3b): This may have been used for polishing or burnishing. It is a piece of tangentially aligned debris measuring 256 × 20 × 8 mm. One end is rounded and appears smooth and polished, leading to the suggestion that it may have been used for some kind of polishing or burnishing. The wood is more dense than other material in this deposit. It is very hard and fibrous although it has been identified as aspen.

<99278> (Figure 29.3e): This was recovered from the detrital wood scatter in close association with two removed splinters of antler: <099270> and <099271>. The splinters had both been detached from the beam but not worked any further and are unusual items within the wider antler assemblage. <99278> is a half split piece of roundwood that measures 116 × 24 × 14 mm with an original diameter of 24 mm. One end has modern damage and the other is lightly charred to a depth of approximately 2 mm. Due to its association with the small cache of blank antler splinters, <99278> was identified on site as a possible antler working tool, perhaps a wedge used for splitting. However, the evidence for this is slight and although these items may have been intentionally placed together as an antlerworking toolkit, it seems equally likely to be the product of other material connections, or pure chance.

<107755> (Figure 29.3c): This is a short length of willow roundwood with one end missing. The other end is trimmed down to a blunt point of approximately 2 mm diameter and appears to be worn. The surviving length is 121 mm and the diameter is 17/22 mm.

  Microwear analysis showed that the worked surface (L3) contrasts with non-worked surface (L1). At times it was possible to see a clear difference in the surface of the object between unworked and worked. Transverse polish located towards the tip in addition to a very rounded/smoothed surface at the very tip of

Number	Context	Area	Type	Conversion	Description	Identification	Function
093553	312	brushwood	utilised debris	tan	One end appears rounded and utilised	aspen	?burnishing
099278	312	detrital wood scatter	utilised roundwood	rad 1/2	One end lightly charred	not identified	?antler working
107755	310	other	utilised roundwood	none	Worn tip of object	willow? Very decayed	?spindle / toggle
107799	312	other	utilised roundwood	none	Proximal end worked, possibly charred and utilised	elder	
109045	319	detrital wood scatter	utilised roundwood	none	Pointed, utilised end	willow	
116084	312	Clark's area	utilised roundwood	none	Several small notches near tip	willow	

Table 29.6: Material interpreted as ad-hoc tools (rad = radial, tan = tangential).
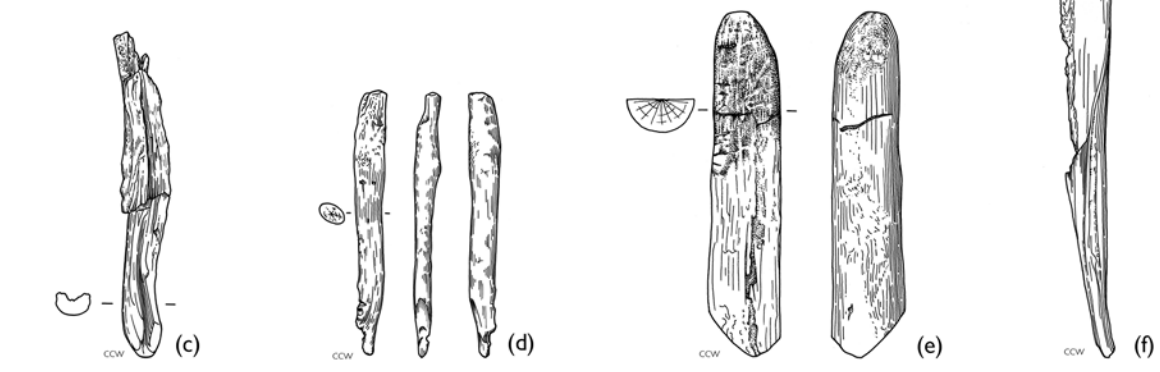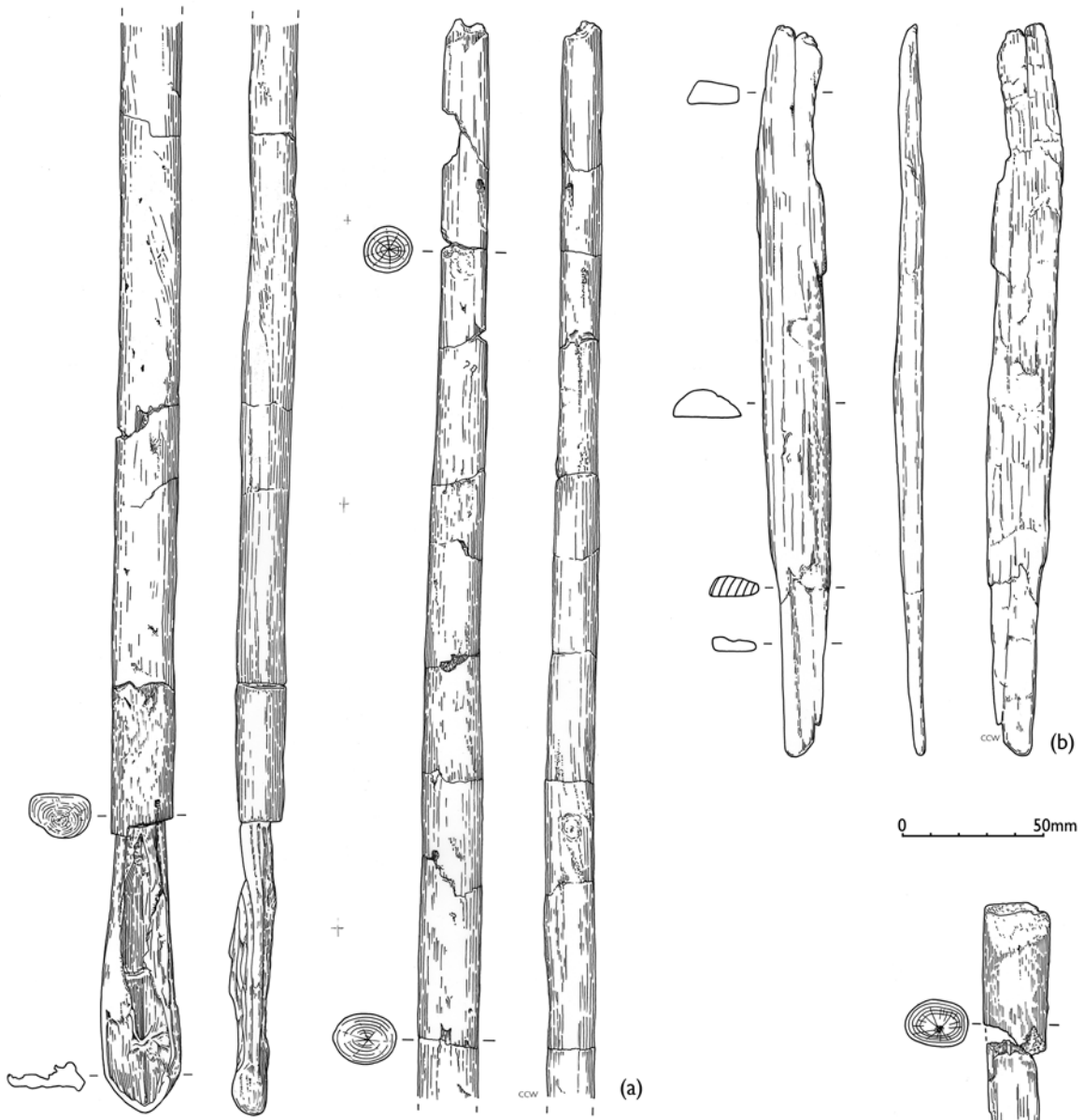
(a) 107799 (b) 93553 (c) 107755 (d) 116084 (e) 99278 (f) 109045

Ad hoc tools

the object suggests it was repetitively used to penetrate and possibly rotate within an unidentified material. Polish that is perpendicular (transverse) to the long axis may be related to manufacture. Possible use-related traces, consisting of a series of parallel shallow grooves, may have been caused by something being wound tightly around the wood, perhaps rather than being pulled. Interestingly, what could be a residue of plant origin was also identified in situ using indirect light microscopy (Figure 29.4). The weave itself is very fine but within the width range (10μ and sometimes below; Figure 29.4) of a number of elements present in different types of plant tissue (e.g. plant hair, plant vessels). Unfortunately, as the wood began to dry, we were unable to remove the plant fibre for analysis under transmitted light, which may have enabled a more accurate identification of the plant species. Nonetheless, the consistency in the morphology and size of such plant material suggests deliberate selection and the overlapping/geometric pattern may be the result of fibre being repetitively wound around the wooden object. However, we cannot completely rule out that it is of wood origin, rather than plant fibres. When combined with the microwear evidence for parallel grooves, it is possible that this small wooden object may have functioned as a spindle, bobbin or toggle. Considering the evidence for plant craftwork that has emerged from microwear analysis of numerous flint tools and a bone bodkin (Chapters 8, 24 and 35), such an artefact fits within the broader body of evidence for plant-working now known from the site.

<107799> (Figure 29.3a): This is a length of elder roundwood with one end broken. It is 765 mm long and slightly tapered: 22/27 mm at the proximal end and 16/19 mm at the distal end. It is straight with no side branches and is probably derived from coppice. The surviving end is worked, possibly slightly charred and appears to have
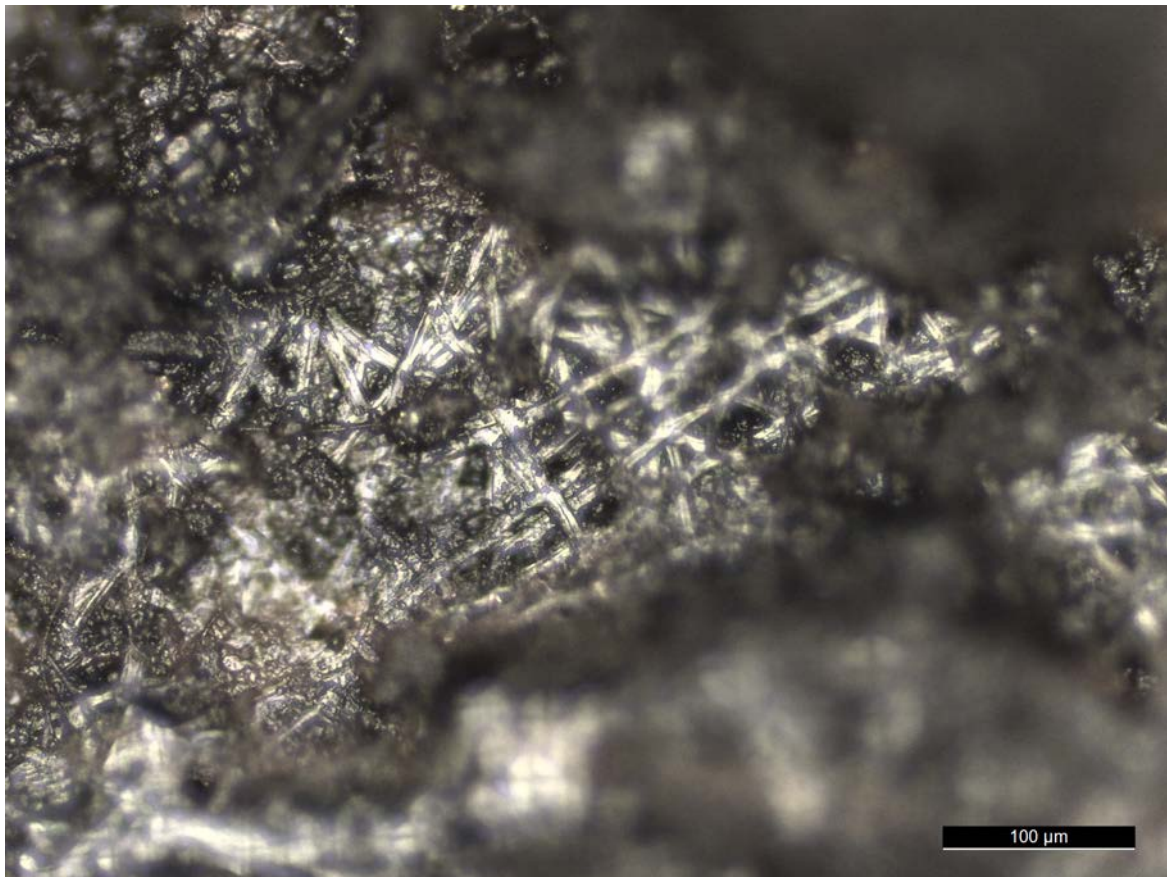
Figure 29.4: Transmitted light micrographs, ×20 magnification, showing possible plant weave identified during microwear analysis of the wooden ad hoc tool <107555> (Copyright Aimée Little, CC BY-NC 4.0).

Figure 29.3 (page 376): Ad-hoc tools (Copyright Chloe Watson, CC BY-NC 4.0).

been utilised. Towards the tip one side has been trimmed by splitting off some of the wood tangentially. No function is suggested for this item. In terms of microwear analysis, no wear or manufacture traces were identified, but the cell structure was intact.

<109045> (Figure 29.3f): This is a piece of willow roundwood with a slender pointed end which appears to have been utilised. It measures 198 mm long with a compressed diameter of 15/22 mm. No original function is suggested for this item. In terms of microwear analysis, no wear or manufacture traces were identified, but the cell structure was intact.

<116084> (Figure 29.3d): This is willow roundwood, with several small notches near the tip. These may represent deliberate working but may also have been caused by root action. One end is broken but 83 mm survives and the compressed diameter measures 7 × 9 mm. No original function is suggested for this item.

Boards

A single item, <115793>, has been identified as a board (Figure 29.5). It does not fall into any of the primary interpretative categories and is therefore listed as 'other'. This item was recovered from context (312) in Clark's area. It is a thin board 338 × 215 mm with a maximum thickness of 10 mm. The board appears to have been tangentially split from a relatively large tree (probably willow) and then has probably been significantly thinned down, likely by hewing. The flat surfaces are smooth and well finished. There is a diagonal cut across one surface, probably a remnant of the thinning-down process. The board has broken on one edge in antiquity, with three smashed fragments pushed into the vertical plane.

0 _____ 100mm
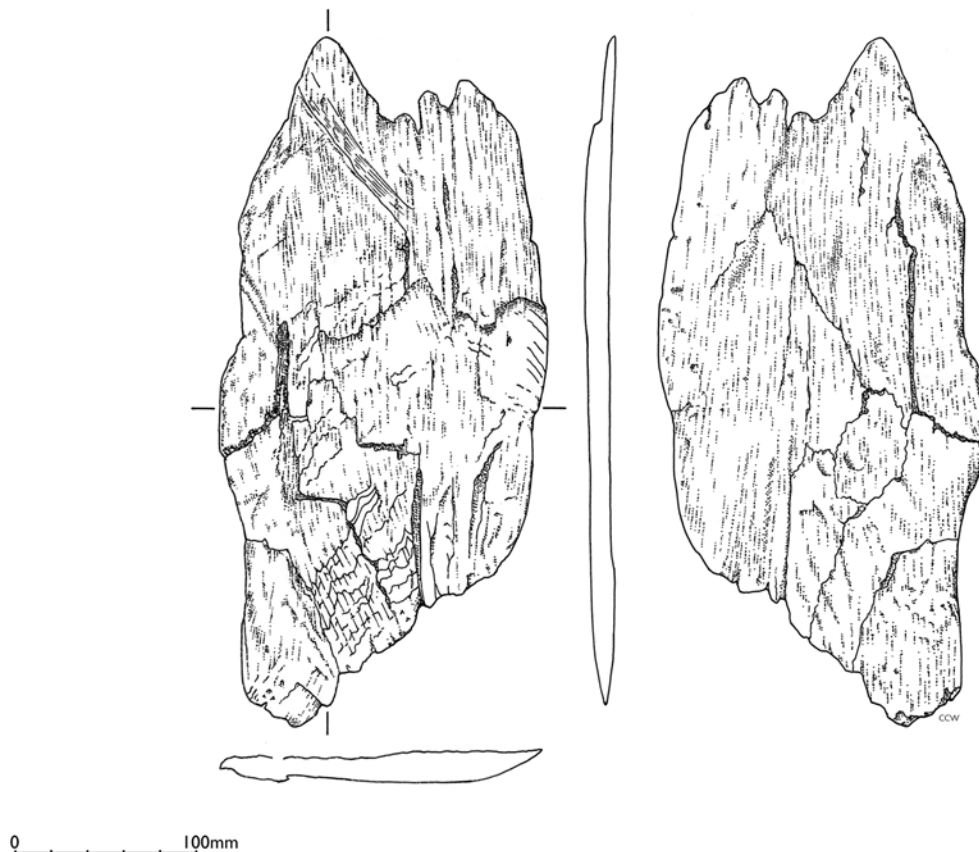
Bow

Dowel <113300> has been identified as a bow (Figure 29.6 and 29.7). This artefact was recovered from Clark's area within the reed peat context (312). This artefact lay point to point with digging stick <92465> in shallow water, some 15 m from the edge of the lake suggesting perhaps a deliberate placement. Initially, only one end of this artefact was excavated within a narrow trench in 2010, when it was thought to represent the end of a digging stick. However, full excavation of the remainder of the item in 2015 showed it to be pointed at both ends and to be of appropriate size, form and conversion to be a bow (Bamforth et al. forthcoming).

Measuring 1411 mm in length with a maximum width of 22 mm and thickness of 19 mm, this tangentially aligned sub-oval dowel (Figure 29.7) was worked to a slender point at both ends with no discernible nock or notch. It was worked down from a willow pole with a diameter of 70 mm or greater (Figure 29.7). The wood is knot free and straight grained with a slight twist along the length. Where the growth rings are visible they display even growth of c. 2.5–3.0 mm. The artefact is well finished with only slight, faint faceting, suggesting it was finished by burnishing, perhaps with a stone tool. The two limbs of the bow are slightly asymmetrical.

A series of experiments were carried out to test the possible function and performance of bow <113300> and three slightly different bows were produced (Figure 29.8). Initially, an 'idealised' version was produced to test the use of willow for bow making. This replica had symmetrical limbs (unlike the original) and the outer growth ring was not truncated on the back of the bow (again, unlike the original). Once the 'idealised' bow had been shown to be effective, two replica bows were produced. One was designed to be as close as possible to the dimensions of the artefact as excavated (Replica A), whilst the second was allowed to be up to 30% thicker in the belly to back plane (up and down as found in the ground) to compensate for vertical compression in the burial environment (Replica B). It is important to note that in all cases it was necessary to some extent to follow the grain and form of the wood that the replicas were created from, leading to some difference between intended dimensions and those achieved (Table 29.7). Indeed, only Replica B had a width and thickness comparable to <113300> as excavated. The bows were strung with twisted linden bast fibre cord.

Replica B took 1.5 hours for an experienced woodworker (DP) to produce from a split willow stave, using stone tools. This replica was able to shoot an arrow to a horizontal distance of 25 m and a vertical height of around 15 m. Despite this relative success, it was felt that the replica bow was too 'light' to have been effective for hunting big game. It was with this in mind that Replica B was used to shoot a small dead fish, held some 0.3 m below the surface of a lake (in a swimming position) with a barbed point tipped arrow (Figure 29.9). This was a success with the barbed point penetrating the fish by some 120 mm and securely holding the fish on the barbs.

Figure 29.6: Photograph of western portion of bow <113300> in situ (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 29.5 (page 378): Board <115793> (Copyright Chloe Watson, CC BY-NC 4.0).

BACK

1.

2.

3.

4.

5.

6.

BELLY

0   30mm

BACK   SIDE   BELLY

SC15 113300 Bow

0   50   100   150   200   250   300mm
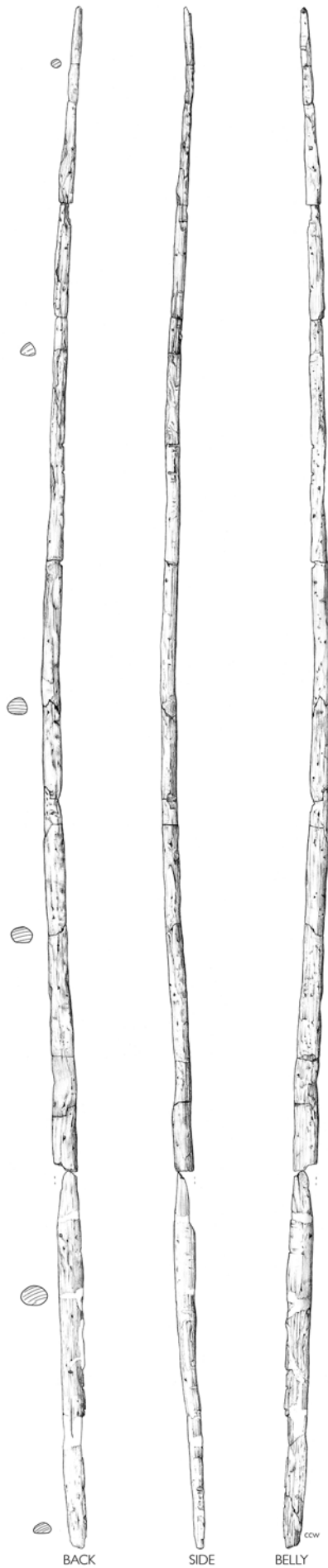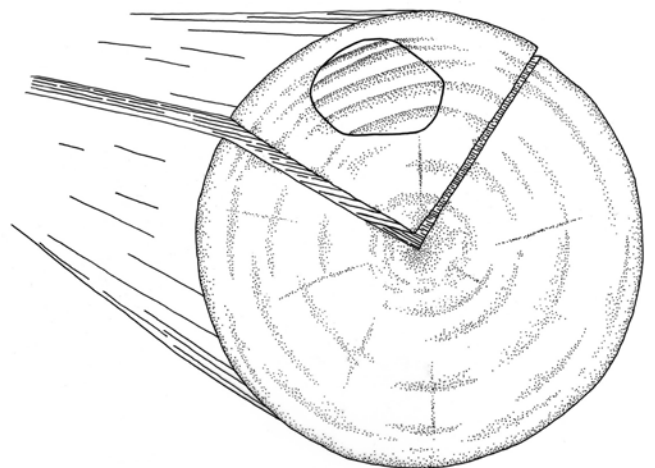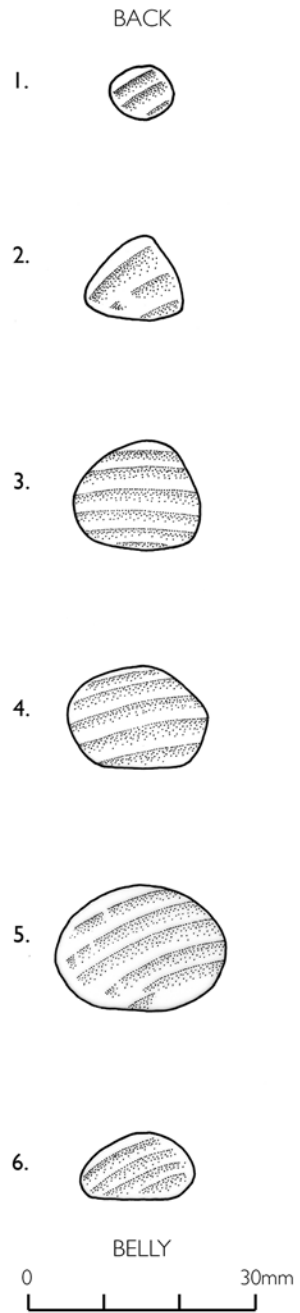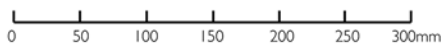
Bow	Length (mm)	Width (mm)	Thickness (mm) belly to back	Draw weight @ 0.25 m	Draw weight @ 0.45 m	Maximum draw weight
113300	1411	22	19	N/A	N/A	N/A
Idealised	1370	15	15	7 lb	N/A	N/A
Replica A	1370	16	16	4 lb	N/A	N/A
Replica B	1450	21	20.5	7 lb	9 lb	10 lb

Table 29.7: Dimensions and draw weights of bow and replicas.

Figure 29.7 (page 380): Bow <113300> alongside cross sections through bow and cross section of bow within pole (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 29.8 (page 381): Flexing the bow during its production to test its strength. Note the quantity of woodworking debris produced (Copyright Aimée Little, CC BY-NC 4.0).

Figure 29.9 (below): Bowfishing using a replica bow and hafted antler barbed point (Copyright Aimée Little, CC BY-NC 4.0).

Although relatively small for a bow, <113300> lies within the size range of published Mesolithic and Neolithic Bows (Bamforth et. al. forthcoming). Other finds from the site provide further evidence for archery, including flint and a stone tool that may have been an arrow burnisher (Chapters 34 and 35). No arrows or possible arrow shafts were identified from the wood assemblage. The absence of arrow shafts in the archaeological record at Gwisho was also noted (Fagan and van Noten 1966, 151) and here Fagan suggests that reeds from the adjacent reed beds may have been used as arrow shafts given that the arrowheads are light and made of wood.

Decorated item

Only one wooden item from the excavations shows traces of possible decoration. Woodchip <98042> was recovered from context (312) in the brushwood. It is a parallel-sided willow woodchip, measuring 85 × 25 × 7 mm (Figure 29.10 and 29.11). It is probably radially aligned but the wood is very fine grained making it hard to assess. It is heavily charred on one face and one edge, which again obscures the grain. The charring has dried out the wood so that it has distorted and is concave in two planes. There are several straight grooves criss-crossing the uncharred face. The profile of the grooves is not symmetrical. One side is cut straight with quite a sharp edge but the wood is slightly 'feathered' on the other side. Where the lines begin (or end) there is a slightly bulbous depression. It has not been possible to ascertain how these marks were made and whether they represent deliberate working.

Digging sticks

The first digging stick encountered was a complete dowel example excavated in 2010 <92465> (Figure 29.12). At first it was clear that it was an artefact but its function was less clear. The definitive identification of this item as a digging stick was made by Brian Fagan who saw it whilst it was being recorded and drawn. He also supplied a reference for closely similar objects which he had excavated in Africa (Fagan and van Noten 1966).

Using the complete digging stick <92465> for comparison, seven other pieces were identified as parts of possible digging sticks (Table 29.8; Figures 29.13 and 29.14). Four of the items are radial dowels and four are roundwood, generally with a natural, spherical 'handle' section.

Figure 29.10: Photograph of decorated woodchip <98042> (Copyright Michael Bamforth, CC BY-NC 4.0).
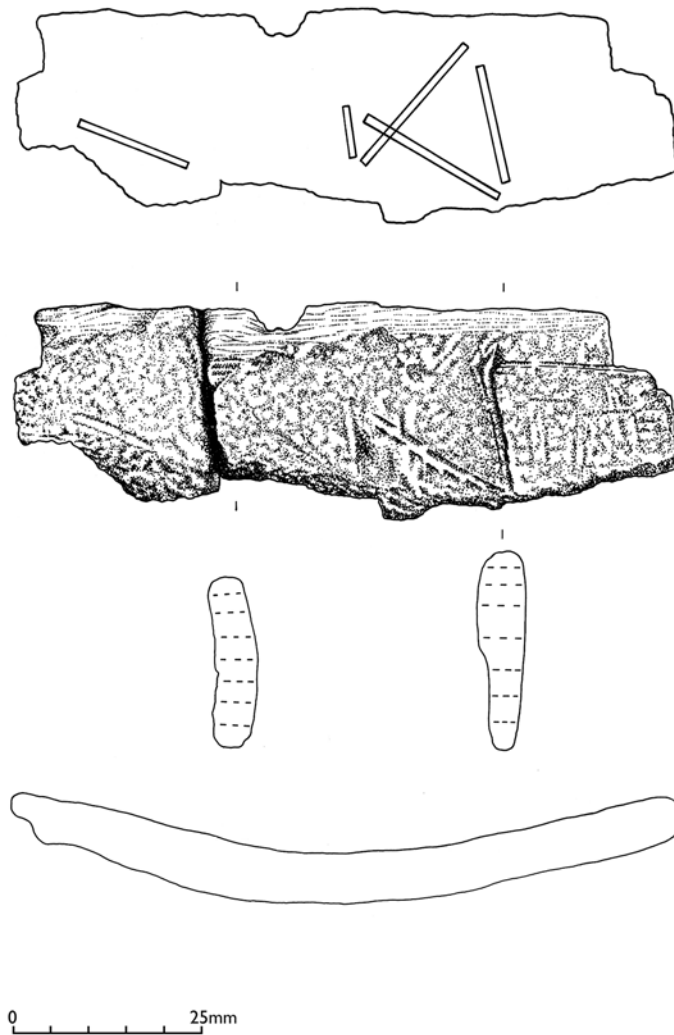
Figure 29.11: Illustration of decorated woodchip <98042> (Copyright Chloe Watson, CC BY-NC 4.0).

Two digging sticks were recovered from the brushwood, five from Clark's area and one from other areas. It is interesting to note that none were recovered from any of the three lake edge platforms or from the detrital wood scatter.

<92465> (Figure 29.13): This is a complete digging stick, 1100 mm long and made from a well-carved dowel measuring 15/28 mm, worked down from a quarter split log of willow. One end gradually flattens from one side, and this flattened end is rounded. The other end has been carved into a roughly spherical knob. The grain of the knob or handle is slightly gnarled suggesting that it comes either from near the base of a tree trunk or from the bottom end of a coppiced stem. It is so well made that it was only after a cross-section was examined that it became apparent that it is a dowel and not roundwood.

This artefact was replicated using experimental archaeology in order to test whether it functioned as a digging stick. It was fashioned from a 1 m section of 'green' birch tree trunk with a diameter of 130 mm (this round of experimental work was carried out prior to the taxonomic identification of the wooden artefacts: the

Figure 29.12 (page 385): Digging stick <92465> (foreground) tip to tip with bow <92684>/<113300> (extending into baulk) (Copyright Star Carr Project, CC BY-NC 4.0).

Number	Context	Area	Type	Conversion	Description	Identification
92465	312	Clark's area	dowel	rad	Complete, used end is flattened and rounded, gnarled spherical handle	willow
94034	312	brushwood	utilised roundwood	none	Possible unfinished digging stick formed from coppice stem with gnarled heel	willow
98032	317	brushwood	dowel	rad	Flattened tip of possible digging stick, with notches	aspen
113765	312	other	dowel	rad	Pointed, sub oval dowel. Possible digging stick or haft / handle	willow
116053	312	Clark's area	dowel	rad / tan	Broken dowel. Pointed at one end. Possible tip of digging stick	alder
116640	312	Clark's area	utilised roundwood	none	Gnarled spherical end. Broken in antiquity. Possible handle of digging stick	alder buckthorn
117152	312	Clark's area	utilised roundwood	none	Spherical end. Broken in antiquity. Possible handle of digging stick	alder buckthorn
117165	312	Clark's area	utilised roundwood	none	Roundwood with spherical end. Possible rough-out for digging stick	willow

Table 29.8: Material interpreted as digging sticks (rad = radial, tan = tangential).

digging stick was subsequently identified as willow). The log was split with unseasoned wooden wedges and a wooden mallet into two radial half splits, one of which was further reduced into two radial quarter splits. A radial quarter split was used to produce the digging stick. The artefacts were trimmed and hewn into shape using flint tranchet axes hafted as adzes in willow, dowel hafts.

A replica digging stick was produced by a non-skilled wood worker (MB) and took two hours with a flint adze to produce. The item was partially finished using a flint flake for 30 minutes. The item was not brought to a high level of finish due to time constraints. In total, about 2.5 hours of work were taken to convert a radial quarter split into a functional, but poorly finished, digging stick. The completed digging stick was successfully used to a dig a hole some 0.5 m in diameter by 0.4 m deep, which took one hour (Figure 29.15). It was noted that whilst the digging stick was efficient when used for the primary task of digging, it broke easily when used to 'lever' an intrusive root in the hole.

<094034> (Figure 29.14): This is a possible unfinished digging stick. It is a coppiced willow stem with a gnarled, bulbous end which is part of the coppice stool. It is 621 mm long with a diameter of 19/36 mm. The tip is missing. The bulbous end strongly resembles the handle of the known digging sticks before completion of carving. Although several of the other pieces identified as whole or partial digging sticks are dowels, it should not be assumed that all digging sticks are dowels. Digging sticks made of roundwood would have been more flexible and could have been used differently. It may be significant in this context that the roundwood is a little more heavyweight than the dowels.

<098032> (Figure 29.14): This is a dowel, made from a radially split piece of aspen which has been further modified. The section is rounded but flattened with a rounded end. It measures $102 \times 20 \times 15$ mm. Although only a short length survives, this piece is closely similar to the flattened end of the complete digging stick <92465>. Only the 102 mm nearest the tips can be used for comparison, but at this point the dimensions are closely similar. Along one edge are a series of parallel notches. There may have been one 40 mm from the tip but the piece is broken at this point, the grain is crumpled and therefore it is impossible to be sure. The two definite notches are 65 and

Figure 29.13 (page 387): Digging sticks (Copyright Chloe Watson, CC BY-NC 4.0).
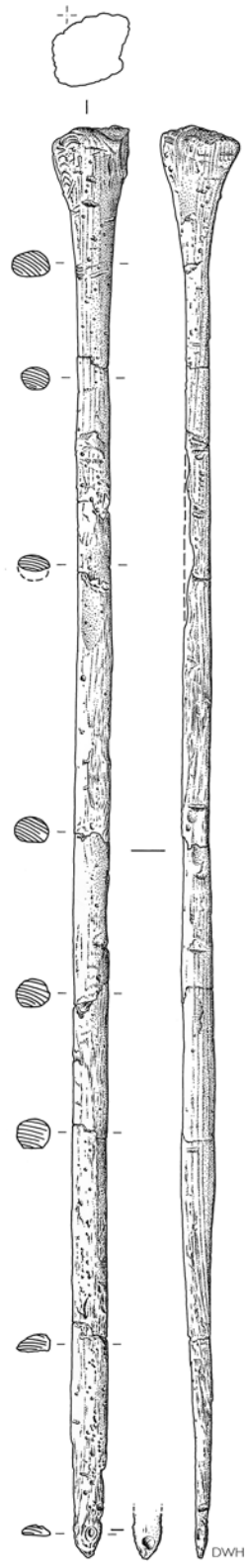
92465

117165

0   100mm
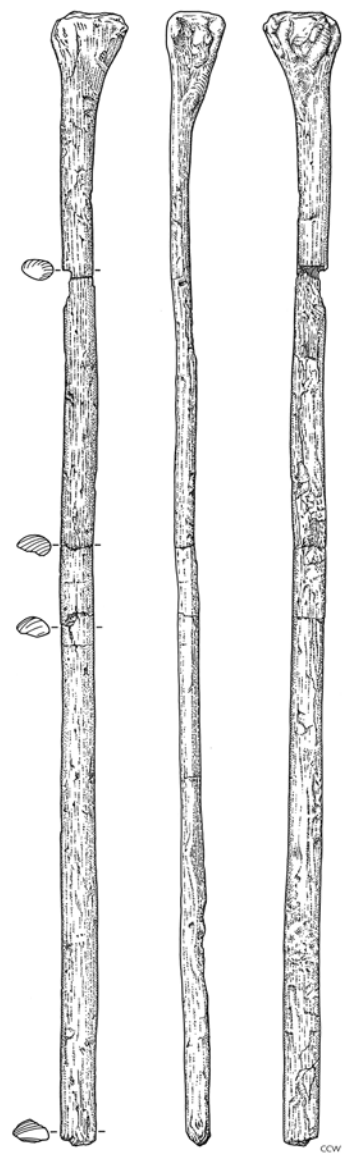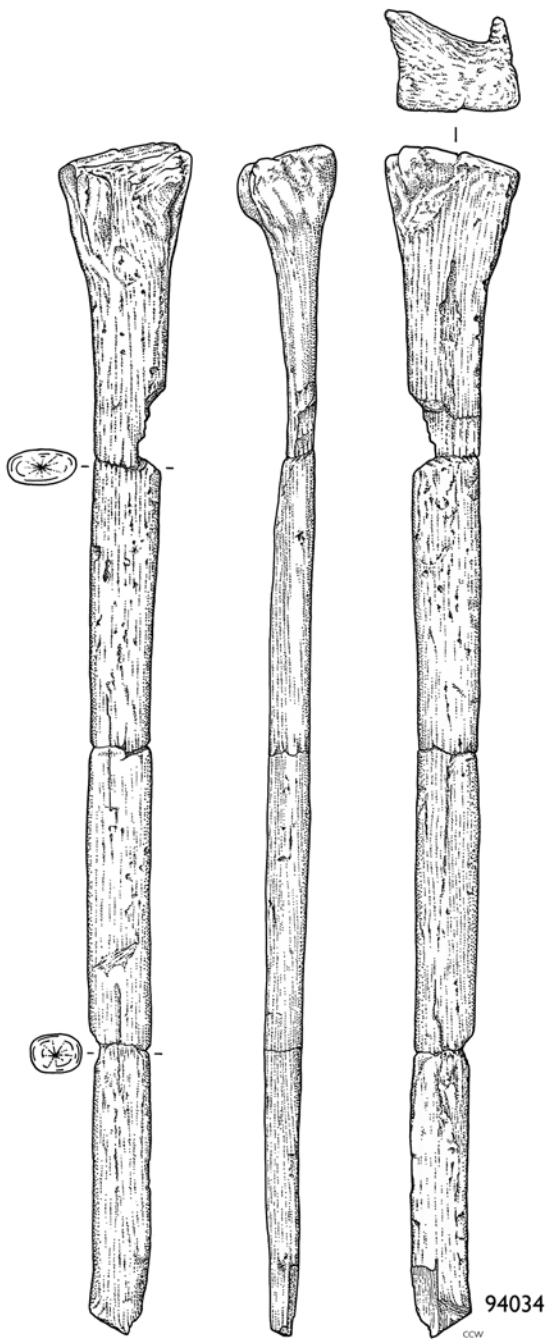
Digging sticks

98032

94034
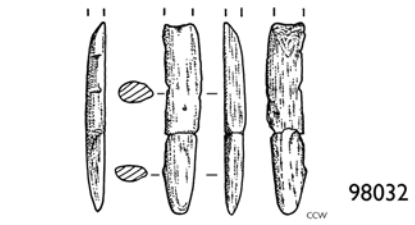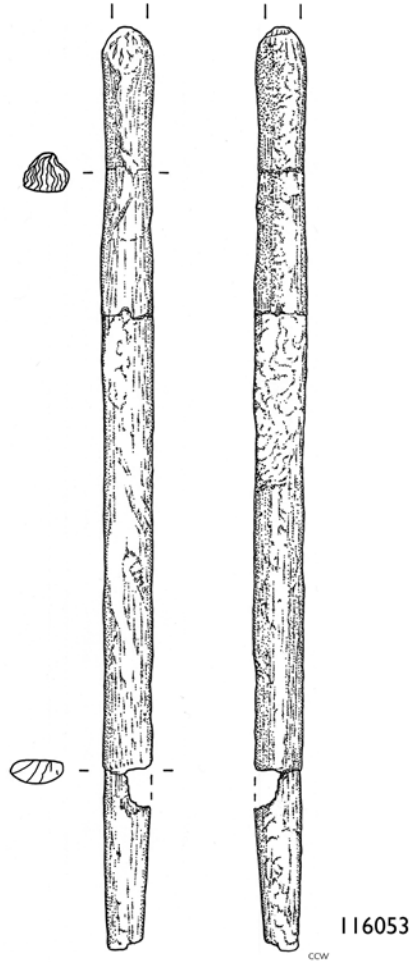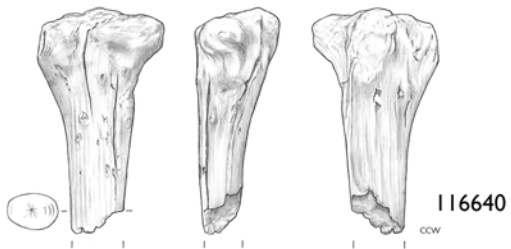
116053

116640
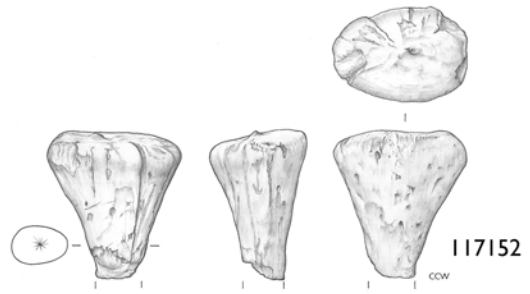
117152

Digging sticks

0   50mm

Figure 29.16: Photo of possible digging stick or haft or handle <113765> (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 29.17: Possible dowel digging stick <116053> in situ (Copyright Star Carr Project, CC BY-NC 4.0).

85 mm from the tip. They are 7 and 9 mm long, respectively, and approximately 2 mm deep at the centre. The bases of both appear flattish.

<113765> (Figure 29.16 and 29.18b): This is radially split from a piece of willow and carved to a sub-oval dowel. It is 761 mm long with the widest point measuring 26 × 11 mm. The thick end is truncated whilst the other end tapers down to 15 × 8 mm towards the point. There is very slight faceting towards the 'pencil' point, which is quite slender. There are tiny 'nicks' in the wood towards the point but it is unclear if these relate to

Figure 29.14 (page 388): Digging sticks (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 29.15 (page 389): A replica digging stick was used for one hour to dig a hole (Copyright Aimée Little, CC BY-NC 4.0).

use, taphonomy or excavation damage. This item may represent a digging stick but is also of suitable size to be a haft or handle. In terms of microwear analysis, no wear or manufacture traces were identified, but the cell structure was intact.

<116053> (Figure 29.14 and 29.17): This is a dowel which is broken at one end, probably in antiquity. Some 400 mm survives with the section measuring 25 × 15 mm. One end is radially aligned, thickened and torn, possibly whilst being removed from an alder coppice stool. The tip is tangentially aligned and pointed. In terms of microwear analysis, no wear or manufacture traces were identified, but the cell structure was intact.

<116640> (Figure 29.14): This is roundwood with a compressed diameter of 29 × 20 mm. It has broken in antiquity and 119 mm survives. One end is expanded, gnarled and somewhat spherical. It appears to be the natural shape of a heel end taken from a coppice stool and is included here as its appearance is strikingly similar to the handle of digging stick <092465>. The maximum size of this end is 59 × 39 mm. Species identification indicates that the wood is alder buckthorn, which is not usually coppiced, although it is a shrub that naturally produces straight stems. Although it is basically a natural shape, it has almost certainly been modified and worn.

<117152> (Figure 29.14): This is roundwood with a compressed diameter of 29 × 18 mm. It has broken in antiquity and 82 mm survives. One end is expanded, gnarled and somewhat spherical. The spherical end has been carved flat and has a chamfered edge. At its maximum it measures 71 × 50 mm. It is included here as its appearance is strikingly similar to the handle of digging stick <092465>. Although it is a natural shape, it shows clear signs of modification and use.

<117165> (Figure 29.13): This is willow roundwood, some 845 mm long. One end terminates in a naturally expanded spherical 'handle' which may have been worked and the other end is broken, possibly in antiquity. It was also broken into two slightly dislocated refitting sections in antiquity. At its maximum the spherical end measures 55 × 40 mm. It tapers down to roundwood with a flattened diameter of 27 × 15 mm. It is included here due to its similarity of form to the complete digging stick and perhaps represents an unfinished rough-out.

Hafts and handles

Hafts or handles are difficult to identify as no hafted tools were found and there are few comparanda. The majority of hafts and handles known from the archaeological and historic record, right through to the present day, are generally heartwood dowels. This is to take advantage of the increased strength of this form over simple unconverted roundwood. Based on their size and form, four of the dowels are classified as possible hafts or handles (Table 29.9; Figure 29.18). All are radially aligned dowels. Two were recovered from Clark's area, one from the detrital wood scatter and one from later deposits located above the detrital wood scatter.

Number	Context	Area	Type	Conversion	Description	Identification
110105	317	detrital wood scatter	dowel	rad	Sub-rectangular dowel, heavily damaged	aspen
113765	312	other	dowel	rad	Pointed, sub oval dowel. Possible digging stick or haft / handle	willow
115338	312	Clark's area	dowel	rad	Sub-oval dowel, one end pointed, one end broken	alder
115752	312	Clark's area	dowel	rad	Sub-oval dowel, one end torn, one end truncated	willow

Table 29.9: Material interpreted as possible hafts or handles (rad = radial).

0   50mm
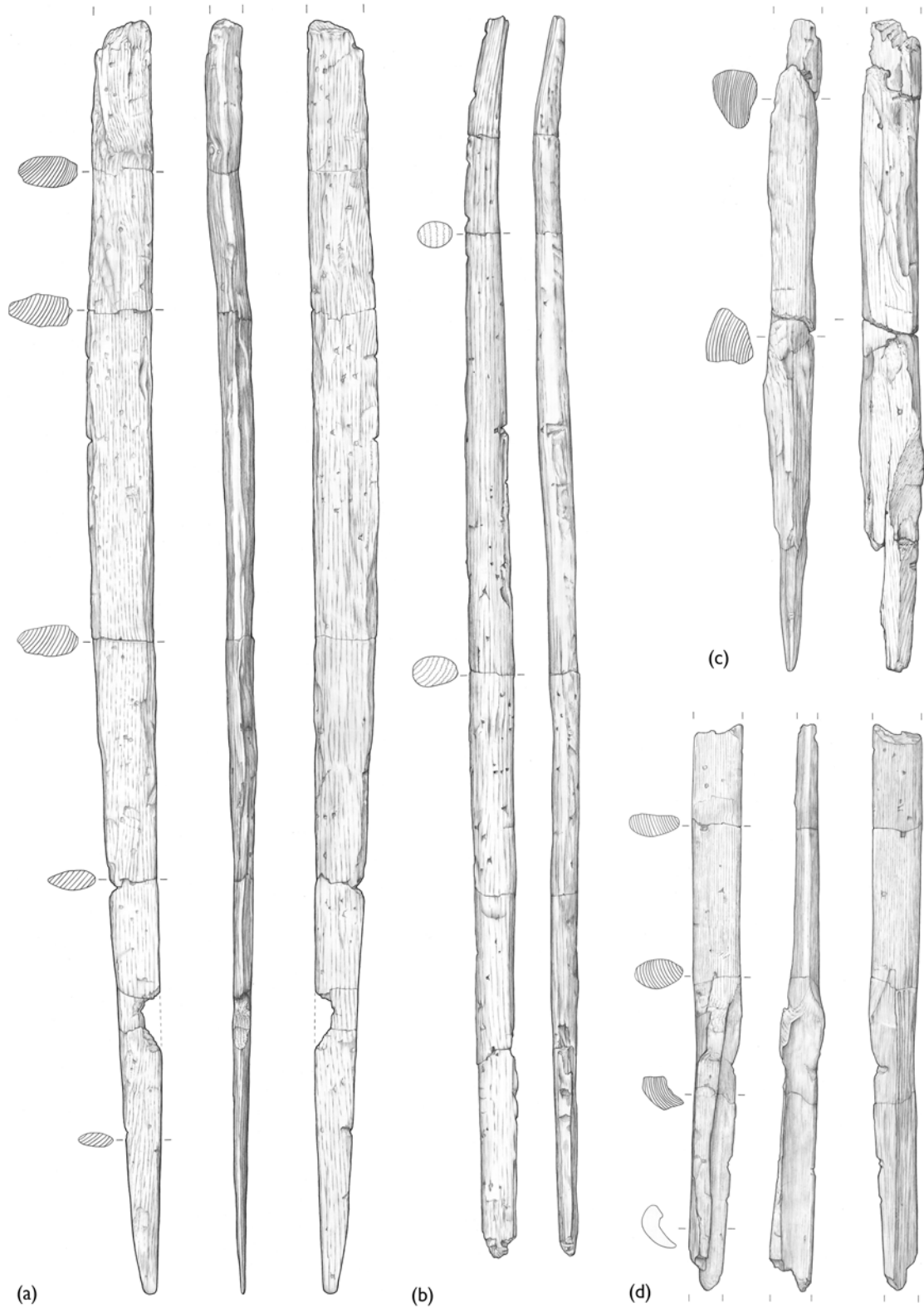
Hafts and handles
(a) 115338 (b) 113765 (c) 110105 (d) 115752

<110105> (Figure 29.18c): This is a short length of sub-rectangular dowel which could possibly be part of a haft or handle. One end extended into the baulk and so the two halves had to be excavated separately. The total length is 423 mm and the measurements along its length were consistently around 34 mm wide, with the thickness only varying between 30 and 24 mm. The wood is straight-grained and slow-grown, with even growth rings about 1.5 mm wide. Analysis was difficult due to the damage where the piece broke in the section, together with other scraping and crushing. It was probably originally radially split from an aspen timber and then carved into a sub-rectangular dowel.

<113765> (Figure 29.18b): This is radially split from a willow timber and carved to a sub-oval dowel. It is 761 mm long with the widest point measuring 26 × 11 mm. The thick end is truncated whilst the other end tapers down to 15 × 8 mm towards the point. There is very slight faceting towards the 'pencil' point which is quite slender. There are tiny 'nicks' in the wood towards the point but it is unclear if these relate to use, taphonomy or excavation damage. This item is a suitable size to be a haft or handle but may also represent part of a digging stick.

<115338> (Figures 29.18a and 29.19): This is a radially aligned sub-oval dowel with one end broken (probably in antiquity) and one end pointed and flattened. It is 755 mm long. The section is 23 × 9 mm above the tip, thickening to 40 × 17 mm before tapering to 33 × 17 mm at the broken end. The dowel has been taken from near the outside of an alder log. In terms of microwear, no wear or manufacture traces were identified but the cell structure was intact.

<115752> (Figure 29.18d): This is a radially aligned sub-oval dowel from willow, with an ancient tear down one side. One end was truncated by Clark's excavation and the other, torn end is an ancient break. The surviving length is 330 mm long and the section is 28 × 15 mm.

Figure 29.19: Haft or handle <115338> in situ (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 29.18 (page 392): Hafts and handles (Copyright Chloe Watson, CC BY-NC 4.0).

Other dowels

There are six dowels of unknown function (Table 29.10; Figure 29.20), with two of each recovered from the detrital wood scatter, Clark's area and other.

<110544> (Figure 29.20b): This is a rough aspen dowel with both ends broken. The surviving length is 265 mm and the width and thickness vary along its length from 25–21 mm and from 21–17 mm. This item appears unfinished. No original function is suggested for this item.

<113250> (Figure 29.20d): This is a sub-rectangular dowel with at least two faces that appear well-finished. One face was badly damaged during excavation. Where the two well-finished faces meet, the join is rounded and also well-finished. It is 126 mm long and the section measures 12 × 10 mm. It was originally a radial quarter split, probably taken from a piece of willow roundwood. No original function is suggested for this item.

<113287> (Figure 29.20e): This is a curved radially split rough dowel, with one end pointed and the other broken. Both the upper surface and the point were damaged during excavation. It is 103 mm long, 11 mm wide and 5 mm thick. There is some gentle faceting and grooves on the surface. It is unclear if these represent deliberate working or taphonomic processes. The piece is a quarter split, taken from a small piece of willow roundwood, which only just misses the pith. It is curved and was shaped from two sides, although it is hard to tell how much of the curvature is original and how much post-depositional. Although it is of unknown function, its form leads to the tentative suggestion that it may have been used to pierce some kind of soft material, or perhaps used as a needle-like device.

The entire surface of <113287> was analysed with low and high power magnification. This object displays three depressions along one edge (L2, L3, L4). One of these (L2) appears to have been cut intentionally as the cut goes against the grain. The other two depressions (L3 & L4) have no clear cut mark; instead they display a more textured 'mashed up' surface. L3 has possible medullary rays visible; this may be working or wear which has led to a 'bottoming out'. The tip has been formed by working in the same direction (towards the point) from both edges.

<113768> (Figure 29.20c): This is a radially aligned dowel taken from a piece of willow roundwood. It has a slight curve and a worn or utilised point. It is 229 mm long and 9 × 5 mm in section. Although one end is degraded and there was some damage during excavation, it is possible to see that it has been thinned down to a point by the removal of a narrow parallel sided strip from one side. The wood is noticeably fine and dense compared to other items in the assemblage. Like <113287> this is also of unknown function, though it too may have been used to pierce some kind of soft material or used as a needle-like device.

Number	Context	Area	Conversion	Description	Identification	Function
110544	320	detrital wood scatter	rad / tan	Rough, unfinished dowel	aspen	
113250	317	detrital wood scatter	rad 1/4	Sub-rectangular dowel with one rounded corner	willow	
113287	312	Clark's area	rad 1/4	Rough dowel with pointed, possibly utilised, end	willow	?piercer
113768	317	other	rad	Dowel with worn or utilised end	willow	?piercer
113778	312	other	rad	Slender, sub-rectangular item with pointed end	alder	
116655	312	Clark's area	rad	Sub-oval with trimmed end	aspen	

Table 29.10: Material interpreted as other dowels.

Figure 29.20 (page 395): Other dowels (Copyright Chloe Watson, CC BY-NC 4.0).
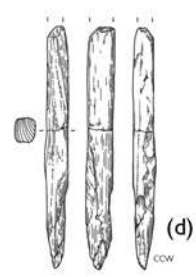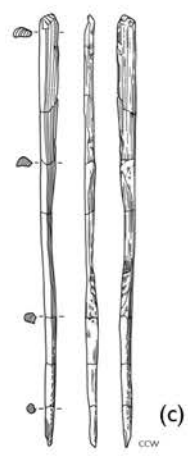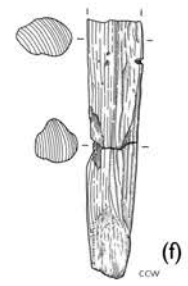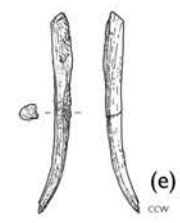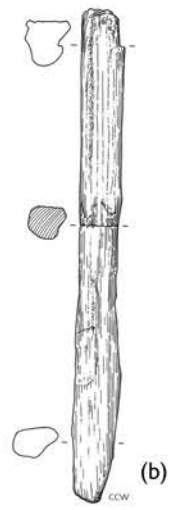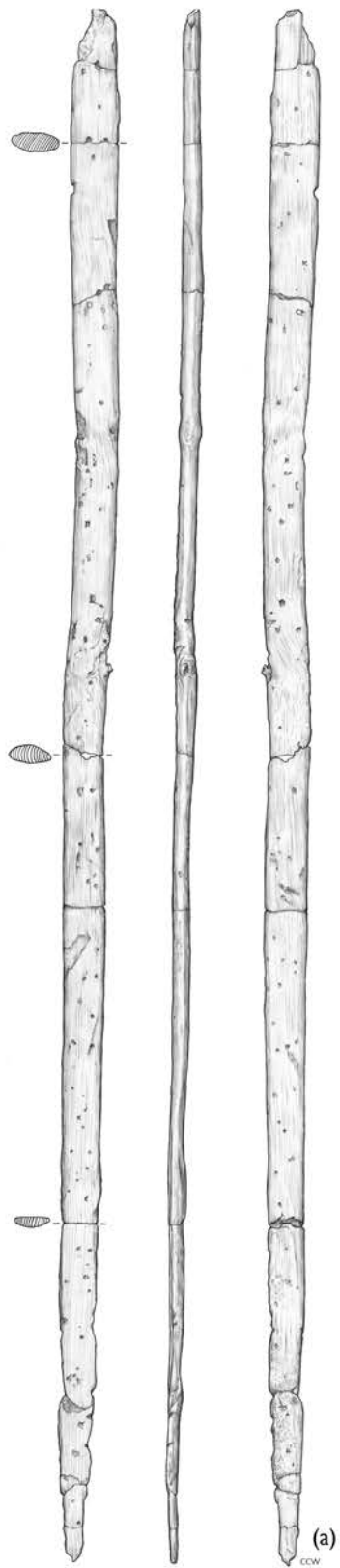
Dowels

0 _____ 50mm   (a) 113778 (b) 110544 (c) 113768 (d)113250 (e) 113287 (f) 116655

This was analysed in its entirety with low and high-power magnification. No manufacture or wear traces were identified. The cell structure was still intact. Some very bright PDSM (post-depositional surface modification spots) were noted. The very end of the tip had been broken in antiquity, possibly through use.

<113778> (Figure 29.20a and 29.21): This is a slender, sub-rectangular, radially split dowel of alder with one end badly degraded and the other end pointed and possibly utilised. There is excavation damage along its length. The dowel measures 855 mm long and the section is 25 × 10 mm. No original function is suggested for this item. No wear or manufacture traces were identified from microwear analysis but the cell structure was still intact.

<116655> (Figure 29.20f): This is a radially aligned, sub-oval dowel of aspen. One end is broken and the other end has a clear, concave tool facet where it has been trimmed with a single chop. The surviving length is 137 mm and the section measures 19 × 28 mm. No original function is suggested for this item.

Pegs and wedges

A wedge of willow, <116520>, was identified during the excavations. It was recovered from reed peat (312) in Clark's area (Table 29.11). Another piece, also willow, was identified as a possible peg or wedge <103149> and was recovered from reed peat (312) in the detrital wood scatter (Figure 29.22).

<103149> (Figure 29.22): This is the buckled tip of a peg or wedge measuring 148 × 22 × 18 mm. It is split across the grain and buckled at one end through use.

<116520> (Figure 29.22): This is a piece of woodworking debris which has been tangentially split out of a larger timber. It is 164 mm long with a triangular cross section and the split fades to a wedge shape. The thicker end measures 40 × 29 mm and has been chopped almost flat with a cut across the grain. There are slight signs of 'bruising' on the surface of this end, implying that the piece has been hammered. The thin end of the wedge is

Number	Context	Area	Type	Conversion	Description	Identification
103149	312	detrital wood scatter	utilised debris	cross grain	Debris with buckled tip	willow
116520	312	Clark's area	utilised debris	tangential	Wedge with bruising to top	willow

Table 29.11: Material interpreted as pegs and wedges.

Figure 29.21: Dowel <113778> in situ (Copyright Star Carr Project, CC BY-NC 4.0).
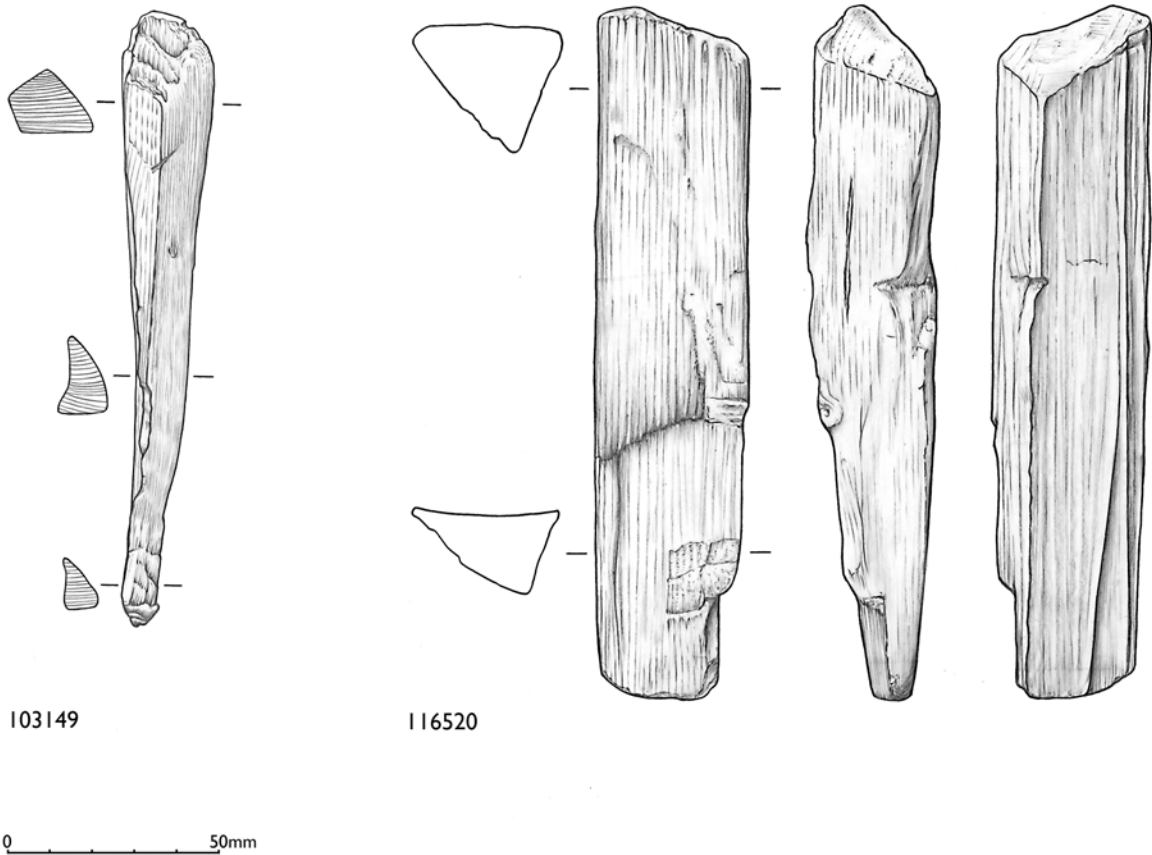
Figure 29.22: Pegs and wedges (Copyright Chloe Watson, CC BY-NC 4.0).

Number	Context	Area	Description	Identification
109586	317	detrital wood scatter	Light faceting along length, one end rounded, one square, small spherical hole	aspen
115952	312	Clark's area	Item with hole, worn face and broken end	willow

Table 29.12: Material interpreted as roundwood with holes.

29 mm wide and 2 mm thick. The piece is slightly buckled along most of its length, including the thin end where the grain is distinctly distorted. Given the item's shape and the bruising to the top, it seems highly likely that this item has been used as a wedge to split wood.

Roundwood with holes

Only two pieces of wood with deliberate, anthropogenic holes were encountered during the excavations. Both are roundwood and were recovered from the detrital wood scatter and Clark's area (Table 29.12; Figure 29.23).

<109586> (Figure 29.23): This is aspen roundwood measuring 172 mm long with a compressed diameter of 12/20 mm. It has been crushed in the middle during excavation. There is slight faceting on the ends and along its length. One end is rounded and the other square. There is a small spherical hole that does not pass all the way through the object, on what was the underside, towards one end. No original function is suggested for this item. No wear or manufacture traces were identified from microwear analysis but the cell structure was intact.

115952

0 _____ 50mm

109586

0 _____ 50mm
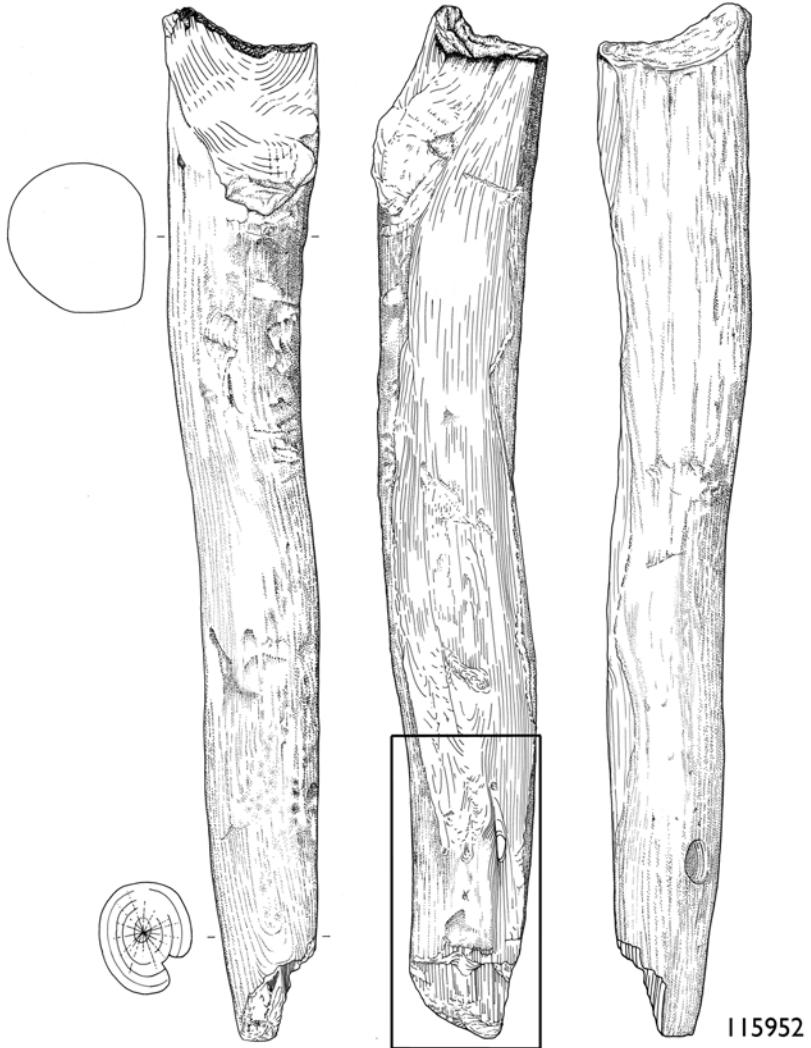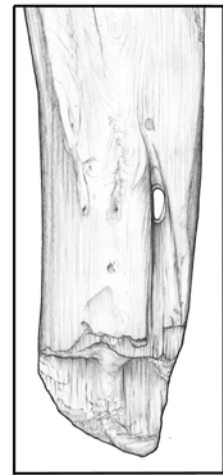
Enlarged drawing of
hole within central
elevation
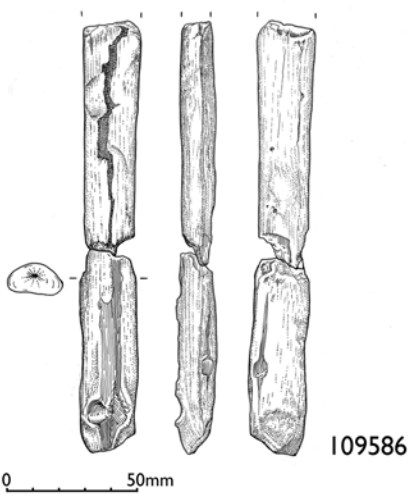
Figure 29.24: Roundwood with hole <115952> (Copyright Michael Bamforth, CC BY-NC 4.0).

Number	Context	Area	Type	Conversion	Description	Identification
098878	317	western platform	utilised debris	rad 1/4 / tan outer	Side branch that has been torn from a tree	willow
107784	317	detrital wood scatter	utilised roundwood	none	Trimmed at base and charred at top	willow
110020	312	western platform	utilised debris	rad	Split and trimmed to point	aspen
116654	312	Clark's area	utilised roundwood	none	Possibly trimmed to point	aspen
116678	312	Clark's area	utilised roundwood	none	Trimmed at both ends, striations	willow

Table 29.13: Material interpreted as stakes (rad = radial, tan = tangential).

<115952> (Figures 29.23 and 29.24): This is heavily shaped and partially charred willow roundwood with a hole in one end. It is one of the few pieces which could have been jointed. A joint is simply a means of articulation with another component to make a structure or more complex artefact. This piece is 398 mm long with the section measuring 62 × 59 mm maximum and 43 × 37 mm minimum. It is naturally curved, suggesting it originated as a coppice stem. One end is trimmed and lightly charred. The other was broken in antiquity and has a hole 10 × 4.5 mm which passes through the grain at an angle, emerging onto a surface which is flattened and appears worn. On this side the hole measures 12 × 4 mm. The wood is torn from the hole to the broken end and a parallel-sided piece is missing. This damage suggests that the hole was drilled or cut from the upper side, tearing this piece and pushing it away from the surface. There is no sign of the classic 'hour-glass' shape which indicates drilling from two sides and the wood is not well enough preserved to show internal working or wear. Given the hole and the wear to one face, it is tentatively suggested that this item may have formed one half of a wooden frame.

Stakes

The rarity of vertically set stakes at Star Carr has led to their categorisation as artefacts. Five vertically set pieces, all interpreted as stakes, were recorded from around the site (Table 29.13; Figure 29.25). The tops of two of the stakes had totally decayed. Of the five stakes, three are roundwood and two are utilised debris. One was recovered from the detrital wood scatter, two from the western platform and two from Clark's area.

Figure 29.23 (page 398): Roundwood with holes (Copyright Chloe Watson, CC BY-NC 4.0).
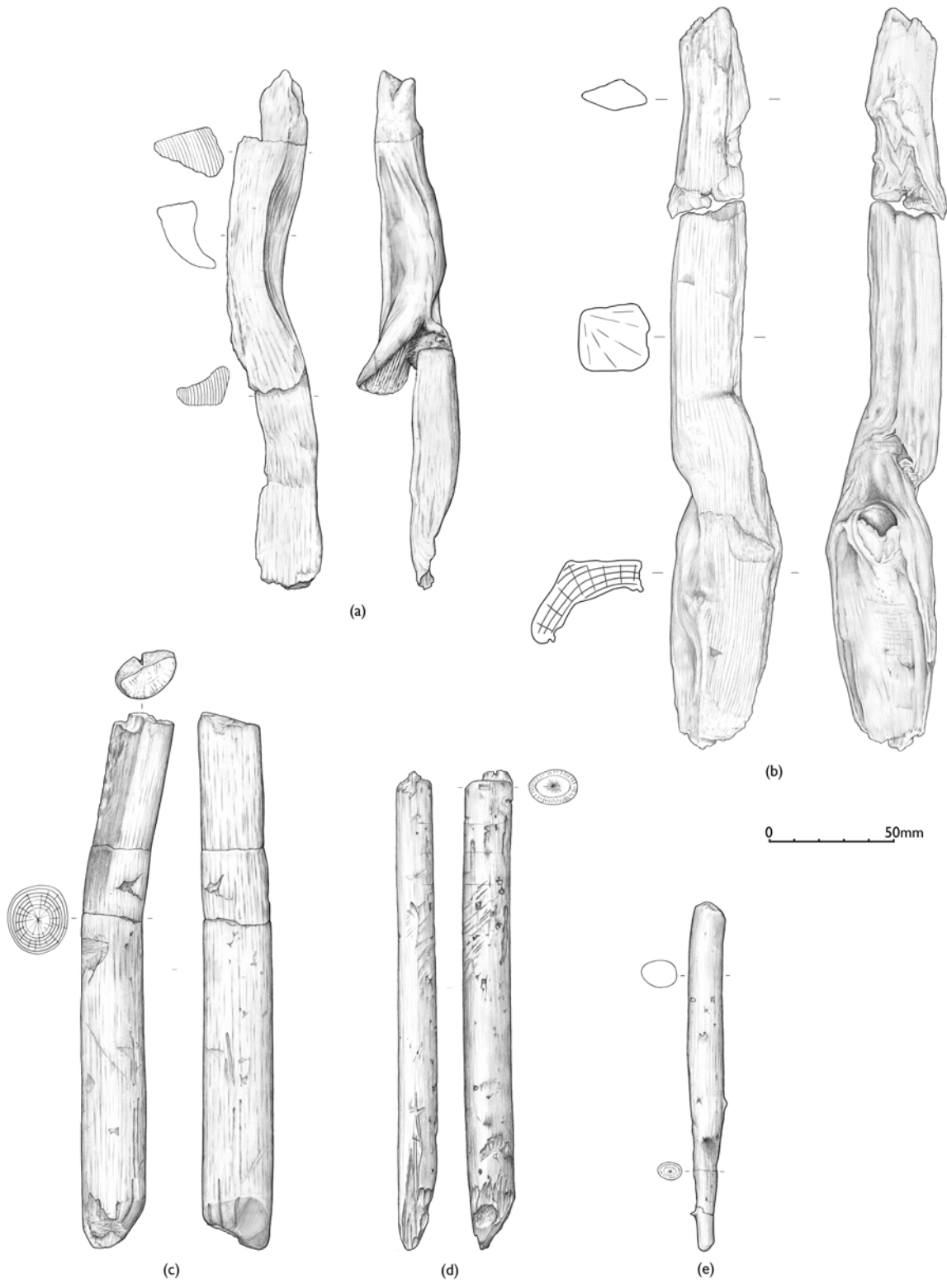
(a) 110020 (b) 98878 (c) 107784 (d) 116678 (e) 116654

<98878> (Figure 29.25b): This is a piece of modified and utilised debris 470 mm long. The top section is a radially quarter split side branch of willow that measures 35 × 40 mm. The side branch has been torn from the tree and the tear carries through to form the point. At this point it measures 21 × 51 mm. The top is damaged, possibly by hammering and the tip was damaged when it hit a stone.

<107784> (Figure 29.25c): This is willow roundwood which is worked at both ends, indicating that it is complete with a total length of 325 mm and maximum diameter of 45 mm. The tip is trimmed bluntly from several directions. The top end is charred but it features a sharp 'step', which may be a horizontal chop.

<110020> (Figure 29.25a): This is a piece of radially split aspen timber debris found set vertically. It is 313 mm long with a maximum breadth of 52 mm and width of 31 mm. The tip is trimmed in one direction, possibly utilising a split surface which fades towards the end. It has been damaged by vertical compression so that it has broken in two. The top end has deteriorated.

<116654> (Figure 29.25e): This is a short length of aspen roundwood 185 mm long. The diameter is slightly distorted at 16/19 mm. One end is pointed and possibly shows light faceting. The other end is degraded.

<116678> (Figure 29.25d): This is another piece of roundwood which appears to have both ends intact, showing that it was 284 mm long. It is a straight piece of willow roundwood, with no side branches and a slight curve at one end, which suggests it could have been a coppice stem. The top looks as if it may originally have been chopped and torn but the tear has been truncated close to the end. There is slight faceting where the tip has been trimmed. There are also small diagonal striations near the top, which could be from taphonomic processes, wear or use, but which look almost as if something had been wrapped tightly around it.

Vessels and containers

Two pieces, <115316> and <115317>, possessed the characteristics of a carved vessel or container (Figure 29.26 and 29.27). It was not clear at first whether they represented two different vessels or whether they were two parts of the same vessel which had become separated in the ground: they were found 2 m apart in reed peat (312) in Clark's area. However, they are now thought to be parts of the same artefact, a platter modified from a naturally shaped piece of willow.

   Unfortunately, the pieces had been damaged in antiquity and then further damaged by roots and during excavation. The end of the 'dish' <115317> was broken in antiquity. The end of the handle, a dowel worked down from a radial quarter split, is also broken, probably in antiquity. It is difficult to measure accurately because of the damage and because part of it is missing. The total length is approximately 500 mm and it is 235 mm across at the widest point. The thickness of the wood varies but is generally around 25 mm. The 'dish' is approximately 50 mm deep and there is possible charring on the handle, which is 40 mm wide.

   Although it is definitely carved and modified, it is probably based on a natural shape, which has been carved to exaggerate the existing form. Such natural curvature can be found around a knot, where the increasing circumference of a tree grows over a side branch, or some natural damage. The branch may already be dead, but if not, it simply continues growing, but at a different rate to the trunk. Tension wood forms on the upper side, and reaction wood on the lower. This process would produce the distinctive lenticular shape seen in the vessel and the bulge which is the 'bowl'. If the side branch was dead when the process began, it would form a classic 'knot' which would be a weakness. There is no sign of a knot in this piece. If the side branch continued to grow, even if only for a while, it would be less weak and easier to shape. The growth of trees could be manipulated to produce wood of useful shapes (see Figure 29.28).

Figure 29.25 (page 400): Stakes (Copyright Chloe Watson, CC BY-NC 4.0).

Figure 29.26: Platter <115317> in situ (note that the piece of wood next to the platter was a piece of debris that was not part of the platter) (Copyright Star Carr Project, CC BY-NC 4.0).

Withies

Only one withy <94048> was found, but it had been carefully made from two twisted and plied coppice stems of willow (Figure 29.29). It was recovered from reed peat (312) in the brushwood. It is formed out of two strands of small-diameter roundwood and one of the stems still had the heel of a coppice attached. Both pieces have slightly compressed diameters: 15/5 mm and 10/5 mm. They are respectively 222 mm and 291 mm long. Both stems have been twisted in an anticlockwise direction. They then cross each other in a way which suggests that they may subsequently have been plied in a clockwise direction. However, the twisting of the individual stems to increase flexibility weakened the fibres and added to the level of degradation, making it very frail when excavated. It was recorded and illustrated in the ground (by Hayley Saul) and did not survive lifting.

This technique of twisting stems in one direction (in this case an 'S' twist) before plying them together in the opposite ('Z') direction has been recorded elsewhere, but much later in prehistory (Brennand and Taylor 2003). The presence of the coppice heel here may also be of significance, as it is needed to hold the stems securely during twisting: the simplest way to do this is to stand on the enlarged end (Brennand and Taylor 2003, 30). This is an extremely early example of a withy made using the same technique that was later employed for making rope.

Figure 29.27 (page 403): Platter <115316-7> (Copyright Chloe Watson, CC BY-NC 4.0).

115317

115316

a

b

0   100mm

Annual growth

Annual growth completely encases a dead or decaying side branch with reaction wood

Cut

The large knot is detached from the drying wood

A negative impression of the side branch within the off-cut forms a dished shape

LIVING TREE ···➤ FELLED or DEAD TREE   RECONSTRUCTION
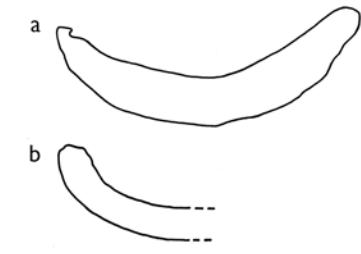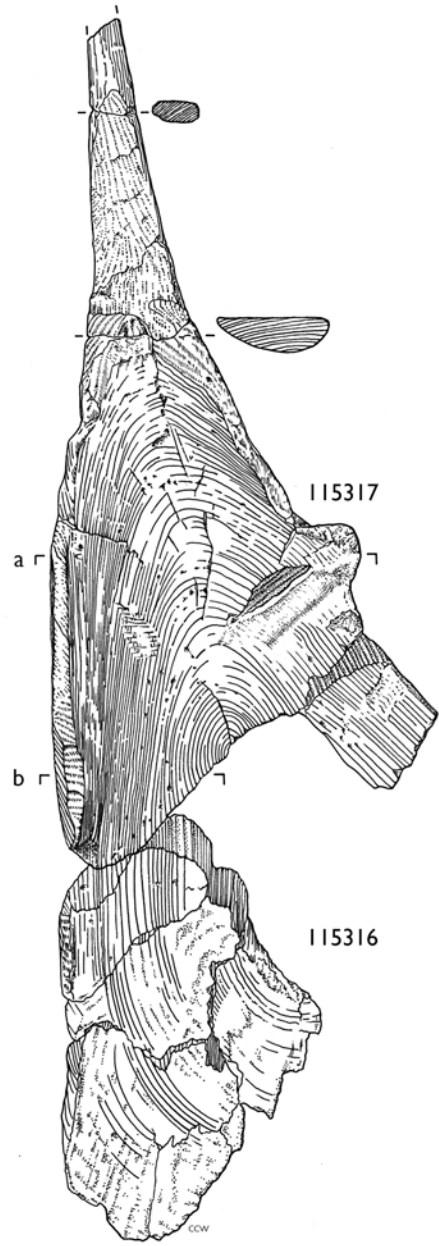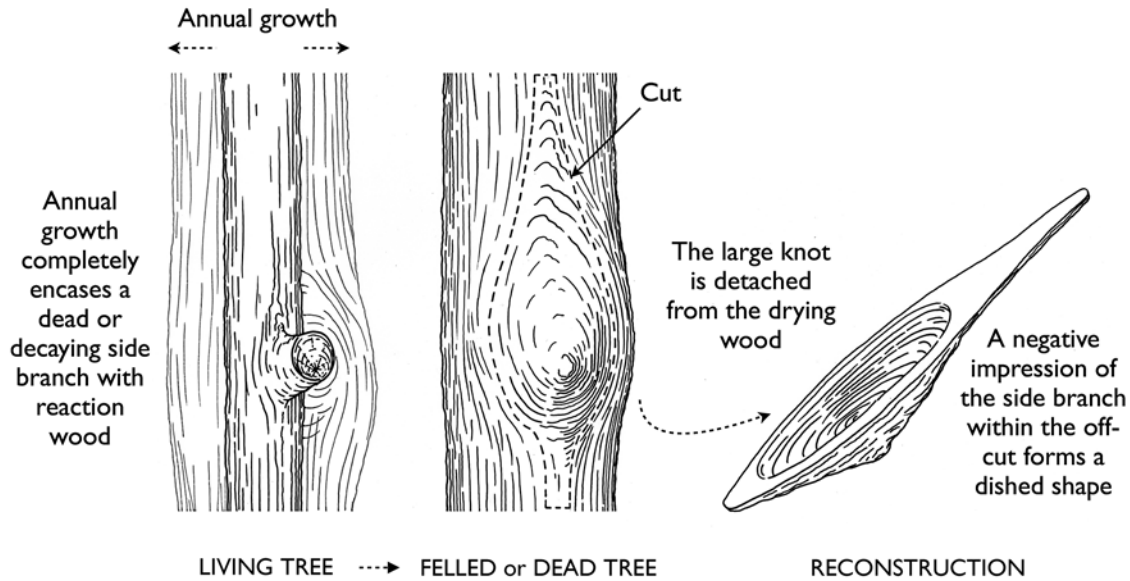
Figure 29.28: Origins of platter <115316-7> (Copyright Chloe Watson, CC BY-NC 4.0).

Examination of Clark's artefacts

In addition, the paddle and carbonised wood associated with the antler mattock head were examined by MT at the Museum of Archaeology and Ethnology at Downing Street in Cambridge.

The 'mattock handle' (Accession no. 1953.68.4) is a heavily carbonised piece of roundwood and although the wood has opened up along the medullary rays it has survived reasonably well. This effect may have been caused by carbonisation or by drying out through time; the effects of both are roughly the same. Splitting along the medullary ray exaggerates the radial structure of the wood, making it easier to identify as simple, unmodified roundwood with a diameter of 12 mm and length of 204 mm (Figure 29.30).

A replica of one of Clark's elk antler mattocks, complete with roundwood haft, was produced by DP in order to test the efficacy of this item as a woodworking tool. It was noted that it functioned efficiently as a woodworking adze even with the relatively weak roundwood haft in place (see Figure 29.30).

However, it should be noted that there are problems with assuming that the piece of roundwood found in Clark's mattock is the original handle. Although roundwood might appear to be the most obvious material for hafts and handles, some of the properties associated with dowels make these more desirable. Certainly it appears that by the Bronze Age, roundwood poles are never used as hafts for items such as spear shafts and only specific species are selected. The reasons for this are functional and the same criteria would have applied in the Mesolithic. Good handles and hafts for tools and weapons will affect efficiency and ease of use. A roundwood pole has bark, sapwood, heartwood and pith. These four components all have different properties. Bark is designed to protect the cambium, which is directly below it, and which is the part of the tree that lays down new wood cells. The cambium and newly created wood (sapwood) is designed to carry sap (nutrients) around the tree. In most species it is soft, flexible and not very durable. The heartwood contains no living cells, is harder, less flexible and more durable than the sapwood. The pith is at the very centre of the tree trunk or branch. It is the point from which the tree begins to grow, with the first growth ring laid concentrically around it. However, a dowel, because it is carved down from a section of a trunk or branch need not, and usually does not, have the same four components. Dowels are usually carved entirely from heartwood, and occasionally sapwood, without bark or pith present.

Figure 29.29 (page 405): Withy <94048> (Illustration by Chloe Watson, after Hayley Saul. Copyright Chloe Watson, CC BY-NC 4.0).
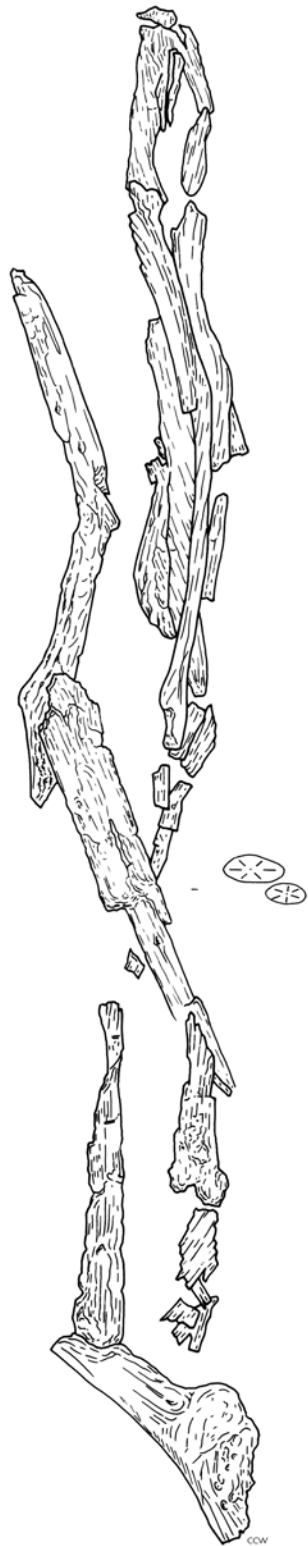
0   25mm

Figure 29.30: (left) Clark's mattock with charred roundwood; (right) a replica elk mattock with a roundwood haft is used to trim a piece of roundwood (Left photograph copyright Nicky Milner, CC BY-NC 4.0, reproduced by the permission of the University of Cambridge Museum of Archaeology & Anthropology. Accession no. 1953.68.4. Right photograph copyright Aimée Little, CC BY-NC 4.0).

If roundwood is to be used as a shaft or spear it will need considerable preparation. First of all it is quite difficult to find totally straight poles, of any size, growing naturally. Even when a species such as willow is coppiced there still tends to be a curve at the bottom end of the stem where it attaches to the tree. The bark would not normally be left on roundwood which is to be utilised. It is often rough and may come off unevenly as the wood dries. The outer surface of roundwood may also have small snags (such as nodes) on the surface which would need to be smoothed. At certain times of the year, the sapwood may be wet and sticky and liable to fungal or insect attack. Although it will be very flexible when fresh, it may quickly become brittle as it dries. When a dowel is fashioned, the removal of the bark and sapwood removes these complications. The surface can then be smoothed and the wood will dry evenly throughout, making it less likely to crack. The behaviour of the material will be more predictable. A dowel may be less flexible than roundwood but when cut from a young pole will still have considerable flexibility and is likely to become brittle less rapidly. It will also retain its shock-absorbing qualities, which are important for the hafts and handles of impact tools, such as axes.

There is one scenario in which a roundwood haft may be a superior choice: an antler mattock head is extremely light and portable, and if carried unhafted, a suitable stick could be rapidly sourced and shaped with a flint flake to provide a temporary haft. However, the main reason for suggesting that this is not a handle is that the wood is carbonized but the elk antler mattock is not. This suggests that the wood was not in place when it was charred and it seems very unlikely that a severely weakened and unstable piece of charred wood would have been used as a haft. It is more likely that it was in the hole in the mattock-head for some other

Figure 29.31: Photograph of the paddle (Copyright Nicky Milner, CC BY-NC 4.0, reproduced by the permission of the University of Cambridge Museum of Archaeology & Anthropology. Accession no. 1995.446).

purpose, or by accident. The oval dowel <110105> described above has a more likely form for the handle of a mattock to take, measuring 34 × 29 mm. Unfortunately, not enough of the length survives to be sure.

The paddle (Accession no. 1995.446) is in very good condition given its age and the length of time it has been in storage. The detail is not now as sharp as it is in the published drawing and photograph, but it is quite clear that the paddle was carved from a tangentially split plank (Figure 29.31). The paddle was identified by Donald Walker as birch (Clark 1954, figure 77, plate xxi). There are traces of a flange surviving along one edge of the paddle blade. Careful examination shows that this is not post-depositional distortion as the curve of the blade crosses the grain of the wood. Its dimensions are L. 422 × 180 × 30 mm. Although it has a slender blade, it may have been used as a paddle, as similar examples are known from around the world. However, there are also examples of paddle-shaped objects known from later British Prehistory that are interpreted as tools for processing plant or animal fibres (Earwood 1993).

Discussion

Tree species and technology

Several different tree species have been used to produce wooden artefacts at Star Carr. The most frequent is willow, with moderate aspen, alder and occasional birch, alder buckthorn and elder (Figure 29.32). The wood from each of these trees has different characteristics. Even the wood of poplar and willow, which are often indistinguishable microscopically, do not share the same characteristics when worked or used. The majority of these species have been identified in the wider wood assemblage, the exception to this being alder, alder buckthorn and elder.

Willow seems to be the favoured wood for working into artefacts at Star Carr (Figure 29.32). Although it shares many of the properties of aspen, it has the advantage of coppicing well and regrowth is rapid. This means that it is possible to generate large amounts of small- to medium-sized pieces of wood of straight grain and good quality. Like aspen, it burns well if completely dry and is nearly smokeless. However, once the wood is dry, it rapidly becomes brittle and snaps easily (Edlin 1973, chapter xvi). The flexibility of the wood when fresh would be a useful property in a tool like a digging stick, but this flexibility would soon be lost.

Aspen trees do not coppice well, as they do not always sucker reliably; however, they do respond quite well to pollarding. The stems from pollarded aspen are not usually as long, straight and even as they are with other trees, such as willow. The fact that it does not coppice reliably probably explains why aspen was generally used in the form of large, unmodified trunks in the Star Carr platform. It is not a good fuel wood and only
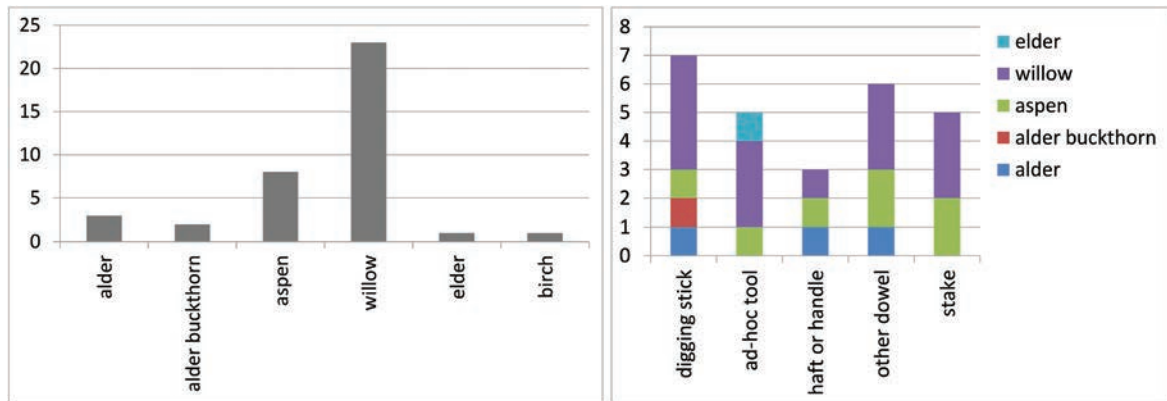
Figure 29.32: (left) Frequency of tree species used to produce wooden artefacts; (right) frequency of wood types used for the main categories of tools (Copyright Star Carr Project, CC BY-NC 4.0).

burns when it is well dried, possibly after a year or more. The wood is very soft and not durable outside, but is surprisingly resistant to wear and splitting. Large trees, which often develop a pronounced curve when growing in windy places, have been used for the timber frame in medieval cruck buildings, such as barns (Brunskill 1985, 28–9). This is an example of exploiting natural shapes and forms in woodworking: the curve of the trunk is very strong. As long as it remains dry, aspen wood will resist rot. A heart-shaped paddle found in Denmark and dated to the early Ertebølle period (in the mid-5th millenium cal BC) was identified as aspen (Myrhøj and Willemoes 1997, 164).

Birch is generally an ornamental tree in modern Britain but it was very important in the past and indeed still is in Scandinavia and Russia. Birch wood occurs in a number of contexts at Star Carr, generally as roundwood but notably the paddle from Clark's excavations is the only wooden artefact made from birch. Birch cannot be coppiced as it does not sucker. It rots quickly when wet but is very strong if kept dry and it is an excellent fuel wood and yields good quality charcoal. In a prehistoric context its most important asset is perhaps its bark, which is waterproof. It is readily removed in strips or pieces, is easily worked and can also be sewn. It is rich in resin, which means that it burns with a clear flame. Recently in Scandinavia the wood has been burnt to produce smoke for smoking fish, and beer can be brewed from its sap (Edlin 1973, chapter xvi). At Star Carr it does not appear to have been used extensively for wooden artefacts, but it does occur frequently in the form of birch bark rolls (Chapter 30). Indeed, some species of birch trees produce bark rolls as part of the natural shedding process. Bark can easily be detached from the tree without killing it, especially in the spring and early summer months, because of the heavy flow of sap. However, the tree may be weakened, sometimes fatally, if the sap continues to flow strongly after the bark has been removed. It is important that sufficient bark is left on the tree to support future growth. Where a tree continues to grow after the removal of a substantial amount of bark it will always carry scars.

Virtually every part of the elder has been exploited for food, drink, dyes and medicines but the wood has seldom been utilised either now or in the past (Usher 1974, 521). When the shrub is young it produces long, straight stems which can be very pithy. The later wood is harder but is seldom produced in pieces of a usable size or shape. The ad-hoc tool here is made from roundwood which probably represents a couple of years of growth, so it would still have been quite flexible.

Alder buckthorn also naturally produces long, straight stems. It has traditionally been used for walking sticks (www.forestry.gov.uk) and so is probably also well suited for making into digging sticks.

Alder is not related to alder buckthorn, although they look very similar. Alder can grow into a large tree and produce substantial timbers. It also regenerates well when coppiced. The wood is soft and easily worked and it is not particularly durable unless it is kept permanently wet (Edlin 1973, chapter xvi).

The artefacts themselves are generally relatively light and slender. With the exception of <115952> there is no evidence for jointing or multiple pieces of wood being joined together. Dowel technology is a central aspect of the artefact assemblage, with a clear preference for radially aligned objects, the exception being bow <113300>.

Alongside the well-planned, executed and finished items sits a group of ad-hoc tools. These are conveniently shaped and proportioned pieces of roundwood and debris that were to hand when a task needed to be performed, and have been used as tools.

The artefacts show an excellent understanding of wood in terms of selection of suitable raw material and its physical properties when used in both converted and unconverted forms. Raw material was carefully selected for the production of artefacts to ensure that the items can be 'brought out' of the raw material and into their finished form. For instance, the complete digging stick <92465> was notable for the use of a natural feature in the shaping of the knob or handle. It was made by cutting a stem from a coppice, but cutting it in such a way that a chunk of the stool was still attached. This chunk, which would have been roughly the right shape to fit into the hand, was then shaped, slightly flattened and smoothed to make the finished handle. The stem had most of the wood split off its length, until it could be shaped into a dowel for the shaft. The stool wood of the handle is slightly gnarled by the coppice-cutting (and subsequent regeneration), which would make it naturally resistant to splitting or breaking. The join between the stool wood and the shaft, previously the join between the stool and stem, is also strong because, when growing, it would flex and absorb the energy of the wind. This stronger wood at the join between the stool wood and stem is used on several pieces: <116640>, <117152> and <117165>. The similarity is so great that it seems likely these pieces are derived from broken digging sticks.

The artefact which is most remarkable for the use of a natural shape/growth pattern is the carved 'platter' which survived in two pieces: <115316> and <115317>. This vessel utilises the natural shape of a knot and its surrounding wood. 'Knots' in wood are formed where a trunk grows faster than a side branch until it completely encases it. If the side branch is long dead and/or decaying when it becomes encased in the living wood, it will not be integral with the wood surrounding it. It may be loose or even disintegrating. Where the remnant of the side branch is sound, the wood may grow round it so that it is securely fixed; this is known as a 'tight knot' (Corkhill 1979, 289–290). Wood grows eccentrically around side-branches and not just because it has to accommodate the form of the branch. Other factors that influence and distort wood growth include the weight of the side branch (gravity) and the way it flexes in windy conditions. The wood thus formed is called 'reaction wood'. In hardwood trees (dicotyledons) this is the wood laid down above the branch, where it is known as 'tension wood'. In tension wood, the growth rings are further apart than normal; this leads to an eccentric growth pattern in which the pith is closer to the lower side (Jane 1970, figure 108). Tension wood may be harder and denser than normal wood, with a more compact structure and more fibres, although the latter are only visible under magnification. It also has a different pattern of drying from normal wood, shrinking much more longitudinally (Jane 1970, 210–222). This would mean that if there was a large knot formed (or forming) in a tree which had been felled or had died, it would be relatively easy to detach, once the dead wood started drying out. The hardness of the reaction wood might make it difficult to work, but in the case of the platter formed from <115316> and <115317>, very little extra shaping was necessary. The reaction wood has naturally formed a dished shape. The growth rings are highly visible, which could be due to wear. The earlier wood laid down in growth rings is softer than that laid down later, making it more susceptible to erosion (Jane 1970, figure 139).

The woodworking practices of the Bindibu people of Central Western Australia illustrate the importance of understanding the natural properties of the raw material (Thompson 1964). These people cut parallel-sided tangential planks from standing Mulga trees (a species of acacia) using groove-and-splitting techniques. This, as reported in experiments along similar lines elsewhere in this volume (Chapter 28), is difficult and time consuming. For the Bindibu this was the longest and most skilful part of making a spear thrower. The planks were cut in this particular way because the natural curve of the sapwood formed the basic shape of the artefact (Thompson 1964). The tangential planks produced by this method are not dissimilar to those recorded from the wooden structures and also from which Clark's paddle was manufactured. Another striking example from the Bindibu people is the description of how they excavated long, straight shrub roots, when there were no standing saplings with wood straight enough for making spears.

The wooden artefacts were recovered from five of the spatial analytical groups: brushwood, detrital wood scatter, Clark's area, western platform and other (Figure 29.33). However, it is important to note that although the brushwood has the earliest start date, the wooden artefacts were all recovered from the upper portion, stratigraphically above the western platform. In most areas dowels and utilised roundwood are used most often, though in the western platform only utilised debris has been found in the form of two stakes (Figure 29.34).
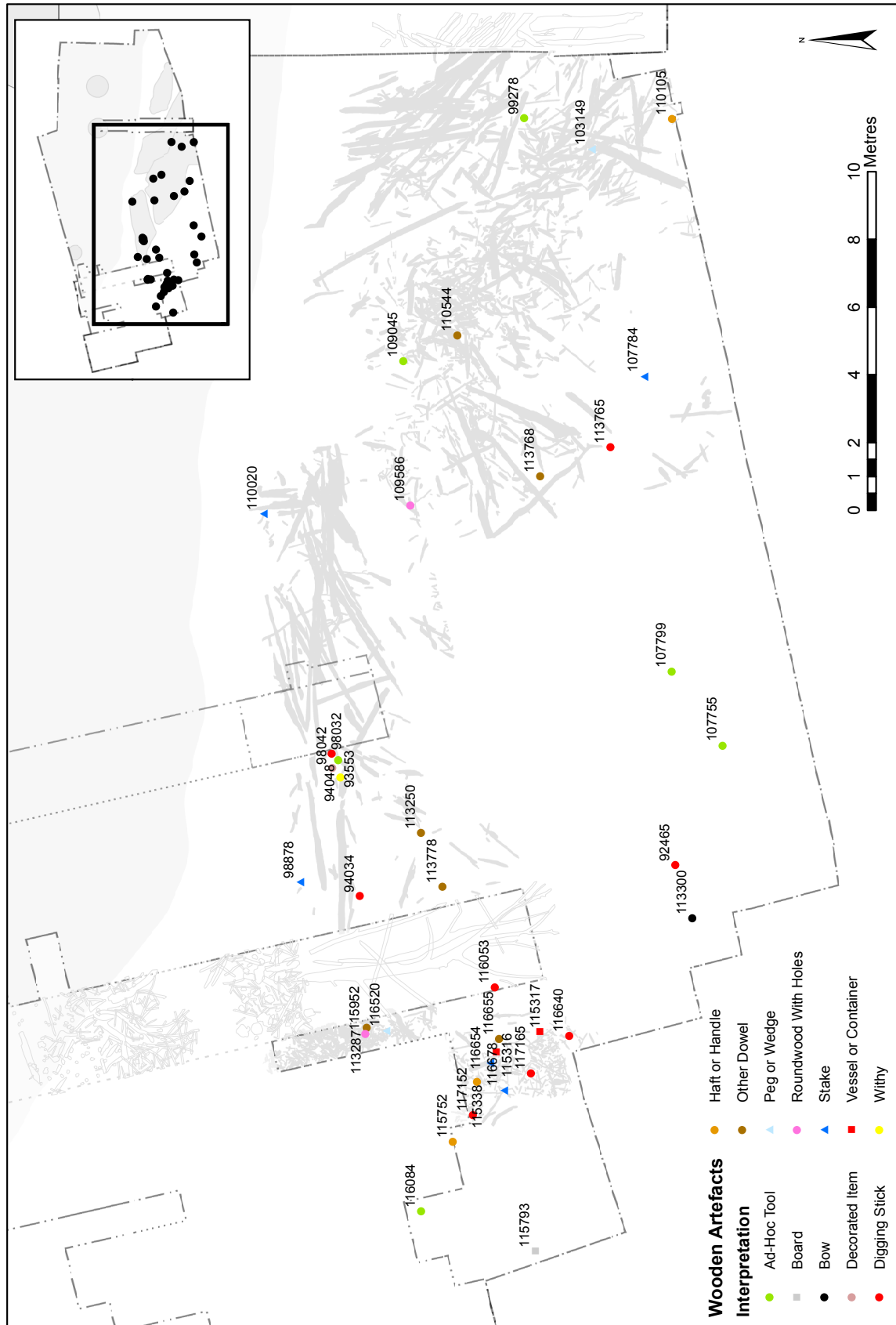
Figure 29.33: Wooden artefacts by interpretation of function (Copyright Star Carr Project, CC BY-NC 4.0).
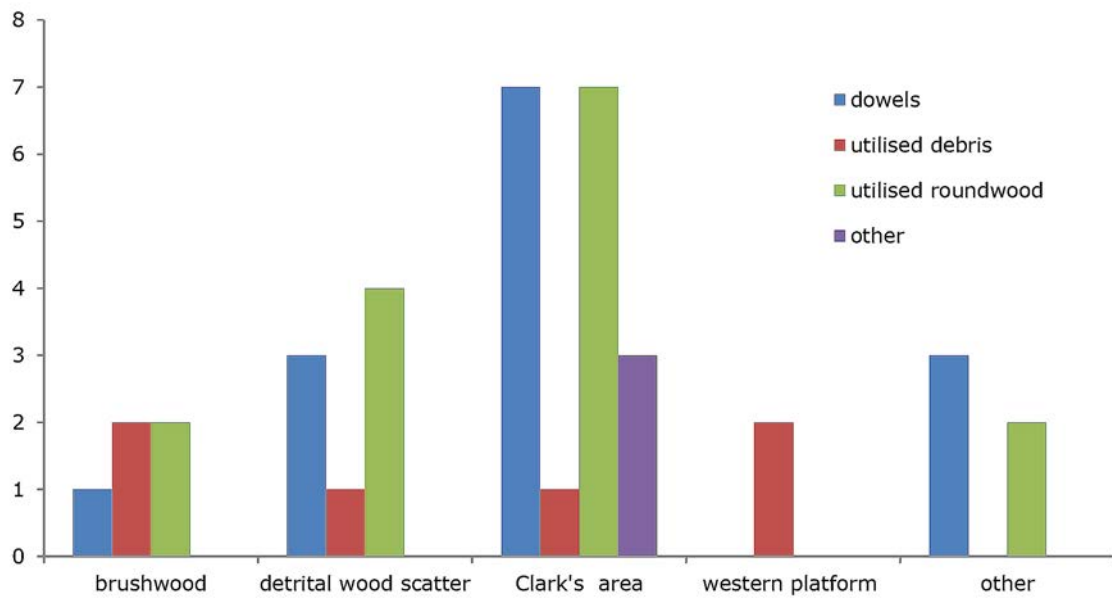
Figure 29.34: Technological groupings by area (Copyright Star Carr Project, CC BY-NC 4.0).

	Brushwood	Detrital wood scatter	Clark's area	Western platform	Other	Total
Ad-hoc tool	1	2	1		2	6
Board			1			1
Bow			1			1
Decorated item	1					1
Digging stick	2		5			7
Digging stick / haft or handle					1	1
Haft or handle		1	2			3
Other dowels		2	2		2	6
Peg		1				1
Roundwood with holes		1	1			2
Stake		1	2	2		5
Vessel or container			2			2
Wedge			1			1
Withy	1					1
Total	5	8	18	2	5	38

Table 29.14: Function by area.

Apart from these items, the platforms are not associated with any other artefacts. In addition, it is only Clark's area which includes the category of 'other'.

There is no clear patterning to the distribution of certain artefact types, such as digging sticks, which appear to occur in a number of areas (Figure 29.33, Table 29.14). A single item, utilised roundwood spindle/toggle, is the only wooden artefact recovered from the latest waterlogged deposit encountered, wood peat (310) in

'other'. However, by far the greatest frequency and diversity of wooden artefacts were recovered from Clark's area (Table 29.14), a situation mirrored by the osseous artefact assemblage (Chapter 24).

As has been discussed elsewhere in this volume (Chapter 22), the wood at Star Carr has been subjected to a variety of taphonomic processes including shrinkage, compression and movement of the surrounding matrix caused by changing groundwater levels as well as desiccation and mechanical damage from roots. During the many campaigns and seasons of fieldwork, several items have been truncated by previous trenches. Furthermore, due to the extremely fragile nature of the material, some artefacts were damaged during excavation. There is also an unusually high level of ancient damage recorded from the artefact assemblage.

The combination of these factors means that only 10 artefacts are complete: digging stick <92465>, ad-hoc tool <93553>, decorated woodchip <98042>, stake <98878>, peg/wedge <103149>, stake <107784>, roundwood with hole <109586>, bow <113300>, wedge <116520> and stake <116678>. Waterlogged stakes are generally degraded at the top, where they pass through the preservation horizon for waterlogged wood, so it is surprising that three of the five encountered have their tops intact.

A further 18 artefacts are incomplete due to truncation, modern damage or degradation: digging stick <94034>, withy <94048>, digging stick <98032>, ad-hoc tool <99278>, ad-hoc tool <107755>, ad-hoc tool <107799>, ad-hoc tool <109045>, stake <110020>, haft or handle <110105>, dowel <110544>, dowel <113250>, dowel <113287>, digging stick/haft or handle <113765>, dowel <113768>, dowel <113778>, ad-hoc tool <116084>, stake <116654> and dowel <116655>.

The other 10 artefacts are incomplete due to ancient damage: vessel/container <115316-7>, haft or handle <115338>, haft or handle <115752>, board <115793>, roundwood with hole <115952>, digging stick <116053>, digging stick <116640>, digging stick <117152>, digging stick <117165>. Half of the eight possible digging sticks were broken in antiquity, as were two of the three possible hafts or handles. This is an unusually high percentage, perhaps suggesting that for the most part, these items were discarded because they had broken through use or perhaps had been deliberately broken to decommission the objects.

The 10 artefacts which have been broken in antiquity make up a much higher prevalence (26%) than for the waterlogged wood assemblage as a whole (1.8%). Interestingly, these items are all located in Clark's area (Figure 29.35) which is similar to the patterning of barbed points broken in antiquity which also occur mainly in Clark's area (Chapter 25). There are also two interesting cases of ancient damage: digging stick <117165> was broken in two pieces in antiquity, which were close to each other in the ground; the vessel/container <115316-7> was also broken into two pieces, hinting perhaps at trample or of possible structured deposition.
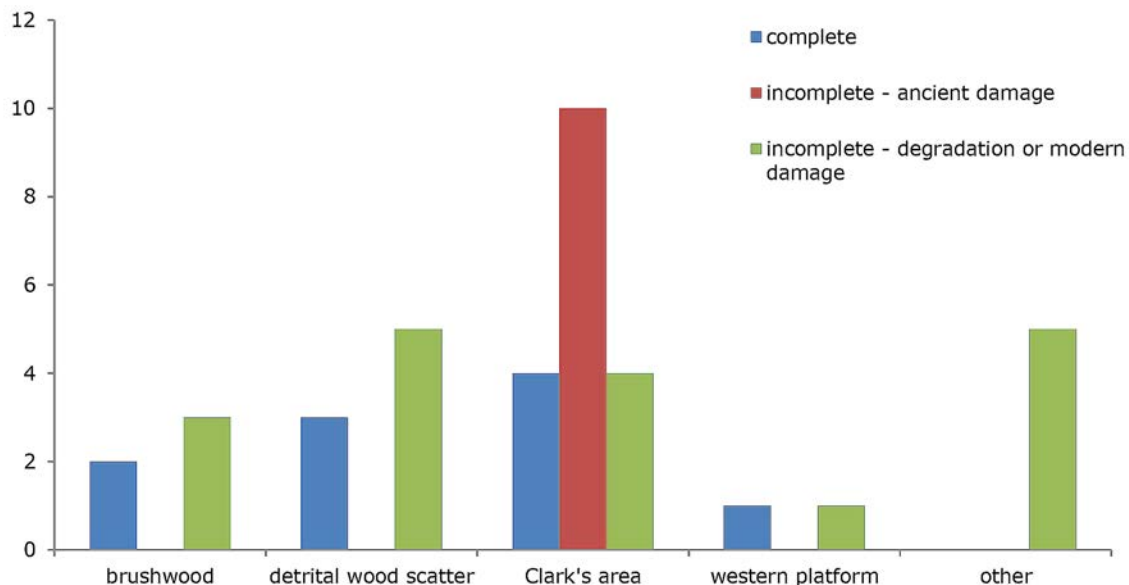
Figure 29.35: Damage to artefacts by area (Copyright Star Carr Project, CC BY-NC 4.0).

European wooden artefacts

Introduction

The Shigir Idol is the most outstanding Mesolithic wooden artefact, found under 4 m of peat in 1894 at Shigir (in the Urals, Russian Federation). It is a tall figurine which currently stands at 2.8 m high, though it may have been even taller as it was found in pieces (Figure 29.36). The piece was constructed from a single piece of larch (*Larix* sp.) which was 159 years old and dates to the 8th millennium cal BC. In total, seven faces as well as numerous symbols, straight and wavy lines have been identified on the piece (Chairkina et al. 2001; Lillie et al. 2005; Savchenko et al. 2015).

The presence of other, numerous wooden artefacts and traces of their manufacture from Northern European Mesolithic sites, in particular Southern Scandinavia, demonstrates the importance of wood as a resource during this period (Brunning 2007). Although the majority of sites in Northern Europe are dated to the later Mesolithic (see Klooß 2015), there are several Early Mesolithic sites that have yielded spectacular assemblages such as Friesack IV in Germany. In comparison, the UK evidence is remarkably scant for the entire Mesolithic period. This is partly due to preservation but also the substantially lower number of excavations conducted on submerged and wetland sites. This section is not intended to act as a gazetteer (see Klooß 2015 for a comprehensive overview of wooden artefacts in Northern Europe); instead, we consider a number of sites which provide good examples of wooden artefacts and in particular focus on bows, digging sticks, hafts/handles, paddles and stakes, to provide comparisons for the artefacts found at Star Carr.

Mesolithic worked wood in Britain is restricted to around a dozen sites (Brunning 2007; Taylor 2011). Of these, several Late Mesolithic sites at Goldcliff East in the Severn Estuary, dated to the 6th millennium cal BC, have more than doubled the number of UK Mesolithic wooden artefacts in recent years (Brunning 2007, 125). However, in general, the assemblages from Goldcliff East were poorly preserved; many pieces were highly fragmented, eroded and/or showed signs of decay, and several had been compressed within the burial environment. These data suggested that some of the wood in the assemblage, particularly from Site J, had been deposited by water action, perhaps along the strandline, although its location in relation to the bone and lithics indicated that it had not moved very far (Brunning 2007, 130). Overall, a total of 38 pieces of worked wood were identified (Bell 2007, 81). These included modified and/or utilised roundwood (possibly the remains of a fish structure), woodchips, probable stakes, small tools, a Y-shaped tool, a charred drum-shaped wooden object (which may represent a bead), a V-shaped tool, a pointed tool tip or pin, a pronged object and several artefacts of unknown function (Bell 2007; Brunning 2007).

Bouldnor Cliff is another Late Mesolithic site that has been excavated in the last decade. It is situated in the Solent and is a submerged site also dating to the 6th millennium cal BC (Smith et al. 2015). The wood was in a good condition although compression had occurred. Here, several pieces appear to have been artificially modified in some way and show definite signs of working; however, others were not as clear (Taylor 2011, 85). The assemblage, albeit small, comprised two pieces that had been trimmed at one end and from two directions, four pieces that retained all or part of the heel, two pieces that had both ends modified, three pieces of roundwood that had been split and modified in various ways, three pieces that had been split in half, one chip that had been removed from a piece of roundwood, one piece of roundwood that had been split and squared, and four further pieces that had also been trimmed or modified using the chop and tear technique (Taylor 2011, 86). In addition, one larger timber that was identified as oak (*Quercus* sp.) had been tangentially split. On this piece, charring was evident on one end and along one side, and it could have been hewn. Although this technique was used for boat building in later prehistory such as the Bronze Age, the evidence at Bouldnor Cliff is inconclusive (Taylor 2011, 89).

In Northern Europe, the situation is notably different. Excavations on submerged and wetland locations have yielded far more wooden artefacts, many of which have become well-known due to their craftsmanship and in some cases decoration; for instance the decorated paddles from the Late Mesolithic Ertebølle sites of Hjarnø (Skriver and Borup 2012) and Tybrind Vig (Andersen 2011). The range of artefacts is also greater and includes bows and arrows, digging sticks, dugout canoes, paddles and spears, to name but a few. In general the majority are dated to the Late Mesolithic Ertebølle culture, whilst only a handful of Early Mesolithic sites are represented. In addition, focus has primarily been on the artefacts themselves and not necessarily the utilised debris or roundwood.
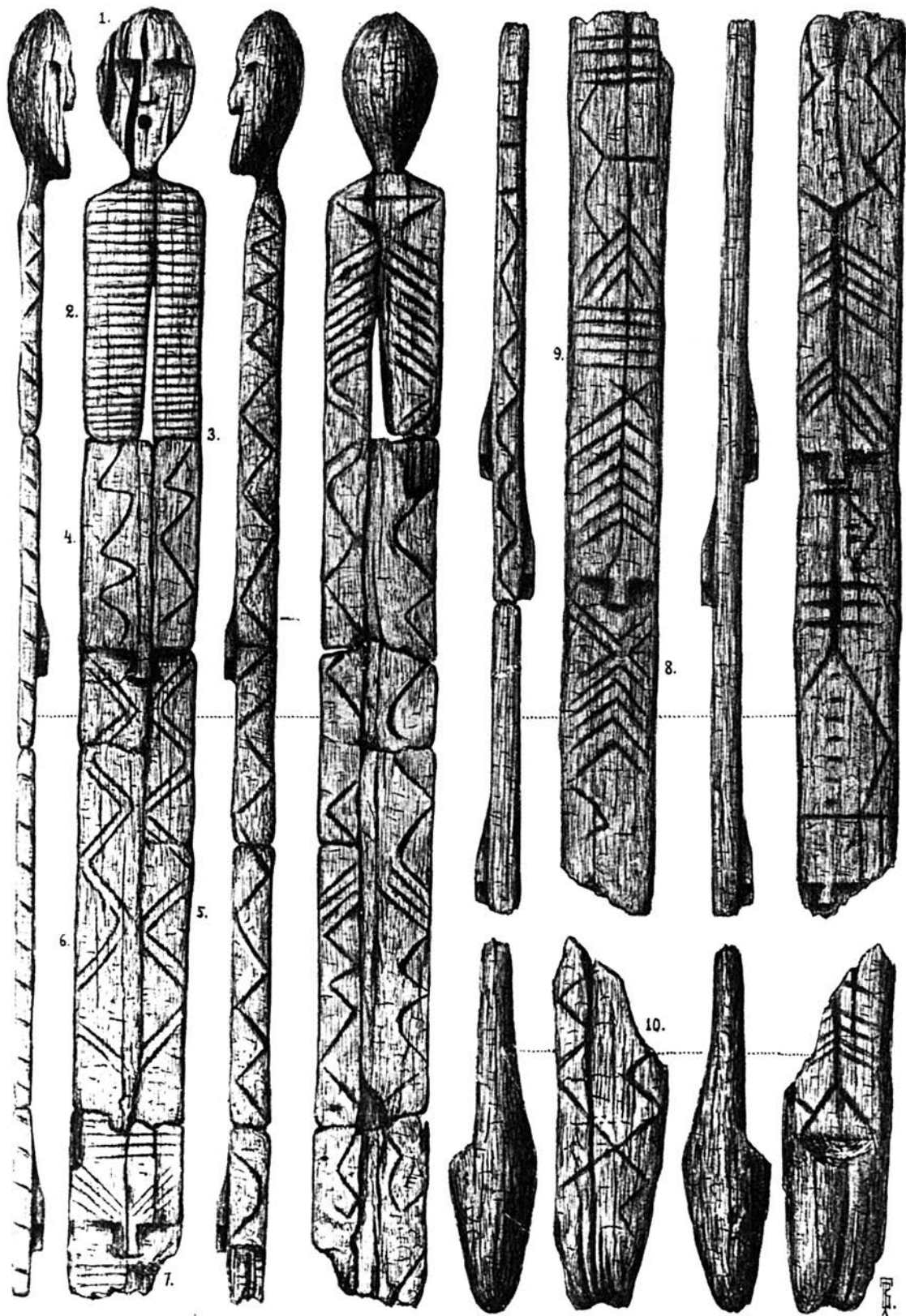
Figure 29.36: The Shigir idol (courtesy of Svetlana Savchenko and Mikhail Zhilin; original drawing by Vladimir Tolmachev: adapted from Milner et al. 2013c).

One of the most important Early Mesolithic wooden assemblages is that from Friesack IV (see Chapter 12). Here, 134 artefacts made from bark and/or wood were recovered but again these were generally fragmented and in varying states of preservation, meaning that little can be said regarding function (Gramsch 1992, 2016; Gramsch and Kloss 1989). The wooden implements that were recovered include fragments of spears and arrows, a probable bow, blunted arrows (thought to be for bird hunting or the recovery of undamaged pelts), two possible digging sticks (one of which had a 'fire-hardened semi-circular end'), fragments of paddles, fragments of possibly more than one dugout canoe, sticks, poles, planks and slats (of unknown function) and worked fragments, two small boards with opposing notches for winding bast cord, one net float made of birch bark, as well as hafts and shafts (Gramsch and Kloss 1989, 322; Gramsch 1992, 2016). In addition, a carefully worked, pointed-end trough was found like the Australian aboriginal 'koolamon' with a handle that was made from twisted rods, thought to have been used as a basket or carrying net (Gramsch and Kloss 1989, 322).

A later Mesolithic site that has yielded important wooden artefacts is Vis I in Russia. Dated to the 6th millennium BC, a total of 39 pieces of wood with manufacturing traces were found (Burov 1989). Noteworthy artefacts include sledge runners, skis, bows, arrows, spears, throwing-sticks, hoops of landing-nets or fish traps, a wooden disk, an oar, an arched scraper, a series of stakes, a fragment of a fishing basket or mat, a net made from sedge fibres, a pine bark float and a birch bark vessel (Burov 1989). Similarly, Veretye I in Russia has produced a range of artefacts, including rectangular or round wooden boards with handles or holes; on one of these, fish scales were identified and so they may have been used for fish processing (Oshibkina 2007).

Bows

Potentially the oldest known bow from Northern Europe, c. 18,000 years old, is a fragment of pine (*Pinus* sp.), which was recovered from the French site of Mannheim-Vogelstang (Rosendahl et al. 2006). However, this is generally thought to be unconvincing. Two fragments of potential bows were also recovered from the German site of Stellmoor. They were made from pine and accompanied by more than 100 fragments of arrows (Bokelmann 1991; Rust 1943). Unfortunately the assemblage was destroyed by bombing during the Second World War, meaning that the only data available is derived from the original publication (Rust 1943). Whilst the arrows appear to be unequivocal in terms of form, the bows are generally considered to be unconvincing.

Prior to the discovery of the bow from Star Carr, the oldest, irrefutable example from Northern Europe were recovered from Holmegård in Denmark. In total, the remains of five bows were recovered, dated to the younger Maglemose culture (Becker 1945). At least two of the bows were constructed from elm (*Ulmus* sp.) and measured 1540 mm and 900 mm respectively (Becker 1945). A slightly younger example was recovered from Ulkestrup Lyng (Andresen et al. 1981). Here, one side of an elm bow had been charred prior to deposition, the pointed end is flat and there is no evidence of a notch (Andresen et al. 1981). However, an examination of the literature has demonstrated that at least one possible pine bow was recovered at Friesack IV from a middle Preboreal context (Gramsch and Kloss 1989, 322). The example was incomplete measuring c. 300 mm in length (Gramsch pers. comm. 2016).

From Russia, the Early Boreal site of Veretye I has produced bows with indentations for affixing the string (Oshibkina 2007). Similarly, at least six bows (potentially eight) are known from the site of Vis I. These examples were smaller when compared with numerous other Mesolithic examples and were interpreted as being used for boring antler and bone or for making fire (Burov 1989).

Digging sticks

Until the recent discoveries at Star Carr, the oldest known digging stick in Northern Europe was said to have been recovered from the Ertebølle site of Lindholm I in Nyborg Fjord, Denmark, dating to the 5th millenium cal BC (Figure 29.37) (Fischer and Pedersen 1997). The piece measures 1170 mm in length and 35 mm in diameter and is sharpened to a point (Fischer and Pedersen 1997; Troels-Smith and Fischer 1992).

Figure 29.37: Illustration of the Lindholm I digging stick (Illustration by Eva och. Reproduced with permission of Slots- og Kulturstyrelsen).

At least two examples of digging sticks were recovered from the Early Mesolithic site at Friesack IV, Germany. Both were made of ash (*Fraxinus excelsior*). One measures 470 mm in length and has a rounded cut at one end which was subsequently charred. It was recovered from a layer which has been dated to the Early Boreal (Gramsch 1992; pers. comm. 2016).

Several Middle and Late Mesolithic sites in Southern Scandinavia have also yielded digging sticks: Smakkerup Huse (Price and Gebauer 2005), Tybrind Vig (Andersen 2013), Rüde LA 2 (Hartz pers. comm. 2015); Ringkloster (Andersen 1998); and Tågerup (Karsten and Knarrström 2003). These have been made from a variety of wood species including hazel, oak, ash and dogwood.

The only Mesolithic site in the UK that has yielded a potential digging stick is Site J at Goldcliff East in the Severn Estuary, dating to the 5th millenium cal BC (Bell 2007). Described as a 'carefully worked curved pointed stick' (Bell 2007, 81), the specimen measured 1160 m in length, and 45 mm × 30 mm at its widest point and was interpreted as either a digging stick or a spear-like object. It is constructed from oak roundwood, one end is broken and several side branches have been removed. Cut marks are present on several sides, and it is pointed, though the stick also has a slight bend in it (Brunning 2007, 125).

Hafts and handles

Although numerous examples of hafts and handles are known from the Middle Mesolithic Kongemose and Late Mesolithic Ertebølle cultures of Southern Scandinavia (Klooß 2015), specimens dating to the Early Mesolithic are extremely rare. However, a haft with a handle made from pine was recovered from Wp 1 at Duvensee (Bokelmann 1971, 14, figure 8), and at least one socket (for an elk antler axe) made from hazel (*Corylus* sp.) was recovered from Hohen Viecheln (Schuldt 1961, Tables 141 and 142). In addition, at least six axe shafts and handles are known from Friesack IV (Gramsch 2016). During the Preboreal and Boreal occupational phases at the site hazel was used, whereas hazel or hornbeam (*Carpinus betulus*) was utilised in the Atlantic period. In all instances they were either made from trunks or branches (Gramsch 2016, 42).

Paddles

Numerous paddles dating to the Mesolithic are known in Northern Europe (Klooß 2015). At Friesack IV at least two paddles were recovered (Gramsch and Kloss 1989; Gramsch 1992). One of these was made from rowan (*Sorbus aucuparia*) and dates to the younger Preboreal, whereas the second specimen has not been identified to species and is dated to the early Boreal (Gramsch 1987a; 1987b; 1992; Gramsch and Kloss 1989). From the Duvensee peat bog a pine paddle was recovered (Holst 2007; Hartz and Lübke 1999; 2000; Jenke 2009; 2011; Schwantes et al. 1925). It derived from the gyttia layers next to Wp 2 and has recently been dated to the mid-8th millenium cal BC; the Boreal phase of the Early Mesolithic Maglemose culture. A paddle made from willow was also found within the later Maglemose site of Holmegård I in Denmark (Broholm 1924).

An almost complete hazel (*Corylus* sp.) paddle is known from Ulkestrup Lyng (Andresen et al. 1981). It had been compressed due to the overlying peat and unfortunately was damaged during excavation, but it was possible to note that the handle measures 900 × 20.5 × 20.5 mm and was virtually circular, and the blade measures 300 × 120 × 13 mm (Figure 29.37). The annual rings demonstrate that it had been constructed from a single piece of wood: it is assumed that core axes had not been used in the manufacture as they would have left traces; instead antler axes and wooden wedges are suggested (Andresen et al. 1981).

Figure 29.38: The hazel paddle blade from Hut I at Ulkestrup Lyng, Denmark (Copyright Harry Robson, CC BY-NC 4.0).

Stakes

At Ulkestrup Lyng several vertical posts relating to the two huts at the site were recovered (Andresen et al. 1981). Nearly all of these are hazel branches, about 50 mm thick, all of which terminate close to the wooden floor (Andresen et al. 1981, 87). As the paddle was found in the same location as some of the posts, it has been suggested that these must have been mooring posts for a boat; however, unfortunately, no boat was found (Andresen et al. 1981, 89). In addition, several stakes were identified on the Danish, Maglemosian site of Lavringe Mose. These were found either vertically or at a slight angle and have been interpreted as the remnants of a structure (Sørensen 1987, 54).

From the UK, a possible stake made from alder roundwood was identified in the wood assemblage from Site J, Goldcliff East in the Severn Estuary. The piece was 28 mm in diameter and both ends had been broken. It showed signs of buckling in several places, which suggested that it had been driven into a hard substrate when green (Brunning 2007). Four further stakes were also identified, although they were categorised as either probable, possible or rather doubtful (Brunning 2007). A further dubious example was recovered from under 4 m of peat at Lordenshaw hillfort in Northumberland (Brunning 2007).

Conclusions

There is no assertion that all the objects considered herein are 'artefacts'. However, based on their conversion, context or possible evidence for utilisation they are all potential artefacts. It is hoped that the analytical approach used within this chapter has, where possible, provided interpretations for the function of as many of the objects as feasible. It is felt that the approach of considering all items by their technological conversion before attempting to infer use has proved robust. In addition, the microwear analysis has provided data in some cases, though this technique on waterlogged wood provides a challenging workflow and the condition of the material has, in many cases, impeded the collection of microwear data. Unfortunately, organic residue analysis did not provide any conclusive results. The experimental work showed that as long as suitable raw material could be sourced, an experienced woodworker could, with a small tool kit, produce wooden artefacts similar to those excavated at the site both quickly and efficiently. Many of the artefacts are well finished and show a concern for aesthetic in addition to function.

The potential uses of the wooden artefacts very much mirror the evidence for activities being carried out at the site gleaned from other types of artefacts. The bow provides evidence for hunting and the digging sticks for gathering. The wooden wedges for splitting wood and perhaps antler and the spindle/bobbin for processing plant fibres. The possible hafts or handles may have originally hafted the flint tranchet axes, barbed points or elk antler mattocks. Within the ad-hoc tool assemblage are items that may have been used as burnishers,

piercers or perhaps needles. The greatest frequency and diversity of wooden artefacts were recovered from Clark's area, a distribution that is mirrored by the bone and antler artefact assemblage. In contrast, the three platforms produced no wooden artefacts, with the exception of two wooden stakes from the western platform; this again mirrors the bone and antler artefact distribution, both material types being relatively scarce amongst the platforms.

No intact hafted items were encountered, despite the recovery of several dowels that are a suitable size to be hafts or handles and microwear evidence showing that both flint tools and barbed points were hafted with wood. When considering the size of the barbed point assemblage, this strongly suggests deliberate de-hafting of artefacts prior to deposition in the lake.

There is a higher prevalence of ancient breakage among the artefact assemblage, particularly amongst the dowels than recorded from the wider wood assemblage. These broken items are all clustered within Clark's area and similarly, this is an area from which barbed points that have broken in antiquity have been discovered. It is unclear whether these items have broken during use or have been deliberately broken to decommission them before being deposited in the shallow water at the edge of the lake. The 'platter' <115316-7> and broken digging stick <117165> both provide tantalising glimpses of possible deliberate breakage and subsequent deposition. The broken halves of the digging stick were next to each other (raising the possibility that they may in fact have been broken by trampling) whilst the two pieces of the platter were recovered several metres apart. The close association of the two complete, unbroken artefacts, bow <113300> and digging stick <92465> (Figure 29.12), also hint at structured deposition, representing a hunting tool and a gathering tool, lying tip to tip with one another.

The Use of Birch Bark

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and Becky Knight

Introduction

Birch (*Betula* sp.) bark is a versatile multipurpose material that has been utilised by hunter-gatherers across the globe in many ways, including food preparation and storage, construction material for mats, lining storage pits, shelter, transportation, baby care, fishing net floats, paper, decorative items, grave goods, medicine and as a source of adhesive. These functions and many others have been documented in the ethnographic and archaeological record (Vogt 1949; Croft and Mathewes 2014).

The birch bark that was uncovered during the recent excavations was typically extremely fragile and easily subject to damage. The bark of birch trees possesses lenticels: small corky elongated horizontal structures where a minimal amount of gas exchange occurs. The lenticels were still visible on all the birch bark artefacts examined, although some were disintegrated, leaving only their outline in the bark. Authigenic crystal growth was visible with the naked eye on several bark artefacts. Based on microscopic observations of a small sample of the crystals removed from the bark, the crystals are consistent with microcrystals previously identified with confocal Micro-Raman spectroscopy as gypsum (Croft 2017). Microscopic analysis of a resin-impregnated and cross-sectioned birch bark roll also revealed framboidal pyrite and fungal hyphal growth between the layers of birch bark. Together, these mineral and fungal factors have acted to delaminate and degrade the condition of the bark.

However, despite the issues with deterioration, a number of interesting discoveries were made: a possible mat composed of layers of birch bark, a possible container, two composite torches, 30 pieces of birch bark as well as 161 birch bark rolls (Figure 30.1). The first three artefacts are significant because artefacts such as these were not identified during the original excavations undertaken by Clark. The recovery and detailed examination of the birch bark rolls has also been important, largely because Clark had not recorded charring on any of the birch bark rolls that he found. However, 41% of the birch bark rolls, including those held in museums from the original excavations, exhibited signs of charring. This chapter presents the analysis of the birch bark, experimental work and the wider context for birch bark artefacts in the European Mesolithic record.
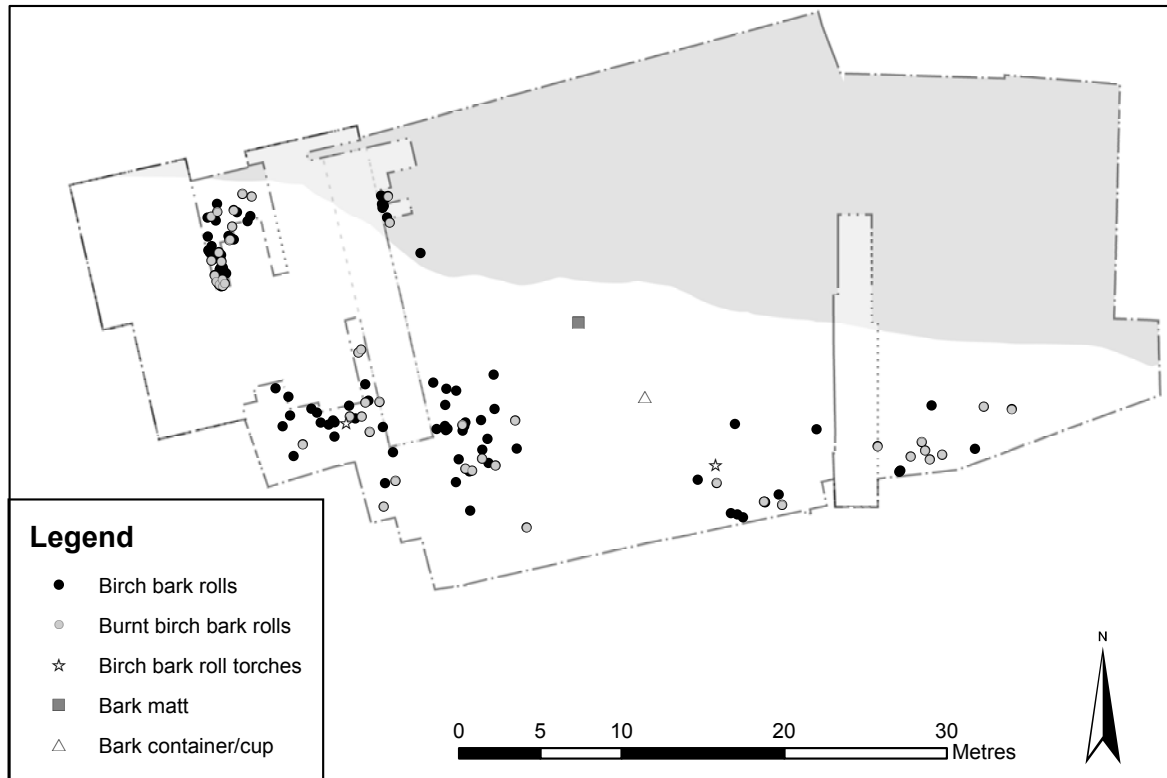
Figure 30.1: Distribution map of artefacts across the site (Copyright Star Carr Project, CC BY-NC 4.0).

Previous analysis

In the original excavations a number of birch bark rolls were excavated, though we do not know the actual quantities. Clark may have found more birch bark artefacts, which may not have been retained (as noted for other artefacts when the backfill was excavated, see Chapter 7) or are housed in other museums (as the assemblage was further dispersed through loans). In our original collation of museum data (Milner et al. 2013b), only 40 birch bark rolls and small pieces of bark were catalogued. Since then, LF visited a number of museums and catalogued the birch bark rolls that were available for study: the majority (n=38) of the collection is stored in Scarborough with several now on display in the Rotunda Museum; three are stored in The Yorkshire Museum (one of which is on display); two are on display at Whitby Museum; three are stored in the Museum of Archaeology and Anthropology, Cambridge (MAA) and three are stored in the Natural History Museum (NHM). This brings the total to 49. Since then, two more have been noted as being on display in the British Museum and three more have been found in the Scarborough Museum stores. These latter five are not included in this study.

In the first interim report on the excavations, Clark (1949, 63) stated that

'Rolls of birch-bark, varying in width from one to eight inches and tightly rolled abounded in the culture layer. The largest specimen illustrated comprises a strip of bark approximately 30 inches long, representing a band removed from a trunk around 9 inches thick. Birch-bark is stored in similar rolls among the Lapps of the modern birch zone. Among people who did not use pottery birch bark may well have played a leading part as a material for containers … Professor E. Vogt has argued that the utilisation of birch-bark for this and other purposes by the neolithic lake-villagers of Switzerland carried on a tradition, which probably originated during the birch phase of early Post-glacial times. Here at Seamer we may well have evidence for this, though traces of actual objects made from birch-bark have yet to be found. Similar rolls were noted at Mullerup.'

Although he did not provide any further information concerning these artefacts, a photograph of five birch bark rolls of varying sizes was included. Furthermore, Clark (1950, 118–119) stated the following in the second interim report:

> 'Many more examples of birch-bark rolls were encountered, though most of these were in a more or less decayed condition. A careful watch was kept for signs of birch-bark with stitch-holes or similar signs of having been utilised to make containers or other equipment, but no indications were noted.'

The most comprehensive account of this class of artefact was provided in the monograph on the site (Clark 1954). The birch bark rolls were described as being tightly wound rolls of bark which varied in size from as small as '1 in. in width' to '8 in. wide and about 30 in. long' [25.4–203 mm in width and 762 mm long] (Clark 1954, 166). Clark did not provide any further details than this; however, he did consider the ways in which they might have been used. He noted that narrow rolls, shaped like a cigar, have been used as tapers up until recently in parts of Europe. He also observed that 'no certain case of charring has been noted on specimens from Star Carr' (Clark 1954, 166). He further pointed out that birch bark rolls have been used as floats for nets, which was also the interpretation for examples found at the Danish Maglemosian site of Mullerup Syd (Sarauw 1903). A further explanation Clark deems more likely for the larger rolls is that rolling the bark up provides a convenient means of storage, although the bark also naturally curls into loose rolls when it is removed or falls from the tree. He explained how even in present day Europe, birch bark is unwound from trunks and stored in rolls for future use.

Pitts (1979) suggested that the Star Carr birch bark could have played a part in tanning animal hides. Tannins are contained in the inner bark, and along with a mixture of gathered mosses and bracket fungus, this vegetable matter could have been used to create a bath which would help accelerate the rate of enzymatic action, creating a tanning agent. Andresen et al. (1981, 41) later suggested that the evidence was inadequate to determine such a use.

However, birch bark is also a useful source of resin, which can be distilled to make tar (a type of adhesive), which has various uses. The most well-recognised use of birch bark tar is as a binding agent for hafting projectiles. At Star Carr we know that tar was used for hafting flint tools because a microlith with tar adhering to it was recovered during the original excavations. In addition, at least five thin, flat 'tar cakes' were also discovered: 'the resin was found caked on charcoal as though spilt in the process of extraction or use' (Clark 1954, 167).

These resin cakes and the tar adhering to the microlith were subsequently analysed by Aveling and Heron (1998). Lipid extracts from the residues were analysed using gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS), which were compared to modern and Mesolithic birch bark. Aveling and Heron's (1998) secure identification of birch bark tar suggests that there may be other tools in the Star Carr assemblage that contain this adhesive material. Lipids were also extracted from some birch bark rolls sampled by Aveling and Heron (1998) and found to yield spectra more similar to birch bark tar than actual bark. In addition, three birch bark rolls from Star Carr were analysed alongside a sample of peat-buried birch bark from Davenham (Aveling and Heron 1998, 76). They determined that all samples derived from tar formed from the heating of birch bark. Therefore, it is possible that the birch bark rolls represent a waste product from the production of birch bark tar.

Birch at Star Carr

Three species of birch were present in the immediate environment of Star Carr: the downy birch (*Betula pubescens*, Ehrhart), silver birch (*Betula pendula*, Roth) and dwarf birch (*Betula nana*, Linnaeus), which were identified from macroscopic remains, particularly the catkin fruits (Dark 1998b, 127 and 130 Fig 11.4; Dark 1998c, 167). However, the bark can only be harvested from *B. pubescens* and *B. pendula*, which possess naturally horizontally peeling bark; the bark of *B. nana* is non-peeling and is unlikely to have been used by Mesolithic peoples. *B. pendula* and *B. pubescens* are closely related species which easily hybridise and were previously grouped into one species by Linnaeus called *B. alba* (Bean 1976, 427). All birch species possess elongated pores or lenticels on the bark. The bark of both *B. pendula* and *B. pubescens* is tough, waxy and waterproof, but also flexible and able to be shaped. *B. pendula* (silver birch) bark is shiny, smooth, and silvery-white, with black fissures on the lower trunk of older trees (Hart and Raymond 1973, 6; Godet and Mitchell 1988, 28).

B. pubescens (downy birch) has bark similar to *B. pendula* that is more or less smooth throughout, and papery, but is usually grey, yellow, brown or, rarely, white in colour (Elwes and Henry 1909, 962; Clapham et al. 1989, 313; Stace 2010, 293). The colour of the artefacts from Star Carr in general has been altered by peat staining. *B. pendula* and *B. pubescens* are closely related and the bark exhibits overlapping characteristics that preclude differentiation when bark is examined isolated from the tree. Even when microscopic analysis of the cell structure of birch bark artefacts is undertaken for conservation purposes, the bark is identified only to genus (Florian 1990, 71). Thus, the birch bark artefacts recovered from Star Carr were identified by macroscopic examination to the genus *Betula*.

When birch bark exfoliates and peels from the tree naturally, it does so in thin layers and small strips, the ends of which are tapered. Birch bark indicative of anthropogenic harvesting exhibits right angles due to people making straight vertical cuts in the bark and it is also often several millimetres thick, traits which do not occur naturally. There were four main criteria that were used to recognise potential birch bark artefacts at Star Carr: right angles, thick bark, tight rolling and charring.

Birch bark container

What appeared to be a container <113780> was recovered from detrital mud (317), amongst the timbers of the detrital wood scatter (Figures 30.2 and 30.3). The three fragments of bark were in the shape of a small cup or vessel with a maximum diameter of 80 mm and a height of 75 mm. The bark had a maximum thickness of 1.5 mm and was orientated cambium/inner face in and cork/outer face out. Cut edges, folds and stitch holes were used by Croft and Mathewes (2014) to identify compressed and fragmentary birch bark containers from British Columbia, Canada, but none of these features were identified here. However, birch bark containers can

Figure 30.3: Possible birch bark container <113780> (Copyright Chloe Watson, CC BY-NC 4.0).

be made by folding and fastening using twigs. It is not clear whether it could have been a container, though the thickness of the bark indicates that it was deliberately harvested.

The oldest known birch bark containers in Northern Europe have been recovered from Friesack IV in Germany and Vis I in Russia (Burov 1998; Gramsch 1992; 1993; 1998; 2016; Gramsch and Kloss 1989): one example from Friesack IV measured 188 mm in length by 98 mm in width and was found within a pit which has been interpreted as a water hole or well on the habitation site (Gramsch 1992; Gramsch 2016). Given its location, it could have served as a water filter or to draw the water from the pit (Gramsch 1993; 1998). Further birch bark containers are known from the Boreal sites of Veretye I and Zamostje 2 in Russia (Lozovskaya and Lozovski 2016; Oshibkina 2007). At Veretje I the container was recovered from the top of the old land surface and situated next to the exit of a dwelling. It contained lithics and may be interpreted as a cache (Oshibkina 2007). Four fragments of birch bark are also known from Szczepanki Site 8 in Poland; these had been perforated and may represent two kinds of containers (Gumiński 2012).

Birch bark mat

Analysis

A birch bark mat <99307> was recovered in 2013 from the top of the reed peat (312); this would have been wet and potentially periodically flooded (Chapter 19) (Figure 30.4). Measuring 750 mm × 970 mm, the mat was

Figure 30.2 (page 422): Photograph of the birch bark container in situ (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 30.4: Illustration of the birch bark mat <99307> in situ that was recovered in 2013 (Illustration by Chloe Watson, after Hayley Saul. Copyright Chloe Watson, CC BY-NC 4.0).

lifted in several blocks and partially micro excavated under laboratory conditions by MT and BK. Several questions were asked in order to determine whether the item represented a cultural artefact:

- Are there multiple layers of bark?
- Is any wood attached to the bark or is it bark alone?
- Is there any evidence that the edges of the bark are cut, either straight or curved?
- Is there any evidence for additional technology such as stitch holes?

Micro-excavation identified four layers of bark, all of which were lying with the inner (cambium) face upwards and the outer (cork) side down:

- Layer A: the top layer of bark was quite fragmented, 1–2 mm thick and could be lifted off quite easily. This layer of bark lay almost directly on top of the next one with approximately 1 mm of sediment separating them.
- Layer B: the second layer was very thin, less than 1 mm. This layer was in direct contact with the one beneath.
- Layer C: the third layer was very slightly thicker, 2–3 mm. This layer was in direct contact with the one beneath.
- Layer D: the fourth and lowest layer of bark was 2 mm thick.

The bark has the full bark structure and is definitely not derived from the small, natural curls of bark which some young birch trees develop and naturally shed. Although it was very thin, sometimes barely 1 mm thick, none of the bark had any trace of bast fibres or sapwood on the inner face. Due to compression and fragmentation it was impossible to reconstruct the original size of each bark fragment and therefore estimate the minimum diameter of the tree from which the bark was harvested. However, given the thinness of the bark, it must be derived from quite a small tree(s).

Birch bark is more easily harvested in spring, when the sap or phloem is actively running to support new growth of the tree (Turner et al. 1990; Turner 1998). However, this can cause the tree to 'bleed', which will foster disease and/or weaken it. Some of the bark had straight, thickened, edges. It is likely that this thickening is scar tissue caused by regeneration after damage. Although it is impossible to say what caused the damage, it could have been caused by earlier bark removal. If bark is damaged or removed from a tree in such a way that it is not killed, the bark will gradually grow back over the area that was stripped.

Although no cut edges or stitch holes were identified, the presence of four layers of bark, each in the same orientation, with no bast fibres or sapwood adhering to the inner surface, suggests a culturally constructed artefact. The layers of bark seem to form a mat, though it must have been deposited into a fairly wet context (Chapter 19). Flotation samples recovered from the top, working surface of the mat and from the sediment interdigitated between layers A and B did not produce any evidence for its use, i.e. no charred macrofossils or microdebitage. In addition, no obvious activities had taken place in the area around the mat. Therefore, it is not clear what it might have been used for.

Wider context

In the UK an extensive area of bark flooring was found in Area E1, at the Late Mesolithic site of Williamson's Moss, Cumbria (Bonsall et al. 1989). Here, the flooring was well preserved in places and was 'made of superimposed layers of bark fragments laid down as a dense mat up to 10 cm thick' (Bonsall et al. 1989, 192). In total, it covered an area greater than 6 m and was interpreted as the 'remnants of the internal floors of one or more building constructed on the platform and the adjacent land surface' (Bonsall et al. 1989, 192).

Similarly, when bark matting has been discovered in Southern Scandinavia, it has largely been interpreted as the remnants of dwelling-places with flooring, such as examples made from aspen, pine and pine/birch at the Danish sites of Barmosen I, Bara Mosse I, Holmegård IV, Lavringe Mosse, Lundby II, Ulkestrup Lyng I (Becker 1945, Grøn 2003; Sørensen 1987). Other Danish sites include the Early Mesolithic site of Ulkestrup Lyng II where a birch bark floor, measuring 6 × 4.5 m in size, was found; 'the floor consisted of bundles of branches, twigs, remains of leaves, and leaves of Marsh Fern' (Andersen et al. 1982; Grøn 2003, 686). The Late Mesolithic, Ertebølle culture site of Møllegabet II, Denmark, produced a bark layer with twigs and bracken leaves measuring 5.2 × 3.2 m in size with a depth of up to 200 mm. The presence of stakes around its edge as well as two hearth zones strengthened the argument that this was used as a dwelling (Grøn 2003; Grøn and Skaarup 1995). Similarly, at the Late Mesolithic site at Smakkerup Huse, mats constructed from lime or birch bark were recovered and were interpreted as serving as a floor within structures (Price and Gebauer 2005).

Duvensee in Germany is perhaps the most renowned Early Mesolithic site that has yielded matting (Chapter 12). A total of six bark mats made from either birch, aspen or pine were recovered over the course of excavations in the Duvensee peat bog: Duvensee 1 (n=2), Duvensee 2 (n=1), Duvensee 6 (n=1), Duvensee 8 (n=1) and Duvensee 13 (n=1). Some of these were found on top of one another, whilst at one site, the lowest lay on top of a 'platform made up of twigs and thick, straight branches' (Grøn 2003, 686). The majority of these mats measured 4 × 4 m in size (Bokelmann 1971; 1975–7; 1983; 1986; 1989; Bokelmann et al. 1981; Holst 2010), with the largest measuring at least 6 m^2 (Holst 2010, 2873). Of these, at least two have been interpreted as roasting hearths and had been constructed with pine and birch bark (Bokelmann 1975–7; Holst 2010). One of these had a layer of white thick sand (20–140 mm thick) and a mixture of charcoal, hazelnut shells and lithics were recovered from the top of it (Holst 2010, 2873).

Bark mats have also been found at three Late Mesolithic/Early Neolithic sites in Satrupholmer Moor, Germany, although details are lacking as to the species of wood that were used (Feulner 2011). At the site of Rüde LA 2, a compact package of bark mats was found, which consisted of bark pieces that were up to 4 × 1 m. Feulner (2011) states that they were not specifically positioned but some were found overlapping or at an oblique angle with the majority being orientated north-south. On top of these mats, which covered a total area of around 6 × 2 m, traces of fireplaces were found (Feulner 2011). Nearby, at the Middle/Late Mesolithic site at Satrup LA 2 Bondebrück, overlapping bark mats were recorded which were up to 5 m in length. At another nearby locality, Satrup LA 71 Förstermoor, wooden timbers and bark pieces were found which are likely to have served to reinforce the boggy terrain (Feulner 2010; Feulner 2011). Further afield, a birch bark layer has been found at the Middle/Late Sub-Neolithic site of Riihimäki Silmäkeneva E in Finland (Koivisto 2011), whilst a large number of bark floors are known from Sarnate in Latvia (Vankina 1970).

Birch bark rolls

Methods

During the recent excavations, 142 birch bark rolls and small pieces of bark were retained, the vast majority of which were recovered during 2013–2015 in the waterlogged deposits within trench 34 (Figure 30.1). Others were encountered but many were too degraded to be lifted. All 142 rolls and pieces of bark retained from the years 2007, 2013, 2014 and 2015 as well as the 49 held in museum collections were analysed (n=191). All of the museums were visited with the exception of the Natural History Museum. The examples at Whitby could not be handled because they were on display. In these two cases records have been made from photographs or by observations made by looking through the display cases.

The rolls were catalogued in a spreadsheet (archived in ADS: https://doi.org/10.5284/1041580), and characteristics were noted such as charring and location of charring, whether it was rolled or a piece of bark (as a result of being originally flat, unrolled or broken), and measurements were taken using digital calipers: height (top to bottom when looking end on), width (side to side when looking end on) and length (length from one end to the other). The bark was then examined for evidence of cutting. In some cases it was possible to determine that the birch bark was humanly modified because the bark was thick (about 3 mm or more), usually cut in a straight line vertically and often tightly rolled; alterations which are not observed in naturally shed bark.

Many of the specimens were extremely fragile and in some cases broken, compressed or flaking to pieces and so not always possible to tell whether it had originally been rolled or not. It was difficult to be sure of charring in every case due to the dark organic peat-staining on the bark surface making it difficult to identify any traces, particularly in cases where the rolls were still wet-packed from excavation. It is also difficult to identify internal charring without taking the rolls apart, though sometimes it is visible externally. Measurements posed a problem particularly in terms of height, where the roll had been compressed by the peat, and so few height measurements were made. In addition, often the height at one end was different to the other, in which case, and where possible, both measurements were recorded. Where there was uncertainty a characteristic was not recorded.

Results

Of the 191 specimens, 161 rolls and 30 pieces of bark were identified. The pieces of bark varied in size, ranging from fragments to a piece 210 mm in length. Three pieces of bark showed definite signs of cutting: for example, <94289> is a thick, flat piece of bark which has been cut vertically and cannot have come off a tree in this way naturally (Figure 30.5). Overall, the bark shows no distinct spatial patterning and comes from the dryland, the detrital wood scatter, the bead area (to the north of cutting III), and Clark's area (Figure 30.1).

Of the 161 rolls, 74 were broken. Of the 117 rolls which provided length and width measurements, there was a range of sizes and shapes with some very large pieces of bark as well as some very small pieces (Figure 30.6). None are as long as the largest one found by Clark of 30 inches [c. 760 mm] (it is interesting to note that this one was not found in the museum collections). The lengths generally fall below 150 mm, with the majority falling below 100 mm, and the widths are generally smaller than 60 mm with the majority under 40 mm. A number of the rolls are tightly rolled and some of these have been termed 'cigar-like' (Figure 30.7). In some cases, where the rolls had broken or the ends were in good condition, it was possible to count up to seven or eight layers.

Each specimen was also carefully analysed for evidence of charring. The degree of charring varied and in four cases was very obvious; the bark had turned black and shiny with a crazed or bubbly, honeycomb-like surface. Overall, charring was evident on 66 (41%) of the rolls with a further eight possible cases. This is a remarkably greater frequency of charring than seen among the wider wood assemblage (3.7% across the entire assemblage; 5.3% across the culturally modified assemblage).

Of the charred rolls, four had burning at both ends and all were found in Clark's area. A further 14 were burnt at one end: six from the museum collections that had been recovered during the original excavations, and the rest from reed peat (312), of which four derived from Clark's area, two from the eastern platform and two from the wetland deposits. A total of seven exhibited clear signs of burning within the rolls: two from the Scarborough collections (and so dating to Clark's excavations), two from reed peat in Clark's area, two from wood peat (310) in the area north of cutting III where the beads were found (Chapter 33), and one from the reed peat in

Figure 30.5: Photograph showing thick, cut bark from <94289> (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).
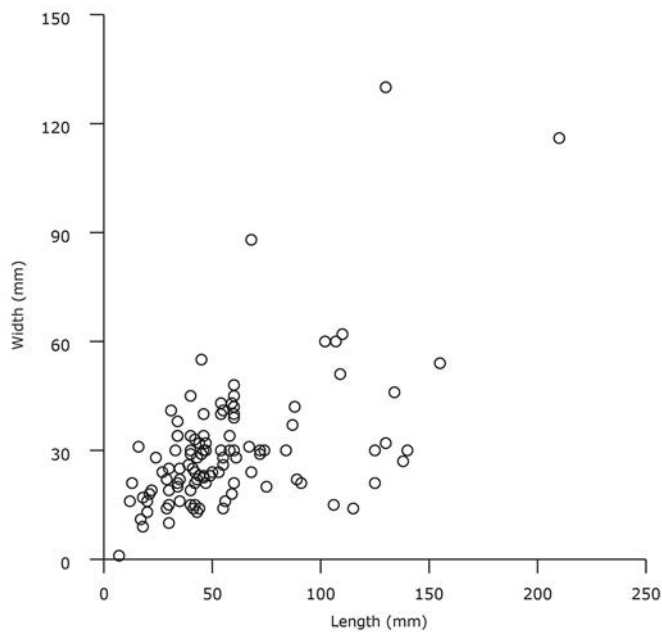
Figure 30.6: Graph showing the length and width of the birch bark rolls that could be measured (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 30.7: Photograph of a 'cigar' type birch bark roll <115225> which also exhibits signs of charring on the lower side (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

the area of the eastern platform. A further three exhibited burning at both one end and inside: lake area wood peat, wood peat in the bead area, and a roll from the Scarborough collection. A further sample was burnt on the outer surface and internally, and this again was a museum sample from The Yorkshire Museum. Nine showed traces of charring on the outer edge: two of these came from reed peat and detritral mud in the detrital wood scatter; two from the wood peat, and one from the eastern platform reed peat; one from Clark's area reed peat; and three from museum collections. All other records of charring were on fragmented pieces.

Overall, the charring shows no clear patterning (Figures 30.1 and 30.8). It occurs across the site and in each area there are similar numbers of rolls which have not been charred. The different types of charring on the birch bark rolls can be explained in a number of ways. Firstly, it is possible that some charring can be attributed to natural or anthropogenic fires across the reed beds, as has been suggested by Dark (1998b). Those birch bark rolls which are heavily charred, or even which have one end charred, could have been naturally occurring birch bark rolls which were charred by accident. It is harder to suggest accidental charring for those which have two ends charred or which exhibit charring inside but not on the outside, many of which have been deposited in Clark's area. The most likely explanations, as already suggested by Clark, are that they were being used as tapers, torches, or for the production of tar.

What is surprising from our recent excavations is the absence of further identifications of birch bark tar, despite conducting extensive residue and microwear analysis across the site. No more 'resin cakes' or macroscopically visible residues on tools have been found since Clark's discoveries (1954), confirmed as originating from birch bark tar by Aveling and Heron (1998). Whether the lack of further birch bark tar discoveries is due to unexplained taphonomic factors or, perhaps more simply, that birch bark tar was not present in the excavated parts of the site is unknown. Amorphous orange-red deposits were found on several lithics during microscopic residue analysis that were hypothesised to be possible resinous residues. However, when tested by chemical characterisation techniques, specifically Micro-Raman and GC-MS, these residues were demonstrated to be mineral in origin, and they were identified securely as iron oxide (Croft 2017). This research provides an important warning against identifying amorphous residues using visual methods only.

Torches

The examination of the birch bark rolls also led to the discovery of two multiple component torches. These are composed of a stick with birch bark wound around one end, with clear evidence for combustion of the bark. The locations of fire exposure on these artefacts and appearance of carbonisation is unmistakable, with shiny black colouration, and fragile bubbly honeycomb appearance where the fire was alight.
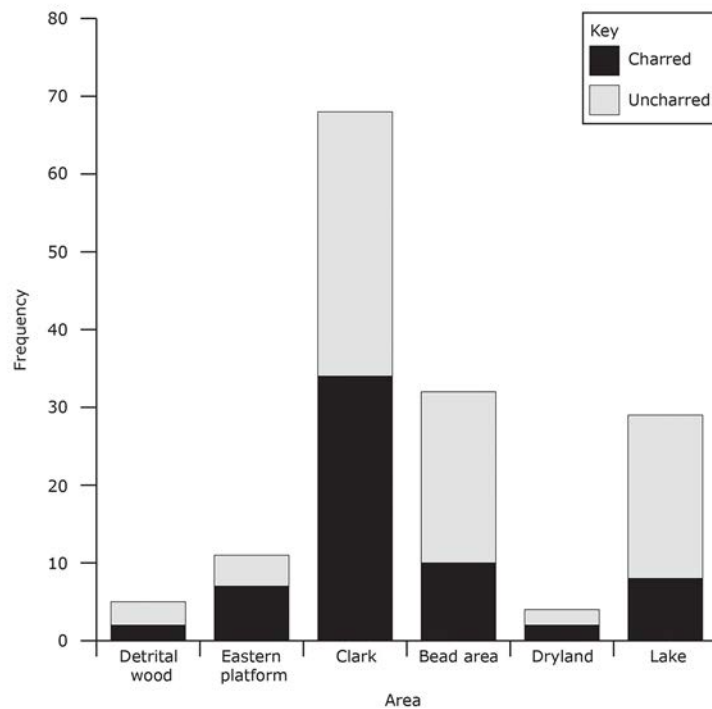
Figure 30.8: Graph showing the distribution of charred and uncharred birch bark rolls found at Star Carr (Copyright Star Carr Project, CC BY-NC 4.0).

<115628>, recovered from Clark's area, was wrapped around a small length of roundwood identified as aspen (*Populus* sp.) (Figures 30.9 and 30.10). The roundwood was moderately charred, broken at both ends and measured 41 × 19 × 17 mm. A further possible torch is <107756>, which was found in the detrital wood scatter in the reed peat (312). This appeared to be a birch bark roll but had a piece of moderately charred roundwood at its centre (130 × 17 × 15 mm), broken at both ends and also identified as aspen. There is no evidence of woodworking, although the item is twisted through a half turn along its length, somewhat reminiscent of a twisted withy. The roll contained charcoal and fragments of bark.

The uncharred rolls

The rolls which have not been charred may have been collected for tar production or the creation of torches at a later date. Alternatively, they may have been gathered for other purposes such as fishing floats (Robson et al. 2016). Ethnographic analogies (for example, Svensk uppslagsbok 1956, vol. 9:1112) have demonstrated that birch bark rolls were used as net floats in conjunction with fishing (Figure 30.11).

A number of sites have revealed evidence for net floats made of birch or pine bark: Friesack IV (Gramsch 1992; Robson 2016), Antrea Korpilahti in Russia, Riihimäki Sinivuokkoniemi in Finland (Koivisto 2011), Siivetsi in Estonia (Kriiska and Roio 2011), Sventoji 6 in Lithuania (Rimantiené 2005), Møllegabet II in Denmark (Skaarup and Grøn 2004), and Vis I in Russia (Burov 1989). At the inland peat bog site at Zamostje 2 in Russia, three fishing floats were recovered, two made from willow (*Salix* sp.) and the other from pine (*Pinus* sp.) bark. All three floats were egg shaped with a 'hole shifted to the end' (Lozovski et al. 2013, 31). Although absent at Star Carr, wooden discs with perforations have also been recovered from a number of Early to Late Mesolithic sites including: Holmegaard IV, Maglelyng (Troels-Smith 1960), Møllegabet I (Skaarup 1983) and Tybrind Vig (Andersen 2013) in Denmark; Rüde LA 2, Satrup LA 71 Förstermoor, Südensee LA 1b (Schwabedissen 1960; Feulner 2012), Grube-Rosenhof LA 58 (Hartz and Kraus 2009) and Hohen Viecheln (Schuldt 1961) in Germany; Veretye I in Russia (Oshibkina 1983); and Sventoji in Lithuania (Rimantiené 1979).

Figure 30.9: Side view of a composite torch <115628>. The wood stick is shown by the white ring and birch bark is wound around it. Both the stick and the bark are charred (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 30.10: Illustration of composite torch <115628> (Copyright Chloe Watson, CC BY-NC 4.0).

0   50mm
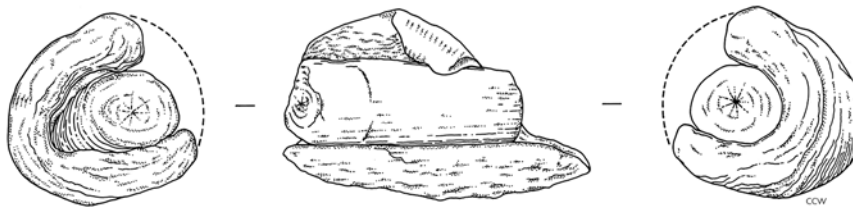
European context

Birch bark rolls have been found on a number of Early Mesolithic sites in Europe. In Denmark, excavations at the site of Mullerup Syd (Sarauw 1903) produced bark rolls made from a number of wood species including birch and hazel. Sarauw (1903) suggested that although some may be natural, one of the smaller rolls (20 × 8 mm) had a cut mark on it. At the Danish site of Ulkestrup Lyng at least two birch bark rolls were recovered from the floor layer (Andersen et al. 1982, Tauber 1971). At the Late Mesolithic Ertebølle site of Tybrind Vig a birch bark roll was found in mud deposits; four tightly fitted layers of thin bark (< 0.5 mm thick) were found bound together, which were interpreted as being used for the production of birch tar (Andersen 2013). In Germany, at Friesack IV, numerous specimens were recovered including one which had resinous material (pitch) adhering to it, which may represent tar production, perhaps for hafting composite tools or use as a sealant (Gramsch 1992, 2016; Gramsch and Kloss 1989, 321; Gramsch 1992). Furthermore, a small number of birch bark rolls were recovered in the gyttia deposits at the Swedish Middle to Late Mesolithic site of Tågerup (Karsten and Knarrström 2003).

Based on these data, it would appear that birch bark rolls were used throughout the entire Mesolithic period in Northern Europe. In many cases, they are interpreted as being used for the manufacture of tar, which is also found at a number of sites, such as Ageröd V, Bökeberg and Segebro in Sweden (Larsson 1982, 1983; Karsten and Regnell 1995; Regnell et al. 1995) and Locality 17 and Øvre Storvatnet in Norway (Bang-Andersen 1989, 348). Broadly contemporaneous with Star Carr, the Early Mesolithic Maglemose sites of Barmosen I in Denmark and Huseby Klev in Sweden yielded numerous pieces of birch tar, some of which had human teeth impressions (Hernek and Nordqvist 1995; Johansson 1990). At Barmosen I, a total of 22 pieces were found. Of these, two had human teeth impressions (Johansson 1990). At Friesack IV, lumps and flat pieces of resin, some with teeth impressions, have also been found (Gramsch and Kloss 1989, 321; Gramsch 1992). Although lacking teeth impressions a number of 'resin lumps' or 'resin blocks' have been recovered from several Early Mesolithic sites, including Pulli in Estonia (Vahur et al. 2011) and Thatcham III and Lackford Heath in Britain (Hedges et al. 1994). Furthermore, birch bark tar, used as a hafting adhesive, has been identified on a number of different artefacts from several Mesolithic sites. At Ageröd V in Sweden at least four micro-blades had varying amounts of tar adhering to them (Larsson 1983), and in Rönneholms Mosse in Sweden, birch bark tar was found adhering to a wooden arrow (Larsson and Sjöström 2010; Larsson et al. forthcoming). Tar has also been identified on an unretouched stone tool from Thatcham III, Britain (Hedges et al. 1994), as well as a microlith from Holm Mølle, Denmark (Rysgaard et al. 2016), Pulli, Estonia (Vahur et al. 2011) and Seedorf, Germany (Aveling and Heron 1999). Lastly, it was also identified on seven barbed points from Friesack IV in Germany (Gramsch 2011).

Experimental analysis

Rationale

In order to test how and why some of these birch bark rolls have been charred, a number of experiments were carried out. In particular, we wanted to test a variety of different uses of birch bark rolls involving charring: tapers (used for lighting fires), torches and heating for tar extraction.

Tapers

A number of attempts were made by creating birch bark tapers out of thin strips of bark. The birch strip was lit at one end and although at first it started to burn, the flame died out seconds later. During a second attempt the

Figure 30.11 (page 431): Photograph of birch bark rolls used as fishing net floats at the Koguva Fishing Museum, Estonia (Copyright Harry Robson, CC BY-NC 4.0).

Figure 30.12 (page 433): Photograph of a lit torch made from rolled birch bark (Photograph by Aimée Little. Reprinted from Boreham et al. 2011b. Copyright (2011) with permission from Elsevier).

end of a small roll of birch bark was used. This also caught alight and continued to burn quickly whilst curling into a tighter roll. However, it too died out after a few seconds. Although this method did reproduce the same pattern of charred ends seen on the archaeological examples, it did not appear to be a very effective taper. It is possible that the bark was not dry enough, but even so, it is hard to see why birch bark would be used as tapers; if fires were blazing, a stick can be used more effectively to transfer fire, and if fires are being lit from scratch, it is better to use very fine bark material to get a fire to catch rather than a roll.

Torches

A number of different methods were used to produce a torch. The first simply involved wrapping a roll around a stick. To make the bark more pliable for rolling, it was first held over flames for a few seconds. Once rolled, it took several attempts to get it to catch fire, and even then it only burned for a few seconds, resulting in a small percentage of the outer birch bark roll being charred. It is likely that it did not burn well due to the restriction of airflow between each layer of the roll.

In order to improve the duration of burning, a second torch was made by placing dried leaves within the roll. Once again it was wrapped around a stick and staked into the ground. Again the torch only burned for a few seconds and then died out, leaving a charred outer surface. A further attempt was made by placing sticks and twigs between each layer of the roll, then wrapping the roll around a stick and staking it into the ground. This too was unsuccessful: the torch charred the outer bark roll and then burnt out. A variation on this attempt was tried using ripped layers of birch bark to make a roll, with linden bast fibre then wrapped around the roll and tied to a stake which was then placed in the ground. Although the torch burned, the dried materials fell out and the roll then unravelled.

Finally, rather than using fresh bark, old bark was used instead. These torches proved very successful, burning for almost ten minutes (Figure 30.12). It is likely that the success of these is that old birch bark does not curl up as tightly as fresh bark, which means air can circulate between the layers of the roll.

Aceramic birch tar production

The use of tar extracted from birch bark can be traced as far back as the Middle Palaeolithic (Mazza et al. 2006). As birch bark tar had previously been identified at Star Carr, it made sense to investigate whether birch bark rolls could have been used for this purpose, using an aceramic method of tar production (see Meijer and Pomstra 2011). A fire was built early in the morning and continually added to over the course of the day to sustain the fire and increase temperature. In the late afternoon, three birch rolls were placed upright into the ground underneath the fire and covered with soil and hot ashes (Figure 30.12). The fire was not placed directly over the top of the rolls but to the side. After 30 minutes, the rolls were inspected but they were not charred. The rolls were kept covered for another 15 minutes and then taken out of the ground one at a time. All three rolls were hot from the ashes and also very soft. The tops of each roll were charred. Each roll was unravelled and inside the centre of each one charring was visible and the bark had begun to turn to ash. We believe this attempt was unsuccessful because high wind and a damp autumn day had made it difficult to reach the high temperature required to produce tar. On another occasion, when weather conditions were favourable, the same experiment was repeated, reaching a maximum temperature of 570°C. On this occasion we were able to produce tar, though not in any substantial quantity but enough to haft a couple of flint tools.

This low production of tar is interesting. As well as being dependent on weather conditions (though windbreaks may have been used, or even huts), it suggests that if these rolls were being used for this purpose, people probably made tar and stored it on sticks, to be reheated and used at a later date. It is also important to note that like the archaeological birch bark rolls, the replica rolls were also only partially burnt, typically at one end. This was not the case with the birch torches which burned away entirely. Thus, when burning patterns are compared, replica rolls used in tar production are more comparable with what is seen archaeologically.

Figure 30.13: (left) Photograph of a bound birch bark roll amid hot embers; further hot embers were placed over the roll that heated it for several minutes; (middle) the roll emerged charred at one end; (right) tar was used for hafting a microlith (Copyright Aimée Little, CC BY-NC 4.0).

Conclusions

The analysis of the birch bark from Star Carr has revealed some important new discoveries. The birch bark mat, made up of several layers, is a new type of artefact for Star Carr. Unlike the other mats known from Europe, this does not appear to be part of a floor or a particular activity zone, although perhaps any evidence has long since disappeared. Alternatively it might be a stack of birch bark left at this location with the intention for further production at a later date. The possible container is a very different piece of bark again, though lacks evidence that it was actually a vessel.

There is clear evidence that many of the birch bark rolls have not fallen from trees naturally: several pieces of bark have clearly been cut. In addition, they are found in discrete areas and particularly in zones of other anthropogenic activity such as Clark's area, and north of cutting III where bead manufacturing appears to have taken place (Chapter 33). The birch bark and the rolls also show evidence of burning. It is surprising that this was not noticed during Clark's excavations, but from the letters in Scarborough museum stores (Milner et al. 2013b) it looks likely that most of the birch bark rolls may have been collected by Moore whilst he was excavating the baulks and as a result Clark may not have had not studied them in as much detail as much of the other material.

The burning may be a result of a range of factors, some of which are potentially due to natural fires, but there is clear evidence for the use of torches and potentially the production of tar: although tar has not been found in the recent excavations, it was found in the original excavations by Clark. The experimental work has shown that when creating tar, the birch bark rolls can take on a bubbly, honeycomb effect which is evidenced on a number of the archaeological specimens.

Some of the birch bark is rolled but not charred, and there is the possibility that these rolls were used as some sorts of floats in fishing. Alternatively, they may have been collected for future tar production. Overall, it is likely that birch bark was used for a number of different purposes, many of which are likely to be archaeologically invisible, and the resource appears to have been used widely across Northern Europe.

CHAPTER 31

The Star Carr Fungi

Harry K. Robson

Introduction

'*Quantities of a large bracket fungus identified by Mr E. J. H. Corner of the Botany School, Cambridge University, were found. A few specimens adhered to birch stems, but most are presumed to have been gathered. In some examples the flesh has been stripped off, possibly for use, as Mr Corner suggests, as tinder (amadou).*'

(Clark 1954, 18)

Although Clark (1954) referenced the original report by Corner (1950), which was based on the fungi recovered from the 1950 excavation campaign, he does not provide any further information on the assemblage. Consequently there is no way of knowing whether any further specimens were recovered during the 1949 and 1951 excavation campaigns. Moreover, neither Corner (1950) nor Clark (1954) stated how many specimens were found or provided any quantification for the number of specimens that were burnt or modified. From the archive mapping undertaken by Milner et al. (2013a), at least 11 specimens are known to exist. A total of nine specimens were recorded in the collections at the Rotunda Museum in Scarborough. In addition, one is presently on display at the Whitby Museum (Milner et al. 2013b), and another one is on display at the British Museum.

Corner's report (1950) states that the large bracket fungus was identified based on the microscopic structure and comparison with recently collected specimens. According to Corner (1950), the absence of spores was attributable to their germination in water or to their decay. However, it was also noted that spores have not been recorded on living specimens, except during the spring, and so it is possible that those from Star Carr may have been collected during the summer or autumn months 'when it is usual for "foresters" to fell trees or to collect bark (in preference to spring when the sap is rising and makes the wood wet and the implement clog)' (Corner 1950, 124).

Corner (1950) stated that the fungi are likely to have been detached from living birch (*Betula* sp.) trees with ease, procured by felling, rolling, sorting, shouldering, pulling and throwing down of the trunks or branches, or by simply stripping from the bark. He suggested that they were probably purposefully collected because 'some of the specimens have the flesh (or upper layer of the bracket) stripped off from the tubes' (Corner 1950, 124). However, he also noted that some of the specimens were still adhering to the birch stems in the archaeological layer, and so their presence indicates that not all of the assemblage was anthropogenically derived.

Regarding use, Corner (1950, 123) cited Ramsbottom (1923):

'This is the fungus of amadou (soft amadou or German tinder) much used in former times as tinder (for catching sparks engendered by striking steel on flint). It was also employed as a styptic for staunching slight wounds, and for making soft surgical pads: it had its use in dentistry until comparatively recent years. Amadou is used on the Continent for making picture-frames, ornaments, and such like. In certain regions, particularly Bohemia, caps, aprons, chest-protectors, and articles of dress are made from it. The woods of Thuringen are said to produce 1000 cwts of tinder yearly. Amadou is prepared by freeing the flesh from the hard crust and the tubes, cutting it into slices and cooking several hours in lye or soaking in a solution of saltpetre. After drying, the substance is beaten until it becomes lax and spongy.'

Methods

In order to identify what species were present in the assemblage recovered from the recent excavations, the archaeological specimens were compared with modern examples: tinder bracket (*Fomes fomentarius,* Fries 1849), willow bracket (*Phellinus igniarius,* Quél 1886), razor-strop fungus (*Piptoporus betulinus*, Karst), and cramp balls (*Daldinia concentrica*, Cesati and de Notaris); and by consulting the following works: Garnweidner (2013), Læssø (2013), and Phillips (1981). Where applicable, the specimens were measured according to the criteria set out by Læssø (2013) (Figure 31.1). In order to determine whether any of the specimens exhibited traces of having been burnt or modified, the specimens were cleaned using a soft brush with cold tap water and then examined. To determine whether there were any differences on an intra-site scale, the majority of the specimens were plotted using GIS. Lastly, in order to place these data into the wider European context, a comprehensive literature review concerning the occurrences of fungi recovered from other Mesolithic archaeological sites in north-west Europe was undertaken.

Results

In total, 82 fungi were identified. Of these, 81 were derived from the more recent excavations undertaken at the site (Table 31.1). The other specimen was retrieved from Clark's backfill by David Lamplough, a local volunteer, and gifted to the University of York in 2013.

Figure 31.1: Photograph of a modern *Fomes fomentarius* specimen showing the measurements that were undertaken (Copyright Harry Robson, CC BY-NC 4.0).

Excavation season	Number of specimens
1949 (Lamplough collection)	1
SC06	2
SC10	9
SC13	19
SC15	51
Total	82

Table 31.1: Table showing the number of specimens recovered per excavation campaign at Star Carr examined in this study.

Family	Genus and species	Common name	Habitat
Hymenochaetaceae	*Phellinus igniarius*	Willow bracket	Parasitic on willow
Polyporaceae	*Fomes fomentarius*	Tinder bracket	Parasitic on hardwood tree species
Fomitopsidaceae	*Piptoporus betulinus*	Razor-strop fungus	Parasitic on birch

Table 31.2: Identified fungi species with habitat data (Læssø 2013).

The identified fungi taxa are listed in Table 31.2. Of the 82 specimens analysed, 78 could be identified to the genus and species levels. The four specimens that could not be identified were fragments and included the specimen recovered by David Lamplough, two that were recovered during the 2010 excavation campaign and a further one recovered in 2015. *Fomes fomentarius* (Figure 31.2) dominates the assemblage (NISP = 76; 97.4%). There is also one *Phellinus igniarius* specimen and one *Piptoporus betulinus* specimen (Figure 31.2). The data provided in Table 31.3 are based on those 78 specimens and have been divided according to excavation campaign.

In total, 28 of the specimens could be measured: 27 *Fomes fomentarius* and one *Piptoporus betulinus*. Bracket diameters range from 61 to 233 mm, bracket depths measure from 47 to 203 mm and bracket thickness ranges from 20 to 119 mm. The summary statistics for the measured specimens are provided in Table 31.4.

Of the 81 specimens recovered during the more recent excavations, only one was found adhering to a tree; the others may have been removed from their host tree either by people or fallen naturally.

A total of 54 specimens exhibit signs of modification. Modified specimens included the interior or a strip from a fruit body, or a specimen that exhibits removal of the outer surface (Figure 31.2). Of the 54 specimens, one has at least two very clear incision marks. In total, 41 of the specimens appear to have been charred. However, the degree of charring is not uniform. Whilst some of the specimens have been partially scorched or charred, others have been heavily charred and have become carbonised (Figure 31.3). In addition, the location of the heat exposure varies from isolated areas of the specimen to the complete fruit body, and from portions of the interior to intentionally removed strips.

Of the 82 specimens analysed in this study, 64 can be spatially plotted using GIS (five fungi have no spatial data and 13 were recovered from Clark's backfill). It can be seen that there are two main concentrations of fungi deposition at Star Carr: one in Clark's area and a second in the detrital wood scatter (Figure 31.4). In addition, those specimens that have been either burnt or modified were found in both areas. Although the majority of modified specimens are located in Clark's area, the sample size is not large enough to suggest significant patterning (Figure 31.5).

Discussion

In order to place these data into the wider European context, a literature review was undertaken (Table 31.5). Although the majority of archaeological sites that have yielded fungi are dated to the Late Mesolithic Ertebølle

Figure 31.2: Photograph showing the three different species of fungus that were identified in the assemblage. Clockwise from top right: burnt *Fomes fomentarius* specimen, the one *Phellinus igniarius* specimen, the one *Piptoporus betulinus* specimen and a larger and modified *Fomes fomentarius* specimen that has had its outer surface intentionally removed (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Excavation season/genus and species	SC06	SC10	SC13	SC15	Totals
Phellinus igniarius			1		1
Fomes fomentarius	2	6	18	50	76
Piptoporus betulinus		1			1
Totals	2	7	19	50	78

Table 31.3: Identified fungi per excavation campaign with quantification.

Sample group (sample size)	Diameter (cm)	Depth (cm)	Thickness (cm)
All fungi (n=28)	12.0 ± 5.1	9.9 ± 4.0	5.9 ± 2.6
Fomes fomentarius (n=27)	12.2 ± 5.1	10.1 ± 3.9	6.0 ± 2.5
Piptoporus betulinus (n=1)	6.1	4.7	2.8

Table 31.4: Summary statistics for the various categories of fungi analysed in this study.

Figure 31.3: Close-up photograph of a charred *Fomes fomentarius* specimen that is likely to have been initially removed from the original fruit (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).
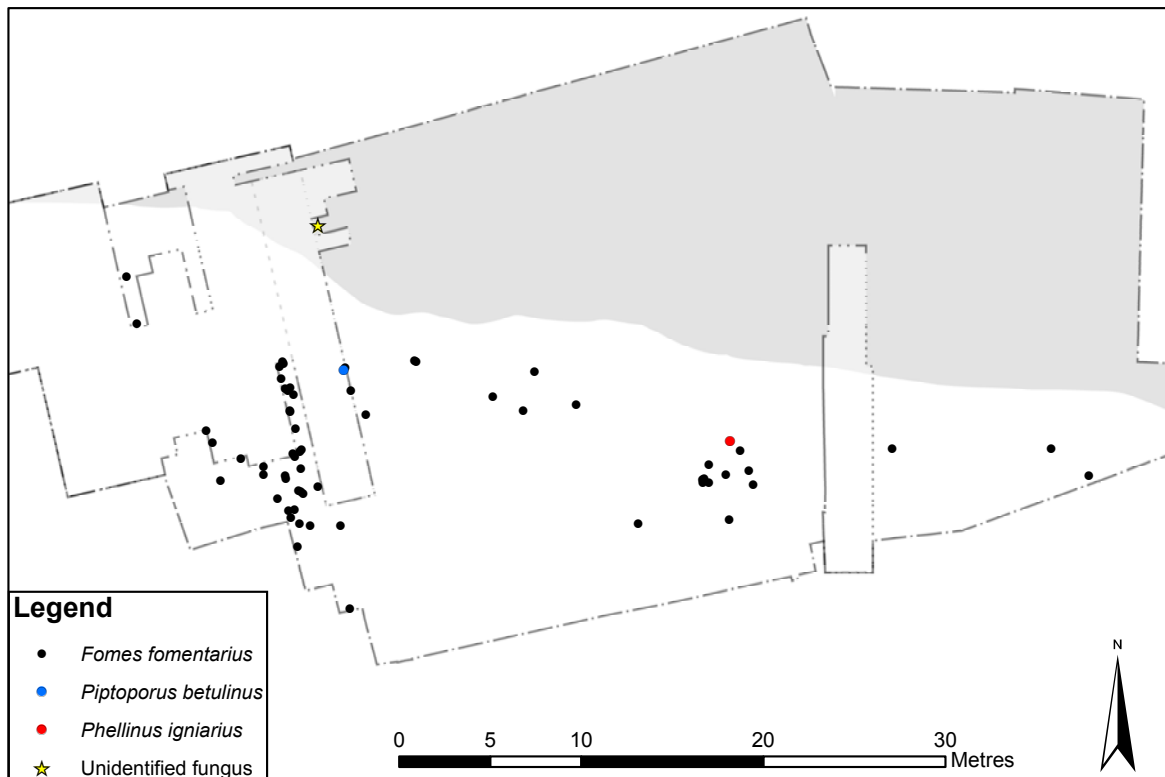
Figure 31.4: Distribution map for the majority of the fungi recovered from the recent excavations at the site. The one *Piptoporus betulinus* specimen was recovered in Clark's cutting II, whilst the one *Phellinus igniarius* was recovered from the detrital wood scatter to the west of the VP85A trench (Copyright Star Carr Project, CC BY-NC 4.0).
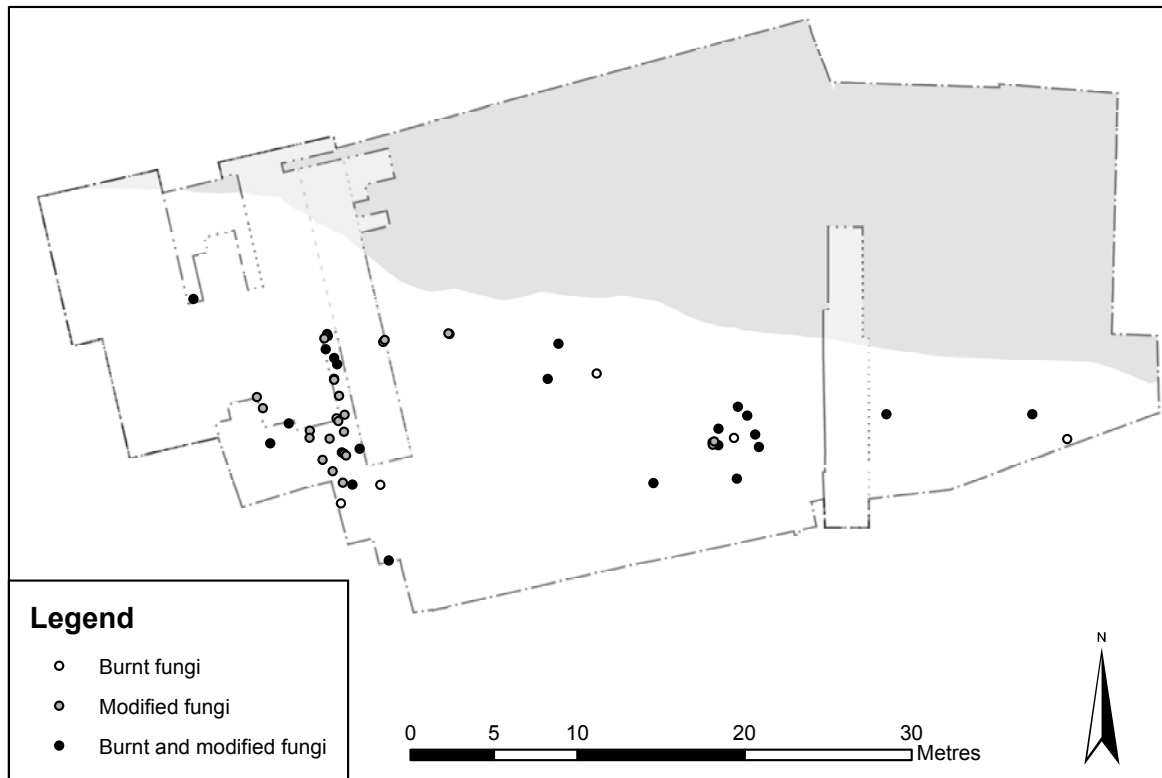
Figure 31.5: Distribution map for the burnt, modified, as well as burnt and modified fungi recovered at Star Carr (Copyright Star Carr Project, CC BY-NC 4.0).

and Swifterbant cultures (n=13), there are at least four Early Mesolithic Maglemosian sites: Mullerup and Ulkestrup Lyng in Denmark, and Friesack IV and Hohen Viecheln in Germany (Gramsch 1973; Sarauw 1903; Schuldt 1961; Andresen et al. 1981; Gramsch pers. comm. 2016) and one Middle Mesolithic site: Vis I in Russia (Burov 1989).

Despite a lack of detail concerning the number of specimens recovered from the four Early Mesolithic sites, 'many' specimens were recovered from Friesack IV (Gramsch 1973; pers. comm. 2016), including fungi from the Polyporaceae family (bracket fungus) (Burov 1989, 400), whilst those from Hohen Viecheln are mentioned in the publication by Schuldt (1961). According to Sarauw (1903, 193), fungi from Mullerup, identified as willow bracket (*Phellinus igniarius*), were encountered in the settlement layers of the site and had probably been harvested, brought to the site and used as fire starters (Sarauw 1903, 193, translation by Theis Zetner Trolle Jensen). Similarly, although it is not stated how many specimens were found at Ulkestrup Lyng, one tinder fungus was recovered from the refuse layer.

A number of younger Mesolithic sites have also produced evidence, for example Vis I in Russia (Burov 1989) as well as sites in Denmark and Northern Germany, including Bloksbjerg, Grube-Rosenhof, Møllegabet II, Neustadt, Timmendorf-Nordmole I and Tudse Hage. Again, it is unknown how many specimens were encountered (Westerby 1927, 124; Skaarup and Grøn 2004, 91–92; Lotz 2008; Andersen 2013, 115; Pedersen 2014). However, of these localities, it has been noted that a couple of the specimens recovered from the submerged North German site at Neustadt had been modified, possessing scrape marks on their lower surface (Hirsch et al. 2008, 35).

At the Danish locality of Møllegabet I at least one *Fomes fomentarius* specimen was recovered, which is currently on display in the Langeland Museum (Andersen 2013). One large tinder fungus was also recovered from within the prow of a dugout canoe at the site of Margrethes Næs, Denmark (Myrhøj and Willemoes 1997). Interestingly, it was noted that:

	Daedalea quercina	*Fomes fomentarius*	*Fomes or Polyporus fomentarius*	*Ganoderma applanatum*	*Gloeophyllum trabeum*	*Kretzschmaria deusta*	*Phellinus igniarius*	Polyporaceae	Unknown	Totals
Early Mesolithic										
Friesack IV, Germany		X						X		Unknown
Hohen Viecheln, Germany								X		Unknown
Mullerup, Denmark							X			Unknown
Ulkestrup Lyng, Denmark		X								Unknown
Middle Mesolithic										
Vis I, Russian Federation								X		Unknown
Late/Terminal Mesolithic										
Bloksbjerg, Denmark		X								Unknown
Hardinxveld-Giessendam De Bruin, Netherlands		2		12	1	9			1	25
Grube-Rosenhof, Germany		X								Unknown
Margrethes Næs, Denmark		1								1
Møllegabet I, Denmark		1								1
Møllegabet II, Denmark		X								Unknown
Neustadt, Germany		X								Unknown
Rødbyhavn, Denmark		20								20
Ronæs Skov, Denmark		8								8
Smakkerup Huse, Denmark			>10							>10
Timmendorf-Nordmole I, Germany		X								Unknown
Tudse Hage, Denmark		X								Unknown
Tybrind Vig, Denmark	1	13								14
Totals	**1**	**>45**	**>10**	**12**	**1**	**9**	**?**	**?**	**1**	**>79**

Table 31.5: Table detailing the number of identified specimens recovered from the 18 known Mesolithic archaeological sites in northern Europe (X indicates presence).

'on this fungus a piece of bark from the host tree (a birch) was preserved. The pores of the fungus were at a right angle to the line of the bark. It must therefore have grown on a fallen birch log.' (Myrhøj and Willemoes 1997, 163)

From Ronæs Skov, Denmark, eight specimens identified as *Fomes fomentarius* were recovered. The specimens measured between 7.5 and 21.0 cm in diameter. Unlike those from Star Carr there was no evidence of charring or modification (Andersen 2009). However, there was one example that was recovered from within a hearth. At the Danish site of Smakkerup Huse a number of large pieces of tree fungi or polypores (*Fomes or Polyporus fomentarius*) were recovered. It was stated that more than 10 specimens were recovered during the excavations. In addition, whilst one specimen had a diameter of between 13 and 22 cm, the others were greater

than 10 cm in diameter (Mason 2005, 82–83). At the Dutch site of Hardinxveld-Giessendam De Bruin, 25 specimens were recovered. Of these, 24 were identified to the genus and species levels (Louwe Kooijmans 2001, 395–397; Adema 2002). At least 20 specimens of *Fomes fomentarius* are known from the recent excavations at Rødbyhavn in Denmark (Sørensen 2017). Remarkably, one had been decorated (in the form of cross hatching) (Sørensen 2017). Although this form of decoration is frequently encountered on Late Mesolithic artefacts, for instance bone and antler tools (Andersen 1971), it has not been previously encountered on fungi.

Perhaps the most informative account of Mesolithic fungi is provided by Andersen (2013) in his monograph on the renowned Late Mesolithic site of Tybrind Vig, Denmark. In total, 14 pieces were recovered from within the archaeological deposits and according to the original analyst, Christian Lange, the specimens were very well preserved (Andersen 2013, 115). A total of 13 were identified as *Fomes fomentarius*, whilst the remaining specimen was identified as *Daedalea quercina* (Andersen 2013). Two of the specimens measured 4.6 and 6.0 cm in diameter, whereas the remainder were larger; the largest being 20 × 27 cm (Andersen 2013, 115). They all possessed a very small attachment surface, although they were lacking any traces of the host tree to which they had once been attached: this suggests that the fungi were cut from the trees while fresh and that they had been systematically selected (Andersen 2013, 115). Two had been connected to the underside of a branch, which may have enabled easier procurement. In addition, one specimen was charred and one specimen exhibited scrape marks on its lower surface where the tinder is located. Andersen (2013) stated that it was difficult to ascertain whether or not they represented a natural phenomenon or had been intentionally collected and then discarded by the inhabitants at the site; it was noted that the smaller specimens may have been washed in with the branches and logs that were also encountered in the gyttia deposits. However, given their relative abundance, and the fact that two had been modified, Andersen (2013) suggested that they had probably been intentionally gathered.

Ethnography

Throughout the northern boreal forest, the flesh of *Phellinus igniarius* has in the past been used as 'chew-ash'. Once roasted to ashes and mixed with chewing tobacco, or tea leaves, this fungus was used to produce a masticant or chew (Kroeger et al. 2012).

Whilst the bark of the fungus *Fomes fomentarius* is grey, thin and very hard, it is well-known that the flesh (which is soft, pale brown and of a corky appearance) can be used as tinder for fire starting (Cave-Browne 1992, 53; Læssø 2013). In addition, its flesh in the past has, and continues to be used for, hat manufacture and other items of clothing (Læssø 2013).

Regarding the extraction of tinder, Cave-Browne (1992, 53) states:

> 'To prepare this tinder, first remove the spore tubes until you reach the soft 'flesh', which is seldom more than 6 mm thick (what you now have resembles a quarter of a globe). Either soak this item for two days or boil it for c. two hours. With care the thin, hard bark can now be chipped away from the flesh with a sharp blade: the natural sharp edge of a strong flint flake will work quite well. Remove the part of the flesh that had been attached to the tree. Now start gently pounding the flesh that remains with a smooth fist-sized pebble, using another smooth rock as an anvil. Gently stretch the flesh with the fingers until it resembles coarse chamois leather. Dry it gently as too much heat hardens it. Char that part that will receive the first sparks, having first made ready a suitable air-tight container in which to extinguish the smouldering amadou'.

The *Piptoporus betulinus* bracket fungus has previously been used for sharpening razors, and for polishing in the watchmaking industry (Læssø 2013), whilst Turner (1998) stated that the aboriginal groups in British Columbia would ignite the corky inner flesh of the fungus, and transport it since it can smoulder for many hours. Since *Piptoporus betulinus* was recovered from the fire-making tool kit used by Ötzi (Chapela and Lizon 1993; Peintner and Pöder 2000; Pöder et al. 1994), it is assumed that a similar practice was undertaken in northern Europe. Furthermore, it has been demonstrated that this species 'could have been ingested as a vermifuge' (O'Regan et al. 2016, 140) in the past as the fungus possesses antibacterial properties (Carpasso 1998; Mears and Hillman 2007). Alternatively, the fungus may have been used for hafting lithics, as has been demonstrated in experimental research undertaken by Diederik Pomstra as part of this project (Figure 31.6).

Figure 31.6: Photograph showing a blade that has been hafted in the inner fruit of a birch polypore (Copyright Aimée Little, CC BY-NC 4.0).

It has also been documented that the First Peoples of British Columbia would transport the flesh of polypores for use as tinder within clam shells, cedar bark, or birch bark rolls (Turner 1998), whilst the flesh from another polypore (agarikon), *Laricifomes officinalis* (Kotlaba and Pouzar 1957), has in the past been used as a purgative (Deur and Turner 2005) or as shaman grave guardian figures (Kroeger et al. 2012).

Some aboriginal groups use a type of fungus, possibly a species of the Ganoderma genus, for tanning buck-skin, whilst others use burnt bracket fungi as a smudge against insects (Turner 1998). Other groups use the felt-like mycelium of a fungus to caulk canoes and boxes made from wood, and the Squamish use the corky inner flesh of another unknown bracket fungus for washing their hands (Turner 1998). Kroeger et al. (2012) state that the Haida use powdered *Echinodontium tinctorium* mixed with pitch as cosmetic face paint or for skin protective purposes from sunburn and insects (Turner 2004). Finally, a very different type of practice is undertaken by the Bella Coola (Kroeger et al. 2012) and Nuxalk peoples, who 'painted faces on large specimens of bracket fungi, attached miniature bodies of cedar bark to them, and used them as dance symbols in a special 'fungus dance' of the Kusiut ceremonials' (Turner 1998, 56).

Conclusions

Given the numerous uses of fungi documented in this chapter, it is likely that those recovered from Star Carr had probably been intentionally gathered by the site's inhabitants. This is supported by the fact that of the 82 specimens examined only one was found adhering to a tree. In addition, since the majority of the assemblage exhibits signs of burning and/or modification, *Fomes fomentarius* were probably preferentially selected for their tinder and primarily used as fire starters, which could have even been assisted with the use of small bows (Burov 1989), as has been suggested for other sites in Europe (Andersen 2009; Andersen 2013; Dal 2002; Gramsch 1973; Louwe Kooijmans 2001; Sarauw 1903; Schuldt 1961; Skaarup and Grøn 2004).

CHAPTER 32

The Palaeoethnobotanical Evidence

Anita Radini, Alison McQuilkin, Emma Tong and Nicky Milner

Introduction

Understanding how plants might have been used for food, fuel and building materials in the past can be very challenging, especially for prehistoric hunter-gatherers who trod lightly on the land and as a consequence left little trace of their presence behind them (Mason and Hather 2002). Indeed, very little evidence for plant use or burning was found in the original Star Carr excavations. Clark noted six shallow lenses of charcoal, two of which appear to be associated with pebbles; however, all that could be said was that fires had left little trace except a shallow lens of charcoal and that even where there were settings of stone pebbles associated with them there was no evidence of prolonged use (Clark 1954, 12, Figure 7).

Further investigation of burning was undertaken following the 1980s excavations: here Hather (1998) examined charcoal taken from monoliths sampled from the wetland, which was carried out in order to examine whether vegetation burning had happened in situ, locally or was a result of distant fires. He found that there was no evidence for domestic wood burning from the adjacent occupation and that the wood charcoal was largely derived from the burning of the reed beds.

In the recent excavations, the wetland deposits have revealed important information on ancient woodworking techniques, wooden structures, wooden artefacts and the use of bark and fungi (see Chapters 6, 28, 29, 30 and 31). In addition, macrofossils and pollen have been used to reconstruct the past environment (Chapter 19). However, we do not have macrofossil data which clearly pertains to human activity such as food processing; and indeed, even if people were dumping hearth waste into the lake, it is likely that most of it would have floated away. The only evidence that has been found is some discrete charcoal patches and these have been bulk sampled and investigated in the lab.

In terms of the dryland, we have looked carefully for evidence of plant-related activities in the form of charred plant remains, e.g. evidence of plants in the diet as well as choices of wood used. However, as with many Mesolithic dryland sites, there are problems with preservation and truncation: at Star Carr very little undisturbed buried soil is present and hearths are not visible. Despite these limitations, there are a number of areas on the dryland which have provided contexts with higher potential, such as the structures and the area of occupation spread around the central structure (see Chapter 20), and samples for flotation have been taken from these deposits as well as spot sampling across the site (see Chapter 15).

In addition, the micromorphology revealed that the hollow of the eastern structure was comprised largely of organic rich matter, and it was suggested that plant material, such as reeds, made a substantial contribution to sediments in the feature, having perhaps been used for flooring (Chapter 5; Conneller et al. 2012). It was therefore felt that phytolithology was a promising technique to employ (Dimbleby 1978; Rovner 1983). This chapter deals first with the charred plant macro-remains and then the phytolith study in order to examine the palaeoethnobotanical interactions at Star Carr.

The charred plant macro-remains

Sampling

In order to sample all archaeological features with strong potential for the recovery of charred remains, a sampling strategy and flotation programme was adopted following Historic England guidelines (Campbell et al. 2011). In total 411 bulk samples were taken for flotation. In 2008, the majority of grid squares in trench SC23 were sampled (Figure 32.1), with higher numbers of samples being taken from around the eastern structure. The lack of data from the vast majority of the trench (except from the structure) meant that in later years we tended to focus on areas with a higher likelihood of success such as features (see Chapter 15 for sampling methods). In addition, a total of 172 charcoal fragments from 80 locations were sampled by hand during the excavation. These were normally collected because they were relatively large pieces.

Importantly, six discrete charcoal dumps (samples 13, 1902, 1903, 1904, 1905, 3585) were found in the water-logged deposits, either at the base of the wood peat or in the reed peat, and these are assumed to be similar to those discovered by Clark (1954, 12) (Figure 32.1). These were cleaned, photographed and bulk sampled (Figure 32.2). In addition, samples were taken from: a large, sub-circular spread of charcoal (318) up to 7 m in diameter and 20–30 mm thick, which was recorded from the reed peat just above part of the central platform; an area of burning between Clark's trenches (sample 1878) and flint cache AC8 (see Chapter 8) (Figures 31.1 and 32.2).

Methods

Soil samples that were less than four litres in volume were sieved using the bucket flotation method to maximise the recovery of remains and larger samples were sieved in a tank (see Chapter 15). All fractions were scanned and sorted for analysis. The plant macrofossils were examined under a stereomicroscope at magnifications of between ×10 to ×40. All charcoal fragments above 1 mm were grouped according to their morphology/type. The fragments of each type were then fractured using an acupuncture needle to obtain the correct sections that allow viewing of anatomical features needed for their identification. The identification and nomenclature that follow are as specified in Chapter 15.

For the purpose of this study, all remains that could be identified were counted. Where this was not possible, because the remains were too small, the overall weight was recorded. Wherever possible, estimated age was also noted. Although most charcoal fragments were too small to be identified, and many features of the growth anatomy were not visible, a number of characteristics could be recorded which provided further details concerning the environment from which the wood was sourced, e.g. the presence of hyphal growth in the charcoal which indicates the use of dead wood (Asouti and Austin 2005; Scott 2010; Théry-Parisot et al. 2010). However, it must be stressed that fragments of charcoal this size or smaller (in the range of micro-charcoal) can be of windblown origin or even residual in soil and are therefore difficult to correctly interpret for analysis.

Results

Introduction

Un-charred seeds from modern arable weeds along with worm egg capsules were present in many samples, suggesting a degree of soil disturbance (this modern material was omitted from the analysis). No charred seeds
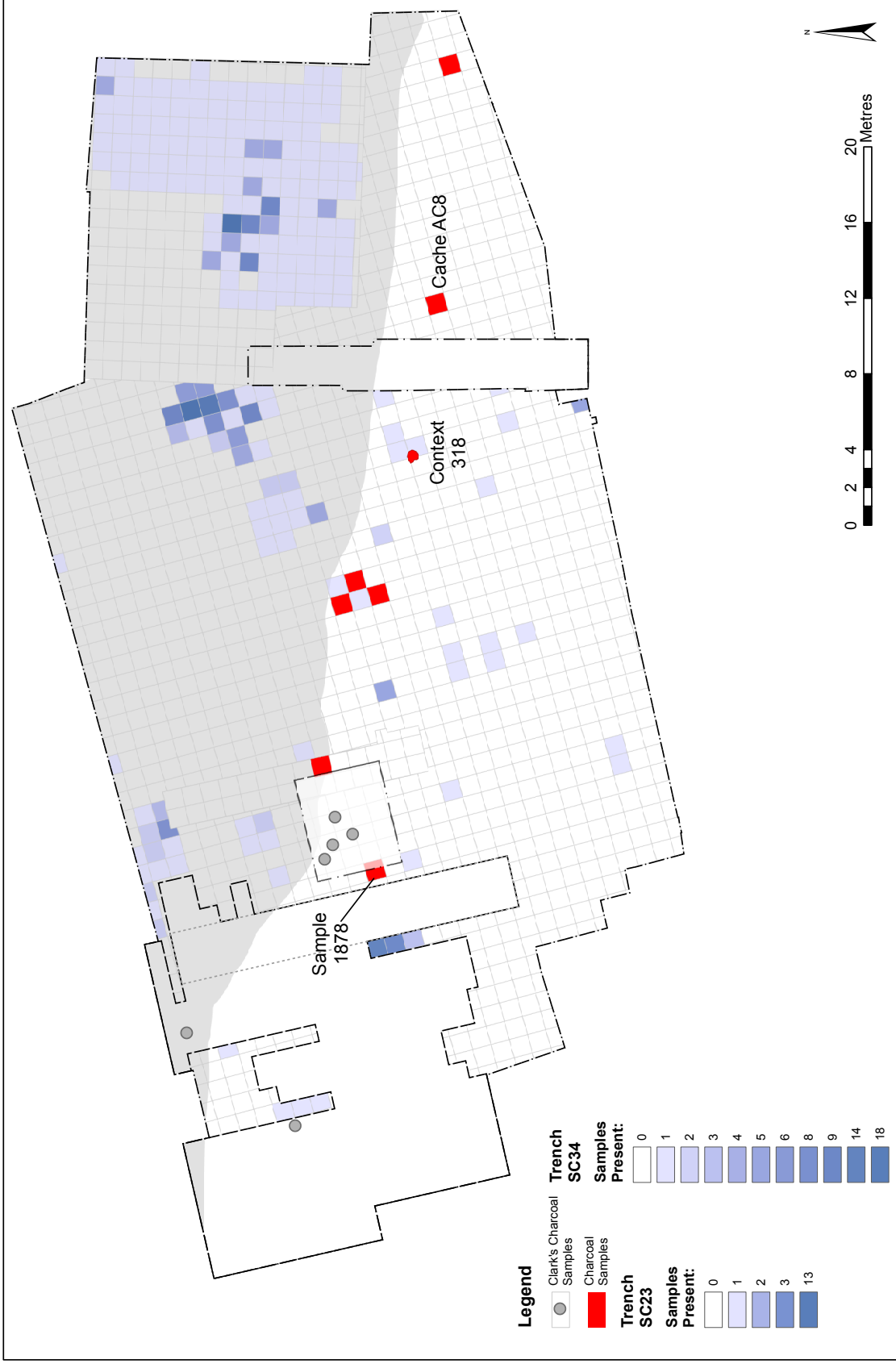
Figure 32.1: A plan of the trench which sets out the grid squares from where the flotation samples were taken. Of the 411 samples, 67 were not recorded by grid square (but instead by context which can cover many squares) and so are missing from this plan. In addition, the charcoal samples mentioned in the text are located on this plan (Copyright Star Carr Project, CC BY-NC 4.0).
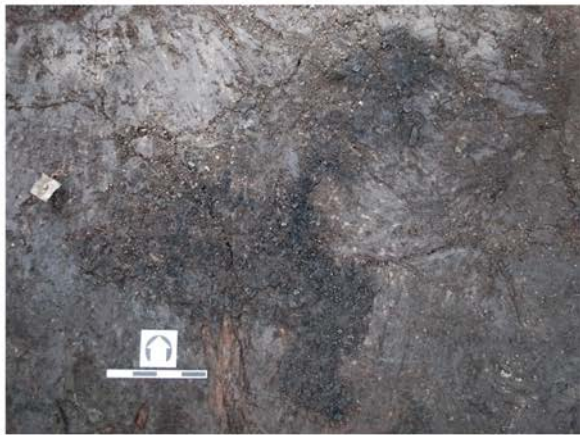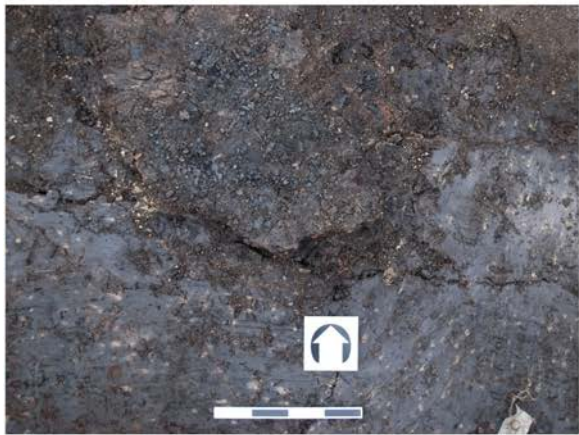
were recovered, and the majority of samples yielded less than 1 gram of charcoal in total weight and consisted of very small fragments (often below 0.5 mm), which made identification impossible.

Despite the fact that charcoal is commonly thought to be very robust, even at a microscopic scale, many charcoal fragments exhibited severe deterioration issues due to the formation of pyrite within their structure, as well as iron/manganese patinas, a condition also observed on other remains (see Chapter 22). The formation of pyrite has, at least in part, had the effect of causing fragmentation, and consequently may be the reason for a lack of charcoal retrieved from a considerable number of samples. Furthermore, the growth of pyrite and the deposition of iron and manganese on important features of the charcoal meant that identification was often impossible.

Hand-picked charcoal

All 172 fragments of charcoal that had been hand-picked on site could be identified to species (Figure 32.3). However, these samples are subject to collection biases and are not necessarily representative of the use of wood
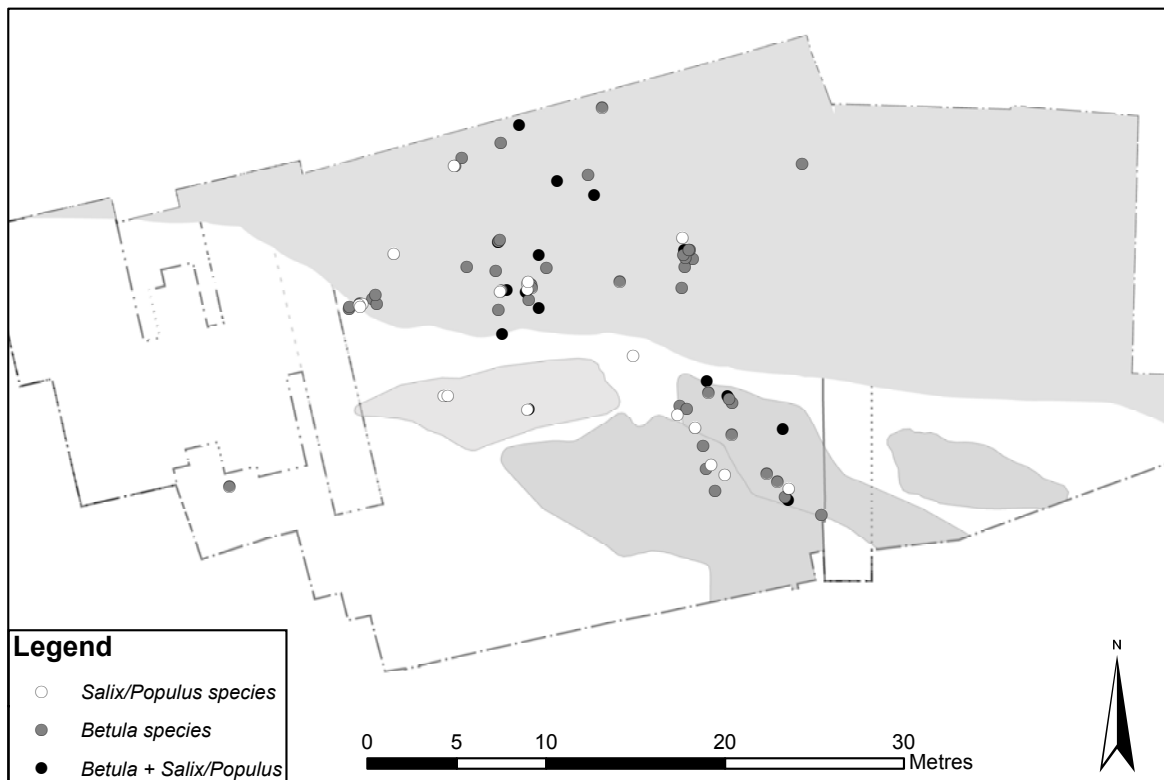
Figure 32.3: Plot of handpicked charcoal samples (Copyright Star Carr Project, CC BY-NC 4.0).

Figure 32.2 (page 450): (top left) sample 13, discrete charcoal patch, in reed peat in trench SC24 (i.e. close to Clark's charcoal patches); (top right) sample 1902 in reed peat; (second row left) sample 1903, in oxidised peat on lake edge; (second row right) sample 1904 just above peat/mineral sediment interface; (third row left) sample 1905 within wood peat (310), on interface with mineral sediment; (third row right) sample 3585 found at base of peat (302) on lake edge; (bottom) part of spread of charcoal (318), half sectioned, and found close to two burnt stones (Copyright Star Carr Project, CC BY-NC 4.0).

across site. The identification was conducted in order to see whether different species were present and if there was any patterning across site. The results show that 67% belonged to birch (*Betula* spp.), and in 20 cases both birch (*Betula* spp.) and willow/poplar (*Salix/Populus)* were retrieved from the same location. Whilst *Betula* spp. seems more abundant, biases in the survival of charcoal as well as biases of collection could have caused this patterning.

Charcoal recovered from flotation

Only 31 of the flotation samples from clearly defined contexts contained charcoal remains that were of a sufficient size (2–4 mm) to be identifiable. All identified fragments belonged to birch (*Betula* spp.) or willow/poplar (*Salix/Populus)* and no other wood taxa were found to be present in the charcoal assemblage. The vast majority of these samples (n=23) come from the area north of Clark's area, one sample comes from the flint cache found in square AC8 (see Chapter 8), one comes from Clark's area (within the baulk) and five come from the discrete charcoal patches (samples 13, 1902, 1903, 1904 and 1905). Among these, only seven samples contained 100 or more pieces of charcoal which allowed wood taxa composition and some growth details to be retrieved. The data must be considered with caution due not only to the formation processes relating to composition and proportions of wood taxa but also to differing responses to the burning of distinct wood types.

The area to the north of Clark's cutting III (the bead manufacturing area, Chapter 33) contained large quantities of birch bark rolls (Chapter 30), ephemeral spreads of burning and two beads in situ. Some large chunks of burnt wood were also found in situ. This is the clearest evidence for a possible hearth across the whole site. Samples were taken through the profile in both the wood peat and reed peat. In all but two samples, only a few fragments of charcoal (less than 15) could be identified to species. Nine of the samples produced only willow/poplar charcoal, three produced only birch charcoal and the rest produced a mixture. The only sample with a fairly large quantity of identifiable charcoal was sample 3467, which consisted of 86 fragments of charcoal: half were birch and half were willow/poplar. Overall, the evidence shows that both birch and willow/poplar are being burnt in this location, and the mix of species occurs at all levels.

A sample containing 1819 fragments of charcoal was retrieved in 2013 (sample 1878) from the edge of trench 34, by Clark's baulk. It produced almost equal quantities of both birch (n=945: 52%) and willow/poplar (n=874: 48%) and contained wood of different ages. The presence of some fungal growth still visible in some of the birch charcoal suggests dead wood was collected and burnt. Such debris suggests a pattern of deliberate selection and while taphonomic processes are not clear, the nature of the assemblage is indicative of the deliberate disposal of the remains of a fire(s).

The flint cache found in square AC8 was a tightly grouped cache of flint most of which came from one nodule. The sediment from within the flint was sampled (sample 3610), though at the time it was hypothesised that the sediment might have been intrusive because there were a lot of voids between the flints: it has since been suggested that the flints may have been contained in a bag, and therefore it is more likely that the charcoal has filtered down with the sediment from above. The sample consisted of small fragments of charcoal: 27 were large enough to identify to species showing that they were a near equal mixture of birch (n=14) and willow/poplar (n=13).

The seven discrete charcoal patches also showed a mix of birch and willow/poplar. Sample 13 consisted of only a few fragments which could be identified. The other samples consisted of several hundred fragments of birch and willow/poplar charcoal all of which showed a mix (Table 32.1). In all of the samples the wood appears to have been gathered from trees of different ages, as well as from different parts of the tree, e.g. the trunk and branches. This demonstrates that each charcoal spread was made up of more than one piece of wood. In addition, a few fragments of birch charcoal provide evidence of hyphal growth, indicating that dead wood was also chosen. These patches of charcoal are very difficult to interpret. Ordinarily, this would be interpreted as representing the remains of a fire; however, some of them (such as sample 13) occur in small, very discrete patches (Figure 32.2), in some cases in the wetland and therefore from their morphology and in many cases their context, they could not have been burnt in situ. The only explanation seems to be that charcoal was perhaps put into a small container, perhaps a bag, and deposited at the edge of the lake.

Finally, a total of 13 samples from post holes and the central hollow of the eastern structure produced a very small amount of charcoal, for the most part below 0.5 mm in size (Table 32.2). These results show no clear patterning: here again birch and willow/poplar were the only species that could be identified, although the latter was more common. Although the fragments were very small, a number were selected for radiocarbon analysis (Chapter 17).

Sample	Context	*Betula* **sp.**	*Salix/Populus*
13	Within reed peat (312=84)	3 (20%)	12 (80%)
1902	Within reed peat (312)	734 (62%)	453 (38%)
1903	Base of oxidised reed peat (312), on lake edge, at interface with basal mineral sediment (308)	321 (46%)	375 (54%)
1904	Base of oxidised reed peat (312), on lake edge, at interface with basal mineral sediment (308)	865 (71%)	345 (29%)
1905	Within wood peat (310), on interface with basal mineral sediment (308)	356 (43%)	463 (57%)
3585	Basal peat on lake edge (302)	32 (68%)	15 (32%)
NA	Charcoal spread (318) (sampled for radiocarbon dating)	0	2 (100%)

Table 32.1: Data for the seven discrete charcoal patches.

Fill	Cut	Feature	Selected Charcoal ID	Number of Fragments
149	164	hollow of eastern structure	Birch (*Betula* sp.) and Willow/Poplar (*Salix/Populus*)	8
178	177	post hole of eastern structure	Willow/Poplar (*Salix/Populus*)	2
182	181	post hole of eastern structure	Willow/Poplar (*Salix/Populus*)	2
325	330	hollow in central structure (upper fill)	Willow/Poplar (*Salix/Populus*)	8
331	330	hollow in central structure (lower fill)	Birch (*Betula* sp.)	2
339	338	post hole on western arc round hollow of the central structure	Willow/Poplar (*Salix/Populus*)	3
343	342	post hole on western arc round hollow of the central structure	Willow/Poplar (*Salix/Populus*)	3
405	411	grey lens associated with burnt debitage around western structure	Birch (*Betula* sp.)	2
507	507	possible post hole around western structure	Willow/Poplar (*Salix/Populus*)	4
508	508	possible post hole around western structure	Willow/Poplar (*Salix/Populus*)	4
503	512	possible post hole around western structure	Willow/Poplar (*Salix/Populus*)	2
506	514	post hole around western structure	Willow/Poplar (*Salix/Populus*)	2
509	515	possible post hole around western structure	Birch (*Betula* sp.)	5

Table 32.2: Fragments of charcoal that could be identified for C14 analysis.

Phytoliths and micro-charcoal

Introduction

Phytoliths are microscopic silica structures formed when soluble silica or monosilicic acid is taken up by the vascular system of plants during transpiration and are deposited within the cells or spaces surrounding the cells (Pearsall 1982; Rovner 1983; Pearsall 2010; Weiner 2010). The shapes, or morphotypes, of these structures vary, not only among the individual parts of the plant such as the roots, stems, leaves and inflorescences, but in some cases also specific to families, genera or species (Pearsall 1982; Rovner 1983; Piperno 2006; Pearsall 2010). When the plant decomposes, the silica particles are generally deposited into the soil where they are known to survive in most conditions for very long periods of time (Weiner 2010). Although phytolith studies have been minimally applied to archaeological sites in Britain (Powers 1992; Powers-Jones 1994), phytolith analysis has successfully been employed on sites throughout the world for the purpose of identifying and characterising evidence of past human occupation, i.e. hearths and bedding material from prehistoric caves (Albert et al. 1999; Karkanas 2002; Madella et al. 2002; Albert et al. 2012), boundary limits of an Iron Age settlement (Cabanes et al. 2012) and storage and food processing areas located in a Neolithic domestic structure (Tsartsidou et al. 2009).

Method

During the 2008 excavation bulk soil samples were collected from within the footprint of the structure and across other areas of the site (Figure 32.4). According to Pearsall (1982), this method of collecting soil samples provides better comparative results between spatially distinct areas of a site, such as with the floors of
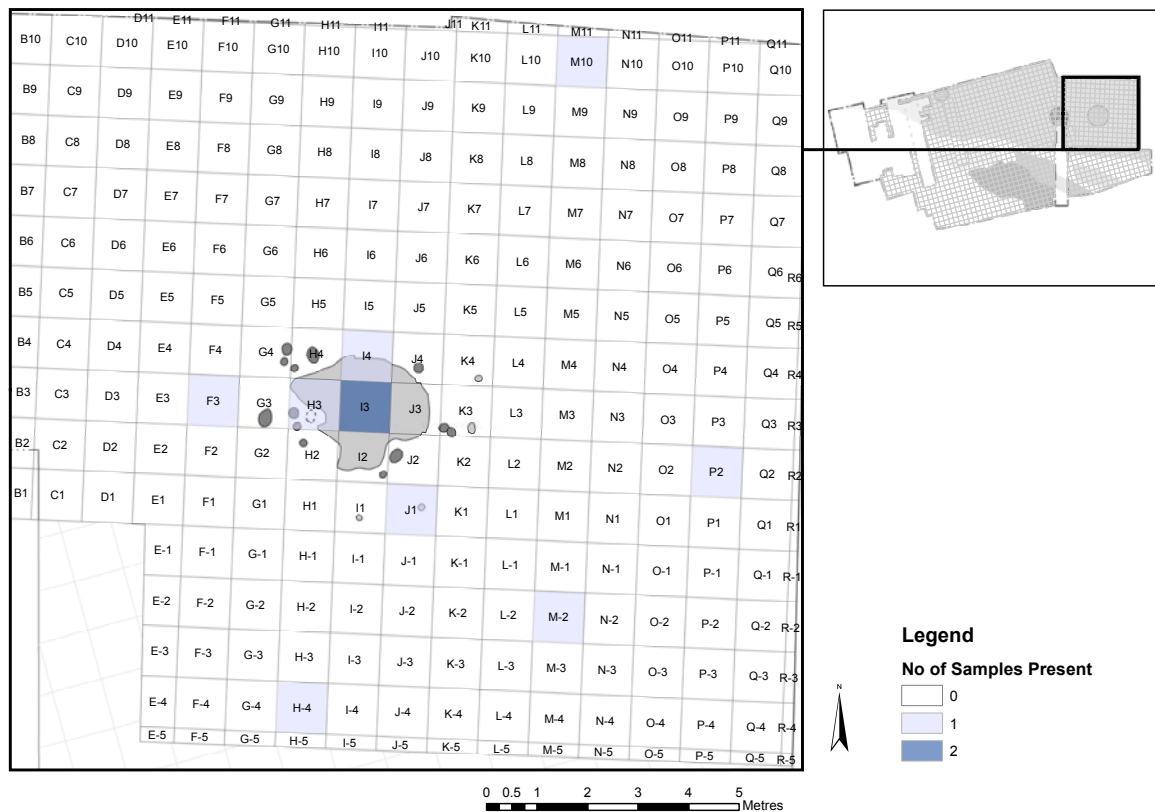
Figure 32.4: Plan showing footprint of the eastern structure and trench grid locations of archaeological soil samples (Copyright Star Carr Project, CC BY-NC 4.0).

domestic dwellings and consequently was the most appropriate procedure to employ for the purposes of this study. To ensure provision of 30–50 g of sieved soil required to obtain sufficient phytolith concentrations from each sample, 200 g sub samples were obtained from 10 grid squares relative to the footprint of the dwelling. To separate the phytoliths from the soil matrix, the removal of all other soil constituents is required (Rovner 1983; Madella et al. 1998). This was accomplished using a combination of mechanical and heavy liquid separation.

Phytolith analysis relies on morphometric comparisons with modern plants and therefore the development of a botanical reference collection was necessary. Plants were selected on the basis of those which were known, through palaeoecological investigations, to be present at this locale during the Mesolithic and therefore widely available for use by the inhabitants of Star Carr. Evidence of the plant materials associated with Mesolithic dwellings recovered from European wetland and submerged sites was also considered. Reference collection phytoliths were extracted from the plant material by the process of dry ashing and were subsequently mounted onto microscope slides. The slides were viewed and photographed using an Olympus IX 71 microscope fitted with an Olympus SC100 camera linked to the digital image software programme 'Olympus, Cell Sens'.

Archaeological phytoliths extracted from the soil samples were similarly mounted onto microscope slides, viewed microscopically and photographed. Phytoliths were counted and classified according to morphological characteristics, and taxonomic specificity was determined where possible. Full silica body counts were 'normalised' and reported per gram $^{-1}$ of the initial sample and patterns of distribution over the sample area were mapped based on the quantitative representation of phytolith morphotypes.

Results of preliminary phytolith analysis

Phytoliths from plants present at Star Carr during the Mesolithic were retrieved in large numbers. This in itself is a novel finding in Britain. Phytoliths from seven of 11 plant specimens represented in the reference collection were found to have satisfactory morphological matches with phytoliths from five archaeological samples. It should be noted that due to the abundance and morphotype variation of the phytoliths retrieved from all 10 archaeological soil samples, a much larger reference collection is currently being developed in order to make further morphometric comparisons and to confirm the identifications proposed here.

One of the five archaeological samples containing phytoliths with satisfactory morphological matches was taken from the periphery of the structure while the others were taken from locations outside the immediate area of the structure (morphometric comparisons between the phytoliths extracted from the archaeological samples and those of the reference collection are shown in Figures 32.5 and 32.6):

1. Common reed (*Phragmites australis* Cav.) stems, matched phytoliths observed in the archaeological sample from square F3, located just outside the footprint of the eastern structure. Since the natural habitat of reeds is a wetland environment, it is reasonable to suggest that reed stems were either used in constructing the structure, or deliberately brought into the structure to be utilised in some way, perhaps as flooring or bedding (Figure 32.5, A–B).
2. Phytoliths from the leaves of silver birch (*Betula pendula* Roth) and leaves of Galingales, which include sedges of the genus *Cyperus* sp., matched phytoliths in the archaeological sample from square H-4 at the south end of the trench (Figure 32.5, C–D, E–F).
3. Phytoliths consistent with those found in the roots of compact rush (*Juncus conglomeratus* L.) matched phytoliths in the archaeological sample from square M-2, south-east of the structure (Figure 32.5, G–H).
4. Phytoliths from galingales leaves (*Cyperus* sp.) and the bark of alder (*Alnus glutinosa* L.) matched phytoliths in the archaeological sample from square M10 at the northern section of the trench (Figure 32.6, I–J, K–L, M–N). It should be noted that wooden artefacts made from alder wood have been found on the site (Chapter 29).
5. Phytoliths from the modern stems of bracken (*Pteridium* sp.) and aspen (*Populus tremula* L.) matched phytoliths from archaeological sample P2 at the eastern section of the trench (Figure 32.6, O–P).
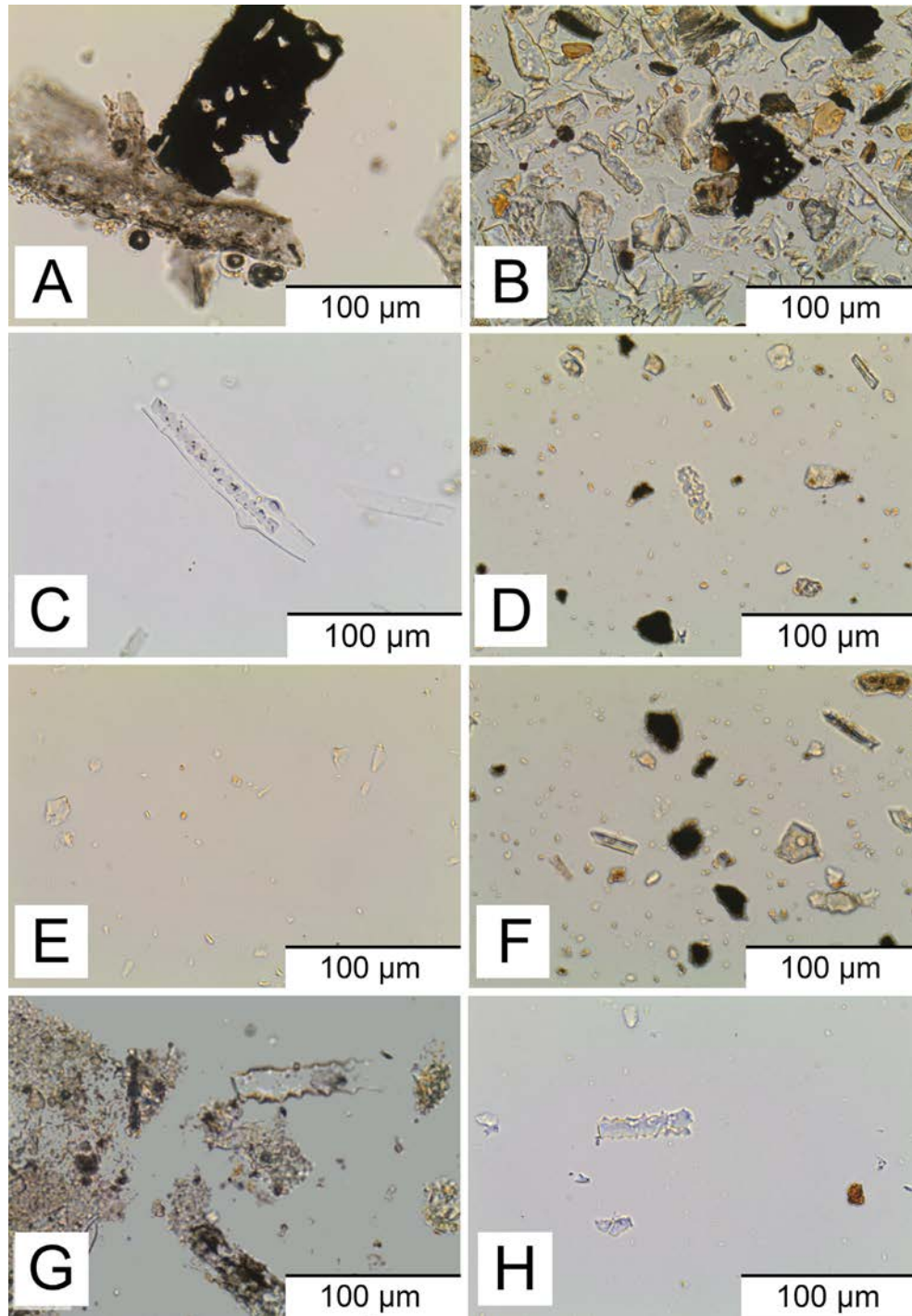
Figure 32.5: (A–H) Morphotype comparisons: phytoliths on the left represent those from the reference collection specimens and those on the right the morphotype matches from numbered archaeological samples with grid location noted.

A–B: stems from common reed *Phragmites australis* Cav.; sample from square F3.

C–D: leaves of galingales *Cyperus* sp.; sample from square H-4.

E–F: bark from silver birch *Betula pendula* Roth; sample from square H-4.

G–H: roots of the compact rush *Juncus conglomeratus* L.; sample from square M-2 (Copyright Alison McQuilkin, CC BY-NC 4.0).
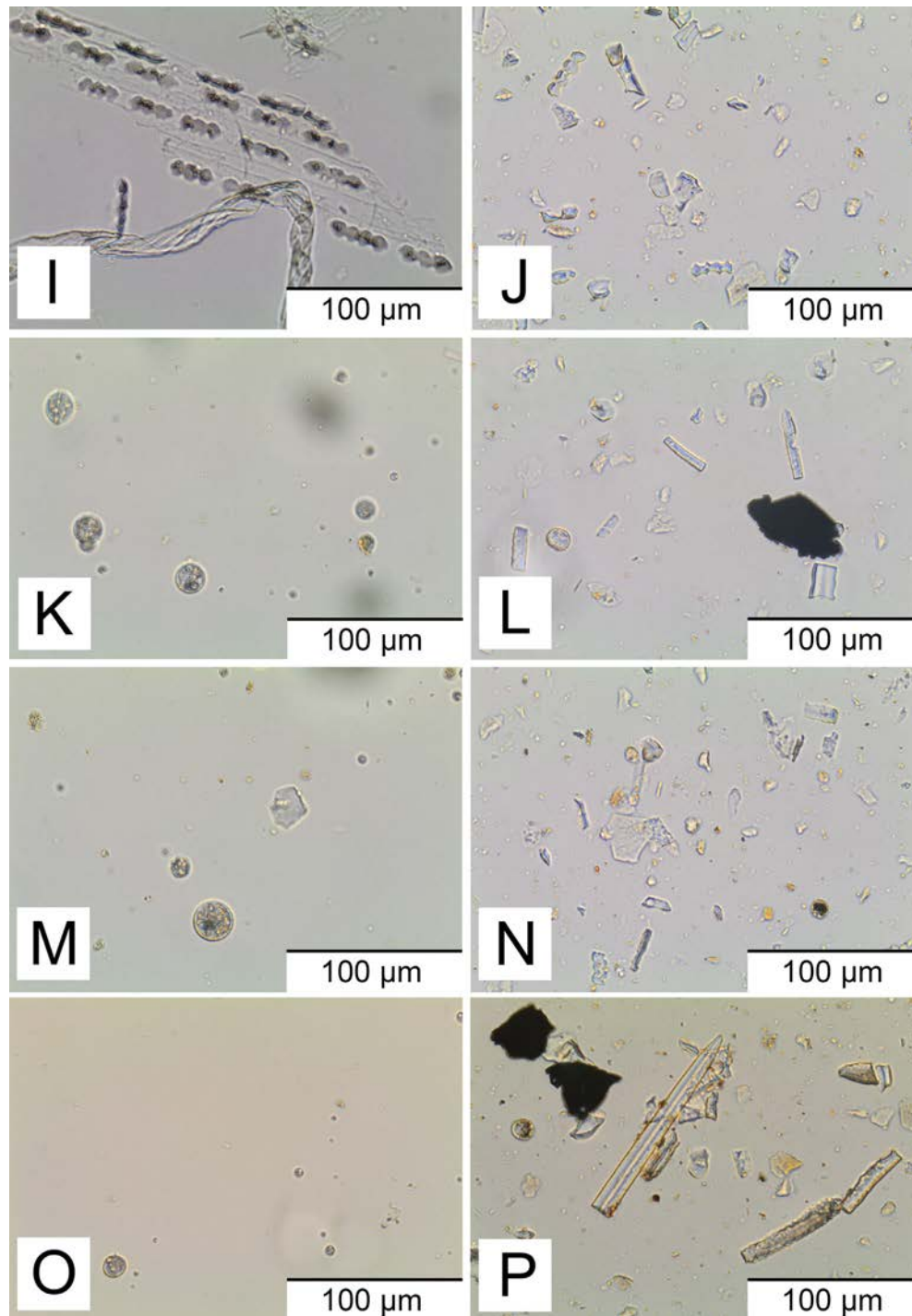
Figure 32.6: Morphotype comparisons: phytoliths on the left represent those from the reference collection specimens, and those on the right the morphotype matches from numbered archaeological samples with grid location noted.

I–J: leaves of galingales *Cyperus* sp.; sample from square M10.
K–L: bark from alder *Alnus glutinosa* L.; sample from square M10.
M–N: bark from alder *Alnus glutinosa* L.; sample from square M10.
O–P: stems from aspen *Populus tremula* L.; N: sample from square P2 (Copyright Alison McQuilkin, CC BY-NC 4.0).

Phytoliths from each sample were tabulated and quantified into categories based on a review of descriptors relating to shape, texture and/or ornamentation (Rapp and Mulholland, 1992; Madella et al. 2010) and subsequently further grouped into categories ('long cell', 'short cell' and 'miscellaneous') in order to illustrate their relative presence (Figure 32.7). While such phytolith typologies can be found in a number of species and families of plants, it was thought that changes in their concentration may indicate a predominance of certain plants and differences in their use. It can be seen that the largest number of phytoliths come from the samples located outside the immediate area of the structure (M10 and P2). Otherwise, the samples have produced similar quantities of phytoliths.

Diatoms were also found on the site in varying proportions with the greatest numbers in squares M10 and P2 and smallest numbers within the structure. Generally diatoms live in water and moist soil, and although it is not clear why these appear on the site, they are likely to have been present in puddles/waterlogged areas (Figure 32.7).

Micro-charcoal was present across the site with a significantly large proportion in sample H-4 (Figure 32.8). The reason for this may be related to burning reeds given that it was very close to the lake edge. When this
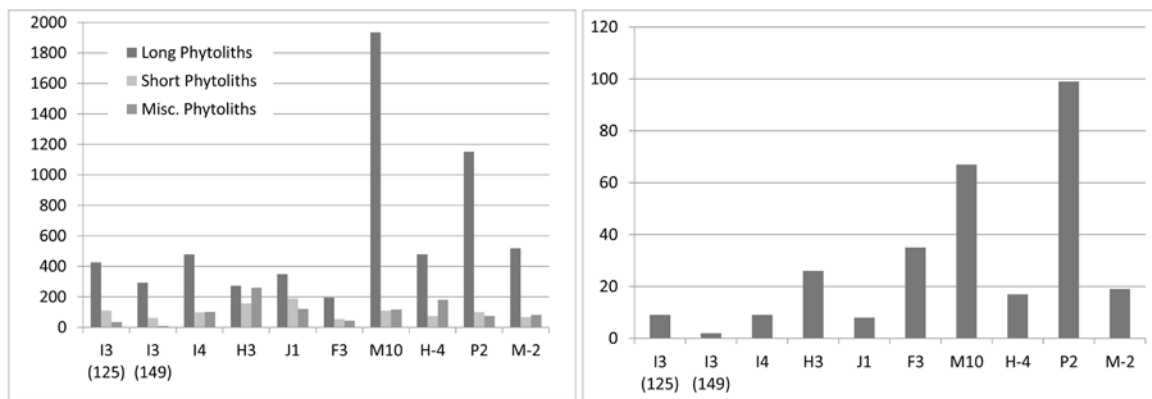
Figure 32.7: (left) numbers of long, short and miscellaneous phytoliths from each archaeological sample labelled by grid square (two contexts were sampled from inside the structure in square I3); (right) numbers of diatoms counted from each sample (Copyright Star Carr Project, CC BY-NC 4.0).
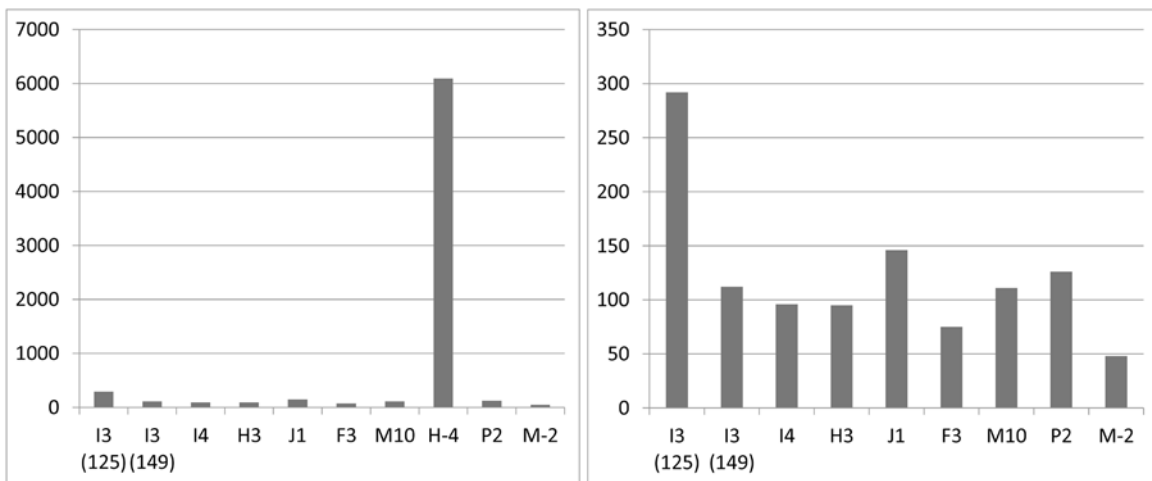
Figure 32.8: (left): bar chart showing the quantities of charcoal from each sample; (right): charcoal quantities with sample H-4 removed (Copyright Star Carr Project, CC BY-NC 4.0).

sample is removed from the dataset, it can be seen that there was also a large proportion of charcoal from within the structure (context 125), providing further evidence for the possibility of a hearth within (see also Chapter 8).

Discussion

Despite the lack of charred seeds and fruits and the small quantity of charcoal found on site, the results obtained have provided some new insights into plant utilisation at Star Carr and particularly concerning the use of fire. The analysis of the charcoal fragments confirms the use of wood both for fuel and for clearing vegetation (Hather 1998). The micro-charcoal recovered from within the structure may also suggest the use of fire in this location.

In general, the wood taxa composition (birch and willow/poplar), the consistency of the composition with what were the most common species naturally present in the environment at this time, along with the variety of wood types from branches to trunk, illustrate that wood was chosen according to what is known as the 'minimum effort' principle' (e.g. Tusenius 1986). The following statement by Asouti and Austin (2005, 2) summarises this well:

> 'According to this hypothesis, firewood collection in the past occurred in those wooded areas situated closest to the habitation site and all species were collected in direct proportion to their occurrence in woodland vegetation'.

The presence of fungal growth in the birch wood strongly suggests that dead birch was chosen for fuel. The availability of dead birch wood is also supported by the fungal remains found on site (Chapter 31). It is useful to note that dead/rotting birch is a very useful wood for smoking meat, if the bark is first stripped off due to the high level of tannin in it (Wickham-Jones et al. 1986).

It is interesting to note that none of the species collected for fuel contain a high caloric value, meaning these species were not a particularly good fuel. The experimental work of Bishop et al. (2015) conducted on birch wood has shown that the caloric value of birch, although good, burns quickly, and works best if used as fuel combined with other species, whilst willow/poplar releases little heat, along with smoke and burns slowly. As these species were both common on site it is therefore likely that the combination of these species was opportunistic. Both birch and willow/poplar were also used to make tools as well as the wooden platforms (Chapter 6), and it is possible that the by-products derived from the initial cutting were used as firewood. Forms of management, such as coppicing the willows and poplars (Chapter 28) would provide a renewable source of wood to burn, despite its poor quality.

However, it should also be taken into account that both smoke and charcoal have uses in themselves, aside from the amount of heat produced during burning. Smoke is very useful for preserving food, preventing plants and animal material from being subject to insect and bacterial damage, curing of animal hides and also acting as an insect repellent (Groenman-van Waateringe et al. 1999; Pennacchio et al. 2010). Birch wood has a pleasant smell when burnt (Bishop et al. 2015) and its smoke would add flavour to food if used for that purpose. It is unlikely that smoking would have been carried out within the 'house' structures, but other structures may have been used, such as a lean-to of poles from which the meat hangs; the smoke can then escape and air is allowed to pass through, also drying the meat (Wickham-Jones et al 1986).

One of the most striking finds in the phytolith assemblage was that of a common reed stem taken from a dryland soil sample located on the periphery of the structure. Since the natural habitat of reeds is a wetland environment, it is reasonable to suggest that reed stems were either used in the construction of the structure or deliberately brought into the structure to be utilised in some way, perhaps as flooring or bedding. At the late Mesolithic structure found at Møllegabet II, Denmark (Skaarup 1995; Grøn 2003; Mason 2004) half the dwelling space was taken up with an earthen platform supported by cloven hazel (*Corylus* sp.) branches. This platform had been covered with a layer of twigs with bracken (*Pteridium sp.)* leaves in between and topped with sheets of bark. Beneath this, was a layer of oak (*Quercus sp.)* twigs, once again with bracken in between (Skaarup 1995; Grøn 2003; Mason 2004). At the Maglemosian site of Ulkestrup I, a dwelling was found to have a floor consisting of bundles of branches 250 mm in length and 50–60 mm thick. Between these bundles there were also twigs and leaves of marsh fern (*Thelypteris palustris*) (Grøn 2003; Mason 2004).

Whilst it is tempting to suggest that reeds may have been used for flooring, bedding or perhaps thatching in the Star Carr structure, reeds have many possible uses which also include rope making, matting and basketry, as well as a potential food source. Clark (1954) suggested that the dried rhizomes and lower stems of reed could be mashed and ground to make an edible flour-like substance (see also Brockmann-Jerosch 1917; Dimbleby 1978; Kubiak-Martens 1999; Mears and Hillman 2007; Bigga et al. 2015; Wohler-Geske et al. 2016; Zhang et al. 2016).

Conclusions

The analysis carried out on charred plant macro-remains and phytoliths has shown that the type of plants utilised at Star Carr were consistent across the site and were dominated by the most common species present in the environment at that time. All species found have several uses, but common reeds and birch provide a great variety of plant material for crafts, building material and even food. While on the one hand the variety of remains is poor; on the other the species represented would have been sufficient to supply plant material for almost all aspects of the daily lives of the Mesolithic inhabitants. Finally, the retrieval of vast numbers of phytoliths from the Mesolithic plants at Star Carr is in itself a novel finding in Britain, clearly illustrating the potential of utilising this method for accessing beneficial palaeoethnobotanical information. In order to broaden current capabilities for using phytolithology for plant identification and to enhance our ability to confirm findings on archaeological sites across the UK in future, a large British botanical phytolith reference collection is presently under development.

PART 12
Mineral

'The flint, on the working of which the whole technology of the Star Carr people depended, was mainly derived from the local drift, which could also have produced chert, stone pebbles of various kinds and iron pyrites—the latter doubtless used in conjunction with flint and tinder for producing fire.'

(Clark 1954, 20)

CHAPTER 33

Beads and Pendant

Andy Needham, Aimée Little, Chantal Conneller, Diederik Pomstra, Shannon Croft and Nicky Milner

Introduction

During Clark's excavations a number of shale beads were found along with three fragments of amber, one of which appeared to have been perforated. In 2015 three beads (two in situ and one in Clark's backfill) and an engraved pendant were found at the site. The two in situ shale beads were discovered close to those plotted by Clark, in wood peat, and the pendant to the south of Clark's excavations in reed peat (Figure 33.1). Not surprisingly, the three shale beads are similar to those found by Clark, though the pendant is unique.

In addition, mèche de foret were also identified in spatial association with the shale beads. Mèche de foret are a specialised form of awl (Chapter 35), with extensive retouch to both long edges of a small blade, creating a pointed tool with irregular long edges, typically used for boring and piercing and well suited to making beads (Jacobi 1976). Clark (1954, 96, 106) reported the discovery of 114 awls of various types at Star Carr, noting that the tip had been worn smooth in some examples and entirely removed in 14 cases, a pattern that would be consistent with a highly abrasive task such as perforating stone. Clark (1954, 166) suggested that the beads found at Star Carr had probably been perforated with a hafted mèche de foret using a bow, which would have meant the tool could have been rotated at speed. More recently, experimental replication suggested that this is the most efficient method of production, while working freehand was reported as cumbersome and time-consuming (David 2007, 105).

This chapter considers the beads recovered from Star Carr, both from the excavations by Clark and those recovered during the most recent phase of excavation. In this study the three beads and the pendant have been examined using microwear analysis and residue analysis to test whether any engraved lines could be located, if any pigment residues were present, and in order to identify any traces relating to their suspension and wear. Actualistic experiments were conducted in order to reconstruct how the pendant, shale beads and amber pendants might have been made and to test the hypothesis concerning the use of a bow versus hand drilling.

Figure 33 (page 461): Making a replica pendant (Copyright Aimée Little, CC BY-NC 4.0).
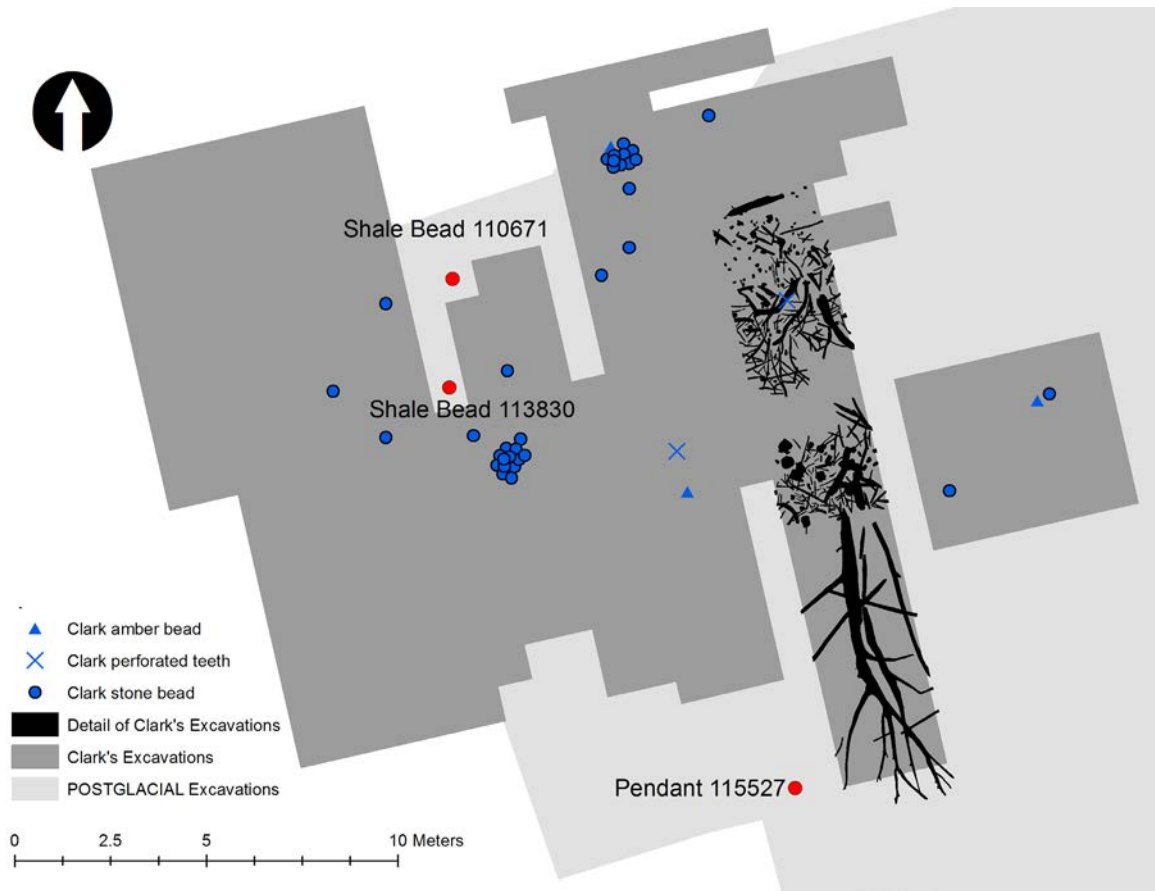
Figure 33.1: Figure to show locations of the beads found by Clark (in blue), and the two beads and a pendant found in our recent excavations (in red) (Sourced from Milner et al. 2016, *Internet Archaeology* licenced under CC-BY 2.0).

Previous analysis

During Clark's excavations, a variety of beads were recovered, made with a range of materials including: three pieces of amber, two of which were broken and another with two perforations at one end; 33 shale beads; two red deer teeth (an incisor and a vestigial canine which had been perforated) and a possible bird bone bead (Clark 1954, 164–166). The collection is now split and resides in numerous museums, though not all examples have been relocated. Only two of the pieces of Star Carr amber have been located in museums (Milner et al. 2013b): the whereabouts of amber 1 is unknown, amber 2 is curated in the Natural History Museum (NHM), while the perforated piece (amber 3) is curated in the Museum of Archaeology and Anthropology (MAA). One of the Star Carr perforated animal teeth is in the NHM, the other has not been located and the possible bird bone bead is located in the MAA.

   All of the shale beads were made from thin disc-like pebbles of Lias shale which can be found locally both in the upcast from cleaning the drains around the site, as well as at the coast around Robin Hood's Bay. Most beads conform to an irregularly circular to oval shape, ranging in size from 7.5 × 9 to 12 × 20 mm, and averaging 1.3–2.0 mm in thickness. One bead stands out as being different in that it is a 'celtiform shape', perforated at one end. The stone beads were found in clusters, as though marking places where breaks had occurred in necklaces, with 12 being found in IJ 23–24 and eight from AB18–19 (Figure 33.2). Clark (1954, 166) noted that because the beads were so thin, they had been perforated from one face only, and suggested that these may have been made rapidly using a drill which could have been rotated at speed by means of a bow, noting that

Figure 33.2: Example shale beads and 'celtiform bead' found by Clark at Star Carr. These examples are curated at the MAA (Photograph taken by Nicky Milner. Sourced from Milner et al. 2016, *Internet Archaeology,* licenced under CC-BY 2.0).

the precision of the perforation was unlikely to be produced working freehand. Not all of the shale beads have been located in museums: 23 are curated in the MAA including the celtiform (Figure 33.2), and there is one in the British Museum.

Pieces of amber can be found washed up on the east coast of Britain, the probable source of the amber used at Star Carr, though they would be a rarity, having been transported and secondarily deposited. As Doggerland was not drowned at this time (Bicket and Tizzard 2015), this may also have been a possible source for amber. The pieces of amber, otherwise a rarity in the British Mesolithic, hint at a connection with Southern Scandinavia where the use of amber to make pendants and carved animals was common. The spatial association of a cluster of shale beads alongside amber led Clark (1954, 165) to suggest that these different distinct bead and pendant forms may have been strung together on the same string of beads (Figure 33.1).

Methods

A suite of digital imaging techniques were applied to the pendant: scanning electron microscopy (SEM), reflectance transformation imaging (RTI) and structured light scanning. In addition, the pendant was examined for

residues using visible light microscopy (VLM), variable pressure scanning electron microscopy (VP-SEM), and confocal Micro-Raman. The results are summarised here, but a more extensive report and access to the RTI (which can be manipulated online) is available in Milner et al. (2016).

The shale beads were washed, handled and analysed in the same fashion as lithics for residue analysis, involving a rinse with a fine stream of ultrapure water, and handling with non-powder nitrile gloves. The beads were air dried on cling film–lined trays and examined microscopically with a stereoscope (GX Microscopes XTL3T101) (×.7-4.5, eyepiece magnification ×10). The stage of the metallographic reflected VLM (Leica DM1750 M) was lined with a new sheet of wax parafilm between sample viewing to prevent cross contamination. The beads were examined using objectives ranging from ×5 to ×100, and with an eyepiece magnification of ×16. Composite z-stacked microscopic images were captured and stitched together using LAS Montage software. Description of residues and their locations were documented. A VP-SEM (Hitachi TM3030Plus) was chosen for analysis of residues and engraved lines because it is capable of imaging objects non-destructively without any coatings that are used in traditional high vacuum SEM. Confocal Micro-Raman (HORIBA Jobin Yvon Xplora) was carried out on in situ residues of interest, allowing chemical characterisation, and LabSpec 6 and IGOR Pro software used to collect and evaluate spectra.

Microwear analysis was undertaken as set out in Chapter 15. In addition, to further enhance understanding of the beads and pendants, actualistic experiments were performed to replicate them.

Description of the beads and pendant

The pendant was found within detrital mud (317) and is likely to be contemporary with Clark's area (Chapter 3, Figure 17.15). The two in situ beads were found in wood peat (310), higher up slope, north of Clark's cutting III dated to c. 88th century cal BC (Chapter 3 and Figure 17.20). Although the deposition activities in Clark's area are likely to be very short lived, the probability distributions for each area overlap, meaning it is not clear whether the pendant is older, younger or contemporary with the beads.

The pendant and beads were made of shale, which as described above can be locally obtained. Dimensions for the beads are: backfill bead, 34 mm × 20 mm; in situ beads <113830>, 14 mm × 11 mm; <110671>, 18 mm × 11 mm (Figure 33.3). A strong question mark must be raised against the bead from the backfill, as it differs both in size and morphology both from those recovered by Clark and during the current excavation, being large, and much less waterworn or polished than the others. Given fakes are known from Clark's backfill (a piece of 'Mesolithic' pottery recovered in 2007, but previously known from oral histories of the site (Milner et al. 2013c)), this piece needs to be treated with caution.

The engraved pendant (Figure 33.4) is weathered, and the engravings are subtle and difficult to see with the naked eye, only visible by angling the pendant obliquely in the light. Analysis revealed that the engravings

Figure 33.3: (left) bead <113830>; (middle) backfill bead; (right) bead <110671> side 1 and 2. Note the abraded surface and damage on side 2 (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 33.4: Photograph of the pendant from both sides (Photograph taken by Michael Bamforth. Sourced from Milner et al. 2016, *Internet Archaeology* licenced under CC-BY 2.0).

consisted of a series of parallel lines with a number of very small lines drawn at right angles from them, creating a 'barbed line' motif. This is comparable to styles known from the continent, most closely matching examples found in Southern Scandinavia (Milner et al. 2016). The digital techniques used facilitated the sequencing of the engraved lines (Figure 33.5). This analysis revealed a repeating pattern of barbed lines flanking parallel lines: group 2, 2a, 2b, and group 3b, 3b1 and 3b2, which both have three parallel lines between them, and group 4c, 4c1 and 4c2 with one line in the middle. There is some patterning to these barbed lines, but this is not consistent from one set to another. Lines in the 2a group are patterned as 5, 4, 3, 2 (from top to bottom). However, the corresponding 2b appear to group as 2 (though the first line crosses beyond the line and is not a true barb in that sense), 6 (though another line crosses), 5 and 5. In the 3b grouping, lines 3b1 follow the sequence (from left to right) 4, 4, 3 (though on the latter there is a very small mark, seen viewed under RTI (see Milner et al. 2016), which could be another line, taking this to 4). The group 3b2 are very hard to read, partly because they are obscured by lines 5; however, they too look to be groupings of 4. The group 4c with barbs 4c1 and 4c2 are very different: 4c1 has a grouping of 3 and 2, and 4c2, groupings of 3 and 7.

Given the patterning in some of these groups of lines, it is interesting to consider whether this was intentional and what it might represent. Barbed points are also known to incorporate groupings of lines at Star Carr (Chapter 25), as well as two elk bodkins (EB1 and EB7) found by Clark (1954, 160).

Complex pieces of mobile art such as the pendant will always be difficult to interpret. The pendant has proved evocative for both the team and the public, with many interpretations raised. A popular theme is that the pendant was a shamanic amulet, an idea that finds support in the ethnographic record (e.g. Hill 2011). Another recurring observation was that the barbed point motif was very similar to Ogham script, an early Medieval Irish form of writing used in the 1st–9th centuries AD, about 9000 years later than the pendant. Although this makes it highly unlikely to be a precursor to Ogham, using groupings of marks can clearly be used for communication and as symbols. If this was the case, the engravings are so faint it is hard to see how this might be used to communicate between different people, but the possibility should not be discounted. Other ideas that have been put forward include it representing a link to the stars, a map, a bird, the lines on the palm of a hand, a river and channels diverting water, a (burning) tree, a leaf or the wooden platforms found on the site. Many

Phase
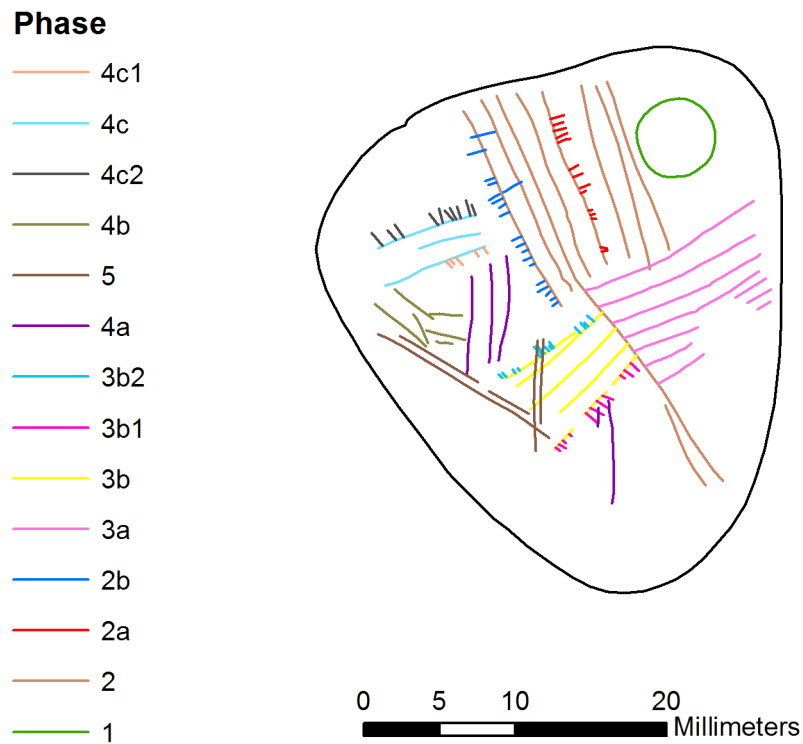
Figure 33.5: The phasing of the lines (see also Milner et al. 2016) (Sourced from Milner et al. 2016, *Internet Archaeology* licenced under CC-BY 2.0).

of these theories share a sense that the engraving contains symbolic content, whether as a numerical or communicative system, or in the depiction of a particular aspect of the Mesolithic world.

Microscopic approaches to identifying residue and wear traces

Pendant

Residue analysis was conducted on the lines of the pendant but showed no evidence that pigments had been used in highlighting the lines, unlike some examples in Denmark where pitch has apparently been used (Milner et al. 2016). The residue analysis used VLM, VP-SEM and confocal Micro-Raman to confirm the presence of framboidal and triangular pyrite on the pendant and also showed lacustrine microfauna were present within the engraved lines. Microwear analysis was undertaken in order to determine whether the pendant had been strung but the results were inconclusive.

Beads

No residues of archaeological significance were identified on the shale beads. However, the soil residues present on the beads shed light on the chemical and biological circumstances of the surrounding soil and

Figure 33.6 (page 469): Possible crosshatch engraving on side 2 of the backfill bead (Copyright Matthew Von Tersch, CC BY-NC 4.0).

deposition (Croft 2017). Crystals suspected to be gypsum were visible macroscopically. During microscopic analysis, these crystals were clear and present in rosette shapes, a crystal habit expected of gypsum. Iron oxide deposits were encountered in association with elongate plant cell walls, possibly the remains of the epidermal tissue of reeds. These traces are all reflective of the burial environment at the site, which is rapidly degrading (Chapter 22).

A general issue encountered during microwear analysis of the beads was the difficulty in identifying clear evidence of wear traces. This is likely due to a number of factors: a) the shale is relatively soft, and when combined with the acidic burial environment, it is possible that wear traces have been affected due to geochemical alteration of the surface, especially if the wear traces were lightly developed in the first place; b) despite having a matt appearance to the naked eye, at a microscopic level the shale is surprisingly reflective, probably as a result of the pyrite microcrystals from the burial environment; this could be obscuring lightly developed polish if present; c) that they were worn for such a short duration of time that no wear traces have developed, an argument previously proposed for the pendant (Milner et al. 2016); and d) considering their association with mèche de foret and the probability that bead production was taking place at Star Carr, it is not inconceivable that the beads were not worn at all, but rather intended for circulation elsewhere in the landscape. Nonetheless, macro and microscopic analysis was able to reveal some interesting information regarding their materiality and possibly even their use.

For the three shale beads examined here, the side which exhibits the wider opening of the perforation (the side from which the perforation was initiated) is referred to as 'side 1', with the opposing side designated 'side 2'.

1) Backfill bead: under certain light, and under closer inspection with a stereoscope, this bead has a series of crosshatch lines, quite regular, and limited to one half of the surface of side 2 (Figure 33.6). However, on side 1, there are clear signs of post-depositional surface modification (PDSM) in the form of trowel marks,

making it difficult to say emphatically that side 2 is engraved. Mindful of the fact it was recovered from backfill and therefore could have received prior damage during excavation, there are a couple of key differences between sides 1 and 2 which deserve note. The trowel damage on side 1 is fresh in appearance and unidirectional, whereas the crosshatch marks on side 2 are, as the term suggests, overlapping and geometric. They are not fresh, but worn, suggesting they were made in antiquity. Furthermore, the geometric design is not unlike that identified on a number of barbed points (Chapter 25). However, we cannot be certain when in antiquity these marks were made. We present the possibility that this is an authentic engraved bead with a strong caveat.

Use-related traces were examined using a high power microscope. Striations were observed radiating out of the perforation and at first it was thought these might have resulted from suspension wear. However, when a greater area of the surface was analysed, comparable striations were also observed, running in multiple directions making it difficult to ascertain what striations are use-related from those caused by PDSM. Given its post-depositional history, we are hesitant to interpret these traces as use-related.

2) <110671>: Immediately visually apparent is the contrast between side 1 and side 2, with the latter displaying an abraded surface, with nearly all the surface area affected. Under low-power magnification this abrasion appears to be the result of the removal of the outer surface: whether that is from taphonomic processes caused by the burial environment or from wear caused by sustained contact with another material, is not certain. However, at each terminus of the long axis of the bead there is damage in the form of micro-crushing and flaking. It is tempting to see this damage as relating to wear: the location of the damage is compatible with where suspension traces might exist if it were to be strung along the long axis of the bead; however, no associated micropolish was identified. In contrast, side 1 shows no surface abrasion, having the same macroscopically good-quality surface condition as bead <113830>. If the abrasion and damage to the terminus of the bead is due to use, its distribution suggests that side 1 was facing outwards and side 2 was attached to another material, perhaps clothing, in which case this bead may have been used/worn as an appliqué.

3) <113830>: Macroscopically a thin line is visible running across the long axis. It can be seen on both sides and is just off centre from the line of the perforation, making it unlikely that this is wear related to suspension. It is probable that this is a natural fault in the geology. Unlike the other beads analysed under high-power magnification, this bead was less reflective, making it easier to distinguish polish when present. Both sides displayed polish, which appeared randomly distributed and was limited to the upper topography of the surface. At times this was well developed. Neither side exhibited more than the other, although within the outer edge of the perforation on side 1, the polish was notably more developed. What contact material and action caused the polish is unclear. In some places it has a mineral-like appearance with numerous microstriae (perhaps the result of contact with other shale beads); other spots of polish are brighter/smoother and could be described as more plant-like. Again, it is tempting to suggest that these traces may be from wear (especially given the developed polish on the rim of the perforation); however, because of their random distribution and given the softness of the shale, we cannot be certain that this is not PDSM, resulting from thousands of years of gentle abrasion from sitting in wood peat.

Actualistic experiments

The pendant

To further enhance understanding of the pendant, an actualistic experiment was performed to replicate it (Figure 33.7). The creation of the perforation and engraving of lines was rapid in both cases, taking only a few minutes to complete. A small blade was used to create the engravings. Each line was produced by a single stroke of the blade. Long lines were engraved first, followed by small barbed lines. Perhaps the clearest point of contrast between the replica and the pendant is the nature of the engraved lines when fresh. These stand out as a clear and vibrant white against the grey of the shale. Weathering has obscured the impact of this feature on the archaeological pendant. Further work is needed to test how resistant this marked contrast is through time and with use. As the white colouration is produced by the deposition of fine powder within the groove as a residue of the engraving process, it is probable that this white colouration was ephemeral, but could be readily refreshed with the re-engraving of the grooves, perhaps for special events.

Figure 33.7: Experimentally made replica engraved pendant (Copyright Aimée Little, CC BY-NC 4.0).

Bead manufacture

Pieces of shale, both weathered rounded discs and larger amorphous shapes, were collected from Whitby and Robin Hood's Bay on the North Yorkshire coast. Baltic amber was used to replicate the amber bead. Bone and stone tool replicas were hafted to wooden shafts made from hazel, and willow bast fibres were used for binding.

Because of their naturally very smooth appearance, we hypothesised that naturally rounded pebbles of shale, weathered by water action, were used as natural bead blanks. The coastal shale required little modification: bead blanks were manufactured by grinding larger, amorphous pieces of shale against a fine sandstone until it was shaped into a thin disc. For pieces of angular, non–water rolled shale, we used flint to scour the shale, before using a hammerstone to gently tap the unwanted shale away (Figure 33.8). This left us with a small blank which was then transformed into a circular shape by grinding, leaving obvious working traces. The archaeological specimens show little in the way of working to either face; however, by burnishing the surface of the ground experimental beads using different materials (including charcoal, raw and soft hide, and a variety of sandstone cobbles ranging in texture from coarse to fine), it was possible to virtually remove all traces of grinding.

The shale beads from Star Carr have characteristic grooves scoring the inside of a conical perforation, with working typically initiated from a single direction. Experimental shale beads were perforated using mèche de foret and using a bone point, cut to give a roughly square cross section.

Two experiments with mèche de foret were carried out: one was used in the hand (Figure 33.9), the other hafted to make a hand drill. It was found that working with an unhafted mèche de foret and applying light pressure rapidly produced a perforation that could then be widened with the retouched edges of the tool, leaving the characteristic grooves within the perforation. By contrast, the use of a haft did not allow the application

Figure 33.8: Creating a bead blank by gently tapping away unwanted shale with a hammerstone (Copyright Aimée Little, CC BY-NC 4.0).

of pressure, took far longer to make a perforation, resulted in higher rates of breakage, and produced grooves within the perforation that were much finer than those observed on the Star Carr beads.

Microwear analysis was carried out on several mèche de foret of different sizes (Chapter 35). Analysis showed that larger mèche de foret were more commonly used for drilling osseous materials, whilst the smaller varieties more frequently display a soft mineral polish. For the latter, the very tip of the tool is sometimes broken, in other instances, it is rounded. It is likely that these traces of damage and rounding probably derived from use. For tools with damage at the tip, traces of polish remain, typically just above the point of breakage which often takes the form of a flake removal. The polish is bright, metallic in appearance, restricted in distribution and transverse to the lateral edges, suggesting a rotating motion. From experimental replication, using mèche de foret to drill shale, it was possible to replicate the polish visible on the archaeological tools. From this research, we have inferred that some mèche de foret were probably used in shale bead production.

A hafted bone tool was used to compare effectiveness. This proved ineffective and barely left a trace on the shale blank. Instead, the shale eroded the tip of the bone tool, suggesting that bone tools would not have been used to make these perforations.

A number of other worked stone with points were also tested. These were largely effective at creating a perforation; however, they tended to lack the characteristic grooves within the perforation, reflective of a retouched

Figure 33.9 (page 473): perforating a shale disc with a flint mèche de foret (Copyright Aimée Little, CC BY-NC 4.0).

edge as found with a mèche de foret. The use of other pointed stone tools cannot be ruled out but taking together the spatial association of mèche de foret in the bead area north of Clark's cutting III (Chapter 8), the microwear evidence (Chapter 35) and the distinctive patterning of grooving seen when experimenting with a mèche de foret, it is highly likely that mèche de foret were used in perforating the shale beads at Star Carr. Therefore, our results differ somewhat from the hypothesis set out by Clark (1954, 166) and David (2007), in that working with an unhafted mèche de foret proved to be highly effective, where a bead could be made in less than a minute by hand, suggesting a haft and bow may be technically unnecessary.

Unlike the shale beads, the two perforated amber beads from Star Carr have small, hourglass-shaped perforations suggesting biconical working (Clark 1954, 165). A complementary set of experiments was conducted on amber to assess whether the same working strategy was in operation for both raw material types. The same range of experiments was conducted on amber as on shale, working with a mèche de foret and bone tool, working uniconically, biconically, with the tool hafted and unhafted. The use of a shaped piece of bone, cut to a square cross section with a sharpened point, hafted with lime bast and a hazel shaft, proved to be highly effective. This tool drilled through even thick pieces of amber with ease. However, the perforation produced does not match the perforation described by Clark, being highly regular and straight sided, and with no obvious grooves or tool marks within the groove. Attempts to perforate with the mèche de foret were successful, but not universally so (Figure 33.10). A successful perforation was more likely with a narrower mèche de foret, with a concomitant reduction in the risk of splitting and breaking the amber. Overall, both the bone and flint tools are viable, but the mèche de foret produced a perforation which more closely matched the hourglass-shaped profile described by Clark.

The beads from Star Carr were most likely intended to be strung, and there are a number of ways in which they might have been suspended; whether as appliqué attached to clothing (Cristiani et al. 2014), woven into hair, strung separately or brought together into strings of beads (Figure 33.11). Our limited current evidence suggests that the Star Carr beads may have been attached to clothing; this is certainly the most common way that beads seem to have been worn in early prehistory (Taborin 2004, White 1997). Future research aims to address this question by conducting more actualistic experiments testing different possibilities of suspension followed by microwear analysis of the resulting wear traces.

Figure 33.11: Experimental replication of different types of suspension that may have been used for the Star Carr shale beads: (left) strung together with plant fibres; (middle) strung separately with raw animal hide; (right) sewn onto soft hide (clothing?) as appliqué (Copyright Aimée Little, CC BY-NC 4.0).

The British context

The shale beads from Star Carr are not unique in the British Mesolithic; stone beads have been found at a number of early Mesolithic sites across the country. However, they are most numerous at the site of the Nab Head I, Pembrokeshire, Wales, which appears to represent a major manufacturing centre. A total of 692 shale beads have been found and further examples are likely to have been lost to erosion and local collections (Gordon Williams 1924, Berridge 1994, 110; David and Walker 2004, 312; David 2007, 105; Nash 2012, 78). At Nab Head the shale used to make beads was collected from local beaches and carefully selected for its natural form, being consistently water worn, oval in shape and around 2–3 mm thick. In addition, the method of working them appears to have been uniconical.

At the Nab Head I site, 7% (44) of all tools are mèche de foret, compared to 8% from Clark's excavations and 6% from the current excavations. This highlights a trend, previously noted by Jacobi (1980) and David (2007), for high concentrations of mèche de foret to be found on bead bearing sites. The Nab Head I mèche de foret show signs of wear and breakage to the tip, as well as wear to the ventral surface, indicative of rotational action, likely reflecting their use as drill bits (David 2007, 101). Although it is tempting to think that these two sites may have been somehow related, on the basis of the two radiocarbon dates currently available from Nab Head I (9210±80 BP, OxA-1495 and 9110±80 BP, OxA-1496), it is *100% probable* that the bead working there post-dates the bead working at Star Carr (*SUERC-66043*; Figure 17.16).

Shale beads also link Star Carr and the Nab Head into a broader network of Early Mesolithic sites where these artefacts have been found, most of which appear to be of Star Carr type (Table 33.1). Isolated examples are found across southern Wales, as far as Waun Figlen Felen (Barton et al. 1994) in the Black Mountains, and these are likely to have been made at Nab Head. Further examples of shale beads are found across Northern England, from the Pennines at Rushy Brow to the west, Staple Crag in County Durham to the north and Manton Warren to the east. Of these northern sites, Star Carr has the largest number of beads (Table 33.1).

It would be tempting to suggest that Star Carr represents the northern counterpart to the Nab Head; however if it is a manufacturing centre it is on a very different scale to that of the Nab Head, especially given the large excavation areas. It is clear that beads were made at Star Carr, as their distribution is strongly associated with areas where awls were recovered, and areas which can be characterised as workshops focused on craft activities. However, what is more unexpected is that they do not appear to have left their area of manufacture. We might imagine that if beads were discarded here that these would be broken examples, with newly made ones moved elsewhere. This is not the case; while broken beads are present, they are in the minority. The same is of course true of the Nab Head, leading David to speculate that this could be the area of a cemetery (no bone was

Figure 33.10 (page 474): Image showing the perforation of amber by a mèche de foret, hafted to a hazel shaft and bound by willow bast, using a sandstone as a support to hold the amber in place (Copyright Aimée Little, CC BY-NC 4.0).

Site	Material	Number
The Nab Head I, Pembrokeshire	Shale (691), old red sandstone (1)	>692
Palmerston Farm, Pembrokeshire	Shale	1
Linney Burrows, Pembrokeshire	Unidentified stone	1
Freshwater East, Pembrokeshire	Shale	1
Newquay, Cardiganshire	Shale	1
Waun Fignen Felen site 6, Powys	Shale?	1
Star Carr, North Yorkshire	Shale (30) and amber (3)	33
Staple Crag, County Durham	Shale?	1
Rushy Brow, Lancashire	Shale	4 fragments
Manton Warren, Lincolnshire	Shale	1
Thatcham V	Stone	1
Thatcham VI (Mudhole)	Chalky pebble	1

Table 33.1: Stone beads from British Mesolithic sites (data from David 2007, and Wymer 1961). Note the number from Star Carr is now higher.

preserved and shell beads at least in British contexts do appear to be associated with mortuary contexts). Clark discovered much of his bead material in two major clusters, which he suggested might represent lost necklaces, but could equally represent cached material, or depositional foci.

Conclusions

The procurement of material for bead manufacture likely involved journeys to the coast to collect pieces of amber; however, the role of exchange in amber acquisition cannot be ruled out. The beach may also have been the place where naturally rounded discs of shale, weathered by water action, were collected. It is also conceivable that shale was collected from Star Carr and the surrounding locale directly, with little difference in the weathered discs derived from the glacial till or from the beach.

The close proximity of beads and mèche de foret in the area to the north of Clark's cutting III has been used to suggest a bead production area in that location (Chapter 8). Shale was likely made into beads by an awl, which was hand-held, used with a rotational action and relatively firm pressure. This pattern of working produces a close visual comparison to the perforations evident in the Star Carr beads and represents the most probable method of working. This method resulted in minimal breakage, expedient perforation, and greater control when compared to the hafted alternative. The use of a bone tool, employed in the interests of providing a comparison, was entirely ineffective. In contrast, amber was easy to work with bone tools, creating a small and neat perforation, but this did not match the archaeological signature. Instead, mèche de foret were likely used to drill holes biconically, with tools of a narrower profile shape likely preferentially selected to aid in perforation. The use of a haft increased efficiency when working with amber.

The research undertaken on the Star Carr beads has provided some insight into how they may have been made, yet the microwear analysis of the beads and pendant is inconclusive. Some microwear traces could have resulted from use but clear evidence for use could not be found during the analysis. It is also probable that some information has been lost as a result of recent degradation of the site, possibly obscuring, if not eradicating, evidence of residues such as decorative pigments or vegetal fibres. It remains possible that a larger study, incorporating more of those beads that were excavated prior to the geochemical changes at the site, may hold information lost in more recent finds. However, for these objects there exists a stronger risk of post-excavation contamination and/or loss of residues through washing and curation.

David (2007, 107) noted that mèche de foret were likely not used exclusively for perforating beads and indeed from microwear analysis we know that mèche de foret were used on other (non-mineral) contact materials so

are not exclusively bead making tools (Chapter 35). The reverse is also possibly true: beads could conceivably be made by stone tools other than mèche de foret. Initial analyses suggest the pattern made by the mèche de foret is distinct but further testing of similar types of pointed tools is required.

The barely visible engravings found on the pendant, and possibly the backfill bead (if made in antiquity) can provide possible links to the lines exhibited on bodkins and barbed points on the site. Conneller (2011, 83–91) has previously brought into question the extent to which some types of Mesolithic art were intended to be viewed. For example, the practice of engraving the cortex of flint nodules in Mesolithic Scandinavia led to the fragmentation and scattering of art when the nodule was knapped (Conneller 2011, 83–91). Given that the engraving on the pendant is so small, and the piece was almost certainly intentionally deposited in the lake, this question of visibility and audience is perhaps also applicable in this case.

The role and life history of the beads from Star Carr remains obscure. The presence of a unique pendant, made from the same shale, perforated in the same way, and almost certainly a deeply significant piece of art, encourages an interpretation in which beads were more than merely decorative. With the presence of esoteric and performative material culture at Star Carr, with the antler frontlets as possible masks (Chapter 26) being the most dramatic example, beads might reflect another facet of the material touching the social and ritual worlds at Star Carr. On the other hand, the lack of convincing evidence for wear, albeit with taphonomic factors taken into consideration, alongside the evidence for their mass manufacture using mèche de foret, may suggest that the bead assemblage from Star Carr was never intended to be worn by the site's inhabitants. Instead, they may represent items of exchange, connecting Star Carr to the wider Mesolithic world.

Stones

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Introduction

Coarse stones are frequently overlooked on archaeological sites, often because they are considered to be 'natural'. However, on a site like Star Carr, within the peat deposits, all stones which are present must have been transported there by some process: they do not occur there naturally. The archaeological and ethnographic record reveals a broad spectrum of activities that stones can be used for. For instance, stones are often used in food processing for pounding and grinding of plant foods, breaking open bones for marrow, and in a variety of cooking practices such as potboilers, grilling stones for cooking meat, or placed within pit ovens for cooking or steaming (Fretheim 2009; Little 2014). They can also be used for making artefacts and may be associated with grinding pigments such as ochre, softening hides and the knapping and polishing of objects made from flint, bone, wood and antler. They may also have been used for other functions such as tent weights. Some of these activities will produce obvious traces of use, some only microscopic traces of use, and some will have been used for such a short duration of time or in such a way that no signs of use have developed even at a microscopic level.

Given this diversity of uses in everyday life, it should come as no surprise that many coarse stones were found at Star Carr. During the recent excavation seasons, 584 pieces of coarse stone were recovered. They were recorded in 3D using a Total Station, regardless of whether they showed any obvious signs of modification (Figure 34.1). The stones collected in 2013 and 2014 (n=295) have been analysed and the results are presented in this chapter.

Previous research

During the original excavations, stones were found in the archaeological layer, which Clark interpreted as an attempt to stabilise the living surface (Clark 1954, 175). He also noted that some showed 'definite signs of use by man', 12 of which were described and seven of which were illustrated. These stones were of greywacke, siltstone, sandstone, quartz and quartzite and were thought to have been obtained from the local glacial sediments.
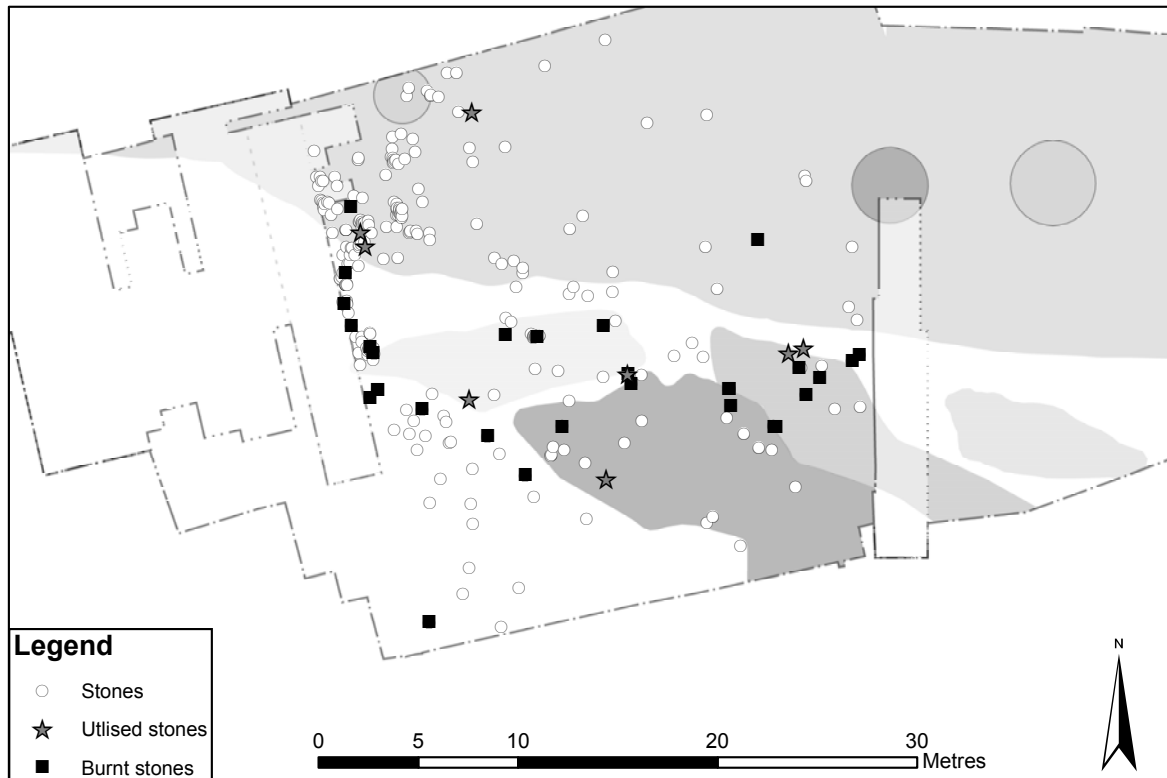
Figure 34.1: Spatial plot of the stones, burnt stones and utilised stones (Copyright Star Carr Project, CC BY-NC 4.0).

Five types of modification were identified on these stones: 1) abrasion of one or both ends; 2) flaking or cut marks on a portion of one edge; 3) irregular pitting on one face perhaps indicating the use as an anvil; 4) finely engraved lines on both faces; 5) staining with a tar-like substance. In addition, one stone (S11) was selected because although it showed no signs of working, it was extremely regular and was considered likely 'that it was selected by man' (Clark 1954, 177).

There are some notable features to two of the stones collected by Clark which stood out from his written descriptions and illustrations. These have both been examined by CC in the Cambridge Museum of Archaeology and Anthropology, and are figured in Clark 1949 (plate XX). Stone S1 (Clark 1954, plate XX, G) is broken but has flaking along one edge. Both ends are discoloured by what Clark describes as a tar-like substance, and which may be resin but might also represent peat-staining or burning. Stone S2 (Clark 1954, plate XX, F) is of an unusual black material probably exotic to the site, which has been smoothed or polished on both sides. A series of parallel lines may derive from the process of smoothing the surface. The ends are bevelled and not smoothed, and may have been used for abrasion. These were found together and are probably the two plotted by Clark (1949, plate VIII) in squares N–O. This is the area immediately adjacent to Clark's baulk, excavated by us. Both these stones would repay further study.

Methods

The majority of the stones were carefully hand washed in water only. Others were too degraded to be cleaned in water, so an attempt was made to remove as much dirt as possible. Measurements of depth, width and length were recorded, using digital callipers. Each stone was carefully inspected for signs of modification or use. Once morphological and wear patterns started to emerge, other stones of a similar size, shape and weight were examined again, to ensure that no signs of modification or use had been overlooked during the first inspection.

The typology created was developed from those constructed for Howick (Waddington 2007) and the Southern Hebrides Mesolithic Project (Mithen 2000).

A representative sample of 30 stones was selected and taken to the geology department of The Yorkshire Museum for identification by Dr Sarah King and Mr Stuart Ogilvy, and these were then used to categorise the rest of the assemblage.

Some stones had been collected on site for residue analysis; however, all of these proved too degraded to analyse for residues. However, preliminary microwear analysis on the stones showed the most potential for microwear traces. Analysis was carried out with a low-power (×5–×10) stereoscope; some were further selected for preliminary high-power analysis using a high-power metallurgical microscope (×20–×50). This study was in no way conclusive but was carried out to assess the potential for future work, and from this assessment, a more extensive and integrated programme of microwear and experimentation will be undertaken in the future.

Results

Geology and morphology

The majority of stones examined at The Yorkshire Museum vary from very fine- to coarse-grained sandstones. In addition, one was siltstone and one could not be identified. Many of the sandstones demonstrate poor cementation within the structure of the stone, which is believed to have been caused by the wet, acidic conditions of the soil (Chapter 22) washing away the cementing material and leaving behind the more robust elements of the stones. According to the geologists, the sandstone most likely comes from a very similar, if not the same source. Some of the pieces are waterworn, with one example being almost completely round, and it is likely that these all came from a nearby water source: perhaps the lake, the river or even the coast, though this would have been much farther away. The stones vary in size (Figure 34.2); there were two outliers, one of which was particularly large in both width and length <108947> and which had been found in reed peat (317).
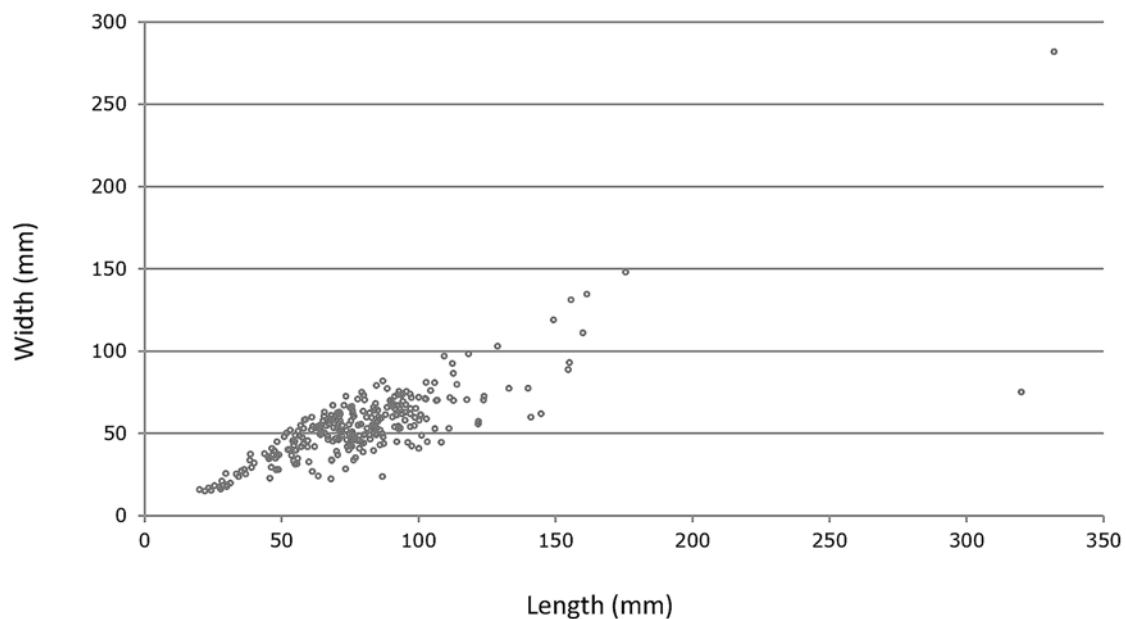
Figure 34.2: Plot of length against width showing the range of sizes, including two outliers (Copyright Star Carr Project, CC BY-NC 4.0).

Burning

A total of 28 (9.5%) stones show indications of being burnt and seem to occur mainly in the wetland area (Figure 34.1). The stones were not identified as burnt until they had been cleaned twice, at which point any patches of blue/grey discolouration that remained was taken as evidence of burning (Figure 34.3). In addition to the sandstone, two pieces of fractured quartz and two discoloured stones of unknown geology displayed the most obvious signs of burning. A small number of stones may have been heat fractured but displayed no signs of burning. These were not catalogued as burnt/heat fractured as there was a possibility they had disintegrated due to the acidic conditions of the soil. The stones with evidence for burning range in morphology from sub-angular to rounded, the majority being medium coarse- to fine-grained sandstone. Most are similar in size, the largest being 103 mm in length and 1.2 kg in weight.

An experiment was undertaken to assess the types of burning and heat fracturing which are visible within the coarse stone assemblage. Two pieces of quartz and two pieces of sandstone were collected from Cayton Bay beach near Star Carr. The four pieces were placed within an open hearth and heated to a maximum of 350°C. Before removing them from the ashes, the surface temperature of the stones was recorded as 300°C. They were immediately lifted onto a metal shovel and dropped into a metal bucket containing approximately two litres of lake water. Initially, the water boiled and produced water vapour; however, it appeared to quickly drop in temperature and within 15 minutes, the water measured 25°C.

Figure 34.3: Coarse stone cobble with blue/grey signs of burning remaining after washing (Copyright Aimée Little, CC BY-NC 4.0).

Upon inspection, the two quartz stones had fractured; one to such a degree that it fell apart upon handling. Stone <99556> was similarly fragile, although no visible signs of discolouration were present. The two pieces of experimentally heated sandstone were intact. These pieces were then washed to remove charcoal and ash. Once dry, they both clearly displayed small patches of grey-blue discolouration which could not be washed away by hand without removing the surface of the stone. This discolouration bore close resemblance to the burnt sandstone from the assemblage.

Utilised stones

Nine stones had clearly been used. One of the stones was found in trench 35 (Chapter 3) (Figure 34.4). The majority of utilised stones were found in the wood peat (310), suggesting activity took place in this area once it had become fen carr. The majority were naturally rounded or oval stones with flat 'upper' and 'lower' surfaces. In profile they appear to have been modified intentionally, almost faceted, as if the natural form of the cobble had been enhanced. However, similar-shaped coarse stone cobbles used extensively as hammerstones for a range of tasks, including house construction, have the same faceted and pecked appearance, making it likely that such modification has resulted incidentally from use. Two archaeological examples of cobbles displaying different morphological form, <96759> and <107884>, suggest alternative functions, and are discussed below.

In some cases it is clear from the morphology of the stone and the visible macro damage that they have been used as hammerstones. In most instances, coarse stone tools are used for more than one purpose, displaying smoothed surfaces from use as polishers as well as peck marks from percussion. Coarse stone tools were likely to have been used for a range of tasks, such as polishers for hide, burnishers for other materials, anvils and hammerstones.
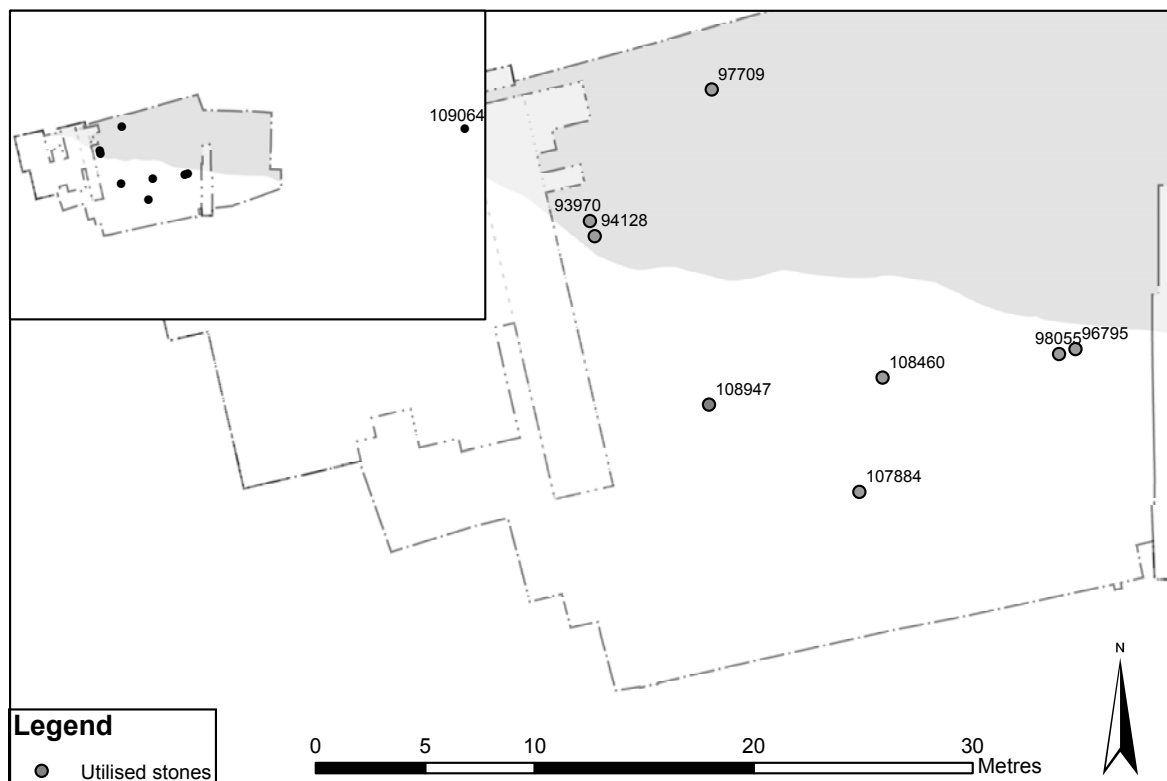
Figure 34.4: Plot of utilised stones. Stone <109064> was found in trench 35 (located within the top frame). Stone <94259> was not 3D located so it not plotted here (Copyright Star Carr Project, CC BY-NC 4.0).

Waterlogged deposits

1) <108947> (detrital mud: context 317) a large flat 'flagstone' of sandstone was found in the wetland deposits, likely to have been underwater at the time of deposition (Figure 34.5). As previously stated, stones do not occur naturally in this context; therefore this object must have been placed there intentionally. No evidence for grinding was observed; however, the surface was in very poor condition with areas of it appearing weathered, probably due to the acidity of the surrounding wetland deposits. A number of pitted areas were observed and may have resulted from its use as an anvil; unfortunately, its poor condition precluded more detailed microscopic analysis. Alternative reasons for its placement in a watery context include the possibility that it was used to weigh something down which has long since perished, or it may have created a stable standing surface whilst fishing, fowling or similar.

Wood peat

2) <108460>: (context 310) is a piece of sub-oval shaped, fine-grained sandstone (Figure 34.6). The upper and lower surfaces are smooth, contrasting with the edges which are rougher and display flaking and peck marks from percussion. It is possible that the surfaces were used for polishing/burnishing activities, and the edges, principally at either end, were employed for hammering. Interestingly, one pronounced edge with peck marks has started to 'flatten' through use, acquiring the 'faceted' appearance of the other sub-oval hammerstones.

3) <107884>: (context 310) is a piece of fine-grained sandstone (Figure 34.7). It tapers to a point at one end, which has percussion damage, probably from use as a hammerstone. The most noticeable feature of this coarse stone tool is the well-defined facet visible on one surface. Microwear analysis of the faceted surface revealed a polish which did not display any clear directionality, possibly resulting from multidirectional movement. The polish was pitted in places, but also bright. Though requiring more detailed analysis, this may be the result of

Figure 34.6: (left) stone <108460>; (right) detail of peck marks (Photographs taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).
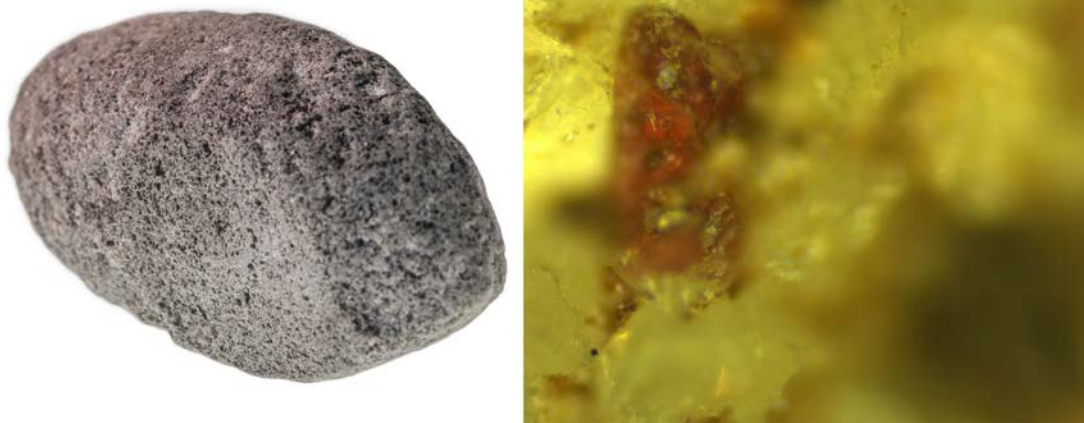
Figure 34.7: (left) oblique view of sandstone artefact <107884>, which has clear signs of modification: pecking at one end and a smoothed facet on one surface, probably resulting from use; (right) red stain deep within the stone matrix of <107884>, visible only microscopically (×20) (Left photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0. Right photograph Copyright Aimée Little, CC BY-NC 4.0).

contact with hide and a mineral component such as ochre. Interestingly, a red residue was identified microscopically, embedded deep into the matrix of the stone (Figure 34.7); further analyses are required to identify this definitively as ochre.

4) <98055>: (context 310) is a piece of medium-grained sandstone (Figure 34.8). Both long edges show clear signs of damage from percussion, which has created a flattened surface. The surfaces of the stone are less smooth than the other stones of this type. Future microwear analysis may help determine whether they have in fact been used as polishers. Both ends of this stone have broken off and exhibit no further signs of use post-breakage.

5) <96795>: (context 310) is a medium-grained sandstone. It is sub-oval in shape, with very smooth upper and lower surfaces, which may have been utilised for polishing. However, the most notable feature on this artefact is a series of parallel grooves worn into one of the edges. These grooves were not immediately visible, only

Figure 34.5 (page 484): Stone <108947>, a large flat stone found within detrital mud (317) (Copyright Star Carr Project, CC BY-NC 4.0).

becoming visible in certain light, clearly captured with macrophotography (Figure 34.9). Microwear analysis of the grooves revealed wood and/or antler polish. A tool like this would have been useful for a number of things, including shaping antler for barbed points or polishing the shafts of arrows. Arrow shaft polishers or 'straighteners' are known from other Mesolithic sites, for example the Bjørnsholm kitchen midden (Andersen and Rasmussen 1991, 85). More commonly, grooves on coarse stone tools interpreted as arrow straighteners are present on the long axis of the cobble to achieve maximum contact between the shaft and the stone. In contrast, the grooves are on the shortest axis, the edge, suggesting use as a polisher for a shorter object.

Figure 34.8: (left) stone <98055>; (right) close up of damage which has created a flattened surface (Photographs taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

6) <94128>: (context 310) is an ovoid, medium-grained sandstone (Figure 34.10). Modification of this stone through percussion damage is visible on one surface and both edges. This has resulted in a regular 'egg-shaped' profile. As well as this, one face has three large flakes removed from it, although at least one of these is most likely post-depositional in nature as it is fresher in appearance than the other two.

7) <93970>: (context 310) the geology could not be determined without using destructive methods, although it is possibly chert (Figure 34.11). It shares similar features to many of the other cobbles in that it has percussion

Figure 34.10: (left) stone <94128>; (right) detail of percussion damage (Photographs taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 34.11: (left) pecking marks on terminus of <93970>; (right) stone <93970>; note the very smooth surface (Left photograph Copyright Aimée Little, CC BY-NC 4.0. Right photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 34.9 (page 486): Macrophotography of the parallel grooves clearly visible on the edge of sandstone cobble <96795>, as well as percussion damage probably from use as a hammerstone. Microwear of the grooves revealed wood or/and antler polish. This object has been interpreted as a possible tool for barbed point production, arrow or other type of shaft polisher (scale: 80 mm in length) (Copyright Matthew Von Tersch, CC BY-NC 4.0).

Figure 34.12: Stone <94259> which may have been used as a hammerstone (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

damage; however, its morphology is different: it is sub-triangular in profile and sub-oval in plan view, with the percussion marks located at both ends of the flat sub-oval surface. On this sub-oval surface linear marks can be seen running along its length probably resulting from the stone being used in a backwards and forwards motion, to polish or similar.

8) <94259>: (context 310) is medium- to fine-grained sandstone (Figure 34.12). It is almost twice as long as it is wide and has a circular cross section. Percussion damage at one end suggests it has been used as a hammerstone. There is a very small amount of percussion damage on two other surfaces. The other end was probably broken off in antiquity and shows no signs of post-breakage use.

Western structure

9) <97709>: (context 303) is a fine-grained sandstone which was probably originally sub-oval in shape but has broken in antiquity (Figure 34.13). The widest edge in profile displays the most percussion damage, although a small quantity of percussion marks are visible on the opposing edge; it is likely that this was well utilised for various hammering activities. Both the upper and lower surfaces of the cobble are very smooth, and it is possible to see a difference between the natural, more rough/textured surface, to the very smooth surface which appears to have resulted from use as a polisher or similar.

Figure 34.13: (left) stone <97709>; (right) detail of percussion marks (Photographs taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Figure 34.14: (left) stone <109064>; (right) detail of percussion damage (Photographs taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).

Trench 35

10) <109064>: (context 327) is a piece of fine-grained sandstone, sub-oval in shape (Figure 34.14). This stone has two relatively smooth, flat surfaces, one of which is particularly smooth, perhaps having been used for polishing. The widest side in profile displays extensive pitting from percussion, ostensibly removing the majority of material from all of the sides. This has resulted in a rounded profile, with flattened edges and rounded corners.

British Early Mesolithic context

In general, coarse stone has been neglected in the British Mesolithic. There are some exceptions: bevel-ended stone tools have seen some study (e.g. Clarke and Waddington 2007), as have pebble mace heads, though the chronological range and attribution of these remains uncertain. The presence of hammerstones is frequently noted in site reports but these are paid little more attention than simply noting their presence. However, even a cursory examination of the literature reveals that imported and utilised stones are ubiquitous. Rankine (1949) was the last individual to undertake a broad survey of imported and utilised stones on a broad scale, and a new synthesis is needed.

In the context of northern England, sandstone hammerstones, likely of local glacial origin, are common across Early Mesolithic sites in the Vale of Pickering. The use of sandstone is also mentioned on the Pennine Star Carr site of Turnpike (Stonehouse 1992, 9), though in this case it is a type that is not of local origin. It appeared to be used for polishing and rubbing. Two pieces of red ochre were also found at the site. The fullest discussion of exotic stone use for a Deepcar site comes from Deepcar itself, where Radley and Mellars (1964) note the presence of rounded gritstone blocks, quartzite pebbles and local flag. The former two had been imported from the River Don, below the site, the latter pulled up from the underlying bedrock. All were considered to be structural in nature. Two stones, a battered piece of basalt and a shaped piece of sandstone, appear to have been artefacts.

More is understood about the movement of stone in Southern England thanks to Rankine's work. Rankine had a long-standing interest in this issue and noted a persistent presence of stones from the southwest across Southern England (Rankine 1949). Rankine's recording of the movement of stone used for the production of chipped stone artefacts is perhaps the best-known part of this work, thanks to further study by Care (1979). The movement of Portland chert appears to have started in the Early Mesolithic, as indicated by its presence at Frensham Great Pond, Surrey, and Oakhanger VII (Jacobi 1981). Rankine also records the transfer of slate artefacts, though these appear to be a late Mesolithic phenomena (Jacobi 1981) and fine-grained elongated pebbles which derive from the Palaeozoic of southwest England (Rankine 1949; 1956, 55). These latter were moved during the early as well as the late Mesolithic, as demonstrated by finds from Oakhanger V/VII, where five siltstone pebbles were recovered. Petrographic analysis indicated a Cornish origin, though they are likely to have been collected as beach pebbles; Rankine (1956, 56) suggests Chesil beach is a possible source. Similar pebbles, with a Devon or Cornish origin were recovered from the mixed Mesolithic site at Farnham (Rankine 1956). Similar types were recovered from the Early Mesolithic site of Kingsley Common, R4 (Jacobi 1981, 20). Sandstone grinding slabs are also known from Oakhanger with possible sources in Kent and Sussex as well as sandstone and quartzite pebbles with likely exotic sources.

Since Rankine's 1949 synthesis further examples have been uncovered, for example sarsen stone was used to line a pit at Thatcham I, Berkshire, and a piece of abraded sandstone and quartzite pebble flaked into a disk were recovered from the same site (Wymer 1962, 333). Two pieces of Devon Sandstone, used as rubbers, come from Hengistbury Head, as well as a more immediately local sarsen block (Barton 1991). However, it is likely that exotic as well as utilised stones are often missed, particularly on sites with complex taphonomic histories.

Conclusions

From a study of morphology and macroscopic traces we have been able to determine that <96759> was likely to have been used to work antler, possibly barbed points, or polish wood, possibly shafts for arrows. Microwear analysis supports this theory with wood and/or antler polish identified within the linear grooves. Other stones, for example <98055> were clearly used as hammerstones. It is interesting that so many hammerstones come from the wood peat (310). This, coupled with the evidence for in situ knapping in the wood peat, for example at the axe factory (Chapter 8), indicates the transformation of a once-wet area into fen, which in turn became a working surface.

When selecting cobbles for use as a hammerstone, there is a preference for sub-oval cobbles with two flat surfaces. It is the profile of the cobble which displays the most percussion traces. Future work on these stones aims to conduct a more detailed functional study integrating microwear with experimental research, although given that these stones were likely to have been employed in a variety of activities, teasing apart discrete episodes of

use through microwear research could prove challenging. From macroscopic analysis it is clear that many of these stones had extensive and varied use lives, probably picked up and reused time and again. As seen in many chapters of this book, coarse stone tools have played a fundamental role in many of our experiments, including tapping out a shale bead blank followed by polishing of the bead's surface, use as an anvil for drilling amber, striking a flint nodule to produce blade and flake blanks, crushing bone to remove marrow, polishing wood to make it smooth, removing the unwanted burnt and brittle part of a deer crania to produce an antler frontlet (e.g. see Chapter 10). One coarse stone could have been used for all of these tasks.

When working with coarse stone, one quickly becomes accustomed to its form and properties, gaining a preference for one stone over another. It is not difficult to imagine how these objects were not only curated and used in a diverse range of tasks, but perhaps became part of one's personal toolkit. Coarse stone is robust, and even when broken, which we have seen on a number of the modified pieces analysed in our study, can continue to be utilised, if not for exactly the same task for other similar activities. We also know that some stones were burnt, possibly as part of cooking activities; although more research is required, coarse stone tools which had come to the end of their use life as hammers, polishers and so forth may have then have been re-used as heat retainers.

Rarely in accounts of material culture from Star Carr, since Clark's publication, has coarse stone technology been mentioned. We are very familiar with the abundance of flint, worked into numerous tool forms, used for an extensive range of activities (Chapters 8 and 35). In comparison, coarse stone technology has been a neglected dimension to our understanding of the material world of Star Carr's inhabitants. Although we have not been able to conclusively identify the function of every coarse stone tool from the site, it is clear that the role of these enigmatic artefacts in daily life was varied. This, combined with evidence for their importation to the site, their curation and extensive reuse, suggests that these seemingly banal and often overlooked objects were an intrinsic part of people's material repertoire.

The Worked Flint

Chantal Conneller, Aimée Little, Virginia Garcia-Diaz and Shannon Croft

Introduction

Techniques, both those of excavation and those associated with lithic analysis, have improved considerably since Clark excavated Star Carr. These have resulted in more detailed and different types of information being recovered from the lithic assemblage. However, we remain motivated by Clark's aim in excavating Star Carr: 'to understand how [people] lived in the past' (Clark 1939, 1), and our improved methods of excavation and techniques of analysis have been focused on this end. For example, our focus on full recovery and retention of all lithics, in contrast to Clark, has had an impact on understanding the lithic assemblage. Clark famously did not retain material smaller than 'finger-nail size' (1954, 96), nor did he sieve sediment. This resulted in the recovery of only 15 microburins. Our excavations have yielded 85 (admittedly in an assemblage around 50% larger), 31 of which were recovered from sieving. Clark was keen to pioneer new scientific techniques, and we have deployed microwear and residue analysis to more fully understand activities at the site.

Following the original publication, the lithics have played a relatively minor role in the subsequent reinterpretations, which have mainly focused on the unusual patterning of faunal remains retained from Clark's excavations (e.g. Caulfield 1978; Andresen et al. 1981; Legge and Rowley-Conwy 1988). However, Jacobi based his interpretations of the settlement patterns in Northern England on the tools found at Star Carr and sites on the North York Moors respectively (1978), while Pitts (1979) used the presence of scrapers and awls to suggest skin-working was the major function of the site. More recently Mellars (2009) used the location and composition of 'lithic scatters' to argue for in situ activity in the lake and wetland edge.

The only new analysis of lithic material since Clark's excavations was made by Dumont (1983; 1988; 1989), who carried out an in-depth analysis of a selection of tools from Clark's excavations. Dumont was critical of the craft focus taken by Pitts and Andersen, which he summarised as craft and manufacturing activities undertaken as 'boredom reducers' whilst waiting for and processing game. Instead he undertook analysis with a view to evaluate presence versus absence of activities and to 'add fuel to the function of the site as a whole' (1983, 128). Unlike the research presented here, Dumont's analysis had no spatial focus (other than the general knowledge that pieces analysed were taken from Clark's area); thus, no comparison of the structuring of activities, as represented by tool use, can be made between his work and that presented here. Despite Dumont's analysis focusing on select artefact types, with no spatial reference, he concluded that the range of activities reflected

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in tool use at Star Carr were too diverse to justify the site being defined as a tannery or hunting blind (as suggested by Pitts 1979 and Andersen et al. 1981). Instead, he suggested that it probably functioned as a base camp.

Methods

All lithics underwent initial identification and cataloguing using the typological system of Healy (1988), with microliths recorded according to Jacobi types (Jacobi 1981) and burin types following Inizan et al. (1991). The presence of retouch and macroscopic edge damage was also recorded on blanks. Extent of cortex was recorded in five categories (0, 0–25%, 25–50%, 50–75%, 75–100%, 100%), in order to understand variation in the reduction sequences across site. Lithic material was assigned to raw material type (either till, Wolds or chert) on the basis of the work of Henson (1982), plus additional sampling carried out by CC. Condition of the cortex was recorded as pebble, derived and chalk in order to understand where material was obtained. Colour was also recorded to investigate whether certain colours of flint were preferentially used for particular tools.

Refitting was employed to understand reduction sequences, movement of material around the site and as a taphonomic tool. Due to the large size of the excavation area and its lithic assemblage, and the time constraints of the project, only certain areas were targeted for refitting. These focused on the larger areas of open excavation where chances of success were greater, whilst areas heavily truncated by earlier excavations, such as Clark's area and Moore's area, were avoided. We also avoided wetland assemblages, as these represent tool use and deposition rather than in situ knapping, though wetland edge assemblages were included. Selective refitting was employed in some areas. The lithic assemblage from the western structure was highly burnt and fragmented (making refitting difficult) and was also extremely large; this area was sampled by selecting only red and black flint for refitting. This sample of rarer and distinctive colours was investigated to understand whether the material in this area represented in situ activity or middening. Material selected for refitting was laid out on trays and sorted by material, colour and cortex. Refits were temporarily stuck together using blu-tack (subsequent to selection of material for microwear and residue analysis), but longer sequences were glued, following analysis, using a water-based glue dissolvable in acetone. Refitting was carried out by CC, with some contribution from Julie Birchenall and University of York students (Chapter 8 presents the main results).

Microwear analysis was carried out by AL with assistance from VGD (see Chapter 15 for methods). Artefacts for microwear were selected by CC following initial techno-typological analysis of the assemblage. These consisted of a representative sample of major tool types and blades and flakes, both unmodified and with macroscopic edge damage or retouch. An additional consideration when selecting this sample was to provide coverage of activities across the entire site. Material for microwear analysis was selected before the start of the refitting exercise in order to avoid possibility of damage to the material. However, on occasion it was deemed useful to investigate material for microwear because it belonged in a refit sequence (e.g. due to the presence of a long distance refit). In this case the piece was sent for microwear immediately on discovering the refit to minimise damage.

Residue analysis was carried out by SC. This involved conducting both a burial experiment to examine the potential survival of different types of residues within this burial environment (Croft et al. 2016) and examining a sample of archaeological worked flint. Lithics to be sampled for residue analysis were not handled and were placed into a clean finds bag using a trowel. A separate sample of soil from underneath the artefact was also sampled. A number of residues were observed using reflected visible light microscopy (VLM) and then examined further using scanning electron microscope with energy dispersive x-ray spectroscopy (SEM-EDS or SEM-EDX), gas chromatography–mass spectrometry (GC-MS), confocal Micro-Raman, and Fourier transform infrared microspectroscopy (FTIRM). Unfortunately, most residues seen on stone tools were natural: minerals such as iron oxide, gypsum and iron pyrites were common, as found in the analysis of the degradation of the site (Chapter 22). However, preliminary microscopic and GC-MS evidence suggested pine (likely *Pinus sylvestris*) compounds were present in trace amounts on nine stone tools (Croft 2017).

The assemblage

A total of 24,883 pieces of flint were recovered from the excavations, testpitting and fieldwalking at Star Carr between 2004 and 2015 (Table 35.1). This is a larger assemblage than that recovered by Clark (n=16,937), but

Category	No.	%
Tools total:	*2475*	*9.95*
Awl	69	0.28
Axe	21	0.08
Burin	232	0.93
Denticulate	22	0.09
Hammerstone	12	0.05
Microdenticulate	23	0.09
Microlith	312	1.25
Notch	14	0.06
Scraper	342	1.37
Scraper/burin	10	0.04
Strike-a-light	20	0.08
Truncation	31	0.12
Wedge	5	0.02
Retouched	115	0.46
Utilised blade	727	2.92
Utilised flake	205	0.82
Utilised fragment	315	1.26
Tool spalls total:	*438*	*1.76*
Axe flake	106	0.42
Burin spall	231	0.93
Microburin	89	0.36
Retouch spall	12	0.05
Core prep. total:	*497*	*2*
Core tablet	219	0.88
Crested blade	202	0.81
Plunging	60	0.24
Step fracture removal	16	0.06
Debitage total:	*21473*	*86.29*
Blade	3081	12.38
Flake	4867	19.56
Fragment	9814	39.44
Chip	2984	11.99
Core	322	1.29
Core fragment	52	0.21
Nodule	12	0.05
Chunk	341	1.37
Total	**24883**	**100**
Burnt	4117	16.54

Table 35.1: The Star Carr assemblage.

using more systematic recovery methods, and over a much larger area. Clark thus seems to have encountered, in general, much higher densities of materials. Nearly 10% of recovered artefacts from the current excavations are tools, with the assemblage fairly 'balanced' (Mellars 1976) between scrapers (n=342), microliths (n=312) and burins (n=232), though this distinction is pretty meaningless for a site that has seen intermittent occupation for round 800 years (Chapter 17). Clark's figures for essential tools are slightly different, with burins most common (n=334), followed by scrapers (n=326) and microliths (n=248), the lower quantities of the latter possibly due to a lack of sieving. Clark also had rather more awls (n=114) than recovered during the current excavations (n=69). The increased number of awls and burins in Clark's excavations reflects the higher numbers of awls in the western part of the site (see Chapter 8) and the large number of burins in the area of wetland deposition represented in the southern part of Clark's cutting I, also encountered during these excavations. 16.5% of the lithic material from the current excavations is burnt, a result of intensive activities round hearths in the dryland area of the site. The spatial dimensions of lithic-focused activities have been discussed in Chapter 8. This chapter therefore investigates different aspects of the assemblage; the raw materials used, the technology employed, and the form, manufacture and curation of the tools recovered. Given the extraordinary temporal resolution of the site, this chapter also explores changes in traditions of lithic manufacture and tool production over time.

Sources

Two types of flint were employed for the vast majority of the assemblage: till flint and Wolds flint. Chert is present but rare. Till flint was most commonly used: this material is extremely heterogeneous, varying considerably in colour and quality. Most common is semi-translucent grey speckled flint but a clear brown flint (ranging in hue from honey coloured to black) and less commonly a red speckled flint is also present. The clear brown flint is of best quality, with fewer irregularities and flaws. The grey and red speckled flint are of variable quality; some nodules are relatively translucent and fine, others coarser, with inclusions and flaws, such as voids and fossils.

Till flint can be obtained either directly from the exposures of glacial till that blanket the east coast, or in a further derived source such as stream or river cobbles, or as beach pebbles. The characteristics of the cortex of the material recovered from Star Carr suggest the majority of the material was obtained as beach pebbles. The remainder was probably obtained directly from the till. Clear brown flint was suggested by Clark to be from a different source to the grey till flint. A few pieces of this flint (often tabular) do have a slightly different cortex, possibly indicating a cobble or closely-derived source, potentially from the current region of south Lincolnshire or an off-shore source. However, the vast majority of this brown flint also has a beach pebble cortex, indicating it was obtained in the same manner as the speckled grey flint.

The exact means of procurement from the till is uncertain, but the large exposures of till cliffs created by coastal erosion are a likely source. Today a range of materials can be procured from East Yorkshire beaches, from small pebbles with a heavily battered cortex, to larger tabular and semi-tabular pieces with a thin sharp cortex, which can be obtained freshly eroded from the cliffs of glacial till that back many of the beaches in the region. While glacial till is present in the Vale of Pickering itself, flint is not a major component of this deposit. The Devensian ice sheet that deposited the glacial till was a two-tier glacier, resulting in differences in the character of the till deposited by each. The lower Skipsea Till contains larger amounts of chalk and flint, and these gradually increase southwards, suggesting that the ice was in fairly continuous contact with the chalk that extends east from the Yorkshire Wolds beneath the North Sea (Madgett and Catt 1978; Catt 1987). Deposits of the overlying Withernsea Till are less extensive; however, Foster (1985) suggests that the till which blankets the eastern end of the Vale of Pickering, existing as surface deposits at least as far as Seamer, is of Withernsea type. As the upper glacier that deposited the Withernsea Till overrode the lower one, before entering the Vale of Pickering, it contains little flint, having never been in contact with the chalk. What flint is present is extremely small and weathered, suggesting that this material was already from a derived source before becoming incorporated into the glacier. This means that it is unlikely that Mesolithic people obtained any flint from the till of the Vale, and instead they would have had to range further afield.

Beach pebbles were used as the predominant source throughout the period, from the earliest occupation of the site (represented by lithic material in the detrital wood scatter), to the latest (represented by the fen peat scatter) (Table 35.2). Sea-level rise was transforming coastal geomorphology immediately to the east of the Vale of Pickering during the Early Mesolithic (Shennan et al. 2006), bringing the coast ever closer. Ascertaining

Cortex type (%)	c. 9300–9000 cal BC	c. 8950 cal BC	c. 8850 cal BC	c. 8800 cal BC	c. 8700 cal BC	c. 8500 cal BC
	Detrital wood	Central platform	Axe workshop	Clark's area	SC22 scatter	Fen scatter
Chalky	8.33	13.64	10.71	8.33	13.04	13.95
Derived	4.17	18.18	32.14	26.04	13.04	16.28
Pebble	87.5	68.18	57.14	65.63	73.92	69.77

Table 35.2: Representation of till cortex types in dated assemblages.

source from cortex is not an exact science, as even beach pebbles can have areas of thicker chalky cortex preserved in dips or as a result of recortication. However, there do seem to be some possible temporal differences in the relative use of beach pebbles and nodules obtained more directly from the till. During the earliest occupation of the site c. 9300–9000 cal BC (as represented by material from the detrital wood scatter), beach pebbles predominated. During the main phase of occupation of the site 9000–8700 cal BC, represented by the central platform, Clark's area, and the axe workshop, use of material direct from the till increased. In the later phases of the site, at the SC22 scatter and the Fen Carr scatter, use of beach pebbles increases slightly. This is likely to reflect a number of factors, most likely the morphology of the changing coastline, but also perhaps shifting mobility patterns and desire for better quality material.

The size of till flint depends on its source. Larger nodules can be obtained directly from the till. In general material obtained from the beach is smaller, with refitted material indicating small to medium-sized pebbles being deployed. Today relatively large nodules of flint can be obtained from east coast beaches, and the same is likely to be true in the Mesolithic. However, these are less ideal for a technology based on bladelet production and also would be more difficult to transport to Star Carr. While caches reveal that sometimes large nodules were brought in whole, on other occasions they were split, probably at source, into smaller packages. Preformed cores from a cache that mostly refit into a larger nodule average at a core height of 56.4 mm and very similar width and depth, averaging 38.75 mm and 38.5 mm. These packages were more easily transportable and more useful for the production of small blades and bladelets.

The quality of material is also affected by source. Flint that has been carried by a glacier is subject to frost fracture and internal flaws. However, material collected as beach pebbles can be even poorer quality through repeated percussion against other pebbles, leading to frequent internal flaws. Sometimes till material was tested, probably at source, by the removal of a flake; other times it was not, resulting in the importing of material to Lake Flixton that was sometimes unusable. The sea would have been in the order of 10–20 km distant, and with no obvious navigable water course between the sea and Lake Flixton to aid transportation of heavy flint nodules. This could suggest that the people that procured the flint were not its users: it may have been obtained through exchange with another group, or perhaps by less-experienced group members, such as children.

Several raw-material caches have been found in the Vale of Pickering (see Conneller and Schadla-Hall 2003), including two in the current excavations at Star Carr. Apart from a single nodule of Wolds flint from the Seamer D cache, all remaining 45 nodules recovered from caches were till flint, indicating the preferential establishment of caches of non-local high-quality till flint in the landscape. These caches consist of flint nodules that have undergone various levels of reduction. The caches from Flixton School (Conneller and Schadla-Hall 2003) and from the Star Carr western platform consist of large nodules, mostly with only a few flakes removed to test for quality. Other caches have seen greater levels of reduction: the AC8 cache found on the wetland edge at Star Carr (Figure 8.43) consists of 19 pieces, most of which seem to derive from a single large nodule which has been split. Almost all pieces in this cache have seen some level of reduction, usually the neat removal of a small number of blades (up to 12 removals, though most have fewer). A cache from Seamer D (Conneller and Schadla-Hall 2003) is very similar, though in this case small to medium-sized beach pebbles have been reduced by the removal of a number of blades. Caches also vary in size from two nodules in the Star Carr western platform cache (Figure 8.30), to 19 pieces in the AC8 cache.

The opaque white or grey Wolds flint is potentially a much more local source as the scarp slope of the Yorkshire Wolds forms the southern boundary of the Vale. But despite its proximity, Wolds flint was less frequently employed in Early Mesolithic assemblages. The chalk plateau of the Wolds is made up of five different

formations: the Flamborough, Burnham, Welton, Ferriby and the Rowe Chalk formations (Hopson 2005). While only 35% of the chalk contains flint, most of the flint-less Flamborough formation remains unexposed. However, both the Burnham and Welton formations contain a number of siliciferous horizons, the Welton Formation containing nodular flint, and the Burnham Formation mainly tabular and semi-tabular flint (Wood and Smith 1978; Henson 1982; Hopson 2005). Exposures of these horizons are likely to have existed through erosion of the Wolds edge. However, Wolds raw material in the present day, whether occurring as isolated examples eroded from the chalk or as a number of flint horizons exposed through quarrying, is rarely of knappable quality, being brittle and usually frost fractured. Mining for unaffected flint was not an option, even in the Neolithic, because Wolds chalk, unlike the chalk of southern England, is very hard. One mechanism for obtaining undamaged Wolds material may have been through the erosional action of the numerous springs and streams which originated on the Wolds edge and drained into Lake Flixton. Here, nodules would have been less subject to the extremes of temperature variation that results in frost fracturing. Large cobbles have been recovered from ancient stream beds elsewhere in the Vale (Zylawyj 1986).

Wolds flint occurs both in nodular and tabular forms, the nodular form being of higher knapping quality, while the tabular form has a tendency to fracture along its natural planes. Durden (1995) suggests that although tabular chalk flint is too brittle for knapping, the nodular type is rather more suitable and was used in Mesolithic industries and for small and simple tools in later periods. While this appears true of some Mesolithic industries (certain Pennine assemblages, for example, appear to be manufactured entirely on nodular Wolds flint: see Chapter 11) during both the Late Palaeolithic and Early Mesolithic periods in the Vale of Pickering tabular material appears to have been utilised as well as nodular Wolds flint.

In comparison to till flint, Wolds material varies relatively little in colour, ranging from opaque bluish grey or grey to white. It is coarser and of much poorer quality than till flint and contains numerous flaws, pinholes and fossils. It is thus more difficult to work and is generally much less abundant in archaeological assemblages in the Vale of Pickering.

Rarer still is chert, which is found only as occasional flakes, and in one instance a core. Only 22 pieces were recovered from the entire site. Two pieces of banded chert may derive from the Yorkshire Dales or Northumberland (Stephen Poole pers. comm.). Where present this chert has a beach pebble cortex suggesting it was obtained in the same way as till flint. While till flint was imported to the Pennines during the Early Mesolithic in large quantities, chert from the Pennines does not seem to have made the journey in reverse (Chapter 11).

Overall at Star Carr, till material outnumbers Wolds flint at a ratio of 4.84:1. An examination of raw material ratios in well-dated areas of the site suggests there does not appear to be any patterning to raw-material choices over time (see Table 35.3).

More striking is the difference in the use of different materials for different tools (Table 35.4). Overall 82.7% of the assemblage was made from till material. In general there was a preference to manufacture tools from till flint, in particular microliths, of which 94.2% were made from this material. The manufacture of awls also shows a strong preference for till, suggesting it was widely viewed as the most appropriate material for manufacturing sharp points. Conversely axes were produced on Wolds material and till material in equal numbers. This may be because Wolds material could be obtained both in fairly large packages and in the flat tabular or semi-tabular form that appears to have been favoured for the axe manufacture. However, there are also other possibilities: axes appear to have been curated tools so may have circulated through exchange mechanisms. Alternatively, as curated objects they may reflect longer-term mobility and embedded procurement patterns than more expedient tools.

	c. 9300–9000 cal BC	c. 8950 cal BC	c. 8850 cal BC	c. 8800 cal BC	c. 8700 cal BC	c. 8500 cal BC
	Detrital wood	Central platform	Axe workshop	Clark's area	SC22 scatter	Fen scatter
Till flint	88.3	84.4	78.2	86	93.2	86.2
Wolds	11.7	15.6	21.5	14	6.8	13.5
Chert	0	0	0.3	0	0	0.3

Table 35.3: Use of different flint sources in well-dated areas of the site.

Till flint in particular is available in a range of different colours. Sampling of material currently available as beach pebbles shows speckled grey flint is the most common, with smaller quantities of brown, red, black and white and grey flint. Wolds flint is less diverse, varying from opaque white to grey specked opaque or semi-translucent, the latter type overlapping with the appearance of till flint. The representation of different colours in the assemblage broadly follows that currently available (Table 35.5), though brown flint is probably better represented. This may be a result of contemporary differences in coastal geomorphology; however, brown flint is in general of higher quality than grey flint, suggesting possibly some selection for quality.

Tools show some variation in choice of colour, though is probably a result of choices related to quality, size or source of material. Axes, for example, show greater use of grey flint, which is related to greater use of Wolds flint (see Table 35.6), for reasons described above. Microliths were much more likely to be made from brown flint, presumably because this is of higher quality and more aerodynamic. The shift to the use of small geometric

Tool type	Till %	Wolds %
Awl	90	10
Axe	50	50
Burin	71.5	28.5
Microlith	94.2	5.8
Scraper	87.5	12.5

Table 35.4: Use of different materials for production of different tool types.

Flint colour	%
grey	58.7
brown	32.2
black	3.8
red	1.9
white	2.8
white and grey	0.6

Table 35.5: Use of flint of different colours.

Tool type	grey	brown	black	red	white	white and grey
Awl	72.2	26	1.8	0	0	0
Axe	83.4	16.6	0	0	0	0
Burin	67.9	18.8	6.1	5.5	1.6	0
Microlith	47.7	46.7	4.7	0.9	0	0
Scraper	61.6	28.3	5	2.7	0.9	1.4

Table 35.6: Use of flint of different colours in the manufacture of different tools.

microliths in the Late Mesolithic has been interpreted as facilitating use of local poor-quality sources (Myers 1989), and this finding is reinforced by the association of microliths with the highest-quality flint in the Early Mesolithic.

Technology

The use of small, often flawed beach pebbles as the predominant flint source constrained the possibilities for the types of reduction sequences employed. The most common methods of reduction for small beach pebbles involved the removal of a single cortical flake to create a platform and then use of any natural ridge the pebble provided to initiate blade production. If such a ridge was not present cresting was sometimes employed. The initial decortication often took place using a hard hammer, while a soft hammer was routinely employed during plein debitage.

Refitting of longer sequences of better-quality material indicates the use of one preferential platform (contra Reynier 2005, 49), with a second platform primarily used to correct mistakes (Figure 8.22). This secondary platform was usually an opposed platform, at 180° to the primary platform, though platforms both perpendicular and at an acute angle to the primary platform were occasionally employed. The use of beach pebbles often containing imperfections necessitated flexibility, and a platform was often completely abandoned due to the presence of a flaw, sometimes generating multiple platforms. Several such sequences have been refitted (see Figures 8.8 and 8.21). Poorer-quality material was less productive; fewer products of such sequences were removed for use elsewhere, so it is likely that there has been greater success refitting these poor-quality nodules.

Refitting indicates that the dynamic nature of reduction sequences is not always reflected in the abandoned core, with the presence of secondary platforms both erased by later removals, or opposed platforms present in a discarded core that refitting indicates has been minimally used. Information present in abandoned cores (Table 35.7) indicates a predominance of single platform cores, reduced part of the way round (usually with a cortical back). Opposed platform cores are nearly as common, with other types rarer. Cores made on flakes (that look similar to burins) are present but very rare. The representation of core types is very similar to that reported by Reynier (2005, 32) for the Star Carr type-site of Pointed Stone on the North York Moors, though multiplatform cores are less common at Pointed Stone, perhaps because people relied on better-quality material for journeys to the uplands.

Cores range in height from 20 to 77 mm with an average of 40 mm, in width from 17 to 71 mm with an average of 35 mm and a thickness from 3 to 77 mm with an average of 26 mm (Figure 35.1). Almost all the cores above 60 mm in height appear to be from caches. Six of the 13 cores in this size range derive from the AC8 cache, and a further three were recorded from test pit SC6, from an area of less than 1 m² , possibly representing a second cache. Core thickness also correlates with cached material, with four of the 10 thickest cores coming from the AC8 cache. Core thickness has a very steep drop-off below 15 mm, indicating that beyond this thickness cores became difficult to work.

Platform/core face angles were maintained through removals of core tablets. Faceting was not used. Butts are usually plain and linear, sometimes punctiform. Re-cresting may occasionally have been employed mid-sequence

Core types	%
A1: Single platform, reduced round entire circumference	4.0
A2: Single platform reduced part way round	34.1
B1: Opposed platform core	27.5
B2: Two platforms, with one at oblique angle	6.6
B3: Two platforms, with one at right angles	4.4
C: Multi-platform core	11.4
D: Core reduced either side of a ridge	5.5
E: As D, but multi-platform	6.6

Table 35.7: Core types represented.
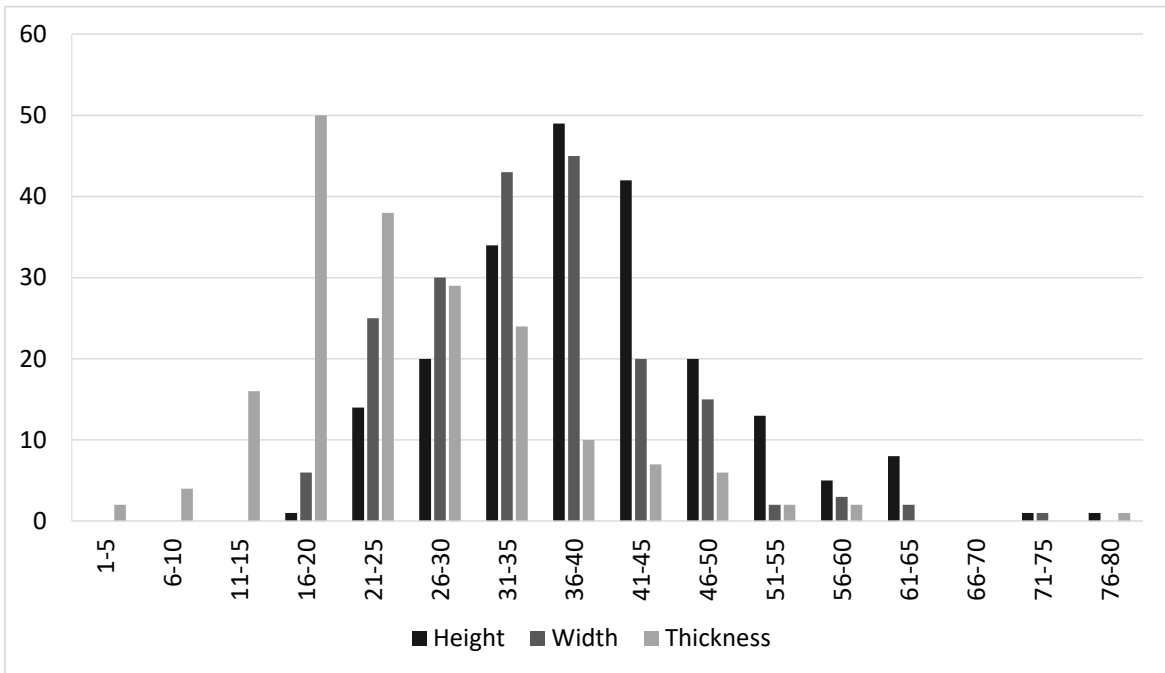
Figure 35.1: Core dimensions (mm) (Copyright Star Carr Project, CC BY-NC 4.0).
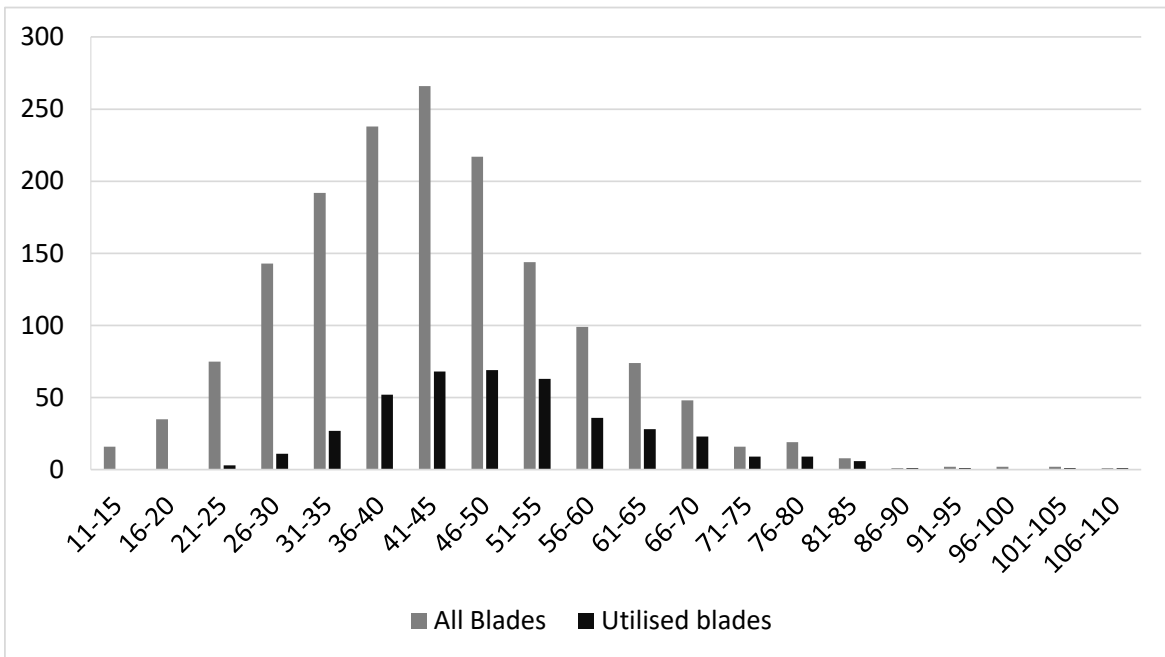
Figure 35.2: Length of all blades (including utilised blades) and length of utilised blades (mm) (Copyright Star Carr Project, CC BY-NC 4.0).
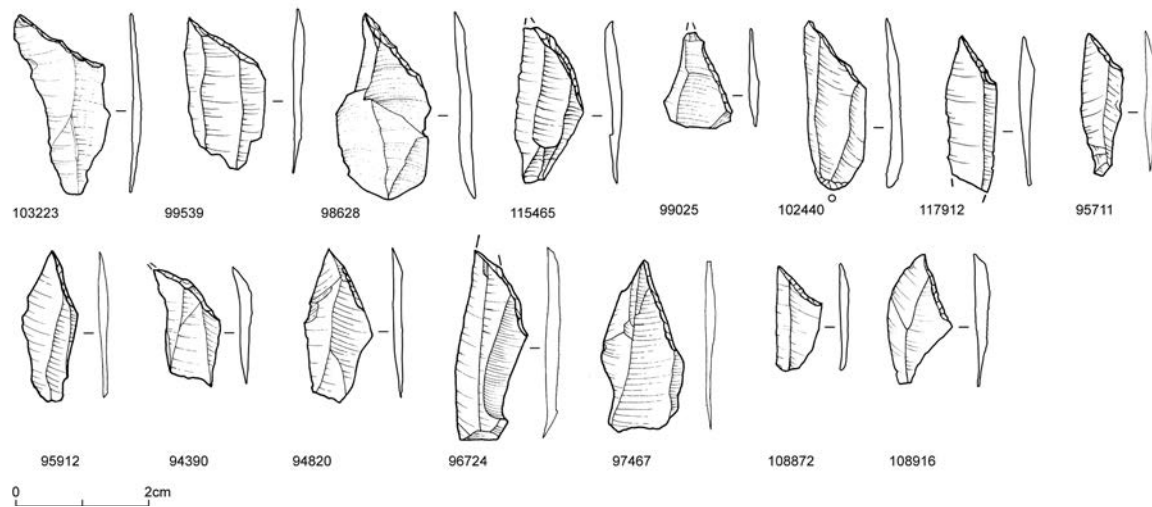
Figure 35.3: Right lateralised obliquely blunted points (Copyright Craig Williams, CC BY-NC 4.0).

to reshape the core; however, in general knappers created a new platform if problems were encountered. If this was perpendicular to the original platform, the original platform/core face was used to guide the first removal. This produced a blank morphologically similar to a crested blade (though the cresting is unilateral).

Debitage was focused on the production of bladelets and narrow flakes, though some larger blades were also produced. Blade/let sizes range up to 110 mm in length (thus overlapping with lengths displayed by Long Blade assemblages in the region), with an average of 42 mm. The larger blades were more likely to have been defined as utilised (displaying macroscopic damage), whilst only a small proportion of blades less than 50 mm show evidence of use (Figure 35.2). Of blades between 51 and 65 mm, around one third shows evidence of use, while the figure rises to around 50% for pieces between 66 and 80 mm. Of the 16 longest pieces (>80 mm), 10 show evidence for macroscopic damage, indicating that the larger pieces were specially manufactured for use (with the two pieces above 80 mm that were analysed for microwear having been used on hard materials, bone and antler). Blades above 80 mm are also more likely to have been made out of Wolds than till material.

Dumont carried out microwear analysis of five cores which he classified as core scrapers. On four of these he observed stone on stone traces consisting of crushing and striae, but believed this to be the result of indeterminate use, not a by-product of technology. As part of this study, we also analysed three cores. One was classified as a denticulate core and so is discussed in that section below. The remaining two consist of an A2 blade core and a type E disc core. The latter was part of the AC8 cache and was used for a short duration of time to scrape wood. The blade core <98992> displayed no visible signs of use. Two core tablets were also analysed and have very ephemeral traces suggesting a very short duration of use: <98985> was probably used to scrape a soft animal material, probably hide, and <107985> was used to scrape an indeterminate material prior to burning.

Tools

Microliths

Microliths, the type fossil of the Mesolithic, are well represented at Star Carr, with 313 examples. With a few exceptions, all are classic 'Star Carr' Early Mesolithic types (Radley and Mellars 1964; Reynier 2005), consisting of obliquely blunted points, trapezes and large isosceles and scalene triangles (Figures 35.3–35.4 and 35.6–35.8). Of these, obliquely blunted points are by far the best represented (Table 35.8). In contrast to later Early Mesolithic assemblages (Deepcar and basally modified assemblage types, see Chapter 11), points lateralised to the
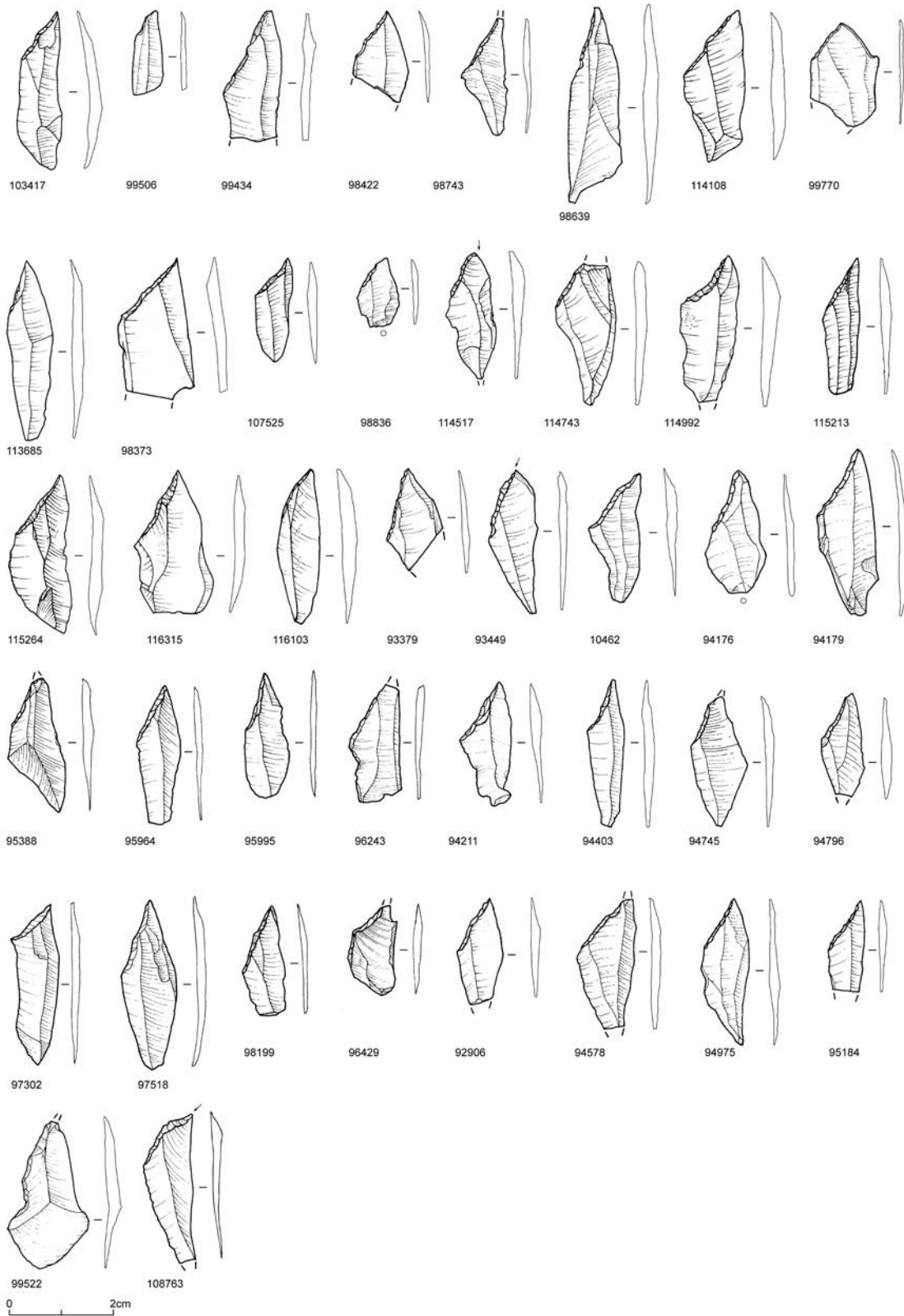
Figure 35.4: Left lateralised obliquely blunted points (Copyright Craig Williams, CC BY-NC 4.0).
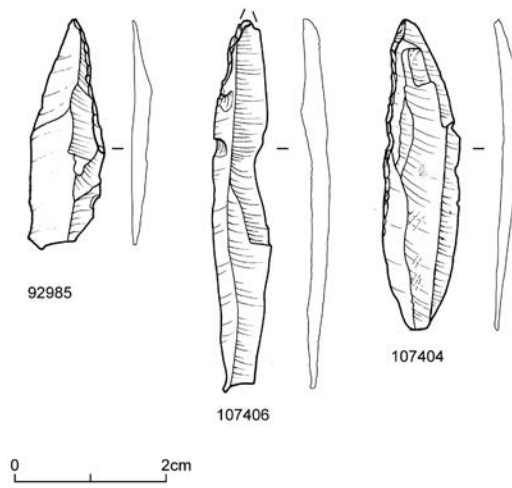
Figure 35.5: Partially backed points (Copyright Craig Williams, CC BY-NC 4.0).
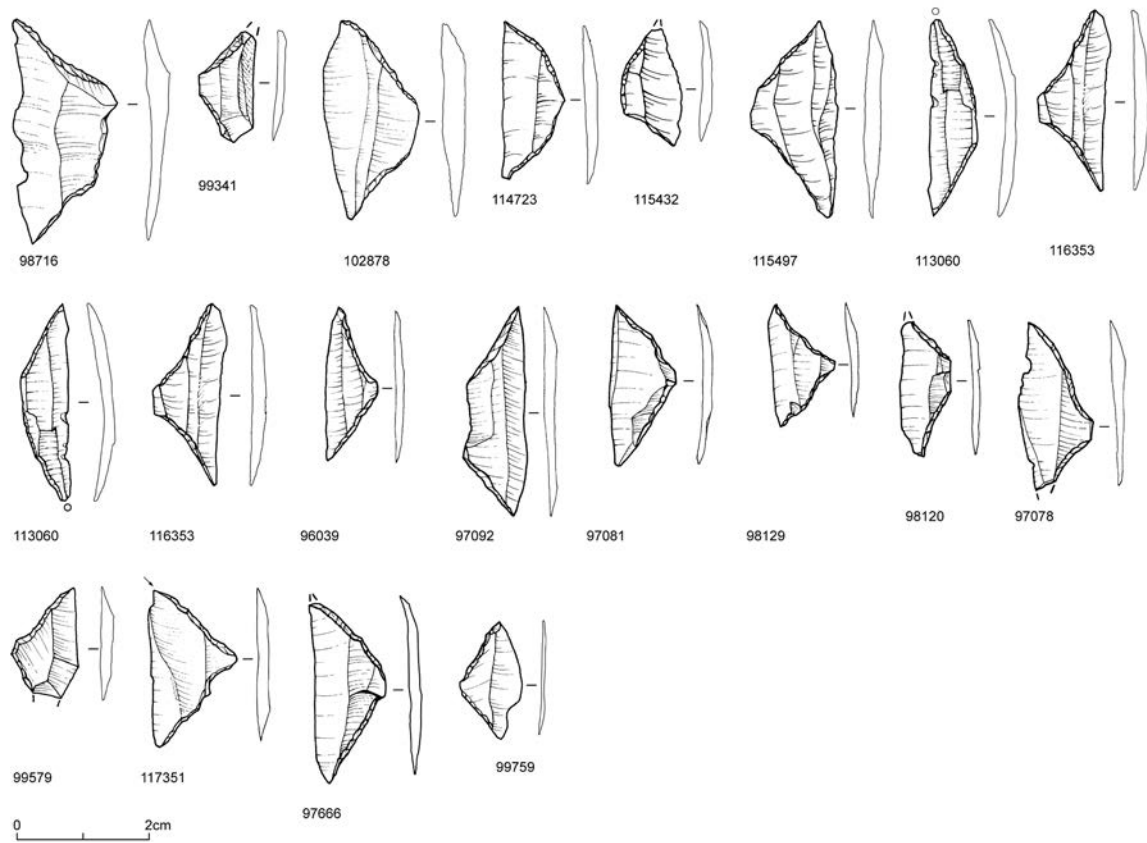
Figure 35.6: Trapezes (Copyright Craig Williams, CC BY-NC 4.0).
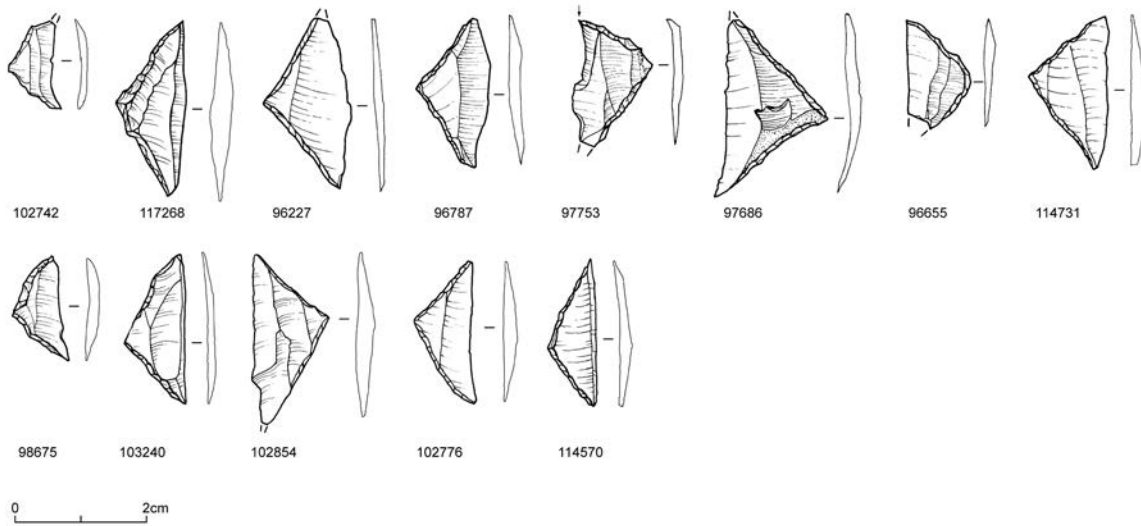
Figure 35.7: Isosceles triangles (Copyright Craig Williams, CC BY-NC 4.0).
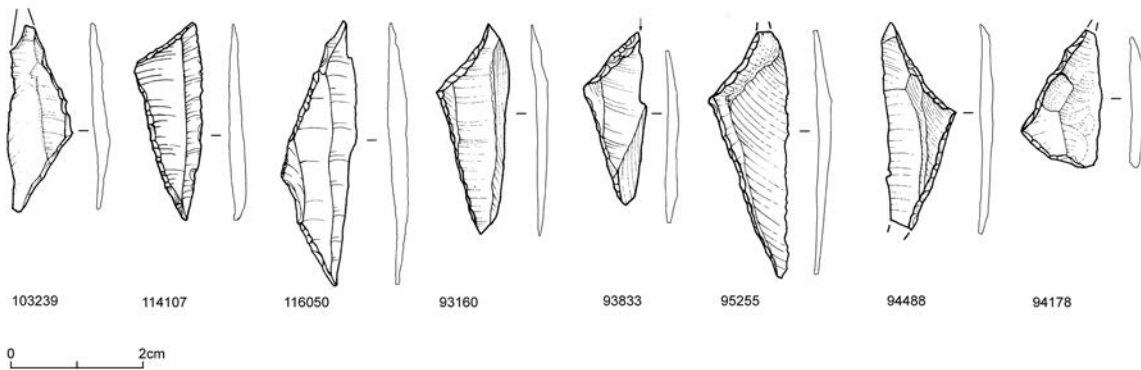
Figure 35.8: Large scalene triangles (Copyright Craig Williams, CC BY-NC 4.0).

Type	No.
Obliquely blunted point	180
Partially backed	8
Trapeze	39
Isosceles triangle	15
Large scalene	31
Rhomboid	2
Small scalene	4
Narrow backed bladelet	1
Microlith/awl	3
Unfinished	4
Unidentifiable fragment	26
Total	313

Table 35.8: Microlith forms represented in the assemblage.

right are present in large numbers (Figure 35.3), though left lateralisation is more common overall (Figure 35.4). Eight partially-backed points were recovered, some of which have retouch extending relatively far down the margin (Figure 35.5). These, and rhomboids, which were also found in small numbers, are more indicative of 'Deepcar' type assemblages (Radley and Mellars 1964; Reynier 2005) that seem to appear slightly later than Star Carr type assemblages (Conneller and Higham 2015, Conneller et al. 2016). It is difficult to know whether these few pieces can simply be encompassed within the range of variation of a large assemblage of Star Carr types. None were found in Reynier's (2005) survey of Star Carr assemblages, though he only looked at three small sites with a total number of 87 microliths. Functional differences are also a possibility: two partially backed examples were examined for microwear and both were used as barbs of projectiles. However, two microliths of this same type, found only 4 m apart in the wetland, date from one of the latest phases of the site (the others come from dryland contexts and cannot be dated), suggesting chronological factors could be an issue. The area they were recovered from has a TPQ of *8670–8475 cal BC* (*95% probability; TPQ fen flint*; Figure 17.9), probably in or after *8605–8515 cal BC* (*68% probability*). This suggests that changes in microlith forms may have occurred during the time the site was occupied.

Two likely composite tools were recovered. One of these consists of three obliquely blunted points, all lateralised to the right. Two, <103421> and <103390>, are relatively narrow and of very similar dimensions (27 × 8 × 1 mm and 26 × 7 × 2 mm), the other, <103392> is shorter and squatter (21 × 9 × 2 mm) (Figure 35.9). All have soft animal traces, which are most developed on <103392> which has longitudinal traces along one lateral, possibly of meat, and hafting traces on the other. The soft animal traces are also well developed on the tip of <103421>, suggesting it served as the tip or point of the composite tool, a function to which it is also morphologically suited. The microliths were recovered in a broadly linear arrangement, with 50 mm separating <103392> and <103390> and a further 150 mm separating these from <103421>. <103390> and <103392> were found at the same time. It was noted on excavation that these were microliths from a wetland context, so particular attention was paid to the search for an arrow shaft, but none was found. Barbed points appear to have been dehafted before deposition into the wetland (see Chapter 25), and the same may have been true of flint projectiles.

A second composite tool was found on the dryland. This also lacks a haft, but here preservational issues are likely to be responsible. The microliths were also slightly dispersed, suggesting some post-depositional disturbance (see Figures 35.10 and 8.45). The composite consists of four small narrow, elongated scalene triangles with two sides retouched, which are likely to have acted as barbs and a narrow backed bladelet, likely to have acted as the tip. This is thus a Late Mesolithic composite, a rare instance of later visits to the area after the main phase of occupation of Star Carr had ceased. These microliths are very similar in size and type to the second composite grouping recovered from Seamer K (David 1998); however, the exact shape of the scalenes represented is slightly different. Barton and colleagues (1991, 102) make a distinction between scalene triangles and narrow backed bladelets with a slightly oblique truncation to describe the differences between discoveries of potential composites at Waun Fignen Felen 1 and 9. The Star Carr composite better approximates the latter. A second difference is the number of microliths represented. The two Seamer composites have 16 and 17 pieces respectively, the Star Carr example only five. This might suggest variation in form; alternatively this one may have snapped and only part of the composite discarded here. All pieces were examined for microwear. Three

0   1cm
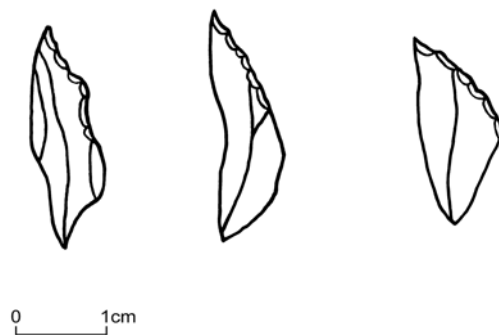
Figure 35.9: Early Mesolithic microliths from probable composite tool. From left to right: <103421>, <103390> and <103392> (Copyright Star Carr Project, CC BY-NC 4.0).
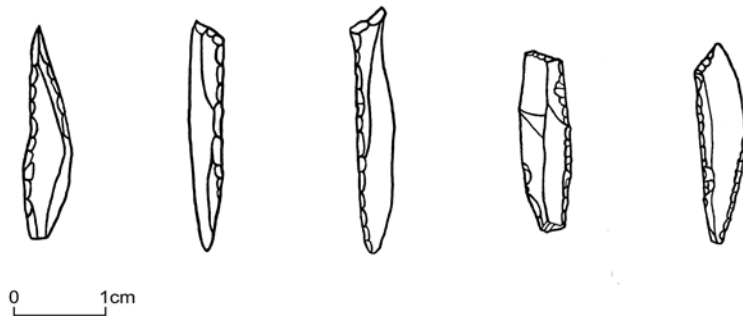
Figure 35.10: Late Mesolithic microliths from composite projectile. From left to right: <110656>, <110657>, <110660>, <110658>, <110659> (Copyright Star Carr Project, CC BY-NC 4.0).

Microlith type	c.9300–9000 cal BC	c.8950 cal BC	c.8850 cal BC	c.8800 cal BC	c.8700 cal BC	TPQ c.8500 cal BC
	Detrital wood	Central platform	Axe workshop	Clark's area	SC22 scatter	Fen scatter
Obliquely blunted point	4	3	1	3	0	0
Small obp < 25 mm	1	0	4	0	1	0
Trapeze	0	0	3	0	0	0
Trapeze/triangle with concave truncation	0	0	0	2	0	0
Isosceles triangle	0	1	1	2	0	0
Large scalene triangle	0	0	0	0	0	1
Partially backed	0	0	0	0	1	2
Average length of obp (mm)	26.6	29	19.6	28.7	26.5	n/a

Table 35.9: Representation of microlith forms in well dated areas of the site.

had no obvious traces, but one <110658> had impact damage and another <110657> had longitudinal meat traces, suggesting it had been used as a projectile.

In order to understand whether there was temporal variation in microlith form within Star Carr type assemblages, microliths in well-dated areas of the site underwent more detailed typological scrutiny (Table 35.9). These well-dated areas are inevitably wetlands, where unfortunately microliths were relatively uncommon, so any potential patterns are extremely tentative. Broadly, there appears to be an increase in diversity over the c. 800 years during which Star Carr was visited, with microliths from the earliest area, the detrital wood scatter, consisting only of obliquely blunted points. After 9000 cal BC diversity increases with the presence of triangles and trapezes. Though this pattern is tentative, a similar sequence does seem to be present in Southern Scandinavia and Northern Germany (Chapter 12). Partially backed pieces, as described above, are present only in the latest contexts of the site. Concave truncations, which do seem to have some chronological component when found on obliquely blunted points (e.g. Lewis and Rackham 2011), are only here associated with triangles and trapezes, and are too few to show any chronological significance. There is some evidence to suggest that obliquely blunted points became smaller over the course of the Mesolithic (Pitts and Jacobi 1979). However, this diminution does not appear to have commenced over the period of time represented by the site. The small

size of the microliths from the axe workshop should be noted, but these are perhaps due to personal choice or the particular raw materials available for what may have been a short-term event.

In total, 24 microliths were analysed for wear traces (Table 35.10). Of these, six displayed MLITS (micro longitudinal impact traces) and therefore can be confidently said to have been used as projectiles (Figure 35.11). Of these four (three obliquely blunted points and a trapeze) were hafted as points, two (both partially backed points) as barbs. A further six examples could have been used as projectiles, but may have had alternative uses. In addition, one microlith has possible impact traces and three have traces resulting from soft animal material (hide and/or meat) and thus may either have been used as projectiles (though display no MLITS) or composite knives (see discussion above). Another, <94728> has very clear longitudinal meat traces along one edge and was either hafted and used as a barb of a projectile or a knife, whilst <107673> displayed fresh hide damage at the tip but no impact damage, making it difficult to determine whether it functioned as a projectile or was perhaps hafted as a knife.

Other microliths can be more confidently attributed a non-projectile function: one microlith, <95813> has both hide and mineral traces and was used to scrape and pierce, suggesting it was used as a craft tool. Another, <113623>, had bone traces resulting from both cutting and scraping. Interestingly, two microliths, <108736> and <110059>, display plant-working traces (one was used for cutting, another for scraping and/or peeling). However, the presence of plant-working traces on microliths is not unusual; such an association is known from other Northwest European Early Mesolithic sites, for example, at Verrebroek, Belgium (Crombé et al. 2001), and Yangtze Harbour, the Netherlands (Sier et al. 2014). Given the clustering of microliths in and around structures and in association with hearth features, which is interpreted as the result of re-tooling episodes as well as the utilisation of microliths in craft work, it is perhaps unsurprising that just three microliths displayed no wear traces at all, with the vast majority representing utilised tools.

However, what is intriguing is how our analyses of microlith function(s) differs from that of Dumont, who identified just one piece (an obliquely blunted point) with wear traces out of the 31 he analysed. The point displayed bone polish along one lateral edge. This, he concluded, could have resulted from impact with bone or from being hafted longitudinally in a bone haft. However, if the latter were the case, adhesive would have been required, resulting in little to no development of polish. As such, the reason for this discrepancy is not clear. One possibility is that Dumont, reflecting common belief at that time, which saw microliths as functioning solely as projectiles, focused on evidence for impact only, potentially missing traces resulting from their various other uses, such as composite knives, hide and plant-working tools. However, the thoroughness of his analyses, covering all parts of the tool's surface, makes it difficult to see how he would have missed impact and non-impact related traces if/when present.

Primary contact material	Secondary contact material	Action	No.
Impact	Impact/plant (1)	Projectile	6
Impact?		Projectile?	1
Indet.		Cutting (1), Indet. (3)	4
Animal soft		Indet. (2), Cutting (1)	3
Animal various		Butchery	1
Plant	Siliceous plant (1)	Cutting	1
Hide	Mineral (1)	Scrape/pierce, piercing	2
Meat		Projectile/knife?	1
Bone		Cutting/scraping	1
Not used		n/a	3
Un-analysable		n/a	1
Total			24

Table 35.10: Microwear results for microliths.
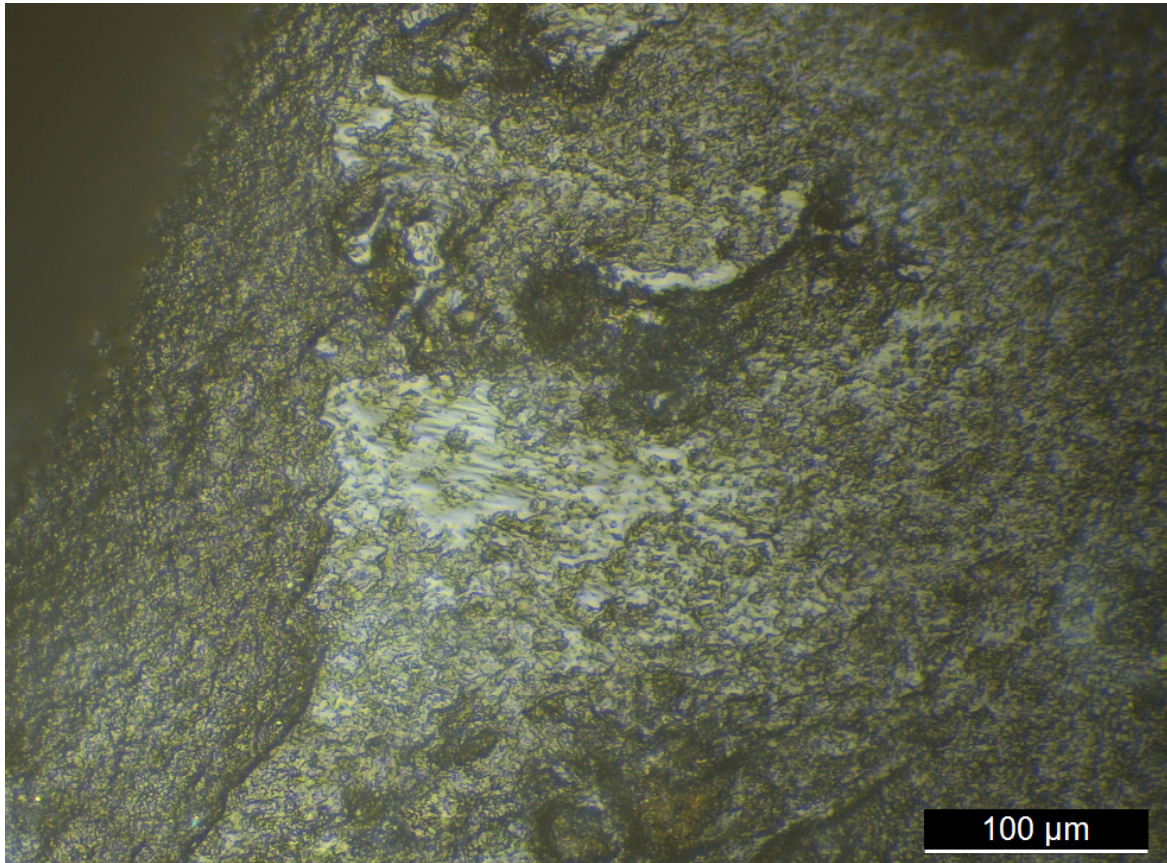
Figure 35.11: Micro longitudinal impact traces and impact fracture on microlith <95542> (×20 magnification) (Copyright Aimée Little, CC BY-NC 4.0).

Microliths and their manufacturing debris, microburins, have a strong association with hearths, structures (except the central structure) and the areas immediately surrounding structures (Figure 35.12). The association with hearths is understandable given that microliths are composite tools that would have needed mastic to haft them. These composites would be made and repaired around hearths, and redundant components seem to have been discarded in the immediate area. Microliths are also common in some wetland edge areas, mainly the axe workshop and the bead area, though here microburins are less common, indicating areas of tool use and discard rather than manufacture. They are less common in wetland areas where they are likely to represent lost composites or material involved in depositionary practices.

Axes

Twenty axes were recovered, plus two further probable axes that had been reworked as cores. This is a large number for an Early Mesolithic site, where axes are generally found in relatively low quantities. Axes vary in their morphology, from fine ovate or elongated forms to triangular sectioned (Figures 35.13 and 35.14, see also Figure 8.38) and small irregular examples. A tapered, pointed or triangular butt is a feature of some (see for example Figures 35.14 and 8.38, <99454>), while others seem to have seen use at both ends (Figure 8.38, <94367>). This variation in form is likely to be due to raw-material constraints (in an area of relatively small and often poor-quality material) and resharpening practices. Axes are found at most stages of their life histories from a large preform 230 mm (Figure 35.15) in length to small, exhausted pieces at c. 50 mm in length. However, most are relatively small. The average of complete, finished forms is 66.7 × 33.8 × 20.5 mm. Several refit
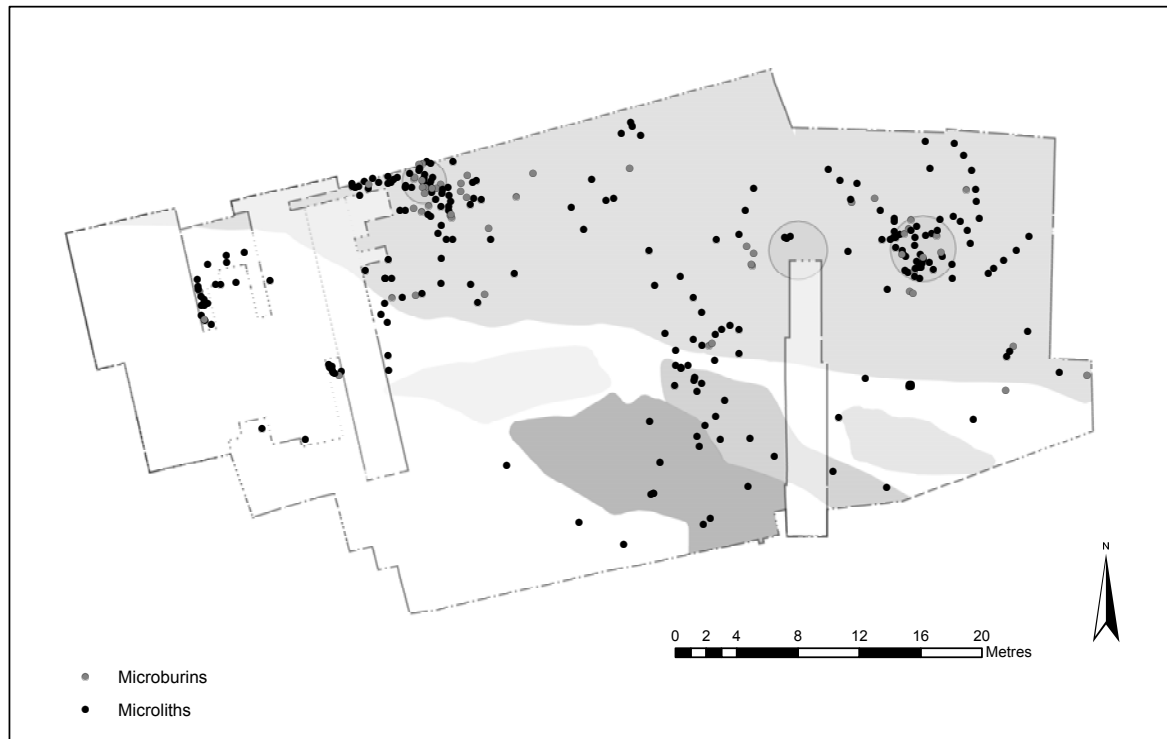
Figure 35.12: Distribution of microliths and microburins across the site (Copyright Star Carr Project, CC BY-NC 4.0).

sequences indicate that axes were reworked and resharpened; however, none retains an entire refit sequence from manufacture through resharpening to discard. This probably indicates axes were mobile tools that underwent a high level of curation and were carried from site to site as personal equipment. With the exception of the preform, roughouts and manufacturing sequences do not seem to be present around Lake Flixton, possibly suggesting roughing out or manufacture at source. However several resharpening sequences are present at Star Carr, indicating a desire to prolong the life of this tool type.

The presence of several refitting sequences reveals the techniques used in axe manufacture and resharpening. Tabular or semi-tabular pieces, or even in cases large flakes, seem to have been preferred, as they were easier to reduce into the desired form. Simple resharpening took place through the removal of a single tranchet flake. More complex resharpening sequences, where reshaping was also required, was brought about through the use of tranchet blows to sharpen the obverse tip of the axe, while the surface created by the tranchet blow was used as a platform for the removal of longitudinal thinning flakes and blades along the reverse face. This was used to adjust the angle, which was then refined by a tranchet blow along the obverse side of the axe tip. This sequence could occur either using the same face for all tranchet blows (Figure 8.39), or alternating the face, so tranchet blows and longitudinal thinning flakes occurred on both faces (Figure 8.41). Additional transverse thinning flakes were also removed from the long margins of the axe. Simple resharpening sequences seem to have occurred with the axe remaining within its haft. More complex sequences, at least on occasion, involved the dehafting of the axe and the sharpening of the end previously enclosed within the haft. The tranchet blow on the longer sequences is always removed from the left. This is likely to be related to predominant right-handedness of the makers of these axes. Axes and sharpening flakes from the axe workshop indicate these tasks were carried out only by right-handed individuals.

Within the Vale of Pickering, axes are rarely found in wetland areas (Figure 35.16), with a single example uncovered during fieldwork by the Vale of Pickering Research Trust on No Name Hill. In contrast they are common in fieldwalked collections from the Vale, such as the Stuart Feather collection (see Table 35.11), which

99150

109798

0   2cm
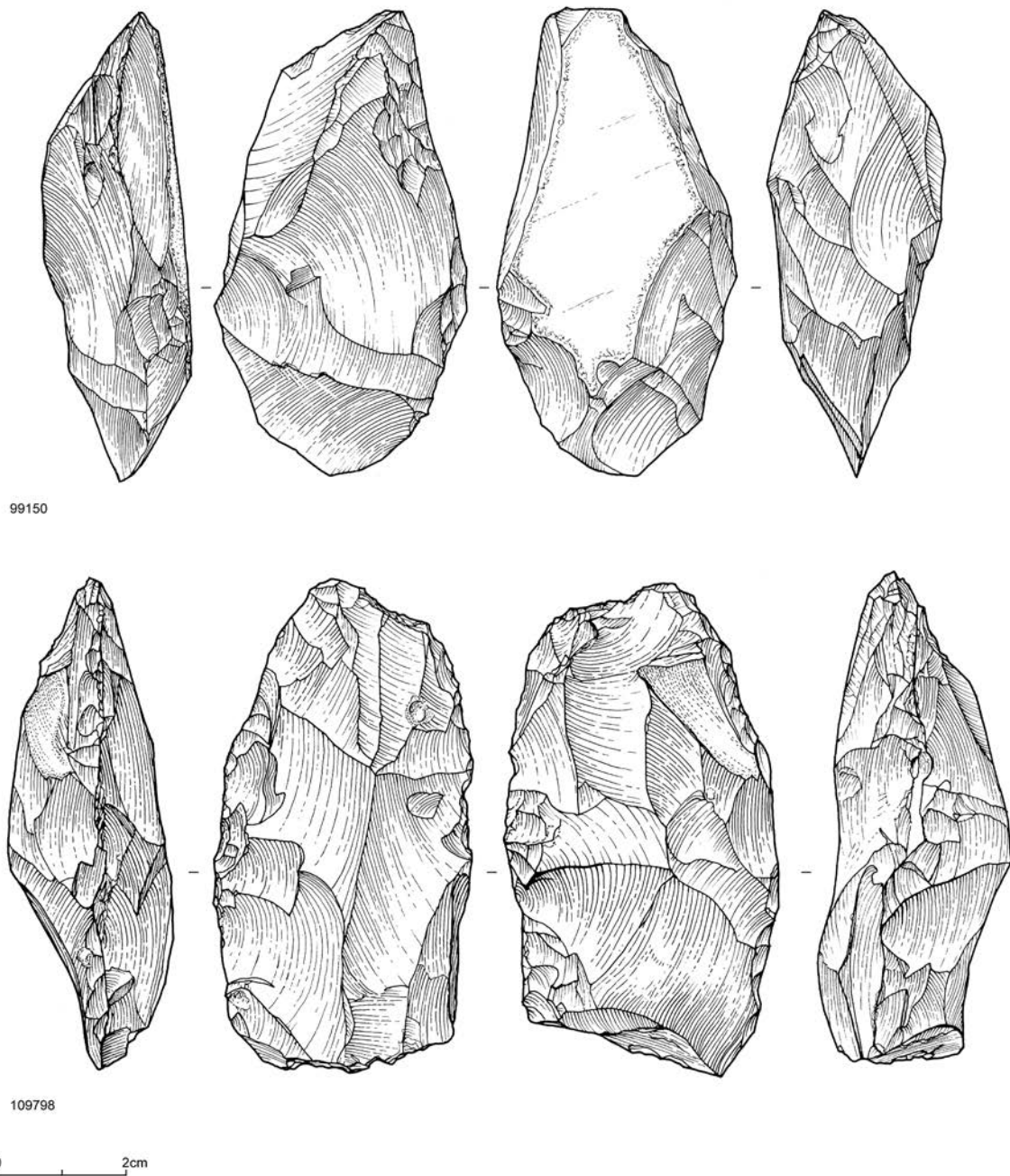
Figure 35.13: Axes (Copyright Craig Williams, CC BY-NC 4.0).

preferentially target higher areas, well beyond the former lake shore, that have been truncated by the plough. The same pattern is broadly, but not entirely, true of Star Carr, as axes are not found in the wetland, but are present on the wetland edge as well as the dry ground. They also have a strong association with structures: three were found in the eastern structure, while one was found in the western structure, with another two examples in the immediate surrounding area. However, the largest cluster of axes on site comes from the wetland edge 'axe workshop'; here six axes, and a large quantity of manufacturing and resharpening debris was recovered from peat above the central platform. These activities took place within a 5 × 4 m area with three axes found

96620

0 _____ 2cm
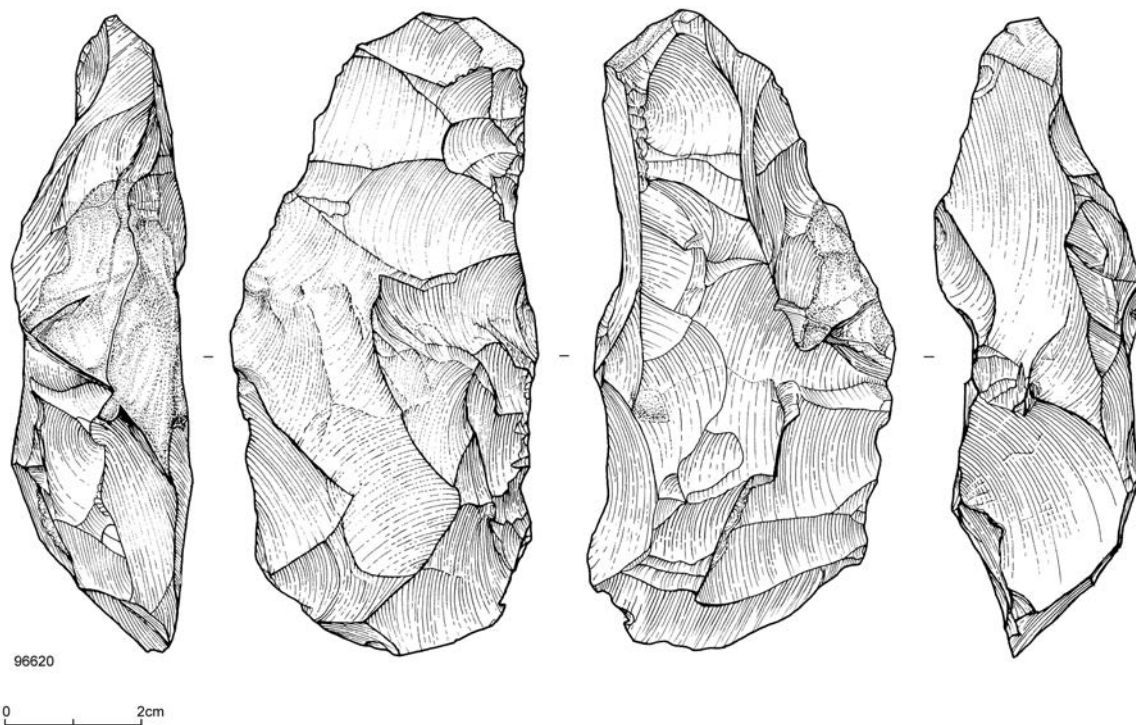
Figure 35.14: Triangular sectioned axe (Copyright Craig Williams, CC BY-NC 4.0).
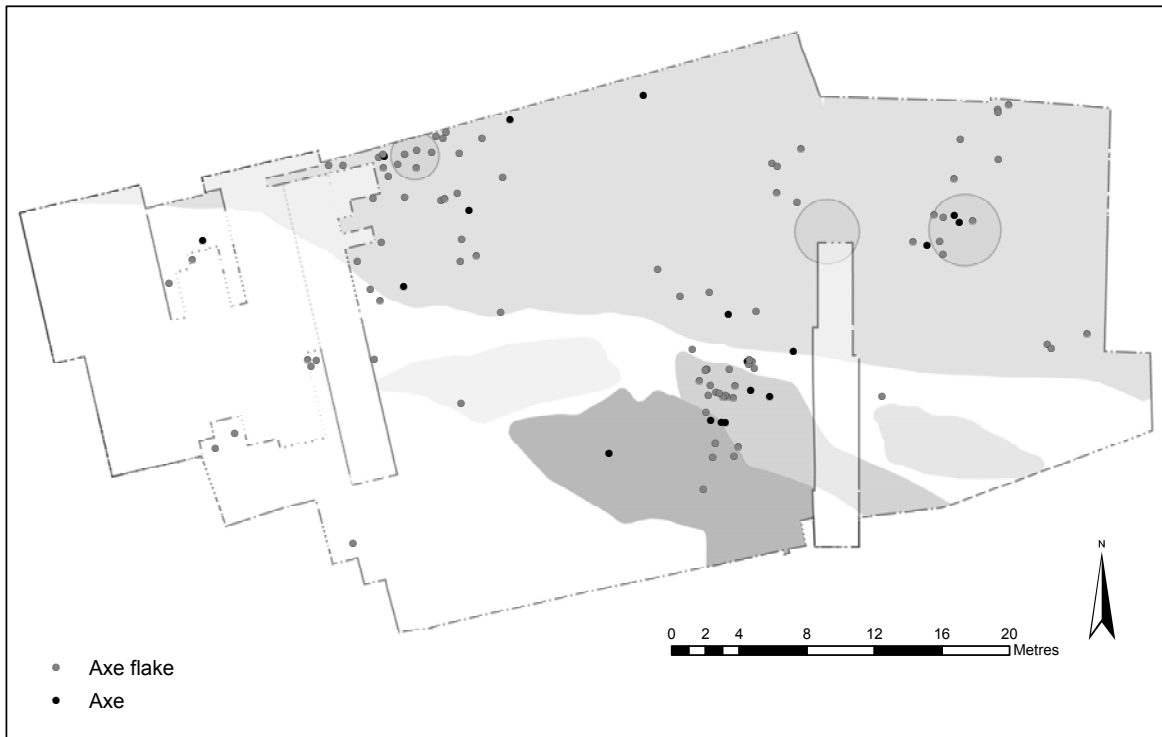
Figure 35.16: Distribution of axes and axe flakes (Copyright Star Carr Project, CC BY-NC 4.0).

Site	No. of axes
Star Carr (mainly north of the Hertford Cut)	6
Ling Lane	4
Killerby Carr	1
No Name Hill	2

Table 35.11: Axes recovered from the Vale of Pickering through fieldwalking by Stuart Feather between 1960 and 1969.

within an area of less than a metre. One of the axes was found immediately below burnt area [318], indicating a date in the 89th century for the axe workshop (see Chapter 17).

In the area of the axe workshop, two axes (one of Wolds flint, one of till flint) were possibly manufactured from preforms but probably represent finished objects that instead underwent extensive reworking and reshaping in this area. Neither of these two axes was found on site. A third axe (Figure 8.39) was extensively reworked, lightly used and then discarded. A further two were reshaped, resharpened and discarded. These three examples were all recovered from the area, as were two further extremely small axes which do not have any refitting debris. At least two further axes seem to have been present at one time in this area as tranchet flakes from additional Wolds raw material units were recovered.

Figure 35.15 (page 512): Large flint axe preform <96773> in situ (Copyright Star Carr Project, CC BY-NC 4.0).

Eight axes and three refitting tranchet flakes were analysed for wear traces (Table 35.12). Two of the tranchet flakes displayed no wear, the third, <98825>, (from refit group 89, Figure 8.41) had transverse wood traces which could suggest it had been used for scraping but were more likely the result of past chopping activity when attached to the axe; the flake was then removed through rejuvenation. An axe, <92077>, located in the eastern structure was also utilised to chop wood and displays possible binding traces but overall exhibits very little hafting damage. Its presence in the house suggests an episode of repair. Of the four very small axes analysed, two displayed wood-working traces commensurate with being used in a chopping motion. One of these, <99469>, was used for a relatively short duration of time; the other, <94367>, (refit group 88, Figure 8.38) was more intensively used. Two axes (<99447>, <99101>) appeared not to have been utilised (Figure 8.38). These also displayed a distinctive post-depositional surface modification (PDSM) across most of their surfaces, which was at odds with the freshness of the flint and contrasted with the general lack of such PDSM on other flint tools from the wetland area, including the other two very small axes which displayed wear traces. One possibility is that these axes had a different life history, and through transportation, perhaps wrapped or in in a bag, their surfaces have become affected, as recognised microscopically for a number of axes dating to the Neolithic (Wentink 2006). In such a scenario they must have been wrapped or bagged separately, as there is no microchipping or any other evidence to indicate contact with another hard material. Despite this surface alteration, it is unlikely that use traces, if present, have been overlooked as there is very little microchipping damage to the working edge. Given the lack of damage and evidence for use, either these axes were only used for a very short duration of time, or working traces were removed during resharpening (although no hafting wear was identified either), or they were simply not utilised at all. All things combined (location, possible transportation wear, lack of use-related traces), these small axes are certainly intriguing.

Dumont's analysis of 26 core resharpening flakes revealed just one piece with traces, which were, as expected, derived from woodworking.

Awls

Sixty-nine awls were recovered from the excavations (Figure 35.17). The majority of these are bilaterally abruptly retouched convergent truncations (mèches de foret or drill-bits). While many of these are fully retouched along

Primary contact material	Primary action	No.
Not used	n/a	7
Wood	Chopping (3) Wedging or scraping (1)	4
Total		11

Table 35.12: Microwear analysis results for axes and tranchet flakes.
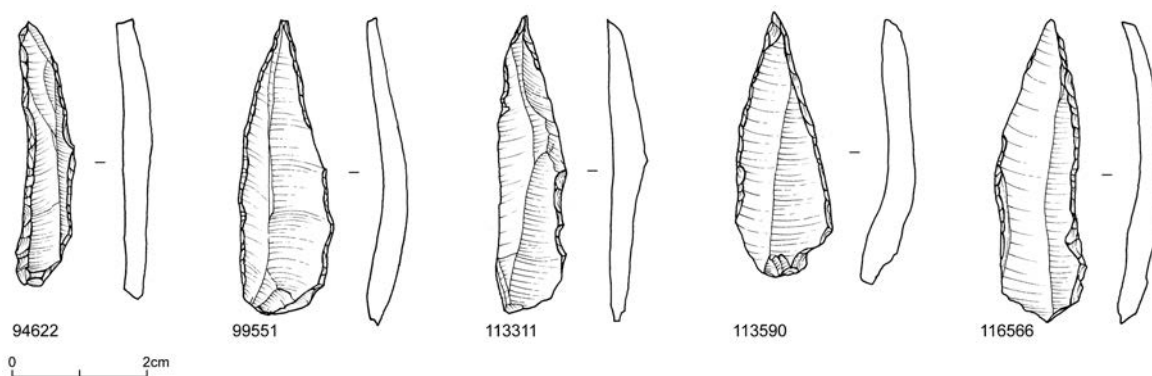
Figure 35.17: Selection of awls (Copyright Craig Williams, CC BY-NC 4.0).

both laterals, some are only partially retouched, and others are fully retouched on one side only. Complete examples range in length from 81 mm to 30 mm, in width from 8 to 21 mm and in thickness from 3 to 9 mm. Average dimensions are 44.1 × 12.8 × 4.6 mm. Only 27 examples are complete, many missing the tip, a breakage pattern that was commonly replicated during experiments using awls to manufacture shale and amber beads (Chapter 33).

Nineteen awls have been studied for microwear (Table 35.13). Of these, six displayed soft mineral polish (Fig 35.18), four bone, three siliceous plant (Fig 35.18), two hide, one was used on an indeterminate hard material (antler and/or bone?), one was indeterminate and three had no evidence of use. Interestingly, the awls used to work mineral, hide and bone were typically used in a piercing or drilling motion, except for a large double-ended awl which had been used in a longitudinal motion to saw as well as drill. The siliceous plant-working tools had polish that was both transverse and parallel to the edge, indicating cutting and scraping motions. Apart from two awls used to work a soft mineral which had possible signs of hafting, no other awl displayed hafting wear. It is thus likely that these tools were mostly handheld.

As discussed in Chapter 33, our experimental research, which aimed to replicate the soft mineral polish seen on several of the awls, demonstrated that a comparable polish developed when drilling shale. This, in conjunction with their spatial distribution (focused on the western area of the site where beads were recovered in these and Clark's excavations, (Figure 35.19) strongly suggests that the soft mineral polish on many of the awls is a

Contact Primary contact material	Secondary contact material	Action	No.
Mineral (soft)		Drilling	6
Hide	Mineral	Piercing	2
Plant (siliceous)		Cutting/Scraping	3
Bone		Drilling	4
Indet hard material		Drilling/sawing	1
Indet. use		Indet.	1
Not used		n/a	3
Total			20

Table 35.13: Microwear analysis results for awls.
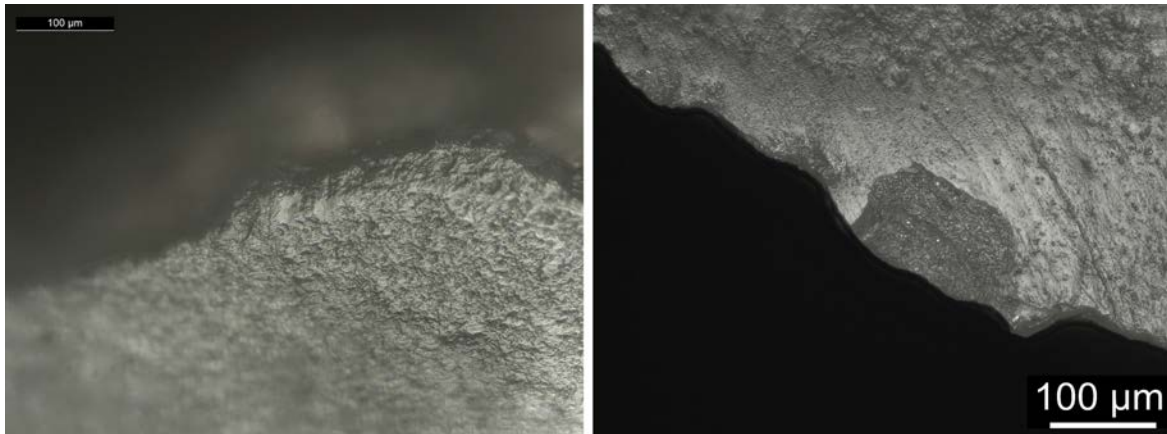
Figure 35.18: (left) awl <93991> exhibiting evidence for soft mineral polish (×20 magnification); (right) awl <93521> exhibiting evidence for siliceous plant polish with oblique directionality (Copyright Aimée Little, CC BY-NC 4.0).
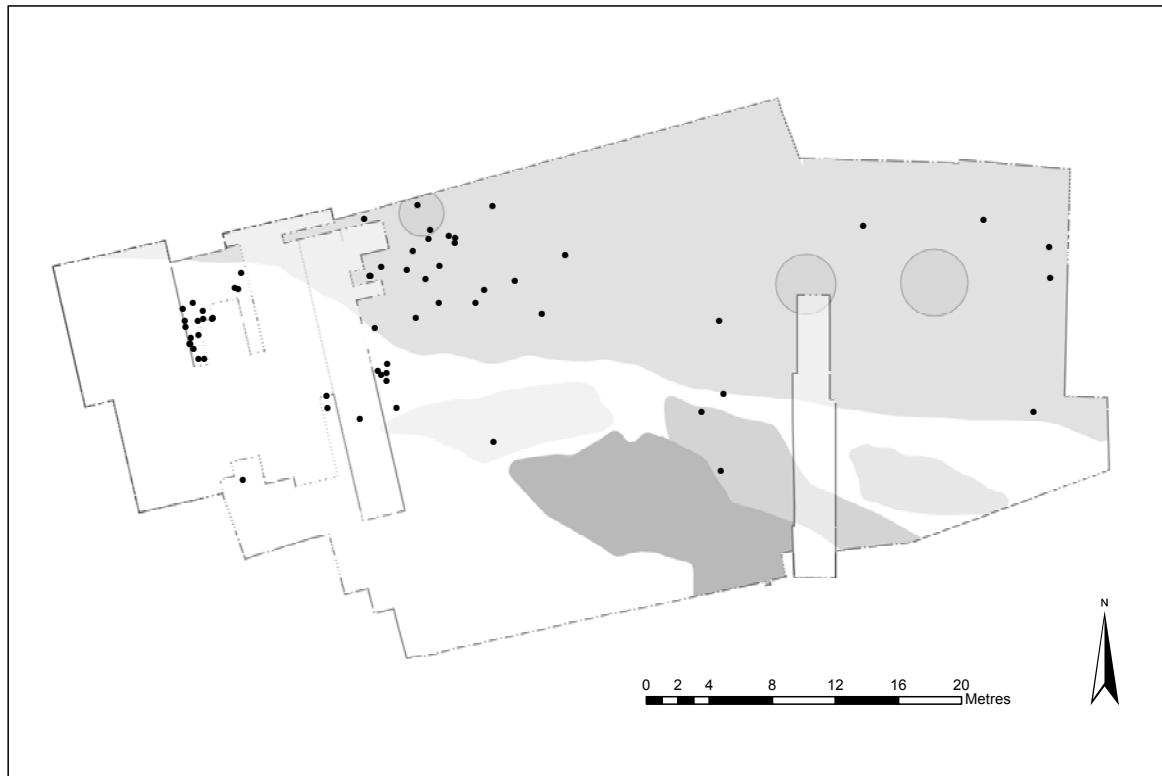
Figure 35.19: Distribution of awls on site (Copyright Star Carr Project, CC BY-NC 4.0).

result of their employment to drill shale beads. Microwear evidence for awls being used to pierce hide, with a mineral additive (ochre?), the drilling of bone, and the working of siliceous plants, further indicates that awls were multifunctional craft tools.

Dumont's analysis of 28 awls, of which 15 had traces and 11 of which were identifiable, revealed a much greater proportion of bone-working (n=8), as well as wood (n=2); the latter was not present on the awls studied as part of this research. He also identified one hide-working tool. It is somewhat surprising that no mineral polish was identified, given the number of mineral-working awls identified in our study. Again, various reasons can be proposed, including a genuine absence of mineral-working awls in Dumont's sample (and therefore from Clark's area). Alternatively perhaps, given the smooth/flat and often restricted distribution of mineral polish (albeit much duller and textured in appearance than bone polish), Dumont was not making a distinction between bone and mineral. In attempting to justify why so many awls had bone-working traces when there is very little evidence for bone objects with perforations at Star Carr, Dumont (1989, 233) suggests the awls could have been used to produce the perforations in the frontlets. Though he concedes that the frontlet holes are far larger than those which would be produced using the awls (see Little et al. 2016 for further discussion on frontlet perforation techniques), he suggests that the awls were instead used to enlarge the parietals on the front of the crania. Interestingly, one awl <113871> with 'bone' drilling traces was found in the bead area, amongst awls used to drill soft mineral, probably shale. Although yet to be replicated experimentally, it is possible that this tool was used to drill red deer teeth pendants. The size of teeth pendant perforation fits well with the morphological size of the awls and may account for why so many bone awls were identified by Dumont when so little other evidence for bone drilling exists amongst the faunal assemblage at Star Carr.

With only nine exceptions, awls were found clustered in the western area of the site. They are associated mainly with the bead area (18 examples) and the area south and southwest of the western dryland structure (the midden) (29 examples). There are some indications that the awls belong to the middle and later phases of the use of the site. There are three in the axe workshop which dates to between c. 8900–8800 cal BC (based on

the dates of the underlying central platform, and the overlying burnt area [318]), two in Clark's area, also dating to c. 8800 cal BC, and several in the midden which probably also dates to this period (See Chapters 9 and 17). The intense activity relating to bead manufacture involving the use of 17 examples, probably belongs to the 88th century cal BC (see Chapter 9, and Figure 17.6). Finally the cluster of five awls in the fen flint scatter, immediately to the east of Clark's trench, is very high in the sequence and relates to activity that took place in or after *8670–8475 cal BC (95% probability; TPQ fen flint*; Figure 17.9), probably in or after *8605–8515 cal BC (68% probability)*.

<div align="center">

Burins

</div>

A total of 232 burins were recovered from the excavations (Figure 35.20, 35.21, Table 35.14). The majority of these are angle burins (n=135), variously on truncations, breaks or natural surfaces (such as plunging terminations). Dihedral burins are present but make up a relatively small proportion of the assemblage. This latter form is the most common type on Long Blade sites in the Vale of Pickering, but there does not seem to be a chronological component to the use of dihedral burins at Star Carr. Burins range in length from 21 to 82 mm, in width from 7 to 58 mm and in thickness from 2 to 25 mm, with average dimensions of $45.3 \times 25.4 \times 10.2$ mm. In comparison with awls and scrapers, relatively thick supports have been selected.

Burins appear to have been tools that underwent some movement and curation, though not to the same extent as axes. They were almost always moved from their place of manufacture, not always very far (an example from central structure surrounds was found 5 m from the knapping scatter in which it was made), though others were moved around more widely. Burins were manufactured in the eastern structure (as indicated by large numbers of primary burin spalls), but a lack of refits indicates most of these were moved for use elsewhere. A burin made in scatter 4 was moved 6.3 m north and used in scatter 1. However, burins are often found close to their final resharpening spalls, indicating they were often abandoned in the areas in which they were used (Figure 35.22).

Despite the suggestion of Andresen et al. (1981) that burins, in particular the side edges of the burin facet, were probably being used as scrapers for hard contact materials such as wood, bone and antler, burin use at Star Carr involved a broad range of contact materials and actions (Table 35.15). Whilst wood was the most commonly worked material (n=5) (Figure 35.23), followed by bone/and or antler (n=2) and an indeterminate hard material (n=2), they were also employed to work mineral (n=2), fish (n=1), plant (n=1) and another indeterminate soft material. Scraping of wood was most common, though burins were also used to groove and whittle wood. In fact, across the spectrum of contact materials burins were used on, we see much greater diversity in activities than suggested by Andresen and colleagues (1981). Not just the burin facet was employed; other edges were too. In essence, the multi-faceted and often robust morphology of these tools lent themselves to a range of functions.

Burin type	No.
Angle burin on break	48
Angle burin on natural surface	27
Angle burin on truncation	60
Dihedral burin	24
Double angle burin	33
Double burin—angle and dihedral	8
Triple burin	6
Quadruple burin	4
Misc/fragment	22

Table 35.14: Burin types.

98926

99043

102633

108649

108896

108937

114565

0   2cm
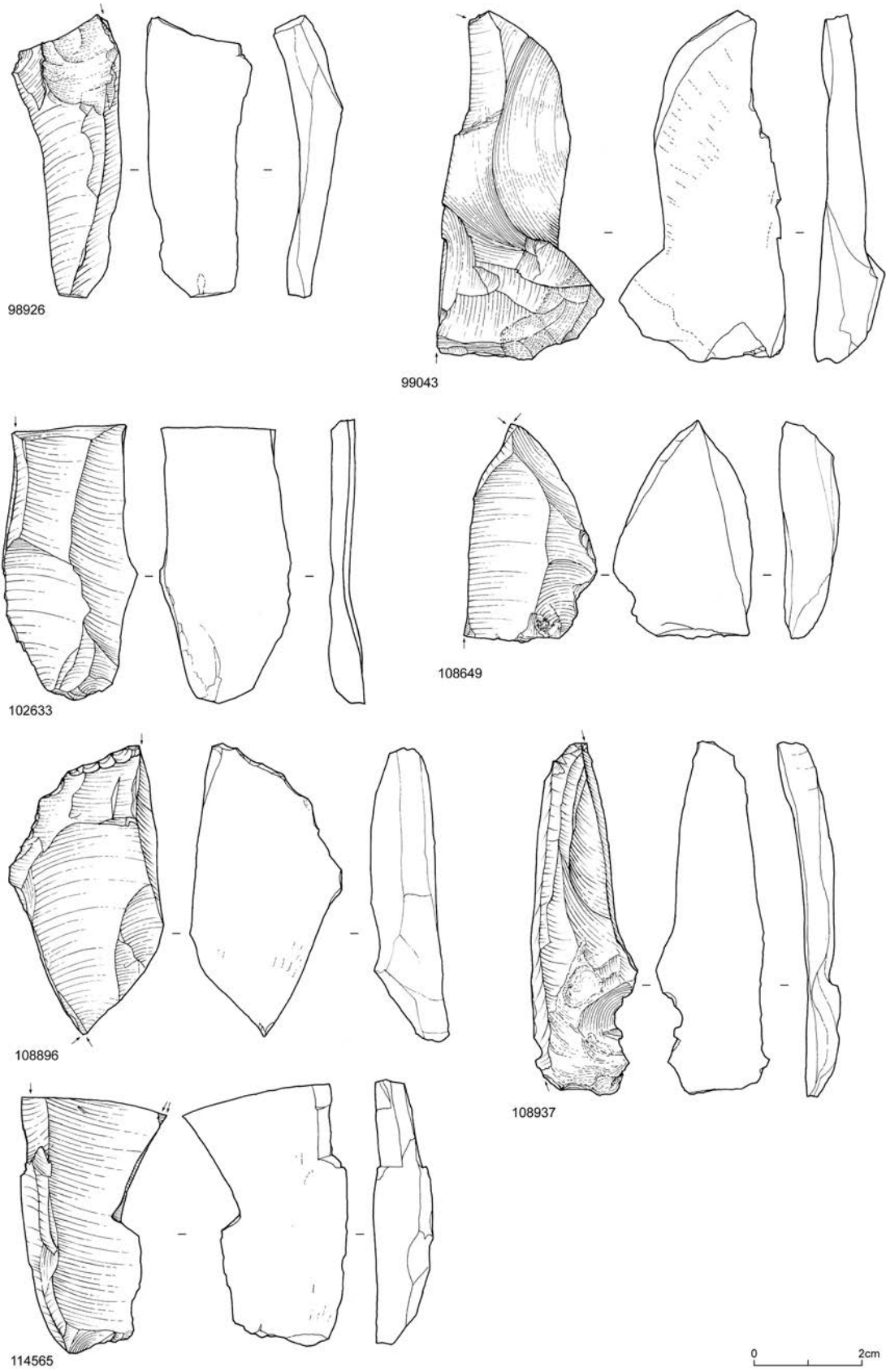
Figure 35.20: Burins (Copyright Craig Williams, CC BY-NC 4.0).
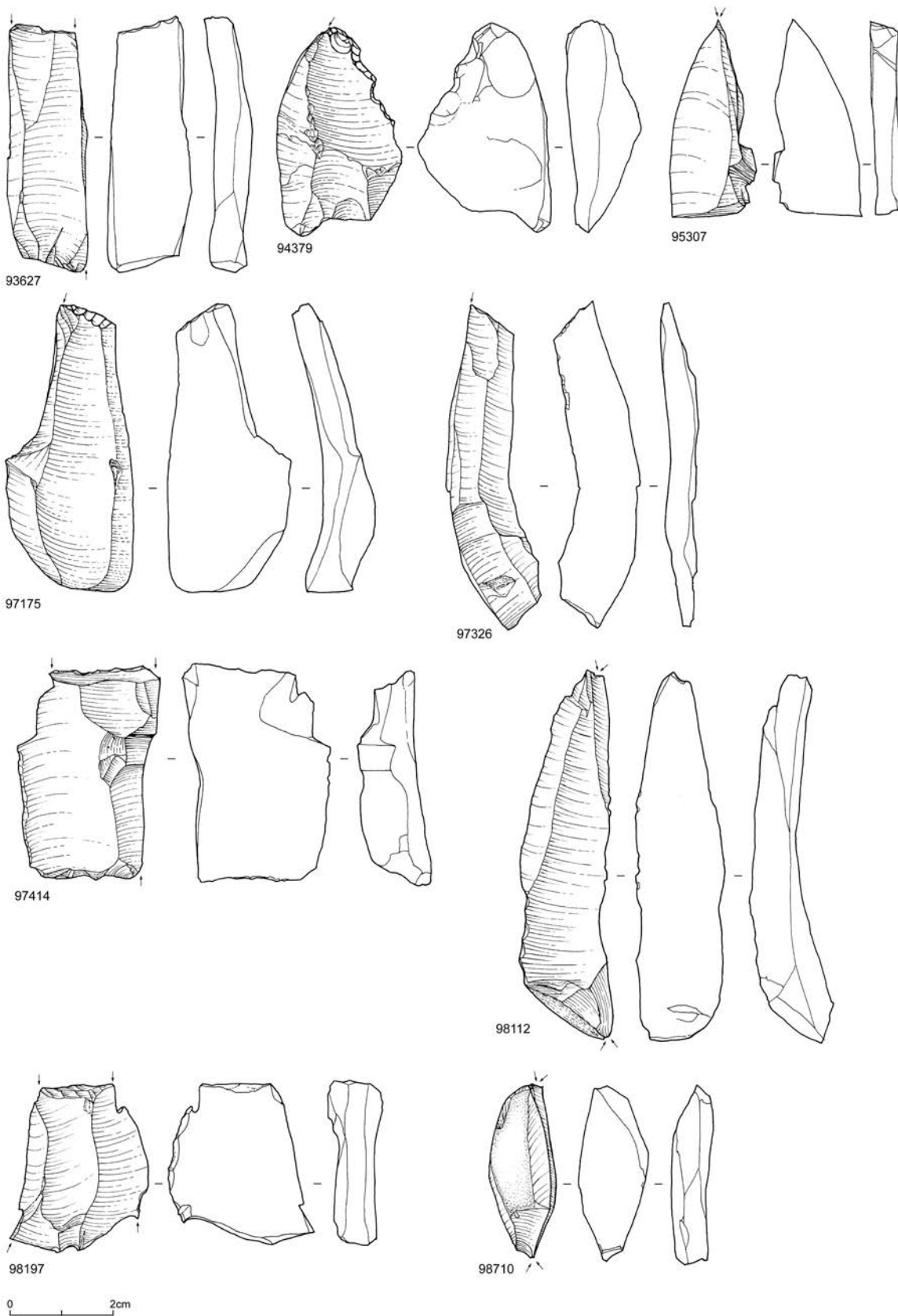
Figure 35.21: Burins (Copyright Craig Williams, CC BY-NC 4.0).
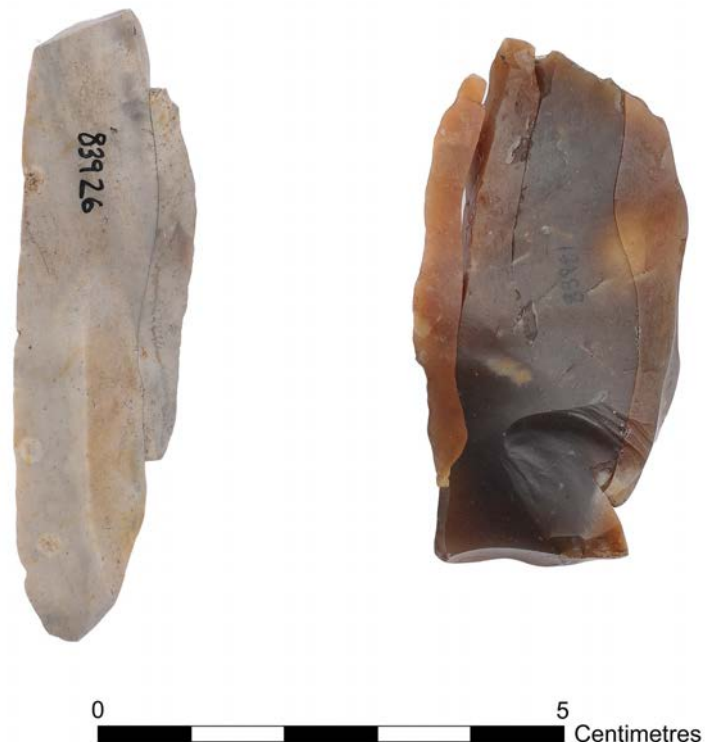
Figure 35.22: Refitting burins and burin spalls (Photograph taken by Paul Shields. Copyright University of York, CC BY-NC 4.0).
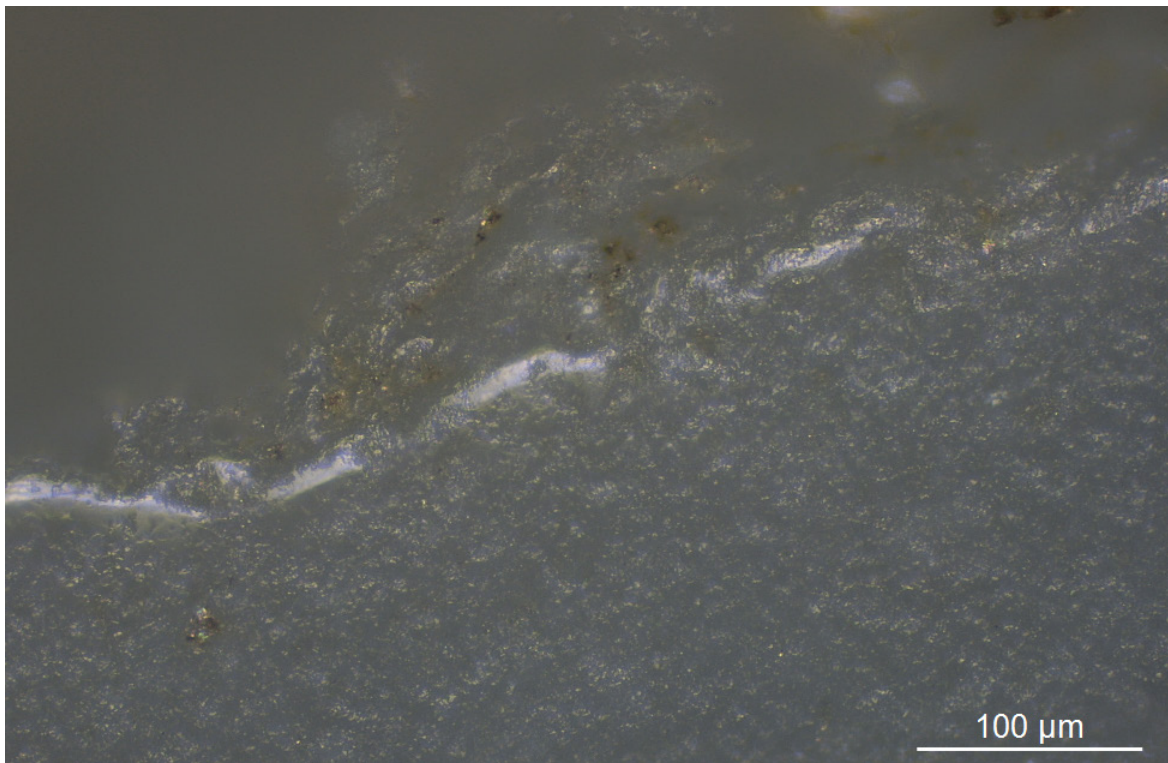
Figure 35.23: Transverse wood polish on burin <117501> (Copyright Aimée Little, CC BY-NC 4.0).

Contact material	Action	No.
Wood	Scraping (3; one of which was burin spall), Scraping/Grooving (1), Whittling/Scraping (1)	5
Hard material indet.	Cutting (1), Boring/Scraping (1)	2
Bone and/or antler	Grooving (1), Grooving/Scraping (1)	2
Mineral	Cutting (1), Scraping (1)	2
Plant (medium hardness)	Cutting	1
Soft material indet	Scraping	1
Fish	Cutting/scraping	1
Indet.	Indet.	1
Un-analysable	n/a	1
Not used	n/a	4
Total		20

Table 35.15: Microwear analysis results for burins.

Burins are found across the site (Figure 35.24). On the dryland both burins and burin spalls have been recovered indicating both manufacture and use. These have strong associations with the structures and their surrounding areas, in particular the various scatters to the north of the eastern structure. The eastern structure was an area where burins were manufactured for use elsewhere, as indicated by the large number of primary spalls (Figure 35.25); the assemblage from the western structure is more balanced between primary and secondary spalls. In the wetland and wetland edge area, burin spalls are rarer (though they do occur in the area north of cutting III (bead area), Clark's area and the axe workshop), and when present are mainly resharpening rather than manufacturing spalls. The two examples found in open water, from the area south of cutting III and the detrital wood scatter, are both large plunging burin spalls that may have both been used as tools. Burins themselves are found in reasonably large numbers indicating use and/or deposition in these areas.

Scrapers

The assemblage contains 336 scrapers (Figure 35.26), making these (by a small margin) the most common tool recovered from the site. Scrapers range in length from 18 to 74 mm, in width from 6 to 44 mm and in thickness from 3 to 25 mm. Average dimensions are 34.6 × 23.7 × 8 mm. Almost all scrapers are endscrapers. A small sharp spur is present on some of the scrapers (Figure 35.26: <95428> and <95980>), a feature also seen on examples from Seamer C. Short endscrapers (that is where the length is less than twice the width) are best represented (Table 35.16). Though some long endscrapers are present, it is likely that the length:width ratio represented by the short scraper was more useful for preventing breakage. Examination of scraper dimensions (Figure 35.27) indicates that while some of the longest scrapers were wider and thicker, in general there does not seem to be a relationship between length, width and, in particular, thickness. This might mean that blanks of broadly similar width and thickness were selected irrespective of length, or that some of the variation in length is due to resharpening practices, with scrapers becoming shorter as they were repaired.

In general scrapers often appear to have been expedient tools for immediate use. There has been a better level of success for refitting scrapers than burins and in general refitting demonstrates scrapers tended not to leave their immediate scatter of manufacture, a pattern found on other sites in the Vale of Pickering, such as Seamer C. Refit distances for scrapers range from 0.5 to 3.5 m, with an average of 2.16 m distance from the previous removal in the refit sequence. In contrast, burins range from 1.59 to 6.30 m with an average distance of 4.13 m.
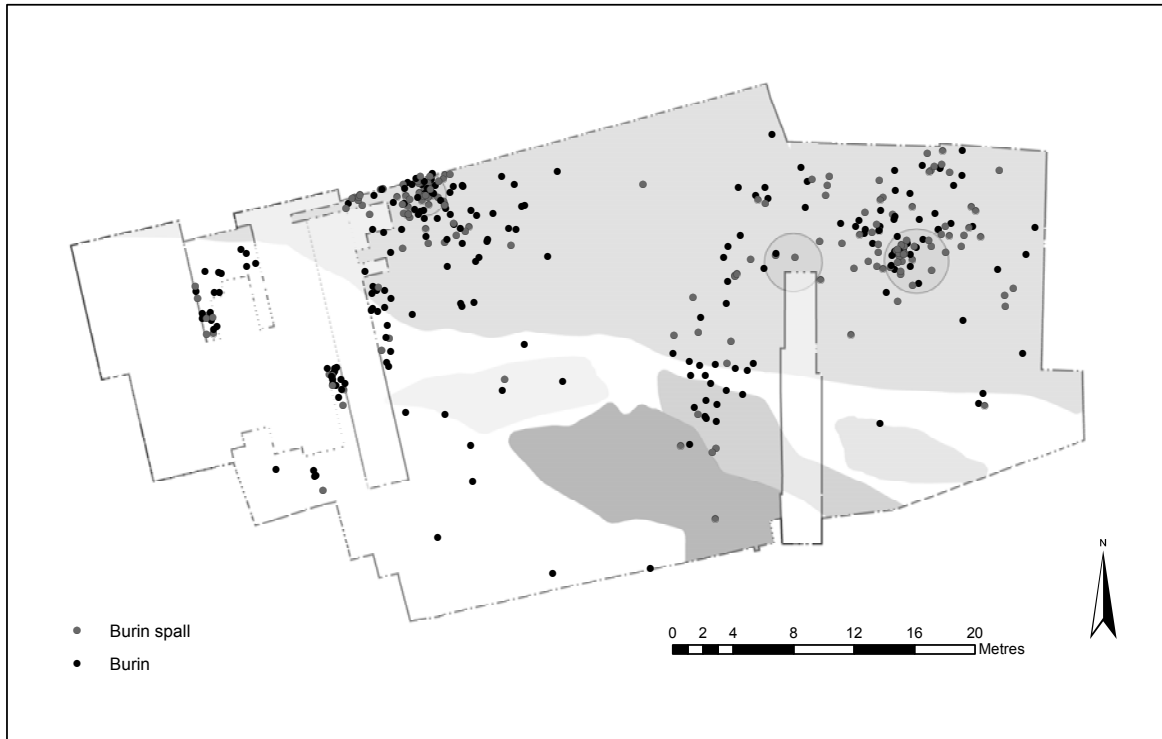
Figure 35.24: Distributions of burins across site (Copyright Star Carr Project, CC BY-NC 4.0).
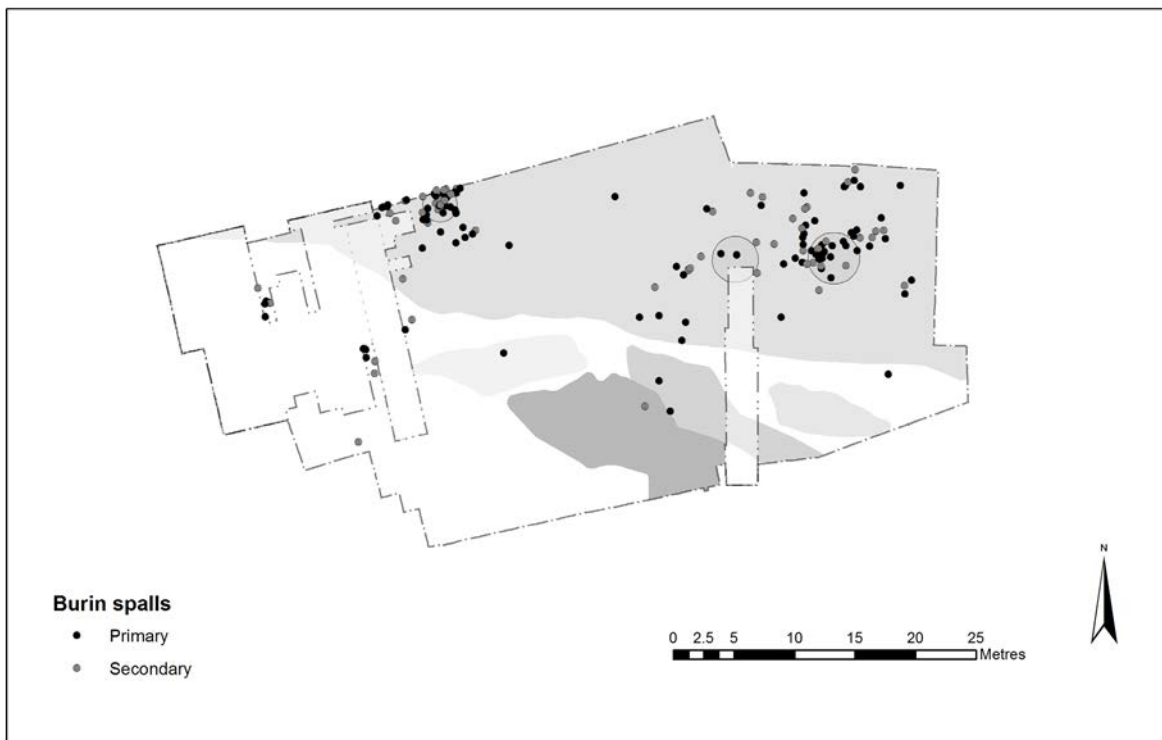
Figure 35.25: Distribution of primary (manufacturing) and secondary (resharpening) burin spalls (Copyright Star Carr Project, CC BY-NC 4.0).
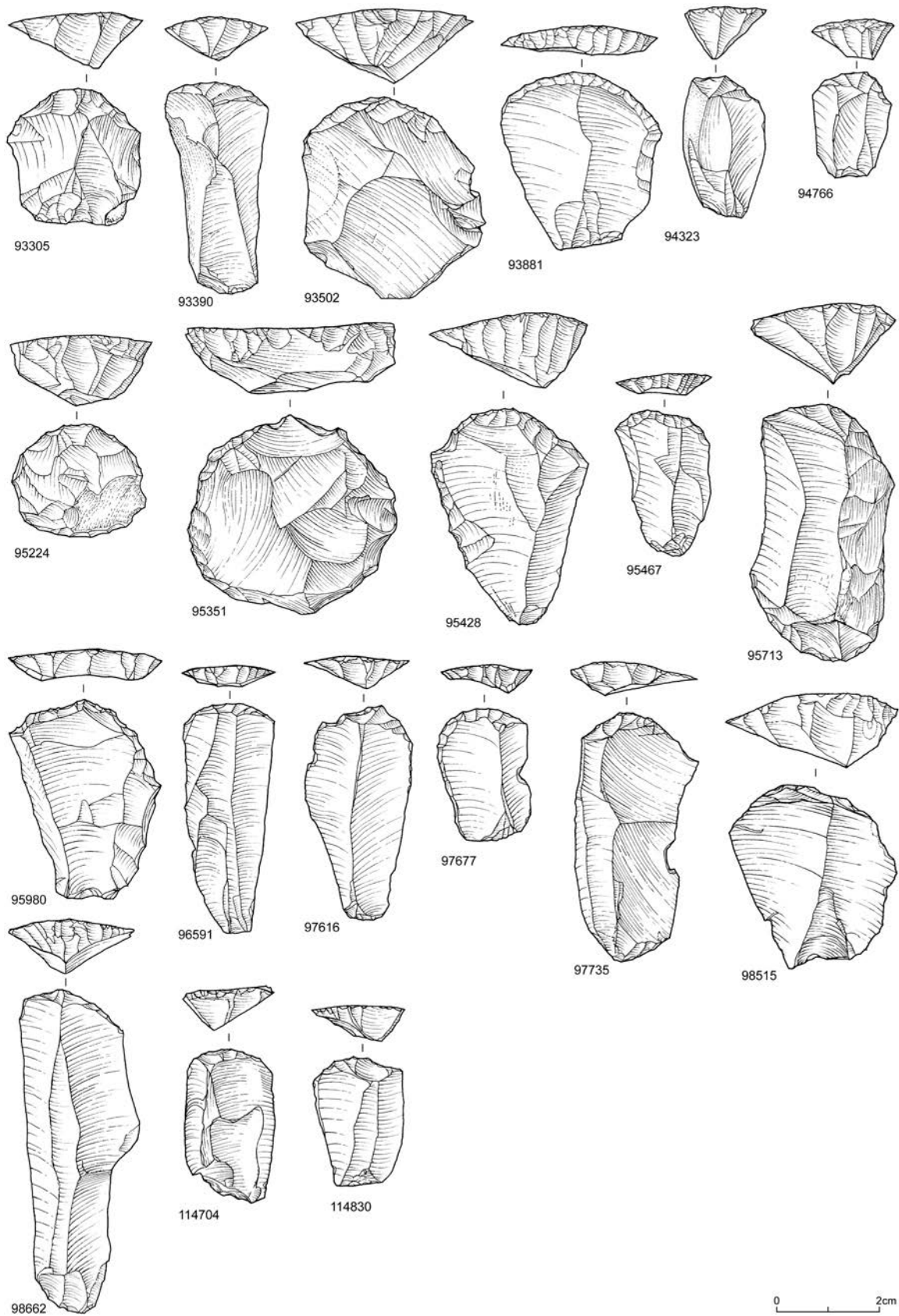
Figure 35.26: Scrapers (Copyright Craig Williams, CC BY-NC 4.0).
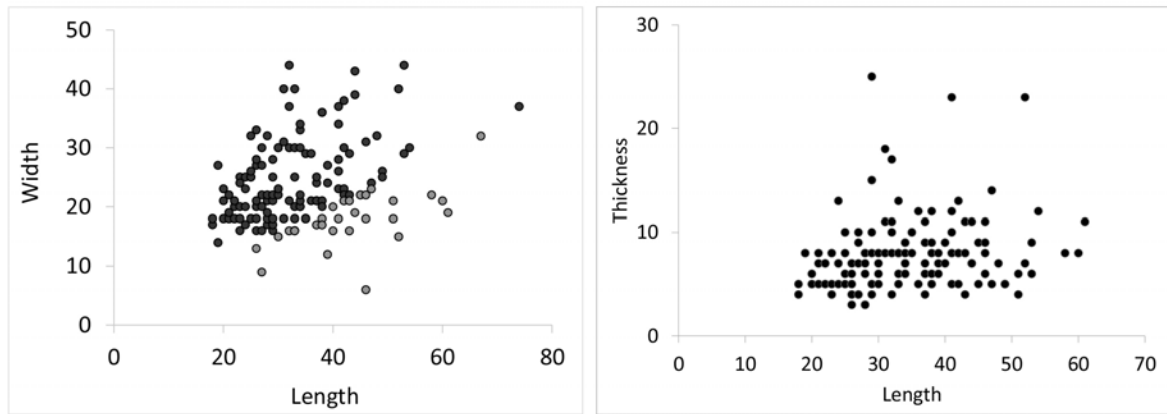
Figure 35.27: (left) length and width of long (grey) and short (black) scrapers; (right) length and thickness of scrapers. All measurements in mm (Copyright Star Carr Project, CC BY-NC 4.0).

Scraper type	No.
Long	52
Short	138
Round	6
Double	27
Irregular/misc.	12
Fragment	98

Table 35.16: Scraper types.

In total, six of the 15 scrapers analysed were used for hide-related activity, either on moisturised or dry hide (Table 35.17). One of these also had mineral traces, probably ochre, which is likely to have been used in the hide preparation. Others had a dual use, one being used for both hide and bone work (a combination also observed by Dumont (1988, 37)) and another scraper had been used on both plant and bone. Three scrapers (two used on hide, one which had indeterminate contact material because of PDSM) were hafted. Hafting was determined by distribution of intense microchipping, which also suggested no or little use of resin as the damage was very intense. Interestingly, nearly a quarter of all scrapers analysed had no signs of use at all, which, given the fact they are the most ubiquitous tool found at Star Carr, suggests one of two things: provisioning may have been taking place, or that re-sharpening events have removed previous wear traces. Three scrapers have indeterminate wear traces, unidentifiable because of PDSM. In all instances where polish was identified, scraping was the primary action.

Dumont analysed considerably more scrapers (n=51), this being the largest category of tool that he examined. However, for his analysis, he grouped truncated blades and flakes together with scrapers, whereas we have treated these tool types separately. Hide traces were the most common, followed by bone, antler, wood, hide and bone, with lesser numbers displaying combinations of two or more of the above materials. His focus on scrapers led to the determination of two morphologies with two functions, bone working scrapers and hide.

Scrapers have broadly similar distributions to burins, found mainly in and surrounding the structures, and in wetland edge contexts (Figure 35.28). However, some differences are apparent. Scrapers are found mainly to the east and west of the eastern structure, in contrast to burins that are found mainly to the north. Scrapers also seem to have a slightly more extensive wetland distribution than burins, found (albeit still in relatively small
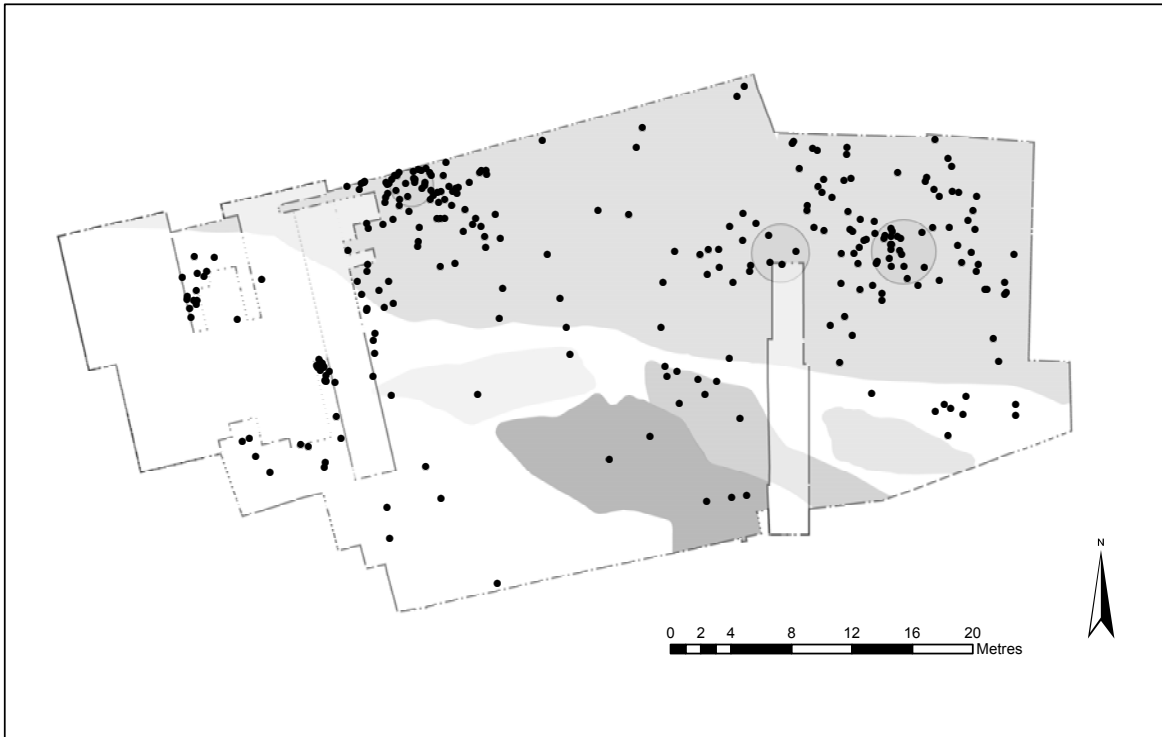
Figure 35.28: Distribution of scrapers (Copyright Star Carr Project, CC BY-NC 4.0).

Primary contact material	Secondary contact material	Tertiary contact material	Action	No.
Hide dry	Hide moist	Mineral	Scraping	1
Hide dry			Scraping	2
Hide moist			Scraping	1
Hide Indet.	bone (1x)		Scraping	2
Plant	bone		Scraping	1
Wood			Scraping	1
Indet. use			Indet.	3
Not used			n/a	4
Total				15

Table 35.17: Microwear analysis results for scrapers.

numbers) in the southern parts of Clark's area, the marl area and the detrital wood scatter. Areas of scraper manufacture are difficult to isolate, because resharpening spalls are extremely small and usually too small to be captured in the 5 mm sieves used on site. Only 12 were recovered from excavation and sieving, and a further five recovered from wet sieving of soil samples. Resharpening spalls have been recovered from the western structure, from the northern and southern part of the central structure surrounds, from the fen carr scatter, the northernmost part of Clark's area and from test pits SC8 and SC10 at the top of the Star Carr peninsula. Often these are too small to ascertain whether they derive from an area of straight or curved retouch, so some may relate to the production of truncations for burins.

Microdenticulates

Microdenticulates, also known as saws or serrated pieces, are not common at Star Carr or Star Carr sites more broadly. Only 23 examples were recovered, of which 12 were made on blades or bladelets, five on flakes, while the remainder were fragmentary. Use traces are extremely varied: two were used on dry hide, one as a projectile, one for butchery and one for cutting plants. Microdenticulates are more common on Deepcar type-sites, such as Marsh Benham, where 52 were recovered (Jacobi nd). Marsh Benham is a fairly late Deepcar site, and it may be that use of microdenticulates on a broad scale has a temporal component, perhaps related to the presence of particular types of vegetation, as in later Mesolithic contexts these are often plant-working tools. Microdenticulates are found mainly in the western part of the site, in and around the western structure and south of Clark's trenches (Figure 35.29).

Notches and denticulates

There were 18 denticulates and 13 notches recovered from the site. These are miscellaneous in form, made on flakes, blades, chunks and as denticulate scrapers. In total, 10 pieces classified as notched or denticulate were analysed for wear traces (Table 35.18). Only one of these, <97569>, was hafted; this was also the only piece used for butchery. Interestingly, of the two denticulates examined by Dumont, only one piece displayed traces, and these were also connected to butchery. However, most common amongst the current assemblage were woodworking traces (n=4), with tools used to scrape (n=3) or plane (n=1) wood. One of these, <99174>, displayed bast polish too, indicating it was a multifunctional woodworking tool. Two pieces were used to scrape bone, one of these, <98438>, had very well-developed dry bone-working traces located within a single notch of a multi-notched tool; the notch was used to shave or scrape the bone (Figure 35.30). It is probable that this was a craft tool. Of the three un-utilised pieces, one, the denticulate core, belonged to the X6 cache, a cluster of lithic
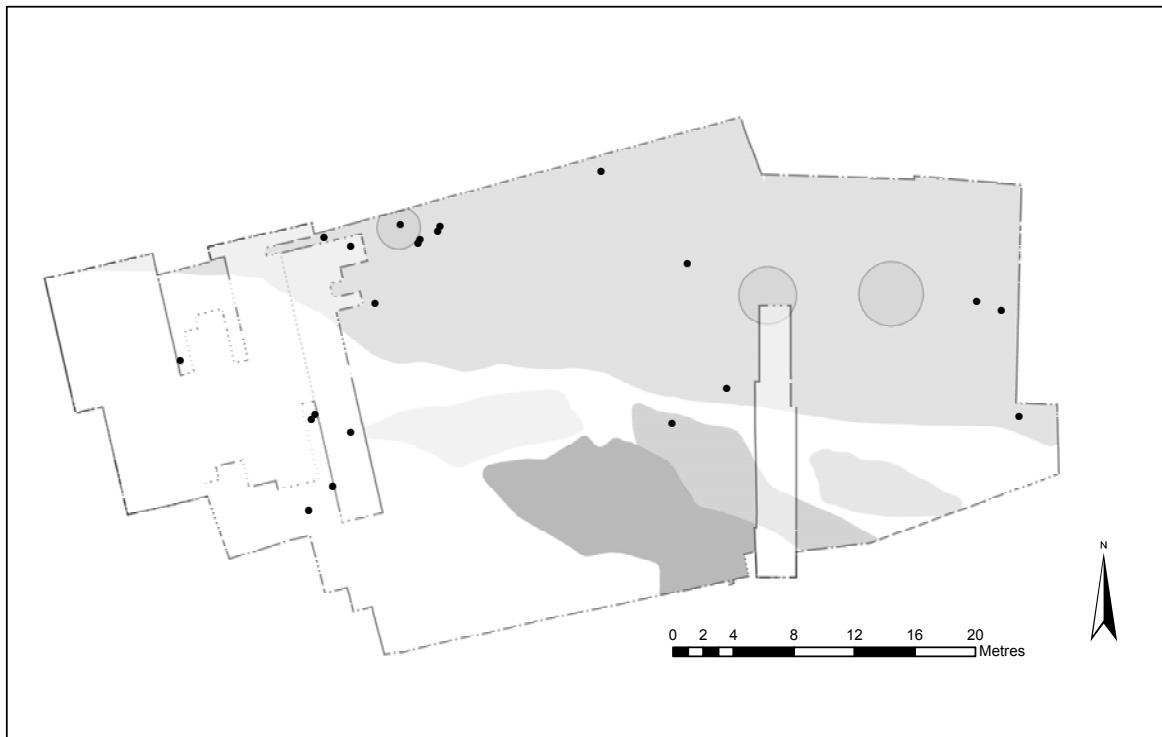
Figure 35.29: Distribution of microdenticulates (Copyright Star Carr Project, CC BY-NC 4.0).
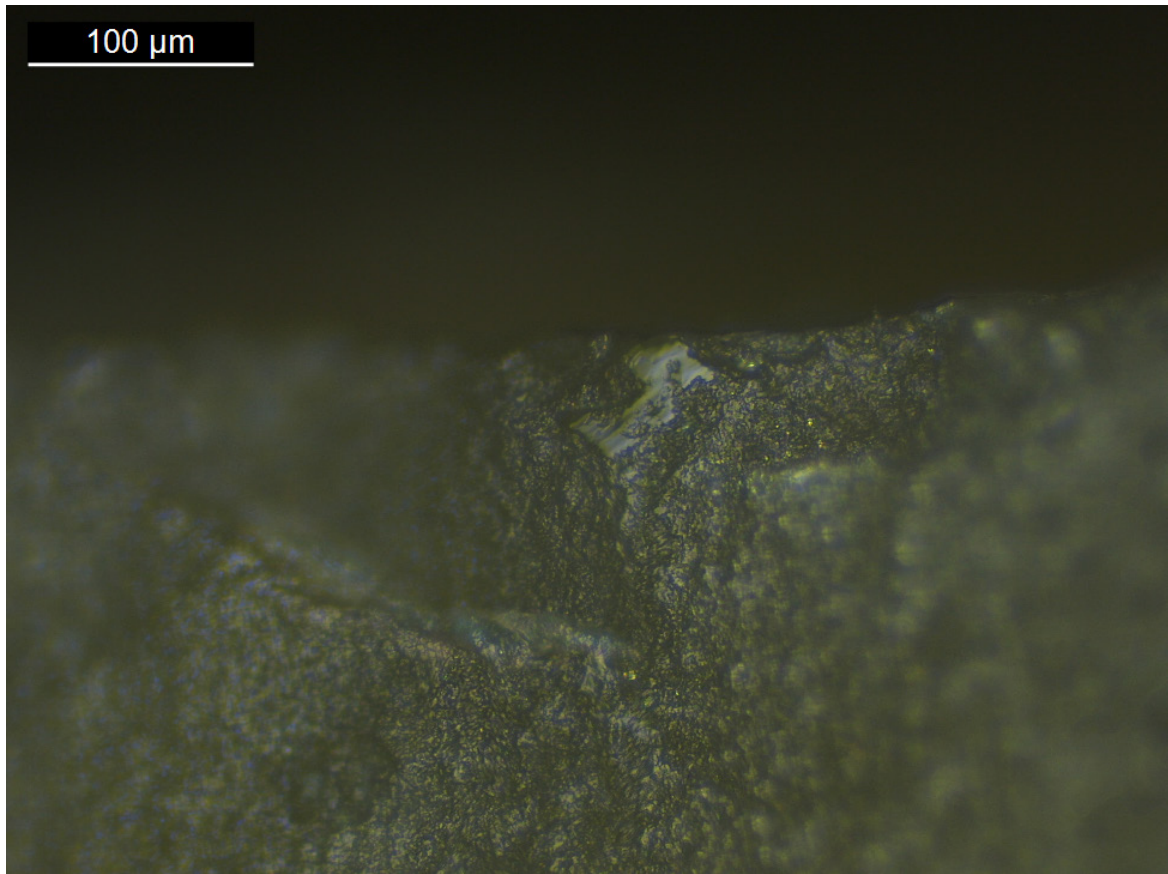
Figure 35.30: Transverse bone polish within notch of <98438> (×20 magnification) (Copyright Aimée Little, CC BY-NC 4.0).

Primary contact material	Secondary contact material	Action	No.
Wood	Plant (1), Bast (1)	Scrape (3), plane (1)	4
Not used		n/a	3
Bone		Scrape/shave	2
Animal various		Butchery	1
Total			10

Table 35.18: Microwear analysis results for denticulates and notches.

artefacts associated with the central platform (see Chapter 8). A further two were recovered from Clark's area. More broadly notches and denticulates cluster in two main areas, in the axe workshop and in and around the western structure (Figure 35.31). All such tools analysed for microwear in these areas were used for woodworking, suggesting specialist activities, perhaps in the case of the axe workshop connected to haft preparation or the same woodworking tasks that involved use of the axes.
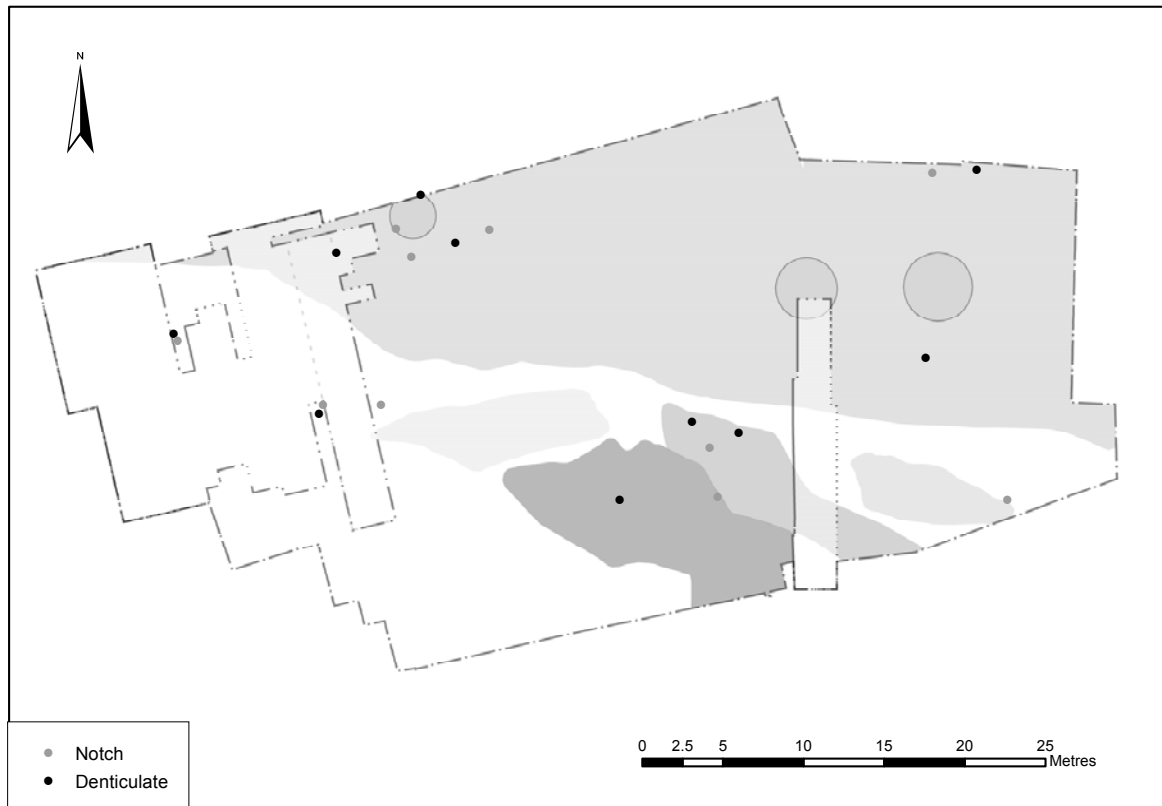
Figure 35.31: Distribution of notches and denticulates (Copyright Star Carr Project, CC BY-NC 4.0).

Truncations

Truncations are also relatively uncommon, with only 30 examples. With one exception, all are oblique truncations and on blades or bladelets. Most are distal truncations, though four are on the proximal and one is a double truncation. There is some overlap between the smaller examples and microliths. Lengths range from 13 to 62 mm, widths from 10 to 29 mm and thickness from 2 to 8 mm, with an average of 40 × 17 × 4.5. The average of 40 mm compares with an average length of blades of 42 mm. Given that some of the length would have been removed through the truncation process, it seems that larger than average supports have been selected. Truncations are found across the site, in dryland, wetland edge and wetland contexts. Three examples are associated with the western structure, and two with both the axe workshop and the fen carr scatter, and they are particularly common in the test pits of the eastern peninsula, to the east of SC23 (Figure 35.32).

Three truncations were analysed for microwear traces. Interestingly, all three displayed hafting traces in the form of edge damage, and all three had been used intensively, but on a variety of materials (bone and/or antler, siliceous plant, wood), and different actions (grooving, scraping/cutting, grooving/scraping). A good example is <89878> (Figure 35.33), which appears to have been used in plant craftwork, involving intensive scraping of siliceous plants, probably reeds, with some cutting of soft wood. The multifunctionality of truncations as tools is perhaps not surprising given their morphology, with different working edges that can be used, amongst other things, to cut, scrape and groove. Such diversity and intensity of use is probably why they were hafted and why they were found in a variety of contexts across the site.

Strike-a-lights

Twenty strike-a-lights were recovered from site. These were all made on recycled cores, apart from one example made on an axe. Three were examined for microwear. All had mineral polish confirming their use as strike-a-lights

Figure 35.32: Distribution of truncations (Copyright Star Carr Project, CC BY-NC 4.0).

(Figure 35.33). The strike-a-lights are rarely found as isolated pieces (Figure 35.34). The largest cluster (of five) is found in a 6 × 2 m area in the low-density area between the western and central structures. Three were recovered from scatter 7, a low-density discrete area of knapping, and a further three from the western structure.

Blades and utilised blades

Rather than functioning simply as blanks for future tool production, blades were frequently used as tools. As described above, many have macroscopic damage. This is particularly true of the larger examples with most blades above 65 mm showing evidence of macroscopic damage. Microwear indicates that blades were clearly multifunctional tools, used to scrape, cut, pierce, peel, bore and butcher a broad variety of contact materials. Of the 68 pieces analysed, just eight displayed no traces at all. Of the analysed blades, 33 had macroscopic damage identified by CC, of which only one had no evidence of use when examined for microwear. Of the 35 pieces with no obvious macroscopic damage, seven had no use traces. This indicates that macroscopic damage identified by the lithic specialist is a fairly good proxy for actual use, but that much used material leaves no visible traces. However, there was a very similar range of actual uses for those blades identified as 'utilised' to those where use was not macroscopically visible.

Thirteen blades were identified as displaying wear traces resulting from the working of various animal materials and have been classified as butchery tools (Table 35.19). These included blades, utilised blades, blade fragments and bladelets. Of the three bladelets with butchery traces, two belong to the X6 cache (see Chapter 8). The only butchery blade with hafting traces was a piece <94931> that had been used intensively for this task, with very-well-developed traces. Seven blades had been used to work siliceous plants and seven had been used to work bone; some of these may also have been butchery tools, used in the later stages of carcass processing.
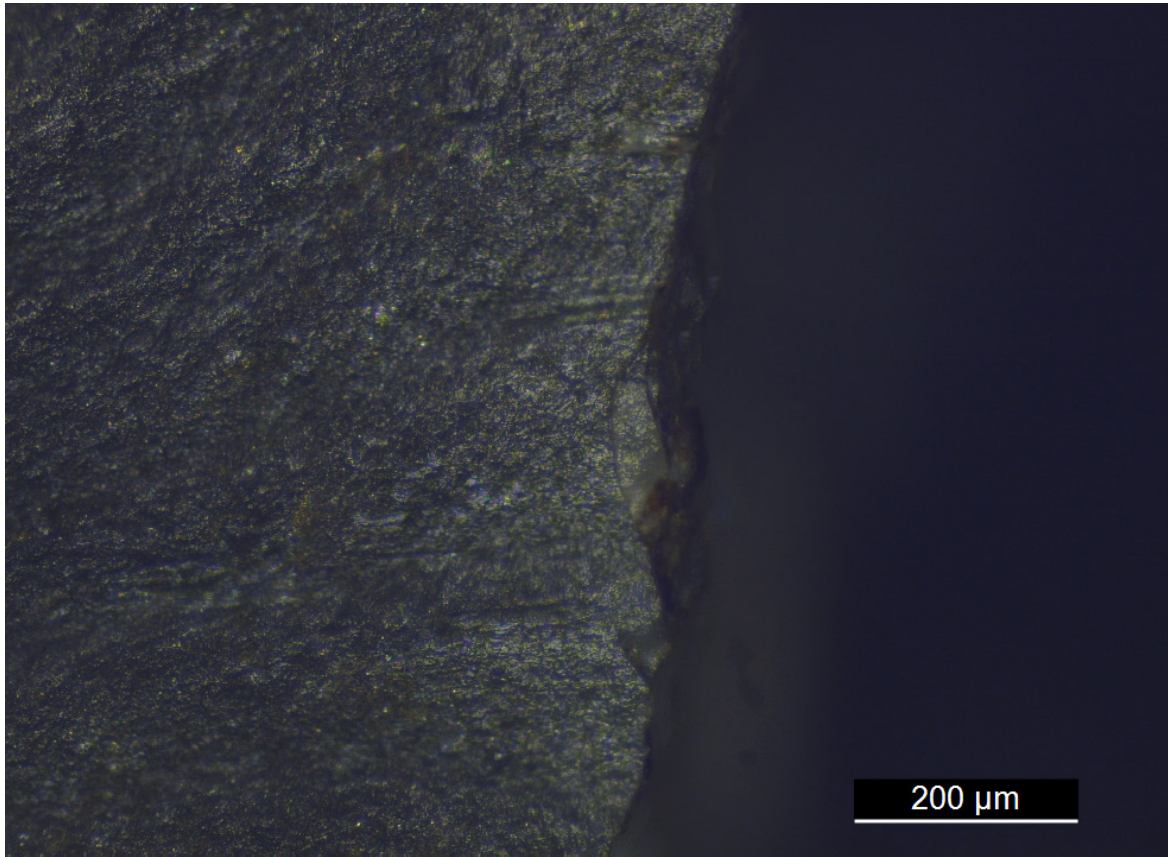
Figure 35.33: Transverse striations on strike-a-light <102669> (Copyright Aimée Little, CC BY-NC 4.0).
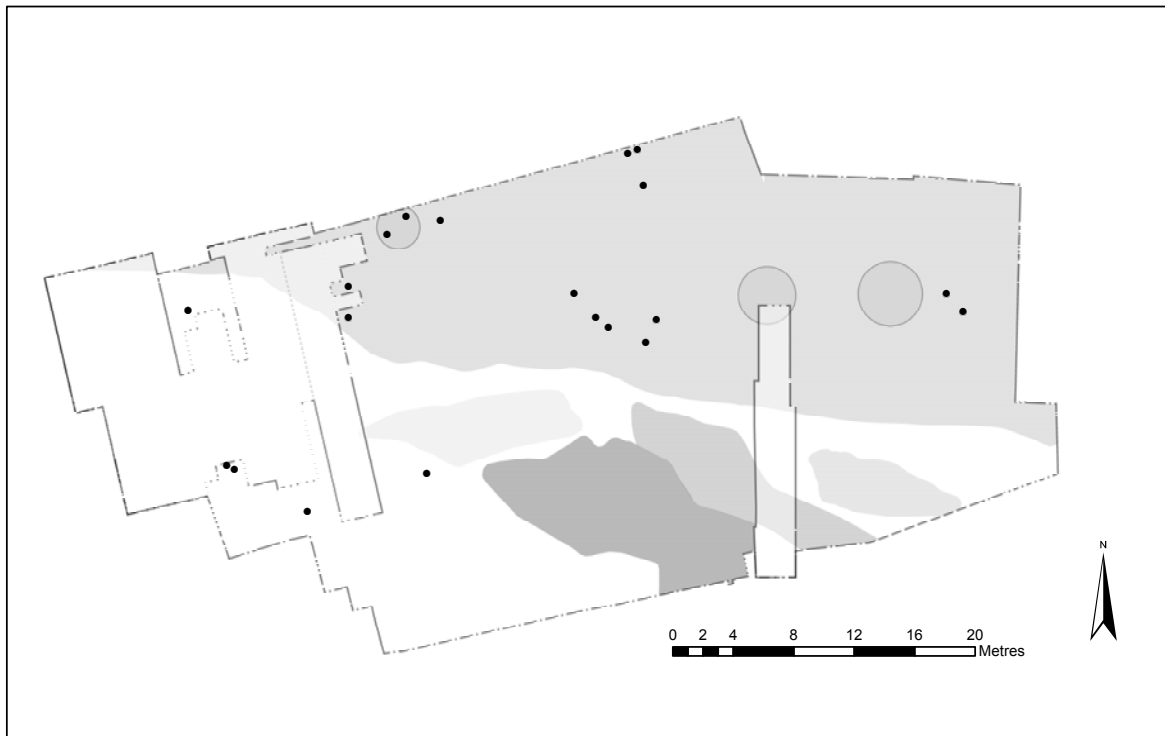
Figure 35.34: Distribution of strike-a-lights (Copyright Star Carr Project, CC BY-NC 4.0).

Primary contact material	Secondary contact material	Tertiary material	Action Various = more than 2 actions identified	No.
Animal various			Butchery	13
Not used			n/a	8
Siliceous plant	Soft wood (2)		Scraping (4), Scraping/cutting (3)	8
Bone			Scraping (3), Cutting (2), Cutting/scraping (1), Various (1)	7
Wood			Boring (2), Scraping (2), Indet. (1)	5
Plant			Scraping (3), Various (1)	4
Hide	Mineral (3), Bone (1)	Bone (1)	Scraping (1), Scraping/piercing (1), Various (2)	4
Antler?	Bone?	Hide	Scraping (1), Various (1)	2
Impact			Projectile	2
Bast	Wood		Debarking	1
Soft wood	Siliceous plant		Cutting/scraping	1
Hard material indet.			Cutting/scraping	1
Medium material indet.			Piercing	1
Un-analysable			n/a	4
Indet.			Indet.	5
Total				66

Table 35.19: Microwear analysis results for blades, utilised blades and bladelets.

At least one (bladelet <107528>) appears to have been a multifunctional craft tool, used to cut, scrape and groove dry bone. Just one bone-working blade <93629> displays clear signs of hafting; it was hafted directly into a hard material, probably bone or antler. Five blades had been used to work wood. On two of these, the distal tip had been used to bore wood, whilst two others had been used to scrape or whittle; both had hafting traces, the other displayed no clear directionality in traces. Four blades were used in hide-work; three of these also displayed mineral polish whilst one had also been used on bone. In all instances craftwork seems to have been the primary function of these tools, which were used to scrape, cut and pierce hide. Two blades had possibly been used on antler but neither had very well-developed traces. Because of the well-known difficulties in determining the difference between wood and antler polish, it is possible these tools were used on wood or even a combination of antler and wood. Two bladelets (<116366> and <102584>) displayed impact traces, indicating use as projectile points.

  Eight flint blades displayed siliceous plant working traces (mostly scraping, but also some cutting), and a further four were identified as being used on a plant material (mostly scraping, but one was a multi-functional tool, probably used in craftwork). The siliceous plant polish on the Star Carr blades is typically transverse, sometimes oblique, indicating a scraping motion. This is commensurate with that produced during experimental work undertaken in order to replicate the numerous archaeological examples of unretouched flint blades and to a lesser extent, flakes, displaying these types of traces from Dutch Mesolithic and Early Neolithic wetland sites (van Gijn and Little 2016). Experiments demonstrated that unmodified replica blades used to scrape the stems of various siliceous plants (*Typha, Juncus* and *Scirpus*) produced the most comparable polish to that seen on the artefacts. It is probable that such tools were used to extract fibres and to make stems pliable for use in basketry, matting and so forth. At Star Carr, like at other North-West European sites, there appears to be a preference for blades with a slight curvature to one lateral margin for plant-working. Only one blade had possible hafting traces. In general, it appears that plant-working tools were handheld.

Dumont analysed 18 edge-damaged and/or marginally retouched blades. Of these, 13 had wear traces, nine of which were wood. No siliceous plant-working traces were identified by Dumont at either Star Carr or Mount Sandel, which is curious given the prevalence of such evidence at other Mesolithic sites in North-West European (Little and van Gijn 2017; see also Perdaen et al. 2004). It is possible that Dumont was either not recognising these traces when in existence, or was subsuming them into the category of 'wood'. With respect to the latter, he states a reluctance to 'resolve the sub-types within each type of polish such as hard vs. soft wood' (Dumont 1983, 132). This potential oversight is important because, when compared with other sites of a broadly contemporary date, the function of tools and related/inferred activities at both Star Carr and Mount Sandel have assumed a much more animal-related focus, in keeping with broader economic trends popular at the time. Yet our analysis shows that different tools, but in particular, unmodified blades, were regularly used to work siliceous plants, probably reeds that would have grown along the lake edge (Chapter 19). In fact, two siliceous plant-working tools, when plotted (see Figure 8.5), are located adjacent to each other at the water's edge, providing an intimate insight of what was probably in situ plant-working activities in and amongst the reeds. A further striking spatial pattern is the high frequency of occurrence (n=5) of blades with plant-working traces recovered from Clark's area, the meaning of which is unclear.

Utilised pieces are distributed across the site, in areas of knapping, tool use and deposition (Figure 35.35). Proportionally to other material, they have a very strong association with the wetlands. They have two areas of main concentration: in Clark's area and in the bead area. There is a strong association of utilised blades from the wetlands with plant working; possibly, on occasions at least, reflecting the harvesting of reeds along the lake edge, though for many of these tools, cutting as well as scraping was involved.

Flakes and fragments

Flakes, fragments and shatter fragments, generally seen as knapping waste, were also used as tools. Of the 34 pieces analysed, most had been used (Table 35.20).
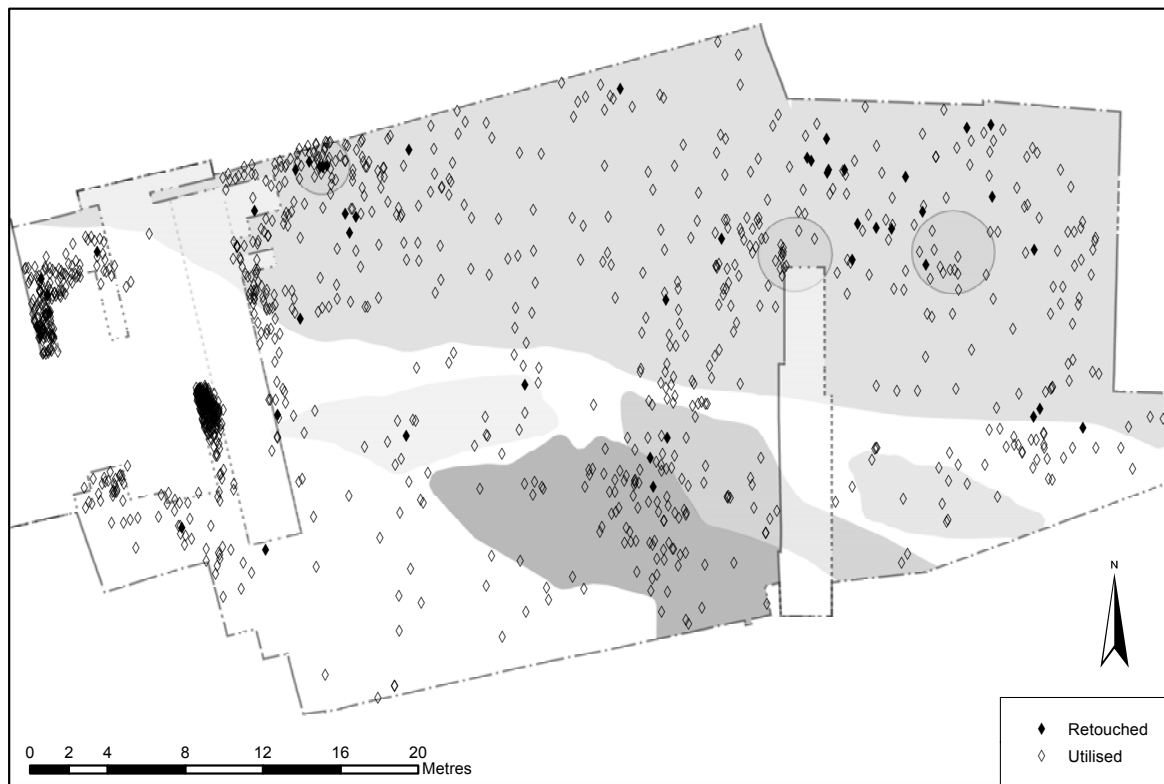
Figure 35.35: Miscellaneous retouched pieces, utilised blades, flakes and fragments (Copyright Star Carr Project, CC BY-NC 4.0).

Primary contact material	Secondary contact material	Action	No.
Indet. use		Scraping (2; one of which was a hard material), Indet. (6)	8
Bone	Antler (1), Soft animal (1)	Sawing/cutting (2), Scraping/cutting (1), Groove/Scrape/Cut (1), Grooving (1), Cutting (1)	6
Wood		Scraping	4
Siliceous plant	Wood (1)	Planing/scraping/cutting (1), Cutting (1)	2
Animal various		Butchery	2
Animal soft		Butchery?	1
Antler		Cutting	1
Plant		Indet.	1
Meat		Cutting	1
Fish		Cutting/scraping	1
Mineral		Scraping?	1
Not used		n/a	3
Total			34

Table 35.20: Microwear analysis results for flakes, fragments, chunks and nodules.

Microwear analysis of flakes, fragments and chunks showed a great variety of tool use functions. The largest quantity (n=8) had indeterminate use traces. This was followed by bone (n=6), animal various (n=3), siliceous plant (n=2) and plant (n=1), with one each of the following: antler, meat, fish and mineral. All but one of the pieces with bone-working traces was identified on fragments, four of which belong to the X6 cache discussed in Chapter 8. The chunky nature of these forms was likely to have been a factor in their selection and use in the working of bone. All the pieces where wood is the primary contact material (worked in a scraping motion) came from the AC8 cache.

Three pieces displayed no use traces, which is surprisingly low considering the proportion of unused scrapers discussed above, and the likelihood of flakes, fragments and chunks representing manufacturing debris. The broad spectrum of contact materials and actions reflected in the microwear analysis results for this grouping of material reinforces the fact that 'debris' was very much utilised in everyday activities at Star Carr.

Conclusions

Rozoy and Rozoy (2004) have discussed the 'behaviour' of Mesolithic tools, and the current study has thrown new light on how tools were moved, curated and valued at this site. Some tools, such as axes were valued tools with extended life histories. They were not made at the site but were used extensively for chopping wood, most likely relating to the building of platforms and structures. Much effort was made to extend their lives through resharpening, often involving long sequences of reworking. Microwear suggests they were resharpened immediately or shortly after use, so that they would be ready for the next occasion, rather than being resharpened in response to an immediate need. They have a strong association with structures, where they were taken for resharpening and storage. Other tools, such as scrapers, seem more expedient, often abandoned in the same place as they were made. These too though were resharpened and on occasions were curated, being taken into the eastern structure for repair and storage. Awls may also have been relatively expedient tools; they certainly seem to have been abandoned in the same place that they were used. Burins have an intermediate position. They were, in general, curated sufficiently to be moved away from their place of manufacture, though occasionally they were used in the same place they were made. They are usually found abandoned with resharpening spalls, indicating discard in areas they were used. The aggregation of tools in the eastern structure suggests at least a household level of ownership of certain tools.

Microwear, as expected, has problematised the equation of tools with their traditional uses, though perhaps not as much as expected. Axes are only associated with woodworking, and scrapers mainly with hide work. Burins have a much more varied set of uses, the most common of which is wood (though the difficulty of distinguishing wood and antler should be noted). Evidence for the use of burins as fish descalers should perhaps be considered more widely. Truncations, though few in number, seem to have been used in similar ways to burins (cf De Bie and Caspar 2000). Awls were used to pierce mineral, bone and hide, and thus seem to have been mainly focused on the production of clothing or other worn items. As seen on other North-West European wetland sites, unmodified blades were regularly utilised for plant-working, probably the scraping of locally growing reeds to extract and process fibres and/or preparing stems for use in basketry and/or matting (van Gijn and Little 2016). Microliths were not just projectiles, though that is their main use; they were used on different types of contact materials and had various functions, including craftwork. In addition, some started life as projectiles but were then re-used. Flakes, fragments, chunks, i.e. non formal tools, were regularly utilised: a useful reminder that an overemphasis on retouched tool types is useful for building typo-chronologies but does not necessarily reflect tool selection and subsequent utilisation. This, it appears, was guided by edge angle and flaked form, for example, the sharpness, robustness and/or angularity of a piece being considered in relation to the softness/hardness of the contact material, and the intended activity.

The combination of refitting and microwear has also permitted an understanding of the landscape 'behaviour' of particular tools. While there was a wide variety of activities across the site, some tools and functions seem more associated with particular areas (see also Chapter 8). Some, such as burins and scrapers, were used across dryland and wetland contexts. Others have more restricted distributions. Axes tend to be found on dryland and wetland edge context, the latter at a stage when these areas were sufficiently dry to allow in situ flint knapping. Utilised blades are found across site, but are particularly common in wetland and wetland edge areas. These tools found in the wetlands also have a more restricted function, being used mainly for plant- and woodworking, but also for the killing and butchery of animals. Other activities took place off-site: the procurement of flint, the testing of nodules and the manufacturing of axes.

To this understanding of space we can also add a temporal dimension, as at least some of the lithic activities can be securely tied into the Bayesian model. There are suggestions of some changes in lithic materials over the temporal span the site was visited, with microlith forms possibly becoming more diverse, and then finally shifting towards forms more typical of Deepcar types. Procurement of till flint also possibly shows changes over time, most likely as a result of shifting morphology of proximate coastal areas. Activities on the dryland are varied and difficult to date; however, there are indications of change, with greater focus on bead production, and perhaps craft activities more broadly, in the middle and later phases of the site. Other activities stayed the same with strong similarities both in the sorts of lithic material found in the wetlands (mainly utilised blades) and the same restricted functions for this material persisting for several hundred years.

The lithic assemblage from Star Carr can be analysed with unusual precision, permitting a rare insight into the spatial and temporal dimensions of lithic-focused activities in the Early Mesolithic. In this we have been fortunate that we have had both the ability to excavate large areas and the presence of stratified wetland deposits permitting Bayesian modelling. However, patterns of lithic procurement, reduction, tool use and deposition are activities that take place across an entire landscape, not simply a single site, and to provide these landscape insights this chapter has drawn upon the decades of Mesolithic excavations undertaken around Lake Flixton as part of the Seamer project and later by the Vale of Pickering Research Trust. These endeavours have hugely enhanced this study of the lithic material, not least by being the stimulus for the current excavations.

Volume 2 Bibliography

Aaris-Sørensen, K. 1976. A zoological investigation of the bone material from Sværdborg I-1943. In B. B. Henriksen (ed.), *Sværdborg I. Excavations 1943–44. A settlement of the Maglemose culture*, 137–148. Copenhagen: Akademisk forlag.

Adema, J. 2002. Paddestoelen in het Mesolithicum. *Coolia* 45(1), 31–32.

Aitken, M. J. 1975. Cementum layers and tooth wear as criteria for aging roe deer (*Capreolus capreolus*). *Journal of Zoology* 175, 15–28. DOI: https://doi.org/10.1111/j.1469-7998.1975.tb01387.x.

Albert, B., Innes, J., Blackford, J., Taylor, B., Conneller, C. & Milner, N. 2016. Degradation of the wetland sediment archive at Star Carr: An assessment of current palynological preservation. *Journal of Archaeological Science Reports* 6, 488–495. DOI: https://doi.org/10.1016/j.jasrep.2016.03.010.

Albert, R. M., Lavi, O., Estro, L. & Weiner, S. 1999. Mode of occupation of Tabun Cave, Mt Carmel, Israel, during the Mousterian period: A study of the sediments and phytoliths. *Journal of Archaeological Science* 26, 1249–1260. DOI: https://doi.org/10.1006/jasc.1999.0355.

Albert, R. M., Berna, F. & Goldberg, P. 2012. Insights on Neanderthal fire use at Kebara Cave (Israel) through high-resolution study of prehistoric combustion features: Evidence from phytoliths and thin sections. *Quaternary International* 247, 278–293. DOI: https://doi.org/10.1016/j.quaint.2010.10.016.

Allen, T., Barclay, A., Cromarty, A. M., Anderson-Whymark, H., Parker, A., Robinson, M. & Jones, G. 2013. *Opening the wood, making the land. The archaeology of a Middle Thames landscape: The Eton College rowing course project and the Maidenhead, Windsor and Eton flood alleviation scheme. Volume 1: Mesolithic to Early Bronze Age. Thames Valley Landscapes Monograph 38.* Oxford: Oxford Archaeology.

ALS Minerals. 2009. *Assay procedure ME- OG46. Ore grade elements by aqua regia digestion using conventional ICP- AES analysis. Revision 02.02.* Available at: http://www.alsglobal.com/~/media/Files/Divisions/Minerals/Geochemistry/Geochemistry%20Resources/Short%20Method%20Descriptions/ME-OG46%20Aqua%20Regia%20Assay%20Grade%20Multi-element%20Method.pdf [Last accessed 15 September 2017].

Andersen, K., Jørgensen, S. & Richter, J. 1982. *Maglemose hytterne ved Ulkestrup Lyng. Nordiske Fortidsminder B7.* Copenhagen: National Museum of Denmark.

Andersen, S. H. 1971. Ertebøllekulturens Harpuner. *Kuml* 1971, 73–125.

Andersen, S. H. 1998. Rinkloster: Ertebølle trappers and wild boar hunters in Jutland: A survey. *Journal of Danish Archaeology* 12, 13–59. DOI: https://doi.org/10.1080/0108464X.1995.10590084.

Andersen, S. H. 2009. *Ronæs Skov: marianarkæologiske undersøgelser af kystboplads fra Ertebølletid.* Højbjerg: Jysk Arkæologisk Selskab.

Andersen, S. H. 2011. Ertebølle canoes and paddles from the submerged habitation site of Tybrind Vig, Denmark. In J. Benjamin, C. Bonsall, C. Pickard & A. Fischer (eds.), *Underwater archaeology and the submerged prehistory of Europe*, 1–14. Oxford: Oxbow Books.

Andersen, S. H. (ed.). 2013. *Tybrind Vig: submerged Mesolithic settlements in Denmark*. Højbjerg: Jutland Archaeological Society, Moesgård Museum.

Andersen, S. H. & Rasmussen, K. L. 1991. Bjørnsholm. A stratified køkkenmødding on the Central Limfjord, North Jutland. *Journal of Danish Archaeology* 10(1), 59–96. DOI: https://doi.org/10.1080/0108464X.1991.10590054.

Andresen, J. M., Byrd, B. F., Elson, M. D., McGuire, R. H., Mendoza, R. G., Staski, E. & White, J. P. 1981. The deer hunters: Star Carr reconsidered. *World Archaeology* 13(1), 31–46. DOI: https://doi.org/10.1080/00438243.1981.9979812.

Arias, P., Cubas, M., Fano, M. A., Pardo, J. F. J., Salzmann, C., Teichner, F. & Teira, L. C. 2015. Where are the 'Asturian' dwellings? An integrated survey programme on the Mesolithic of northern Spain. *Antiquity* 89, 783–799. DOI: https://doi.org/10.15184/aqy.2015.49.

Arias, P., Diniz, M., Cubas, M., Duarte, C., Iriarte, E., Salzmann, C., Teichner, F. & Teira, L. 2017. Looking for the traces of the last hunter-gatherers: geophysical survey in the Mesolithic shell middens of the Sado valley (southern Portugal), *Quaternary International*. DOI: https://doi.org/10.1016/j.quaint.2016.02.016.

Armstrong, L. 1922. Two East Yorkshire bone harpoons. *Man* 22, 130–131. DOI: https://doi.org/10.2307/2840354

Arthur, D. & Vassilvitskii, S. 2007. K-means++: The advantages of careful seeding. *Proceedings of the Eighteenth Annual ACM-SIAM Symposium on Discrete Algorithms*, 1027–1035.

Ashmore, P. 1999. Radiocarbon dating: Avoiding errors by avoiding mixed samples. *Antiquity* 73, 124–30. DOI: https://doi.org/10.1017/S0003598X00087901.

Asouti, E. & Austin, P. 2005. Reconstructing woodland vegetation and its exploitation by past societies, based on the analysis and interpretation of archaeological wood charcoal macro-remains. *Environmental Archaeology* 10(1), 1–18. DOI: https://doi.org/10.1179/env.2005.10.1.1.

Aukema, B. & Rieger, C. (eds.). 1995–2006. *Catalogue of the Heteroptera of the Palaearctic region.* Amsterdam: Netherlands Entomological Society.

Aveling, E. M. & Heron, C. 1998. Identification of birch bark tar at the Mesolithic site of Star Carr. *Ancient Biomolecules* 2, 69–80.

Aveling, E. M. & Heron, C. 1999. Prehistoric gums and glues. *Chemistry Review* 8(3), 18–20.

Bain, C. G., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Gearey, B., Howat, M., Joosten, H., Keenleyside, C., Labadz, J., Lindsay, R., Littlewood, N., Lunt, P., Miller, C. J., Moxey, A., Orr, H., Reed, M., Smith, P., Swales, V., Thompson, D. B. A., Thompson, P. S., Noort, R. van der, Wilson, J. D. & Worrall, F. 2011. *IUCN UK Commission of Inquiry on Peatlands.* Edinburgh: IUCN UK Peatland Programme.

Bamforth, M. 2010. Aspects of wood, timber and woodworking at Flag Fen, 1995–2005. In F. M. M. Pryor & M. Bamforth (eds.), *Flag Fen, Peterborough: Excavation and research 1995–2007*, pp. 67–89. Oxford: Oxbow.

Bamforth, M., Taylor, M., Little, A., Pomstra, D., Robson, H. K., Mears, R., Elliott, B., Rots, V., Carty, J., Watson, C., Conneller, C., Taylor, B., Bayliss, A. & Milner, N. Forthcoming. Discovery of the earliest known bow in the world and its implications for understanding Late Pleistocene/Early Holocene hunting practices in Europe.

Bang-Andersen, S. 1989. Mesolithic adaptations in the southern Norwegian highlands. In C. Bonsall (ed.), *The Mesolithic in Europe: Papers presented at the Third International Symposium, Edinburgh, 1985*, 338–350. Edinburgh: John Donald Publishers Ltd.

Bartlett, J. 1969. Further finds of Maglemosian barbed points from Brandesburton, East Yorkshire. *Kingston-Upon-Hull Museums Bulletin* 2, 5–6.

Barton, R. N. E. 1991. Technological innovation and continuity at the end of the Pleistocene In Britain. In N. Barton, A. J. Roberts & D. A. Roe (eds.), *The late glacial in Europe: Human adaptation and environmental change at the end of the Pleistocene*, 234-245. London: CBA Research Report 77.

Barton, R. N. E., Berridge, P. J., Walker, M. J. C. & Bevins, R. E. 1995. Persistent places in the Mesolithic landscape: An example from the Black Mountain uplands of South Wales. *Proceedings of the Prehistoric Society* 61, 81-116.

Bayes, T. R. 1763. An essay towards solving a problem in the doctrine of chances. *Philosophical Transactions of the Royal Society* 53, 370–418.

Bayliss, A. 2009. Rolling out revolution: Using radiocarbon dating in archaeology. *Radiocarbon* 51, 123–47. DOI: https://doi.org/10.1017/S0033822200033750.

Bayliss, A. & Whittle, A. (eds.). 2007. Histories of the dead: Building chronologies for five southern British long barrows. *Cambridge Archaeological Journal* 17(1, supplement).

Bayliss, A. & Whittle, A. 2015. Uncertain on principle: combining lines of archaeological evidence to create chronologies. In A. Wylie & R. Chapman (eds.), *Material culture as evidence: Learning from archaeological practice*, 213–42. London: Routledge.

Bean, W. J. 1976. *Trees and shrubs hardy in the British Isles. 8th edition*. London: John Murray.

Becker, C. J. 1945. *En 8000-aarig stenalderboplads i Holmegaards Mose*. Nationalmuseets Arbejdsmark 1945, 61–72.

Bell, F. G. 2002. The geotechnical properties of some till deposits occurring along the coastal areas of Eastern England. *Engineering Geology* 63, 49–68. DOI: https://doi.org/10.1016/S0013-7952(01)00068-0.

Bell, M. (ed.). 2007. *Prehistoric coastal communities: The Mesolithic in western Britain*. York: Council for British Archaeology Research Report 149.

Benecke, N. 1987. Studies on early dog remains from Northern Europe. *Journal of Archaeological Science* 14(1), 31–49. DOI: https://doi.org/10.1016/S0305-4403(87)80004-3.

Berridge, P. 1994. The lithics. In H. Quinnell, M. R. Blockley & P. Berridge (eds.), *Excavations at Rhuddlan, Clwyd: 1969–73 Mesolithic to Medieval,* 95–114. York: Council for British Archaeology.

Bertsch McGrayne, S. 2011. *The theory that would not die: How Bayes' rule cracked the enigma code, hunted down Russian submarines, and emerged from two centuries of controversy*. Yale: Yale University Press.

Bicket, A. & Tizzard, L. 2015. A review of the submerged prehistory and palaeolandscapes of the British Isles. *Proceedings of the Geologists' Association* 126(6), 643–663. DOI: https://doi.org/10.1016/j.pgeola.2015.08.009.

Bigga, G., Schoch, W. & Urban, B. 2015. Paleoenvironment and possibilities of plant exploitation in the Middle Pleistocene of Schoningen (Germany). Insights from botanical macro remains and pollen. *Journal of Human Evolution* 89, 92–104. DOI: https://doi.org/10.1016/j.jhevol.2015.10.005.

Biggins, A. 2007. Geophysical survey. In C. Waddington (ed.), *Mesolithic settlement in the North Sea basin*: *A case study from Howick, north-east England*, 9–16. Oxford: Oxbow Books.

Birket-Smith, K. 1929. *The Caribou Eskimos*. Copenhagen: Gyldendalske Boghandel.

Bishop, R. R., Church, M. J. & Rowley-Conwy, P. A. 2015. Firewood, food and human niche construction: the potential role of Mesolithic hunter–gatherers in actively structuring Scotland's woodlands. *Quaternary Science Reviews* 108, 51–75. DOI: https://doi.org/10.1016/j.quascirev.2014.11.004.

Blaauw, M. & Christen, J. A. 2005. Radiocarbon peat chronologies and environmental change. *Applied Statistics* 54, 805–816. DOI: https://doi.org/10.1111/j.1467-9876.2005.00516.x.

Blanchette, R. A., Nilsson, T., Daniel, G. & Abad, A. 1990. Biological degradation of wood. In R. M. Rowell & R. J. Barbour (eds.), *Archaeological wood: properties, chemistry and preservation*, 141–177. Washington, DC: American Chemical Society.

Blinkhorn, E. H. 2012. *The Mesolithic and the planning process in England*. University of York. PhD.

Blinkhorn, E. & Milner, P. 2013. Mesolithic research and conservation framework. York: Council for British Archaeology. DOI: https://doi.org/10.5284/1028202.

Blockley, S., Candy, I., Matthews, I., Langdon, P., Langdon, C., Palmer, A., Lincoln, P., Abrook, A., Taylor, B., Conneller, C., Bayliss, A., Macleod, A., Deeprose, L., Darvill, C., Kearney, R., Beavan, N., Staff, R., Bamforth, M., Taylor, M. & Milner, N. 2018. The Resilience of Postglacial hunter-gatherers to abrupt climate change. *Nature Evolution and Ecology*.

Boas, F. 1835. *The Central Eskimo*. Lincoln, London: University of Nebraska Press.

Bokelmann, K. 1971. Duvensee, ein Wohnplatz des Mesolithikums in Schleswig-Holstein und die Duvenseegruppe. *Offa* 28, 5–26.

Bokelmann, K. 1975–7. Eine neue borealzeitliche Fundstelle in Schleswig-Holstein. *Kölner Jahrbuch* 15, 181–8.

Bokelmann, K. 1983. Mesolithische Wohnplätze im Duvenseer Moor. In *Führer zu archäologischen Denkmälern in Deutschland, Bd. 2 – Kreis Herzogtum Lauenburg II. Exkursionen II–IV*, 93–103. Stuttgart: Theiss.

Bokelmann, K. 1986. Rast unter Bäumen. Ein ephemerer mesolithischer Lagerplatz aus dem Duvenseer Moor. *Offa* 43, 149–63.

Bokelmann, K. 1989. Eine mesolithische Kiefernrindenmatte aus dem Duvensee Moor. *Offa* 46, 17–22.

Bokelmann, K. 1991. Duvensee, Wohnplatz 9: Ein präborealzeitlicher Lagerplatz in Schleswig-Holstein. *Offa* 48, 75–114.

Bokelmann, K., Averdieck, F. R. & Willkomm, H. 1981. Duvensee, Wohnplatz 8. Neue Aspekte zur Sammelwirtschaft im frühen Mesolithikum. *Offa* 38, 21–40.

Bonsall, C., Sutherland, D., Tipping, R. & Cherry, J. 1989. The Eskmeals Project: Late Mesolithic settlement and environment in north-west England. In C. Bonsall (ed.), *The Mesolithic in Europe: Papers presented at the Third International Symposium*, 175–205. Edinburgh: John Donald Publishers.

Boreham, S., Boreham, J. & Rolfe, C. J. 2011a. Physical and chemical analyses of sediments from around Star Carr as indicators of preservation. *Journal of Wetland Archaeology* 11(1), 20–35. DOI: https://doi.org/10.1179/jwa.2011.11.1.20.

Boreham, S., Conneller, C., Milner, N., Taylor, B., Needham, A., Boreham, J. & Rolfe, C. J. 2011b. Geochemical indicators of preservation status and site deterioration at Star Carr. *Journal of Archaeological Science* 38, 2833–2857. DOI: https://doi.org/10.1016/j.jas.2011.01.016.

Bos, J. A. A., van Geel, B., Groenewoudt, B. J. & Lauwerier, R. C. G. M. 2005. Early Holocene environment change, the presence and disappearance of Early Mesolithic habitation near Zutphen (the Netherlands). *Vegetation History and Archaeobotany* 15, 27–43. DOI: https://doi.org/10.1007/s00334-004-0056-5.

Boston, C. M. 2007. *An examination of the geochemical properties of late Devensian glacigenic sediments in Eastern England.* University of Durham. Masters dissertation. Available at: http://etheses.dur.ac.uk/2609/ [Last accessed 15 September 2017].

Bowen, D. Q., Pettitt, P. B., Richards, M., Sykes, B. C., Ivanovich, M., Latham, A. & Debenham, N. 2000. Radiometric dating, stable isotopes and DNA. In S. Aldhouse-Green (ed.), *Paviland Cave and the 'Red Lady': A definitive report*, 61–80. Bristol: Western Academic and Specialist Press Limited.

Bradley, C., Baker, A., Cumberland, S., Boomer, I. & Morrissey, I. P. 2007. Dynamics of water movement and trends in dissolved carbon in a headwater wetland in a permeable catchment. *Wetlands* 27, 1066–1080. DOI: https://doi.org/10.1672/0277-5212(2007)27[1066:DOWMAT]2.0.CO;2

Bradley, C., Grapes, T., Bassell, L., Brown, A. T. G. & Boomer, I. 2012. *Hydrological assessment of Star Carr catchment, Yorkshire*. English Heritage Report.

Brennand, M. & Taylor, M. 2003. The survey and excavation of a Bronze Age timber circle at Holme-next-the-Sea, Norfolk, 1998–9. *Proceedings of the Prehistoric Society* 69, 1–84. DOI: https://doi.org/10.1017/S0079497X00001250.

Bridault, A. 1992. The status of elk during the Mesolithic. In A. Grant (ed.), *Animals and their products in trade and exchange. Anthropozoologica*, 151–160. Paris: Éditions du Centre National de la Recherche Scientifique.

Briederman, L. 1965. Les composantes de l'alimentation du sanglier en Europe Centrale. *Rapports du VIIème Congrès de l'Union des Biologistes du Gibier 1965*, 207–213. Belgrade: L'Union des Biologistes du Gibier.

Brindley, G. W. 1952. Structural mineralogy of clays. *Clays and Clay Minerals* 1, 33–43.

Brinkhuizen, D. C. 2006. Fish. In L. P. Louwe Kooijmans & P. F. B. Jongste (eds.), *Schipluiden, a Neolithic settlement on the Dutch North Sea coast c. 3500 cal BC*, 449–470. Leiden: Analecta praehistorica Leidensia 37/38.

British Geological Survey. 2016. *Geology of Britain Viewer*. Online resource. Available at: http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Last accessed 15 September 2017].

Brock, F., Higham, T., Ditchfield, P. & Bronk Ramsey, C. 2010. Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU). *Radiocarbon* 52(1), 103–112. DOI: https://doi.org/10.1017/S0033822200045069.

Brockmann-Jerosch, H. 1917. Die ältesten Nutz- und Kulturpflanzen. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* 62, 80–102.

Broholm, H. C. 1924. Nye fund fra den ældste stenalder, Holmegaard og Sværdborgfundene. *Aarbøger for Nordisk Oldkyndighed og Historie* 1924, 1–144.

Bronk Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon* 37, 425–430. DOI: https://doi.org/10.1017/S0033822200030903.

Bronk Ramsey, C. 1998. Probability and dating. *Radiocarbon* 40, 461–474. DOI: https://doi.org/10.1017/S0033822200018348.

Bronk Ramsey, C. 2008. Deposition models for chronological records. *Quaternary Science Review* 27, 42–60. DOI: https://doi.org/10.1016/j.quascirev.2007.01.019.

Bronk Ramsey, C. 2009a. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* 51, 1023–45. DOI: https://doi.org/10.1017/S0033822200034093.

Bronk Ramsey, C. 2009b. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 37–60. DOI: https://doi.org/10.1017/S0033822200033865.

Bronk Ramsey, C. & Hedges, R. E. M. 1997. Hybrid ion sources: Radiocarbon measurements from microgram to milligram. *Nuclear Instruments and Methods in Physics Research B* 123, 539–545. DOI: https://doi.org/10.1016/S0168-583X(96)00612-X.

Bronk Ramsey, C., Higham, T. F. G., Bowles, A. & Hedges, R. E. M. 2004a. Improvements to the pre-treatment of bone at Oxford. *Radiocarbon* 46, 155–163. DOI: https://doi.org/10.1017/S0033822200039473.

Bronk Ramsey, C., Higham, T. F. G. & Leach, P. 2004b. Towards high-precision AMS: Progress and limitations. *Radiocarbon* 46, 17–24. DOI: https://doi.org/10.1017/S0033822200039308.

Bronk Ramsey, C., Higham, T. F. G., Owen, D. C., Pike, A. W. G. & Hedges, R. E. M. 2002. Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 31. *Archaeometry* 44, 1–149. DOI: https://doi.org/10.1111/j.1475-4754.2002.tb01101.x.

Bronk Ramsey, C. & Lee, S. 2013. Recent and planned developments of the program OxCal. *Radiocarbon* 55, 720–30. DOI: https://doi.org/10.1017/S0033822200057878.

Bronk Ramsey, C., Pettitt, P. B., Hedges, R. E. M., Hodgins, G. W. L. & Owen, D. C. 2000. Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 29. *Archaeometry* 42, 243–254. DOI: https://doi.org/10.1111/j.1475-4754.2000.tb00880.x.

Brooks, S. J. 2006. Fossil midges (*Diptera: Chironomidae*) as palaeoclimatic indicators of the Eurasian region. *Quaternary Science Reviews* 25, 1894–1910. DOI: https://doi.org/10.1016/j.quascirev.2005.03.021.

Brooks, S. J. & Birks, H. J. B. 2001. Chironomid-inferred air temperatures from late-glacial and Holocene sites in north-west Europe: Progress and problems. *Quaternary Science Reviews* 20, 1723–1741. DOI: https://doi.org/10.1016/S0277-3791(01)00038-5.

Brooks, S. J., Langdon, P. G. & Heiri, O. 2007. *The identification and use of Palaearctic Chironomidae larvae in palaeoecology. QRA Technical Guide No. 10.* London: Quaternary Research Association.

Brown, A. G. 1997. Clearances and clearings: Deforestation in Mesolithic/Neolithic Britain. *Oxford Journal of Archaeology* 16, 133–146. DOI: https://doi.org/10.1111/1468-0092.00030.

Brown, T. A., Nelson, D. E., Vogel, J. S. & Southon J. R. 1988. Improved collagen extraction by modified Longin method. *Radiocarbon* 30, 171–177. DOI: https://doi.org/10.1017/S0033822200044118.

Brown, T., Bradley, C., Grapes, T. & Boomer, I. 2013. Hydrological assessment of Star Carr and the Hertford Catchment, Yorkshire, UK. *Journal of Wetland Archaeology* 11, 36–55. DOI: https://doi.org/10.1179/jwa.2011.11.1.36.

Brown, W. A. B. & Chapman, N. G. 1991a. Age assessment of fallow deer (*Dama dama*): From a scoring system scheme based on radiographs of developing permanent molariform teeth. *Journal of Zoology* 224, 367–379. DOI: https://doi.org/10.1111/j.1469-7998.1991.tb06031.x.

Brown, W. A. B. & Chapman, N. G. 1991b. Age assessment of red deer (*Cervus elaphus*): From a scoring system scheme based on radiographs of developing permanent molariform teeth. *Journal of Zoology* 225, 85–97. DOI: https://doi.org/10.1111/j.1469-7998.1991.tb03803.x.

Brunning, R. 2007. Mesolithic worked wood. In M. Bell (ed.), *Prehistoric coastal communities: The Mesolithic in western Britain*, 125–130. York: Council of British Archaeology Research Report 149.

Brunning, R. & Watson, J. 2010. *Waterlogged wood: Guidelines on the recording, sampling, conservation and curation of waterlogged wood*. London: English Heritage.

Brunskill, R. W. 1985. *Timber building in Britain.* London: Victor Gollancz.

Bu, K., Cizdziel, J. V. & Russ, J. 2013. The source of iron-oxide pigments used in Pecos river style rock paints. *Archaeometry* 55(6), 1088–1100. DOI: https://doi.org/10.1111/arcm.12011.

Buck, C. E., Cavanagh, W. G. & Litton, C. D. 1996. *Bayesian approach to interpreting archaeological data*. Chichester: Wiley.

Buckley, M., Collins, M., Thomas-Oates, J. & Wilson, J. C. 2009. Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry. *Rapid Communications in Mass Spectrometry* 23(23), 3843–3854. DOI: https://doi.org/10.1002/rcm.4316.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G. & Tursina, T. 1985. *Handbook for soil thin section description.* Wolverhampton: Waine Research.

Burov, G. M. 1989. Some Mesolithic wooden artifacts from the site of Vis I in the European north east of the U.S.S.R. In C. Bonsall (ed.), *The Mesolithic in Europe: Papers presented at the Third International Symposium, Edinburgh, 1985*, 391–401. Edinburgh: John Donald.

Burov, G. M. 1998. The use of vegetable materials in the Mesolithic of Northeast Europe. In M. Zvelebil, L. Domańska & R. Dennell (eds.), *Harvesting the sea, farming the forest: The emergence of Neolithic societies in the Baltic region*, 53–63. Sheffield: Sheffield Academic Press.

Cabanes, D., Gadot, Y., Cabanes, M., Finkelstein, I. & Weiner, S. 2012. Human impact around settlement sites: a phytolith and mineralogical study for assessing site boundaries, phytolith preservation, and implications for special reconstructions using plant remains. *Journal of Archaeological Science* 39, 2697–2705. DOI: https://doi.org/10.1016/j.jas.2012.04.008.

Campbell, G., Moffett, L. & Straker, V. 2011. *Environmental archaeology. A guide to the theory and practice of methods, from sampling and recovery to post-excavation. 2nd edition.* London: English Heritage.

Canetti, E. 1984. *Crowds and Power*, New York: Farrar, Straus and Giroux.

Care, V. 1979. The production and distribution of Mesolithic axes in southern England. *Proceedings of the Prehistoric Society* 45, 93–102. DOI: https://doi.org/10.1017/S0079497X00009683.

Carpasso, L. 1998. 5300 years ago, the ice man used natural laxatives and antibiotics. *Lancet* 352(9143), 1864. DOI: https://doi.org/10.1016/S0140-6736(05)79939-6.

Carter, R. J. 1997. Age estimation of the roe deer (*capreolus capreolus*) mandibles from the Mesolithic site of Star Carr, Yorkshire, based on radiographs of mandibular tooth development. *Journal of Zoology* 241(3), 495–502. DOI: https://doi.org/10.1111/j.1469-7998.1997.tb04841.x.

Carter, R. J. 1998. Reassessment of seasonality at the Early Mesolithic Site of Star Carr, Yorkshire, based on radiographs of mandibular tooth development in red deer (*cervus elaphus*). *Journal of Archaeological Science* 25(9), 851–856. DOI: https://doi.org//10.1006/jasc.1997.0230.

Catt, A. C. 1987. The Quaternary of East Yorkshire and adjacent areas. In S. Ellis (ed.), *East Yorkshire field guide.* Cambridge: Quaternary Research Association.

Caulfield, S. 1978. Star Carr: An alternative view. *Irish Archaeological Research Forum* 5, 15–22.

Cave-Browne, P. 1992. The use of iron-pyrites for the creation of fire. *Lithics – The Journal of the Lithic Studies Society* 13, 52.

Chairkina, N. M., Savchenko, S. N., Serikov, Y. B. and Litvyak, A. S. 2001. *Arkheologicheskie Pamyatniki Shigirskogo Torfyankia [The Archaeological Sites of the Shigirsky Peatbog].* Yekaterinburg: Bank Kulturnoi Informatsii.

Chapela, I. & Lizon, I. 1993. Fungi in the Stone Age. *The Mycologist* 7(3), 123. DOI: https://doi.org/10.1016/S0269-915X(09)80070-0.

Chatterton, R. 2003. Star Carr reanalysed. In L. Bevan & J. Moore (eds.), *Peopling the Mesolithic in a northern environment*, 69–80. Oxford: British Archaeological Reports International Series S1157.

Christen, J. A., Clymo, R. S. & Litton, C. D. 1995. A Bayesian approach to the use of 14C dates in the estimation of the age of peat. *Radiocarbon* 37, 431–442. DOI: https://doi.org/10.1017/S0033822200030915.

Christensen, C. 1999. Mesolithic boats from around the Great Belt, Denmark. In B. Coles, J. Coles & M. S. Jørgensen (eds.), *Bog bodies, sacred sites and wetland archaeology: proceedings of a conference held by WARP and the National Museum of Denmark, in conjunction with Silkeborg Museum, Jutland, September 1996*, 47–50. Exeter: University of Exeter, WARP Occasional Paper 12.

Clapham, A. R., Tutin, T. G. & Moore, D. M. 1989. *Flora of the British Isles. 3rd edition.* Cambridge: Cambridge University Press.

Clark, J. G. D. 1936. *The Mesolithic settlement of northern Europe: A study of the food-gathering peoples of northern Europe during the early post-glacial period.* New York: Greenwood Press.

Clark, J. G. D. 1939. *Archaeology and Society. Reconstructing the Prehistoric Past*. London: Methuen & Co. Ltd.

Clark, J. G. D. 1949. A preliminary report on excavations at Star Carr, Seamer, Scarborough, Yorkshire, 1949. *Proceedings of the Prehistoric Society* 15, 52–69. DOI: https://doi.org//10.1017/S0079497X00019198.

Clark, J. G. D. 1950. A preliminary report on excavations at Star Carr, Seamer, Scarborough, Yorkshire (second season, 1950). *Proceedings of the Prehistoric Society* 16, 109–129. DOI: https://doi.org/10.1017/S0079497X00018958.

Clark, J. G. D. 1954. *Excavations at Star Carr: An early Mesolithic site at Seamer near Scarborough, Yorkshire.* Cambridge: Cambridge University Press.

Clark, J. G. D. 1972. *Star Carr: A case study in bioarchaeology.* Reading: Addison-Wesley Modular Publications.

Clark, J. G. D. & Godwin, H. 1956. A Maglemosian site at Brandesburton, Holderness, Yorkshire. *Proceedings of the Prehistoric Society* 22, 6–22. DOI: https://doi.org/10.1017/S0079497X0001714X.

Clarke, A. & Waddington, C. 2007. Bevelled pebbles and other stone artefacts. In C. Waddington (ed.), *Mesolithic settlement in the North Sea basin: A case study from Howick, north-east England*, 110–119. Oxford: Oxbow Books.

Cloutman, E. W. 1988a. Palaeoenvironments in the Vale of Pickering. Part I: Stratigraphy and palaeogeography of Seamer Carr, Star Carr and Flixton Carr. *Proceedings of the Prehistoric Society* 54, 1–19. DOI: https://doi.org/10.1017/S0079497X00005727.

Cloutman, E. W. 1988b. Palaeoenvironments in the Vale of Pickering. Part 2: Environmental history at Seamer Carr. *Proceedings of the Prehistoric Society* 54, 21–36. DOI: https://doi.org/10.1017/S0079497X00005739.

Cloutman, E. & Smith, A. G. 1988. Palaeoenvironments in the Vale of Pickering. Part 3: environmental history at Star Carr. *Proceedings of the Prehistoric Society* 54, 37–58. DOI: https://doi.org/10.1017/S0079497X00005740.

Clutton-Brock, J. & Noe-Nygaard, N. 1990. New osteological and C-isotope evidence on Mesolithic dogs: Companions to hunters and fishers at Star Carr, Seamer Carr and Kongemose. *Journal of Archaeological Science* 17, 643–653. DOI: https://doi.org/10.1016/0305-4403(90)90046-8.

Coles, B. 2006. *Beavers in Britain's past*. Oxford: WARP Occasional Paper 19.

Coles, B. 2010. The European beaver. In T. O'Connor & N. Sykes (eds.), *Extinctions and invasions: A social history of British fauna*, 104–115. Oxford: Oxbow.

Coles, J. M. & Orme, B. Y. 1978. Structures south of Meare Island. *Somerset Levels Papers* 4, 90–100.

Coles, J. M. & Orme, B. Y. 1984. Ten excavations along the Sweet Track (3200 BC). *Somerset Levels Papers* 10, 4–45.

Collins, M. J., Nielsen-Marsh, C. M., Hiller, J., Smith, C. I., Roberts, J. P., Prigodich, R. V., Weiss, T. J., Csapo, J., Millard, A. R. & Turner-Walker, G. 2002. The survival of organic matter in bone: A review. *Archaeometry* 44, 383–394. DOI: https://doi.org/10.1111/1475-4754.t01-1-00071.

Colonese, A. C., Farrell, T., Lucquin, A., Firth, D., Charlton, S., Robson, H. K., Alexander, M. & Craig, O. E. 2015. Archaeological bone lipids as palaeodietary markers. *Rapid Communications in Mass Spectrometry* 29, 1–8. DOI: https://doi.org/10.1002/rcm.7144.

Conneller, C. J. 2004. Becoming deer. Corporeal transformations at Star Carr. *Archaeological Dialogues* 11(1), 37–56. DOI: https://doi.org/10.1017/S1380203804001357.

Conneller, C. J. 2011. *An archaeology of materials: substantial transformations in early prehistoric Europe*. Oxford: Routledge.

Conneller, C. J. & Higham, T. 2015. Dating the early Mesolithic: new results from Thatcham and Seamer Carr. In N. Ashton & C. R. E. Harris (eds.), *No stone unturned: papers in honour of Roger Jacobi*, 157–166. London: Lithic Studies Society.

Conneller, C. J. & Schadla-Hall, T. 2003. Beyond Star Carr: the Vale of Pickering in the 10th millennium BP. *Proceedings of the Prehistoric Society* 69, 1–23. DOI: https://doi.org/10.1017/S0079497X00001262.

Conneller, C. J., Milner, N., Schadla-Hall, T., Taylor, B. & Crombe, P. 2009. The temporality of the Mesolithic landscape: New work at Star Carr. In P. Crombe (ed.), *Mesolithic chronologies*, 77–94. Newcastle-upon-Tyne: Cambridge Scholars' Publishing.

Conneller, C. J., Milner, N., Taylor, B. & Taylor, M. 2012. Substantial settlement in the European Early Mesolithic: New research at Star Carr. *Antiquity* 86(334), 1004–1020. DOI: https://doi.org/10.1017/S0003598X00048213.

Conneller, C. J., Bayliss, A., Milner, N. & Taylor, B. 2016. The resettlement of the British landscape: towards a chronology of Early Mesolithic lithic assemblage types. *Internet Archaeology* 42. DOI: https://doi.org/10.11141/ia.42.12.

Cook, J. & Barton, R. 1986. Dating late Devensian-early Flandrian barbed points. In J. A. J. Gowlett & R. E. M. Hedges (eds.), *Archaeological results from accelerator dating*, 87–89. Oxford: University of Oxford Committee for Archaeology.

Corkhill, T. 1979. *A glossary of wood.* London: Stobart and Son.

Corner, E. J. H. 1950. Report on the fungus-brackets from Star Carr, Seamer. *Proceedings of the Prehistoric Society* 16, 123–124. DOI: https://doi.org/10.1017/S0079497X00018958.

Coutard, S., Ducrocq, T., Limondin-Lozouet, N., Bridault, A., Leroyer, C., Allenet, G. & Pastre, J.-F. 2010. Contexte géomorphologique chronostratigraphique et paléoenvironmental des sites Mésolithiques et

Paléolithiques de Warluis dans la Vallée du Thérain (Oise, France). *Quaternaire* 21(4), 357–384. DOI: https://doi.org/10.4000/quaternaire.5702.

Cox, M. L. 2007. *Atlas of the seed and leaf beetles of Britain and Ireland.* Newbury: Pisces.

Craig, O. E., Saul, H., Lucquin, A., Nishida, Y., Taché, K., Clarke, L., Thompson, A., Altoft, D. T., Uchiyama, J., Ajimoto, M., Gibbs, K., Isaksson, S., Heron, C. P. & Jordan, P. 2013. Earliest evidence for the use of pottery. *Nature* 496(7445), 351–354. DOI: https://doi.org/10.1038/nature12109.

Cristiani, E., Živaljević, I. & Borić, D. 2014. Residue analysis and ornament suspension techniques in prehistory: Cyprinid pharyngeal teeth beads from Late Mesolithic burials at Vlasac (Serbia). *Journal of Archaeological Science* 46, 292–310. DOI: https://doi.org/10.1016/j.jas.2014.03.018.

Croft, S. 2017. *Mesolithic hunter-gatherers at the micro scale: Lithic residue analysis at Star Carr, North Yorkshire.* Unpublished PhD, University of York.

Croft, S. & Mathewes, R. W. 2014. Barking up the right tree: Understanding birch bark artifacts from the Canadian Plateau, British Columbia. *BC Studies* 180, 83–122.

Croft, S., Monnier, G., Radini, A., Little, A. & Milner, N. 2016. Lithic residue survival and characterisation at Star Carr: A burial experiment. *Internet Archaeology* 42. DOI: https://doi.org/10.11141/ia.42.5.

Crombé, P., Perdaen, Y., Sergant, J. & Caspar, J.-P. 2001. Wear analysis on Early Mesolithic microliths from the Verrebroek site, East Flanders, Belgium. *Journal of Field Archaeology* 28(3/4), 253–269. DOI: https://doi.org/10.1179/jfa.2001.28.3-4.253.

Crone, A. 1987. Tree-ring studies and the reconstruction of woodland management practices in antiquity. In G. C. Jacoby & J. W. Holmbneck (eds.), *Proceedings of the International Symposium on Ecological Aspects of Tree-Ring Analysis*, 327–336. New York: U.S. Department of Energy.

Cummins, G. 2003. *Impacts of hunter-gatherers on the vegetation history of the Eastern Vale of Pickering, Yorkshire*. University of Durham. PhD.

Dal, H. 2002. An in situ fireplace from the Mesolithic period at "Ronæs Skov" in the Gamborg Fjord. *NAU* 9, 29–34.

Dark, P. 1998a. Palaeoecological investigations. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the early Mesolithic site of Star Carr, North Yorkshire*, 111–120. Cambridge: McDonald Institute for Archaeological Research.

Dark, P. 1998b. Lake-edge sequences: Results. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire,* 125–146. Cambridge: McDonald Institute for Archaeological Research.

Dark, P. 1998c. The lake-centre sequence: Results. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire,* 163–178. Cambridge: McDonald Institute for Archaeological Research.

Dark, P. 2000. Revised "absolute" dating of the Early Mesolithic site of Star Carr, North Yorkshire, in light of the changes in Early Holocene tree-ring chronology. *Antiquity* 74, 304–307, https://doi.org/10.1017/S0003598X00059330.

Dark, P. 2003. Dogs, a crane (not duck) and diet at Star Carr: A response to Schulting and Richards. *Journal of Archaeological Science* 30, 1353–1356, DOI: https://doi.org/10.1016/S0305-4403(03)00026-8.

Dark, P., Higham, T. F. G., Jacobi, R. & Lord, T. C. 2006. New radiocarbon accelerator dates from the Early Mesolithic site of Star Carr, North Yorkshire. *Archaeometry* 48(1), 185–200. DOI: https://doi.org/10.1111/j.1475-4754.2006.00250.x.

Darling, W. G. 2004. Hydrological factors in the interpretation of stable isotopic proxy data present and past: A European perspective. *Quaternary Science Reviews* 23, 743–770. DOI: https://doi.org/10.1016/j.quascirev.2003.06.016.

David, A. 1998. Two assemblages of later Mesolithic microliths from Seamer Carr, North Yorkshire: Fact and fancy. In N. Ashton, F. Healy & P. Pettitt (eds.), *Stone age archaeology: Essays in honour of John Wymer,* 196–204. Oxford: Oxbow Monograph 102.

David, A. 2007. *Palaeolithic and Mesolithic settlement in Wales: With special reference to Dyfed.* Oxford: British Archaeological Reports British Series S448.

David, A. & Walker, E. A. 2004. Wales during the Mesolithic period. In C. Bonsall (ed.), *Mesolithic Scotland and its neighbours: The early Holocene prehistory of Scotland, its British and Irish context, and some northern European perspectives*, 229–337. Edinburgh: Edinburgh University Press.

David, E. 2005. *Technologie osseuse des derniers chasseurs préhistoriques en Europe du Nord (Xe-VIIIe millénaires avant J.-C.). Le Maglemosien et les technocomplexes du Mésolithique.* Thesis, Universitie Paris I.

David, E., St-Pierre, C. G. & Walker, R. B. 2007. Technology on bone and antler industries: A relevant methodology for characterizing early post-glacial societies (9th–8th millennium BC). In C. G. St-Pierre & R. B. Walker (eds.), *Bones as tools: Current methods and interpretations in worked bone studies*, 35–50. Oxford: British Archaeological Reports International Series S1622.

Davis-King, S. 1980. A note on new barbed points from Brandesburton, North Humberside. *Archaeological Journal* 137, 22–26. DOI: https://doi.org/10.1080/00665983.1980.11078477.

Day, P. 1996a. Devensian Late-Glacial and early Flandrian environmental history of the Vale of Pickering, Yorkshire, England. *Journal of Quaternary Science* 11, 9–24 https://doi.org/10.1002/(SICI)1099-1417(199601/02)11:1<9::AID-JQS210>3.0.CO;2-5.

Day, S. P. 1996b. Dogs, deer and diet at Star Carr: A reconsideration of C-isotope evidence from Early Mesolithic dog remains from the Vale of Pickering, Yorkshire, England. *Journal of Archaeological Science* 23, 783–787. DOI: https://doi.org/10.1006/jasc.1996.0072.

Day, S. P. & Mellars, P. 1994. Absolute dating of Mesolithic human activity at Star Carr, Yorkshire: new palaeoecological studies and identification of the 9600 bp radiocarbon 'plateau'. *Proceedings of the Prehistoric Society* 60, 417–422. DOI: https://doi.org/10.1017/S0079497X00003509.

De Bie, M. & Caspar, J. P. 2000. *Rekem: a Federmesser camp on the Meuse river bank.* Leuven: Leuven University Press.

Dee, M. & Bronk Ramsey, C. 2000. Refinement of graphite target production at ORAU. *Nuclear Instruments and Methods in Physics Research B* 172, 449–53. DOI: https://doi.org/10.1016/S0168-583X(00)00337-2.

Degerbøl, M. 1961. On a find of a Preboreal domestic dog (*Canis familiaris L.*) from Star Carr, Yorkshire, with remarks on other Mesolithic dogs. *Proceedings of the Prehistoric Society* 27, 35–55. DOI: https://doi.org/0.1017/S0079497X0001598X.

DeNiro, M. J. 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317, 806–809. DOI: https://doi.org/10.1038/317806a0.

Deur, D. & Turner, N. J. 2005. *Keeping it living: Traditions of plant use and cultivation on the northwest coast of North America.* Vancouver: The University of British Columbia Press.

Dimbleby, G. 1978. *Plants and archaeology: The archaeology of the soil.* London: Granada Publishing Limited.

Ding, C. & He, X. 2004. K-means clustering via principal component analysis. In C. Brodley (ed.), *Proceedings of the 21st International Conference on Machine Learning*, 225–232. Alberta: ACM.

Dobronika, L. J. 1988. *A field guide in colour: Mammals.* London: Octopus Books Ltd.

Dore, C. D. & López-Varela, S. L. 2010. Kaleidoscopes, palimpsests, and clay: Realities and complexities in human activities and soil chemical/residue analysis. *Journal of Archaeological Method and Theory* 17(3), 279–302. DOI: https://doi.org/10.1007/s10816-010-9092-x.

Dörr, H., Kromer, B. & Münnich, K. O. 1989. Fast 14C sample preparation of organic material, *Radiocarbon* 31, 264–8. DOI: https://doi.org/10.1017/S0033822200011784.

Dresser, Q. 1985. University College Cardiff radiocarbon dates I. *Radiocarbon* 27, 338–85. DOI: https://doi.org/10.1017/S0033822200007128.

Drucker, D. G., Bridault, A., Hobson, K. A., Szuma, E. & Bocherens, H. 2008. Can carbon-13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. *Palaeogeography, Palaeoclimatology, Palaeoecology* 266, 69–82. DOI: https://doi.org/10.1016/j.palaeo.2008.03.020.

Du Bois, C. 1936. Wintu ethnography. *American Archaeology and Ethnology* 36, 1–148.

Duff, A. (ed.). 2012. *Checklist of beetles of the British Isles.* Wells, Somerset: Privately printed.

Dumont, J. V. 1983. An interim report of the Star Carr microwear study. *Oxford Journal of Archaeology* 2(2), 127–145. DOI: https://doi.org/10.1111/j.1468-0092.1983.tb00102.x.

Dumont, J. V. 1988. *A microwear analysis of selected artifact types from the Mesolithic sites of Star Carr and Mount Sandel.* Oxford: British Archaeological Reports S187.

Dumont, J. V. 1989. Star Carr: The results of a micro-wear study. In C. Bonsall (ed.), *The Mesolithic in Europe: papers presented at the Third International Symposium, Edinburgh, 1985*, 231–240. Edinburgh: John Donald Publishers Ltd.

Dunbar, E., Cook, G. T., Naysmith, P., Tripney, B. G. & Xu, S. 2016. AMS 14C dating at the Scottish Universities Environmental Research Centre (SUERC) radiocarbon dating laboratory. *Radiocarbon* 58, 9–23. DOI: https://doi.org/10.1017/RDC.2015.2.

Durand, N., Monger, H. C. & Canti, M. G. 2010. Calcium carbonate features. In G. Stoops, V. Marcelino, F. Mees (eds.), *Interpretation of micromorphological features of soils and regoliths*, 149–194. Amsterdam: Elsevier.

Durden, T. 1995. The production of specialised flintwork in the later Neolithic: a case study from the Yorkshire Wolds. *Proceedings of the Prehistoric Society* 61, 409–432. DOI: https://doi.org/10.1017/S0079497X00003157.

Dypvik, H. 1984. Geochemical compositions and depositional conditions of Upper Jurassic and Lower Cretaceous Yorkshire clays, England. *Geological Magazine* 121, 489–504. DOI: https://doi.org/10.1017/S0016756800030028.

Earwood, C. 1993. *Domestic wooden artefacts in Britain and Ireland from Neolithic to Viking times.* Exeter: University of Exeter Press.

Edlin, H. L. 1973. *Woodland crafts in Britain.* Trowbridge: Redwood Press.

Edson, G. 2005. *Masks and masking: faces of tradition and belief worldwide*. Jefferson, NC: McFarland.

Edwards, C. J., Ho, S. Y. W., Barnett, R., Coxon, P., Bradley, D. G., Lord, T. C. & O'Connor, T. 2014. Continuity of brown bear maternal lineages in northern England through the Last-glacial Period. *Quaternary Science Reviews* 96, 131–139. DOI: https://doi.org/10.1016/j.quascirev.2013.10.015.

Elliott, B. 2009. *Artefact biographies of the Star Carr barbed points*. University of York. Masters dissertation.

Elliott, B. 2012. *Antlerworking practices in Mesolithic Britain*. PhD, University of York.

Elliott, B. 2014. Facing the chop: Redefining British antler mattocks to consider larger-scale maritime networks in the early fifth millennium cal BC. *European Journal of Archaeology* 0(0), 1–23. DOI: https://doi.org/10.1179/1461957114Y.0000000077.

Elliott, B. & Milner, N. 2010. Making a point: A critical review of the barbed point manufacturing process practised at Star Carr. *Proceedings of the Prehistoric Society* 76, 75–94. DOI: https://doi.org/10.1017/S0079497X00000451.

Elwes, H. J. & Henry, A. H. 1909. *The trees of Great Britain and Ireland. 1st edition.* Edinburgh: R. & R. Clark.

Entwistle, J. A. & Abrahams, P. W. 1997. Multi-element analysis of soils and sediments from Scottish historical sites. The potential of inductively coupled plasma-mass spectrometry for rapid site investigation. *Journal of Archaeological Science* 24(5), 407–416. DOI: https://doi.org/10.1006/jasc.1996.0125.

Entwistle, J. A., Abrahams, P. W. & Dodgshon, R. A. 2000. The geoarchaeological significance and spatial variability of a range of physical and chemical soil properties from a former habitation site, Isle of Skye. *Journal of Archaeological Science* 27, 287–303. DOI: https://doi.org/10.1006/jasc.1999.0453.

Entwistle, J. A., McCaffrey, K. J. W. & Dodgshon, R. A. 2007. Geostatistical and multi-elemental analysis of soils to interpret land-use history in the Hebrides, Scotland. *Geoarchaeology* 22(4), 391–415. DOI: https://doi.org/10.1002/gea.20158.

ESRI. nd. *How grouping analysis works.* [Online]. Environmental Science Research Institute. Available at: https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/how-grouping-analysis-works.htm [Last accessed 15 September 2017].

Fagan, B. M. & van Noten, F. L. 1966. Wooden implements from Late Stone Age sites at Gwisho hot–springs, Lochinvar, Zambia. *Proceedings of the Prehistoric Society* 32, 246–261. DOI: https://doi.org/10.1017/S0079497X00014407.

Fandén, A. 2005. Ageing the beaver (*Castor fiber L.*): A skeletal development and life history calendar based on epiphyseal fusion. *Archaeofauna* 14, 199–213.

Fengel, D. & Wegener, W. 1984. *Wood: Chemistry, ultrastructure, reactions.* Berlin: Walter de Gruyter & Co.

Feulner, F. 2010. *Die spätmesolithischen und frühneolithischen Fundplätze im Satrupholmer Moor, Kr. Schleswig-Flensburg. Rekonstruktion einer Siedlungskammer*. PhD, Universität zu Kiel.

Feulner, F. 2011. The Late Mesolithic bark floor of the wetland site of Rüde 2, Schleswig-Holstein, Germany. *Journal of Wetland Archaeology* 11, 109–119. DOI: https://doi.org/10.1179/jwa.2011.11.1.109.

Feulner, F. 2012. Evidence of fishing in the Satrup bog, Kr. Schleswig-Flensburg, Germany. *Quartär* 59, 165–174. DOI: https://doi.org/10.7485/QU59_7.

Field, A. 2009. *Discovering statistics using SPSS. 3rd edition.* London: SAGE Publications.

Fienup-Riordan, A. 1987. The mask: The eye of the dance. *Arctic Archaeology* 24(2), 40–55.

Findlay, W. P. K. 1967. *Wayside and woodland fungi.* London: Warne.

Finlay, N. 2004. Newton, Islay (Killarow & Kilmeny parish), geophysical survey. In R. Turner (ed.), *Discovery and excavation in Scotland. Volume 5*, 29. Edinburgh: Council for Scottish Archaeology.

Finlay, N. 2007. Port Lobh, Colonsay, Argyll and Bute (Colonsay and Oronsay parish), geophysical survey, test excavation. In R. Turner (ed.), *Discovery and excavation in Scotland. Volume 8,* 36–37. Edinburgh: Council for Scottish Archaeology.

Finlay, N. & McAllen, L. 2008. Geophysical survey at Sand, Applecross. In K. Hardy & C. Wickham-Jones (eds.), *Scottish archaeological internet reports* 31(3.17). Available at https://doi.org/10.5284/1000285.

Fischer, A. & Pedersen, L. 1997. Site records. In L. Pedersen, A. Fischer, B. Aaby (eds.), *The Danish Storebælt since the Ice Age*, 319–324. Copenhagen: A/S Storebælt Fixed Link.

Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, Á. E. & Bennike, P. 2007. Coast-inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. *Journal of Archaeological Science* 34, 2125–2150. DOI: https://doi.org/10.1016/j.jas.2007.02.028.

Florian, M. L. E. 1990. Scope and history of archaeological wood. In R. M. Rowell & R. J. Barbour (eds.), *Archaeological wood properties, chemistry and preservation*, 3–32. Washington, DC: American Chemical Society.

Ford, J. R., Hughes, L, Burke, H. F. & Lee, J. R. 2015. *The Vale of Pickering: An initial summary of the Quaternary/superficial geology and data holdings.* British Geological Survey Open Report OR/15/064.

Forestry Commission. nd. *Alder buckthorn.* [Online]. The Forestry Commission. Available at: http://www.forestry.gov.uk/pdf/WyreFOD_alder-buckthorn-acc.pdf/$FILE/WyreFOD_alder-buckthorn-acc.pdf [Last accessed 15 September 2017].

Foster, G. N. & Friday, L. E. 2011. *Keys to the adults of the water beetles of Britain and Ireland (Part 1). Handbooks for the identification of British insects 4(5), 2nd edition.* Shrewsbury: Royal Entomological Society/ Field Studies Council.

Foster, G. N., Bilton, D. T. & Friday, L. E. 2014. *Keys to the adults of the water beetles of Britain and Ireland (part 2). Handbooks for the identification of British insects 4(5b).* Telford: Royal Entomological Society/Field Studies Council.

Foster, S. W. 1985. *The late glacial and early post glacial history of the Vale of Pickering and northern Yorkshire Wolds.* PhD, University of Hull.

Fraser, F. C. & King, J. E. 1954. Faunal remains. In J. G. D. Clark (ed.), *Excavations at Star Carr: An early mesolithic site at Seamer near Scarborough, Yorkshire*, 70–95. Cambridge: Cambridge University Press.

Fretheim, S. E. 2009. Feast in the forest: Creating a common cultural identity in the interior of the Scandinavian Peninsula in the Late Mesolithic. In S. McCartan, R. Schulting, G. Warren & P. Woodman (eds.), *Mesolithic horizons: Papers presented at the Seventh International Conference on the Mesolithic in Europe, Belfast 2005*, 378–384. Oxford: Oxbow Books.

Froom, R. 2012. *The Mesolithic of the Kennet Valley*. Reading: Martin Marwood.

Gaffney, C. & Gater, J. 2003. *Revealing the buried past: Geophysics for archaeologists.* Stroud: Tempus.

Garnweidner, E. 2013. *Mushrooms and toadstools of Britain and Europe.* London: HarperCollins Publishers Ltd.

Gifford, E. 1936. Northeastern and western Yavapai. *American Archaeology and Ethnology* 36, 247–354.

Gillespie, R., Hedges, R. E. M. & White, N. R. 1983. The Oxford radiocarbon accelerator facility. *Radiocarbon* 25, 729–37. DOI: https://doi.org/10.1017/S003382220000607X.

Godet, J. D. & Mitchell, A. 1988. *Collins photographic key to the trees of Britain and northern Europe: a guide to identification by leaves and needles.* London: Collins.

Godwin, H. & Willis, E. H. 1959. Cambridge University natural radiocarbon measurements, I. *Radiocarbon* 1, 63–75. DOI: https://doi.org/10.1017/S0033822200020373.

Gooder, J. 2007. Excavation of a Mesolithic house at East Barns, East Lothian, Scotland: An interim view. In C. Waddington & K. Pedersen*, Mesolithic studies in the North Sea basin and beyond. Proceedings of a conference held at Newcastle in 2003,* 49–59. Oxford: Oxbow Books.

Gordon, C. C. & Buikstra, J. E. 1981. Soil-pH, bone preservation, and sampling bias at mortuary sites. *American Antiquity* 46, 566–571. DOI: https://doi.org/10.2307/280601.

Gordon-Williams, J. P. 1926. The Nab Head chipping floor. *Archaeologia Cambrensis* 81, 86–111.

Gramsch, B. 1973. Das Mesolithikum im Flachland zwischen Elbe und Oder. Teil I. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 7, 1–172.

Gramsch, B. 1987a. Ausgrabungen auf dem mesolithischen Moorfundplatz bei Friesack, Bezirk Potsdam. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 21, 75–100.

Gramsch, B. 1987b. Zeugnisse menschlicher Aktivitäten in Verbindung mit dem spätglazialzeitlichen Ur-Fund am Schlaatz bei Potsdam. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 21, 47–57.

Gramsch, B. 1992. Friesack Mesolithic wetlands. In B. Coles (ed.), *The wetland revolution in prehistory*, 65–72. Exeter: The Prehistoric Society and WARP.

Gramsch, B. 1993. Ein mesolithischer Birkenrindenbehälter von Friesack. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 27, 7–15.

Gramsch, B. 1998. Mesolithische Wasserlöcher in Brandenburg. In B. Beyer (ed.), *Brunnen der Jungsteinzeit. Internationales Symposium in Erkelenz 27. bis 29. Oktober 1997*, 17–23. Köln: Materialien zur Bodendenkmalpflege im Rheinland 11.

Gramsch, B. 2011. Die mesolithischen Knochenspitzen von Friesack, Fundplatz 4, Lkr. Havelland. Teil 2: die Knochenspitzen des späten Prä-, des Früh- und Spätboreals sowie des älteren Atlantikums. *Veröffentlichungen zur brandenburgischen Landesarchäologie* 43/44, 7–84.

Gramsch, B. 2016. Die Artefakte aus Holz und Baumrinde vom Mesolithischen Moorfundplatz Friesack 4, Lkr. Havelland. *Veröffentlichungen zur brandenburgischen Landesarchäologie* 47(2013), 7–54.

Gramsch, B. & Kloss, K. 1989. Excavations near Friesack: An Early Mesolithic marshland site in the northern plain of Central Europe. In C. Bonsall (ed.), *The Mesolithic in Europe: Papers presented at the Third International Symposium*, 313–324. Edinburgh: John Donald Publishers.

Greatrex, P. A. 1983. Interpretation of macrofossil assemblages from surface sampling of macroscopic plant remains in mire communities. *Journal of Ecology* 71(3), 773–791. DOI: https://doi.org/10.2307/2259592.

Griffitts, J. & Bonsall, C. 2001. Experimental determination of antler and bone "bevel-ended tools" from prehistoric shell middens in western Scotland. In A. M. Choyke & L. Bartosiewicz (eds.), *Crafting bone: Skeletal technologies through time and space. Proceedings of the 2nd meeting of the (ICAZ) Worked Bone Research Group. Budapest, 31 August – 5 September 1999*, 207–220. Oxford: British Archaeological Reports International Series S937.

Grigson, C. 1981. Fauna. In I. Simmons & M. Tooley (eds.), *The environment in prehistory*, 110–124. London: Duckworth.

Grigson, C. 1982. Sex and age determination of some bones and teeth of domestic cattle: A review of the literature. In B. Wilson, C. Grigson & S. Payne (eds.), *Ageing and sexing animal bones from archaeological sites*, 7–19. Oxford: British Archaeological Report, British Series 109.

Groenman-van Waateringe, W., Kilian, M. & van Londen, H. 1999. The curing of hides and skins in European prehistory. *Antiquity* 73(282), 884–890. DOI: https://doi.org/10.1017/S0003598X00065637.

Groß, D. 2014. *Welt und Umwelt frühmesolithischer Jäger und Sammler. Mensch-Umwelt-Interaktion im Frühholozän in der nordmitteleuropäischen Tiefebene.* PhD, Christian-Albrechts-Universität zu Kiel.

Grøn, O. 1983. Social behaviour and settlement structure. Preliminary results of a distribution analysis on sites of the Maglemose Culture. *Journal of Danish Archaeology* 2, 32–42, https://doi.org/10.1080/0108464X.1983.10589890.

Grøn, O. 2003. Mesolithic dwelling places in South Scandinavia: their definition and social interpretation. *Antiquity* 77(298), 685–708. DOI: https://doi.org/10.1017/S0003598X00061640.

Grøn, O. & Skaarup, J. 1995. Excavation of a Mesolithic dwelling in a submerged landscape. Preliminary report. *NewsWARP* 17 (May), 28–31.

Guiry, E. J. 2012. Dogs as analogs in stable isotope-based human palaeodietary reconstructions: a review and considerations for future use. *Journal of Archaeological Method and Theory* 19, 351–376. DOI: https://doi.org/10.1007/s10816-011-9118-z.

Gumiński, W. 2012. Nowe wyjątkowe siedlisko osadnicze paraneolitycznej kultury Zedmar na wschodnim cyplu wyspy Szczepanki (sektor „A") na Mazurach. Światowit IX(L) (2011)/B, 87–144.

Gustavs, S. 1987. Das Ur-Skelett von Potsdam-Schlaatz. Der archäologische Befund. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 21, 31–36.

Habermehl, K. H. 1961. *Die Altersbestimmung bei Haustieren, Pelztieren und beim jagdbaren Wild.* Berlin: Paul Parcy.

Hadley, P., Hall, A., Taylor, M. & Needham, A. 2010. To block lift or not to block lift? An experiment at the Early Mesolithic site of Star Carr, north-east Yorkshire, UK. *Internet Archaeology* 28. DOI: https://doi.org/10.11141/ia.28.2.

Hansen, M. 1987. *The Hydrophiloidea (Coleoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica 18*. Leiden: Brill.

Harrison, C. 1987. A re-examination of the Star Carr birds. *Naturalist* 112, 141.

Hart, C. & Raymond, C. 1973. *British trees in colour*. London: Michael Joseph.

Hartz, S. & Kraus, H. 2009. Fischfang in der Ertebølle-Kultur. Beispiele von Küsten- und Inlandsiedlungen Schleswig-Holsteins. In U. Müller, S. Kleingärtner & F. Huber (eds.), *Zwischen Nord- und Ostsee 1997-2007. Zehn Jahre Arbeitsgruppe für maritime und limnische Archäologie (AMLA) in Schleswig Holstein*, 209–224. Bonn: Universitätsforschungen zur prähistorischen Archäologie. Aus dem Institut für Ur-und Frühgeschichte der Universität Kiel, Band 165.

Hartz, S. & Lübke, H. 1999. Paddelfunde aus der Mittel-und Jungsteinzeit Schleswig-Holsteins. In E. Cziesla, T. Kersting & S. Pratsch (eds.), *Den Bogen spannen: Festschrift für Bernhard Gramsch zum 65. Geburtstag. Beiträge zur Ur- und Frühgeschichte Mitteleuropas 20/1*, 147-160. Weissbach: Beier and Beran.

Hartz, S. & Lübke, H. 2000. Stone Age paddles from Northern Germany. Basic implements of waterborne subsistence and trade. In F. Lüth, U. Schoknecht, O. Nakoinz, H. Beer, C. Börker, H. Schlichtherle, T. Förster, M. Mainberger & J. Riederer (eds.), *Schutz des Kulturerbes unter Wasser: Veränderungen europäischer Lebenskultur durch Fluß- und Seehandel. Beiträge zum Internationalen Kongreß für Unterwasserarchäologie (IKUWA '99), 18–21. February 1999 in Sassnitz auf Rügen. Beiträge zur Ur- und Frühgeschichte Mecklenburg-Vorpommern 35*, 377–387. Lübstorf: Archäologisches Landesmuseum und Landesamt für Bodendenkmalpflege Mecklenburg-Vorpommern.

Haslam, S. M. 1970. The performance of *Phragmites communis* Trin. in relation to water supply. *Annals of Botany* 34, 867–77. DOI: https://doi.org/10.1093/oxfordjournals.aob.a084418.

Haslam, S. M. 1972. Stem types of *Phragmites communis* Trin.. *Journal of Ecology* 60(2), 585–610.

Haslett, J. & Parnell, A. 2008. A simple monotone process with application to radiocarbon-dated depth chronologies. *Applied Statistics* 57, 399–418. DOI: https://doi.org/10.1111/j.1467-9876.2008.00623.x.

Hather, J. G. 1998. Identification of macroscopic charcoal assemblages. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*, 183–196. Cambridge: McDonald Institute.

Hausmann, N., Bokelmann, K., Erkul, E., Funkenberg, C., Gorski, L., Gryziecki, R., Höfgen, W., Lübke, H., Rabbel, W., Stümpel, H., Wilken, D. & Wunderlich, T. 2012. *Explorative, geophysical surveys at the Mesolithic site Duvensee, Germany: First results*. Poster presentation: Wild Things Conference 2012, Durham, UK. DOI: https://doi.org/10.13140/RG.2.1.4505.1769.

Haynes, G. 1983. A guide for differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. *Paleobiology* 9(2), 164–172. DOI: https://doi.org/10.1017/S0094837300007545.

Healy, F. 1988. *The Anglo-Saxon cemetery at Spong Hill, North Elmham, part VI: Occupation during the seventh to second millennia BC*. Norfolk: East Anglian Archaeology 39.

Hedges, R. E. M. 1981. Radiocarbon dating with an accelerator: Review and preview. *Archaeometry* 23, 1–18. DOI: https://doi.org/10.1111/j.1475-4754.1981.tb00951.x.

Hedges, R. E. M. 2002. Bone diagenesis: An overview of processes. *Archaeometry* 44, 319–328. DOI: https://doi.org/10.1111/1475-4754.00064.

Hedges, R. E. M. & Law, I. 1989. The radiocarbon dating of bone. *Applied Geochemistry* 4, 249–254. DOI: https://doi.org/10.1016/0883-2927(89)90025-5.

Hedges, R. E. M. & Pettitt, P. B. 1998. On the validity of archaeological radiocarbon dates beyond 30,000 years BP. *Mémoires de la Société préhistorique française* 26, 137–141.

Hedges, R. E. N., Housley, R. A., Law, I. A., Perry, C. & Gowlett, J. A. J. 1987. Radiocarbon dates from the Oxford AMS System: Archaeometry date list 6. *Archaeometry* 29(2), 289–306. DOI: https://doi.org/10.1111/arcm.12134.

Hedges, R. E. M., Bronk Ramsey, C. & Housley, R. A. 1989. The Oxford accelerator mass spectrometry facility: technical developments in routine dating, *Archaeometry* 31, 99–113. DOI: https://doi.org/10.1111/j.1475-4754.1989.tb01007.x.

Hedges, R. E. M., Housley, R. A., Bronk Ramsey, C. & Klinken, G. J. van. 1992. Radiocarbon dates from the Oxford AMS system: Archaeometry date list 14. *Archaeometry* 34(1), 141–159. DOI: https://doi.org/10.1111/j.1475-4754.1992.tb00484.x.

Hedges, R. E. M., Housley, R. A., Bronk Ramsey, C. & Klinken, G. J. van. 1994. Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 18. *Archaeometry* 36(2), 337–374. DOI: https://doi.org/10.1111/j.1475-4754.1994.tb00975.x.

Hedges, R. E. M., Millard, A. R. & Pike, A. W. G. 1995. Measurements and relationships of diagenetic alteration of bone from three archaeological sites. *Journal of Archaeological Science* 22, 201–209. DOI: https://doi.org/10.1006/jasc.1995.0022.

Heinen, M. 2014. Waldjäger – das Mesolithikum im Rheinland. In LVR-LandesMuseum Bonn (ed.), *Eiszeitjäger. Leben im Paradies – Europa vor 15.000 Jahren*, 289–311. Mainz: Nünnerich-Asmus Verlag.

Henson, D. 1982. *Flint as a raw material in prehistory.* M.Phil thesis, University of Sheffield.

Hernek, R. & Nordqvist, B. 1995. *Världens Äldsta Tuggummi? Ett urval spännande arkeologiska fynd och upptäckter som gjordes vid Huseby Klev, och andra platser, inför väg 178 över Orust.* Kungsbacka: Riksantikvarieämbetet Bryån for Arkeologiska Undersökningar.

Hewison, A. J. M., Vincent, J. P., Angibault, J. M., Delorme, D., Laere, G. van & Gaillard, J. M. 1999. Tests of estimation of age from tooth wear on roe deer of known age: variation within and among populations. *Canadian Journal of Zoology* 77(1), 98–183. DOI: https://doi.org/10.1139/z98-183.

High, K. 2014. *Fading star: understanding accelerated decay of organic archaeological remains at Star Carr.* PhD, University of York.

High, K., Milner, N., Panter, I. & Penkman, K. E. H. 2015. Apatite for destruction: investigating bone degradation due to high acidity at Star Carr. *Journal of Archaeological Science* 59, 159–168. DOI: https://doi.org/10.1016/j.jas.2015.04.001.

High, K., Penkman, K. E. H., Milner, N. & Panter, I. 2016a. Fading star: towards understanding the effects of acidification on organic remains (wood) at Star Carr. *Proceedings of the 12th ICOM-CC-WOAM conference (Istanbul 2013).*

High, K., Milner, N., Panter, I., Demarchi, B. & Penkman, K. E. H. 2016b. The vulnerability of organic archaeological remains to environmental change: a lesson from Star Carr. *Proceedings of the National Academy of Sciences of the United States of America*, vol. 113, (46), 12957–12962. DOI: https://doi.org/10.1073/pnas.1609222113.

High, H., Milner, N., Panter, I, Knight, B. & Penkman, K. E. H. In press. An assessment of post-excavation changes observed in bone and wood artefacts from Star Carr. *Proceedings of the 13th ICOM-CC-WOAM conference (Florence, 2016).*

Hill, E. 2011. Animals as agents: hunting ritual and relational ontologies in prehistoric Alaska and Chukotka. *Cambridge Archaeological Journal* 21(3), 407–426. DOI: https://doi.org/10.1017/S0959774311000448.

Hillson, S. 2005. *Teeth.* Cambridge: Cambridge Manuals in Archaeology.

Hirsch, K., Kloss, S. & Kloss, R. 2008. Der endmesolithisch-neolithische Küstensiedlungsplatz bei Baabe im Südosten der Insel Rügen. *Jahrbuch Bodendenkmalpflege in Mecklenburg-Vorpommern 55*, 11–51.

Holland, D. G. 1972. *A key to the larvae, pupae and adults of the British species of Elminthidae.* Westmorland: Freshwater Biological Association Scientific Publication 26.

Holst, D. 2007. *Subsistenz und Landschaftsnutzung im Frühmesolithikum: Nussröstplätze am Duvensee.* PhD, Johannes Gutenberg University Mainz.

Holst, D. 2010. Hazelnut economy of early Holocene hunter-gatherers: A case study from Mesolithic Duvensee, northern Germany. *Journal of Archaeological Science* 37, 2871–2880. DOI: https://doi.org/10.1016/j.jas.2010.06.028.

Homsey, L. K. & Capo, R. C. 2006. Integrating geochemistry and micromorphology to interpret feature use at Dust Cave, a Paleo-Indian through middle-archaic site in northwest Alabama. *Geoarchaeology* 21(3), 237–269. DOI: https://doi.org/10.1002/gea.20103.

Hopson, P. M. 2005. *A stratigraphical framework for the Upper Cretaceous Chalk of England and Scotland, with statements on the Chalk of Northern Ireland and the UK Offshore Sector.* Keyworth: British Geological Survey Research Report.

Humphrey, C. & Onon, U. 1996. *Shamans and elders. Experience, knowledge and power among the Daur Mongols.* Oxford: Clarendon Press.

Ingold, T. 1993. The temporality of the landscape. *World Archaeology* 25, 152–174. DOI: https://doi.org/10.1080/00438243.1993.9980235.

Inizan, M.-L., Roche, H. & Tixier, J. 1992. *Technology of knapped stone. Prehistoire de la Pierre Taillee, Tome 3.* Meudon: CREP.

Jacobi, R. 1976. Britain inside and outside Mesolithic Europe. *Proceedings of the Prehistoric Society* 42, 67-84. DOI: https://doi.org/10.1017/S0079497X00010707.

Jacobi, R. M. 1978. Northern England in the eighth millennium BC: An essay. In P. Mellars (ed.), *The early post-glacial settlement of Northern Europe*, 295–332. London: Duckworth.

Jacobi, R. M. 1980. The early Holocene settlement of Wales. In J. A. Taylor (ed.), *Culture and Environment in Prehistoric Wales*. Oxford: British Archaeological Reports, British Series 76, 131–206.

Jacobi, R. M. 1981. The last hunters in Hampshire. In S. J. Shennan & R. T. Schadla-Hall (eds.), *The archaeology of Hampshire*, 10–25. Winchester: Hampshire Field Club and Archaeological Society.

Jacobi, R. M. nd. *Jacobi archive.* London: British Museum BM[FH]/RMJ.

Jane, F. W. 1970. *The structure of wood. 2nd edition.* London: A&C Black.

Jenke, M. 2009. *Duvensee, Kreis Herzogtum Lauenburg. Neuvorstellung einer Altgrabung.* Masters dissertation, University of Hamburg.

Jenke, M. 2011. Ausgrabungen im Duvenseer Moor, Kreis Herzogtum Lauenburg – zur Rekonstruktion einer Altgrabung. *Hammaburg N.F.* 16, 9–78.

Jensen, G. 1991. Unusable axes? An experiment with antler axes of the Kongemose and Ertebølle cultures. In B. Madsen (ed.), *Eksperimentel Arkæologi: Studier i teknologi og kultur*, 9–21. Lejre: Historisk-Arkæologisk Forsøgscenter.

Jessop, L. 1986. *Dung beetles and chafers. Coleoptera: Scarabaeoidea. Handbooks for the identification of British insects 5(11).* London: Royal Entomological Society.

Jin, J. & Shipman, P. 2010. Documenting natural wear on antlers: A first step in identifying use-wear on purported antler tools. *International Quaternary* 211(1), 91–102. DOI: https://doi.org/10.1016/j.quaint.2009.06.023.

Johansen, K. L. 2013. Wooden stakes and rods. In S. H. Andersen (ed.), *Tybrind Vig: submerged Mesolithic settlements in Denmark*, 343–348. Højbjerg: Jutland Archaeological Society Publications Volume 77.

Johansson, A. D. 1990. *Barmose-Gruppen. Praeboreale bopladsfund i Sydsjælland.* Aarhus: Aarhus Universitetsforlag.

Juggins, S. 2010. *C2 1.66 Software for Ecological and Palaeoecological Data Analysis and Visualisation.* [Computer program]. Available at: https://www.staff.ncl.ac.uk/stephen.juggins/software/C2Home.htm

Jørgenson, S. 1985. Tree felling with original Neolithic flint axes in Draved Wood. *Bulletin of Experimental Archaeology* 7, 17–18.

Karkanas, P. 2002. Ash bones and guano: A study of minerals and phytoliths in the sediments of Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 29(7), 721–732. DOI: https://doi.org/10.1006/jasc.2001.0742.

Karsten, P. & Knarrström, B. 2003. *The Tågerup excavations.* Lund: National Heritage Board, Sweden.

Karsten, P. & Regnell, M. 1995. Bökeberg III – intryck och avtryck från en senmesolitisk inlandboplats. *Limhamniana* 1995, 72–83.

Keeley, L. H. 1980. *Experimental determination of stone tool uses: A microwear analysis.* London: University of Chicago Press.

Kenward, H. 1997. Synanthropic decomposer insects and the size, remoteness and longevity of archaeological occupation sites: Applying concepts from biogeography to past 'islands' of human occupation. In A. C. Ashworth, P. C. Buckland, & J. T. Sadler (eds.), *Studies in quaternary entomology: An inordinate fondness for insects. Quaternary Proceedings 5,* 135–152. Chichester: Wiley.

Kenward, H. K. & Large, F. 1998. Recording the preservational condition of archaeological insect fossils. *Environmental Archaeology* 2, 49–60. DOI: https://doi.org/10.1179/env.1997.2.1.49.

Kenward, H. K., Hall, A. R. & Jones, A. K. G. 1980. A tested set of techniques for the extraction of plant and animal macrofossils from waterlogged archaeological deposits. *Science and Archaeology* 22, 3–15.

Kenward, H. K., Hall, A. R. & Jones, A. K. G. 1986. *Environmental evidence from a Roman well and Anglian pits in the legionary fortress. The archaeology of York volume 14: The past environment of York. Fascicule 5,* 241–288. London: Council for British Archaeology.

Kerr, P. F. 1952. Formation and occurrence of clay minerals. *Clays and Clay Minerals* 1, 19–32.

Kilian, M., van Geel, B. & van der Plicht, J. 2000. 14C AMS wiggle matching of raised bog deposits and models of peat accumulation. *Quaternary Science Reviews* 19(10), 1011–1033. DOI: https://doi.org/10.1016/S0277-3791(99)00049-9.

Klein, R. G. & Cruz-Uribe, K. 1984. *The analysis of animal bones from archaeological sites*. Chicago: University of Chicago Press.

Klooß, S. 2015. *Mit Einbaum und Paddel zum Fischfang: Holzartefakte von endmesolithischen und frühneolithischen Küstensiedlungen an der südwestlichen Ostseeküste.* Kiel: Wachholtz (Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein 6).

Koff, T. & Vandel, E. 2008. Spatial distribution of macrofossil assemblages in surface sediments of two small lakes in Estonia. *Estonian Journal of Ecology* 57(1), 5–20. DOI: https://doi.org/10.3176/eco.2008.1.01.

Koivisto, S. 2011. Prehistoric wetland archaeology in Finland: Sites and settlement in a changing environment. In E. Pranckėnaitė (ed.), *Wetland settlements of the Baltic: A prehistoric perspective*, 31–53. Vilnius: Centre for Underwater Archaeology.

Kotlaba, F. & Pouzar, Z. 1957. Notes on classification of European pore fungi. Česká Mykologie 11, 152–170.

Kragten, J. 1994. Tutorial review. Calculating standard deviations and confidence intervals with a universally applicable spreadsheet technique. *The Analyst* 119(10), 2161–2165. DOI: https://doi.org/10.1039/AN9941902161.

Kriiska, A. & Roio, M. 2011. Prehistoric archaeology of wetlands in Estonia. In E. Pranckėnaitė (ed.), *Wetland settlements of the Baltic: A prehistoric perspective*, 55–73. Vilnius: Centre for Underwater Archaeology.

Kroeger, P., Kendrick, B., Ceska, O. & Roberts, C. 2012. *Outer spores: Mushrooms of Haida Gwaii*. British Columbia: Mycologue Publications.

Kromer, B. & Becker, B. 1993. German oak and pine 14C calibration, 7200–9439 BC. *Radiocarbon* 35, 125–135. DOI: https://doi.org/10.1017/S0033822200013862.

Kromer, B. & Spurk, M. 1998. Revision and tentative extension of the tree-ring based 14C calibration, 9200–11,955 cal BP. *Radiocarbon* 40, 1117–1125. DOI: https://doi.org/10.1017/S0033822200019160.

Kromer B., Lindauer, S., Synal, H. A. & Wacker, L. 2013. MAMS – a new AMS facility at the Curt-Engelhorn Centre for Archaeometry, Mannheim, Germany. *Nuclear Instruments and Methods in Physics Research Section B* 294, 11–13. DOI: https://doi.org/10.1016/j.nimb.2012.01.015.

Kubiak-Martens, L. 1999. The plant food component of the diet at the late Mesolithic (Ertebølle) settlement at Tybrind Vig, Denmark. *Vegetarian History and Archaeology* 8, 117–127. DOI: https://doi.org/10.1007/BF02042850.

Lacaille, A. D. 1966. Mesolithic facies in the Transpontine Fringes. *Surrey Archaeological Collection* 66, 1–43.

Lane, P. & Schadla-Hall, R. 2004. The many ages of Star Carr: Do "cites" make the site? In A. Barnard (ed.) *Hunter-gatherers in history, archaeology and anthropology*, 145–162. Oxford: Berg.

Lane, P. & Schadla-Hall, R. T. Forthcoming. *Hunter-gatherers in the landscape: investigations of the Early Mesolithic in the Vale of Pickering, North Yorkshire. 1976–2000.*

Larsson, L. 1982. *Segebro: En tidigatlantisk boplats vid Sege ås mynning.* Malmö: Malmö Museum. Malmöfynd 4 Utgiven av Malmö Museum.

Larsson, L. 1983. *Ageröd V: An Atlantic bog site in Central Scania.* Lund: Acta Archaeologica Lundensia 8(12).

Larsson, L. & Sjöström, A. 2010. Mesolithic research in the bog Rönneholms mosse, southern Sweden. *Mesolithic Miscellany* 21(1), 2–9.

Larsson, L., Sjöström, A. & Heron, C. Forthcoming. The Rönneholm arrow – a find of a wooden arrow-tip with microliths in the bog Rönneholms mosse, central Scania, southern Sweden. *Lund Archaeological Review.*

Law, I. A. & Hedges, R. E. M. 1989. A semi-automated bone pretreatment system and the pretreatment of older and contaminated samples. *Radiocarbon* 31, 247–253. DOI: https://doi.org//10.1017/S0033822200011759.

Lawson, J. 1967. *A new voyage to Carolina (1709).* Kingsport: University of Carolina Press.

Lyman, R. L. 1994. *Vertebrate taphonomy.* Cambridge: Cambridge University Press.

Leduc, C. 2014. A specialized Early Maglemosian site at Lundby Mose (Zealand, Denmark): a contribution to the understanding of Maglemosian patterns of animal resource exploitation. *Journal of Archaeological Science* 41, 199–213. DOI: https://doi.org/10.1016/j.jas.2013.07.027.

Legge, A. J. & Rowley-Conwy, P. A. 1988. *Star Carr revisited*. London: Centre for Extra-Mural Studies, Birkbeck College, University of London.

Lesbre, F. X. 1897/8. Contribution a l'étude de l'ossification du squelette des mammiféres domestiques. *Annales de la Societé d'Agriculture, Science et Industrie de Lyon* 7(5), 1–106.

Lévi-Strauss, C. 1982. The way of the masks (trans. S. Modelski). London: Jonathan Cape.

Lewis, J. & Rackham, J. 2011. *Three Ways Wharf, Uxbridge: A lateglacial and early Holocene hunter-gatherer site in the Colne Valley*. London: Museum of London Archaeology.

Libby, W. F. 1952. *Radiocarbon dating*. Chicago: Chicago University Press.

Lillie, M. C., Zhilin, M., Shavchenko, S. & Taylor, M. 2005. Carpentry dates back to Mesolithic. *Antiquity* 79(305). Available at: http://www.antiquity.ac.uk/projgall/lillie/ [Last accessed 15 September 2017].

Lindbo, D. L., Stolt, M. H. & Vepraskas, M. J. 2010. Redoximorphic features. In G. Stoops, V. Marcelino & F. Mees (eds.), *Interpretation of micromorphological features of soils and regoliths*, 129–147. Amsterdam: Elsevier.

Linderholm, J. 2010. *The soil as a source material in archaeology. Theoretical considerations and pragmatic applications.* PhD, Umeå University.

Lindley, D. V. 1985. *Making decisions. 2nd edition.* London: Wiley.

Little, A. 2014. Clonava Island revisited: a story of cooking, plants and re-occupation during the Irish Late Mesolithic. *Proceedings of the Royal Irish Academy 114C*, 35–55. DOI: https://doi.org/10.3318/PRI-AC.2014.114.09.

Little, A., & van Gijn, A. 2017. Enigmatic plant-working tools and the transition to farming in the Rhine Meuse Delta. *Excerpta Archaeologica Leidensia II, Analecta Praehistorica Leidensia 47*, 2–9.

Little, A., Elliott, B., Conneller, C., Pomstra, D., Evans, A. A., Fitton, L. C., Holland, A., Davis, R., Kershaw, R., O'Connor, S., O'Connor, T., Sparrow, T., Wilson A. S., Jordan, P., Collins, M. J., Colonese, A. C., Craig, O. E., Knight, R., Lucquin, A. J. A., Taylor, B. & Milner, N. 2016. Technological analysis of the world's earliest shamanic costume: a multi-scalar, experimental study of a red deer headdress from the Early Holocene site of Star Carr, North Yorkshire, UK. *PloS One* 11(4), e0152136. DOI: https://doi.org/10.137/journal.pone.0152136.

Lord, J. 1998. The methods used to produce a complete harpoon. In N. Ashton, F. Healy & P. Pettitt (eds.), *Stone Age archaeology: Essays in honour of John Wymer*, 193–196. Oxford: Oxbow Books.

Lotz, P. 2008. 50 år på havbunden. *Fund and Fortid* 1.

Louwe Kooijmans, L. P. 2001. *Hardinxveld-Giessendam de bruin. Een kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur (5500–4450 v. Chr.).* Amersfoort: Rapportage Archeologische Monumentenzorg 88.

Lozovskaya, O. V. & Lozovski, V. M. 2015. Multipurpose tools from beaver jaws, Zamostje 2 site: technology of manufacturing and use. In O. V. Lozovskaya, V. M. Lozovski & E. J. Giri (eds.), *Traces in the history: dedicated to 75 anniversary of Viacheslav E. Shchelinsky*, 163–180. St. Petersburg: Russian Academy of Science, Institute for the History of Material Culture.

Lozovskaya, O. V. and Lozovski, V. M. 2016. The Use of Wood at the Zamostje 2 Site. In P. Uino and K. Nordqvist (eds.), *New Sites, New Methods: Proceedings of the Finnish-Russian Archaeological Symposium, Helsinki, 19–21 November, 2014*, 59–74. Helsinki: Suomen Muinaismuistoyhdistys ry – Finska Fornminnesföreningen rf-The Finnish Antiquarian Society.

Lozovski, V. M., Lozovskaya, O. V. & Conte, I. C. 2013. *Zamostje 2: Lake settlement of the Mesolithic and Neolithic fisherman in Upper Volga region*. Saint Petersburg: Institute for the History of Material Culture, Russian Academy of Sciences.

Luff, M. L. 2007. *The Carabidae (ground beetles) of Britain and Ireland. Handbooks for the identification of British insects 4(2), 2nd edition.* Shrewsbury: Royal Entomological Society/Field Studies Council.

Lyman, R. L. 1994. *Vertebrate taphonomy*. Cambridge: Cambridge University Press.

Læssø, T. 2013. *Mushrooms and toadstools: The definitive guide to fungi.* London: Dorling Kindersley Ltd.

Madella, M., Powers-Jones, A. H. & Jones M. K. 1998. A simple method of extraction of opal phytoliths from sediments using a nontoxic heavy liquid. *Journal of Archaeological Science* 25, 801–803. DOI: https://doi.org/10.1006/jasc.1997.0226.

Madella, M., Jones, M. K., Goldberg, P., Goren, Y. & Hovers, E. 2002. The exploitation of plant resources by Neanderthals in Amud Cave (Israel): the evidence from phytolith studies. *Journal of Archaeological Science* 29, 703–719. DOI: https://doi.org/10.1006/jasc.2001.0743.

Madella, M., Alexandre, A. & Ball, T. 2005. International code for Phytolith nomenclature 1.0. *Annals of Botany* 96, 253–260. DOI: https://doi.org/10.1093/aob/mci172.

Madgett, P. A. & Catt, J. A. 1978. Petrography, stratigraphy and weathering of Late Pleistocene tills in East Yorkshire, Lincolnshire and North Norfolk. *Proceedings of the Yorkshire Geological Society* 42, 55–108. DOI: https://doi.org/10.1144/pygs.42.1.55.

Majerus, M. E. N. 1994. *Ladybirds.* London: HarperCollins.

Mason, S. L. R. 2004. Archaeobotanical analysis – Møllegabet II. In J. Skaarup & O. Grøn (eds.), *Møllegabet II: A submerged Mesolithic settlement in southern Denmark*, 122–143. Oxford: British Archaeological Reports S1328.

Mason, S. L. R. 2005. Fungus. In T. D. Price & A. B. Gebauer (eds.), *Smakkerup Huse: A late Mesolithic site in northwest Zealand, Denmark*, 82–83. Aarhus: Aarhus University Press.

Mason, S. L. R. & Hather J. G. 2002. Introduction: some issues in the archaeobotany of hunter-gatherers. In S. L. R. Mason & J. G. Hather (eds.), *Hunter-gatherer archaeobotany: Perspectives from the northern temperate zone*, 1–14. Oxford: Routledge.

Matschke, G. H. 1967. Aging European wild hogs by dentition. *Journal of Wildlife Management* 31, 109–113. DOI: https://doi.org/10.2307/3798365.

Mazel, A., Nash, G. and Waddington, C. (eds.) 2007. *Art as metaphor: Prehistoric rock art of Britain*. Archaeopress: Oxford.

Mazza, P. P. A., Martini, F., Sala, B., Magi, M., Colombini, M. P., Giachi, G., Landucci, F., Lemorini, C., Modugno, F. & Ribechini, E. 2006. A new Palaeolithic discovery: Tar-hafted stone tools in a European mid-Pleistocene bone-bearing bed. *Journal of Archaeological Science* 33(9), 1310–1318. DOI: https://doi.org/10.1016/j.jas.2006.01.006.

McQuade, M. & O'Donnell, L. 2007. Late Mesolithic fish traps from the Liffey estuary, Dublin, Ireland. *Antiquity* 81(313), 569–584. DOI: https://doi.org/10.1017/S0003598X00095594.

Mears, R. & Hillman, G. C. 2007. *Wild food*. London: Hodder and Stoughton.

Meijer, R. & Pomstra, D. 2011. The production of birch pitch with hunter-gatherer technology: A possibility. *Experimentelle Archäologie in Europa* 10, 199–204.

Mellars, P. 1976. Fire ecology, animal populations and man: A study of some ecological relationships in prehistory. *Proceedings of the Prehistoric Society* 42, 15–45. DOI: https://doi.org/10.1017/S0079497X00010689.

Mellars, P. 1990. A major 'plateau' in the radiocarbon timescale at c.9650 BP: The evidence from Star Carr (North Yorkshire). *Antiquity* 64, 836–841. DOI: https://doi.org/10.1017/S0003598X00078935.

Mellars, P. 1998. Investigation on the Dryland Areas. In Mellars P. & Dark P. (eds.) *Star Carr in context: New archaeological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*, 73–82. Cambridge: McDonald Institute for Archaeological Research.

Mellars, P. 2009. Moonshine over Star Carr: Post-processualism, Mesolithic myths and archaeological realities. *Antiquity* 83, 502–517. DOI: https://doi.org/10.1017/S0003598X00098616.

Mellars, P. & Dark, P. (eds.). 1998. *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire.* Cambridge: McDonald Institute for Archaeological Research.

Mellars, P., Schadla-Hall, T., Lane, P. & Taylor, M. 1998. The wooden platform. In P. Mellars & P. Dark (eds.), *Star Carr in context: new archaeological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*, 47–64. Cambridge: McDonald Institute for Archaeological Research.

Melton, N. D., Russ, H. & Johnson, D. S. 2014. *Excavation of a Mesolithic site at Kingsdale Head (SD712 799) by the Ingleborough Archaeology Group 2009–10.* Ingleborough via Carnforth: Ingleborough Archaeology Group.

Middleton, W. D. & Douglas Price, T. 1996. Identification of activity areas by multi-element characterization of sediments from modern and archaeological house floors using inductively coupled plasma-atomic emission spectroscopy. *Journal of Archaeological Science* 23, 673–687. DOI: https://doi.org/10.1006/jasc.1996.0064.

Mikołajczyk, Ł. & Schofield, J. E. 2016. A geochemical signal from a Mesolithic intertidal archaeological site: a proof-of-concept study from Clachan Harbor, Scotland. *Geoarchaeology*. DOI: https://doi.org/10.1002/gea.21606.

Milner, N. 1999. Pitfalls and problems in analysing and interpreting the seasonality of faunal remains. *Archaeological Review from Cambridge* 16(1), 51–67. http://eprints.whiterose.ac.uk/885/1/milnern1.pdf [Last accessed 15 September 2017].

Milner, N. 2005. Can seasonality studies be used to identify sedentism in the past? In D. Bailey, V. Cummings & A. Whittle (eds.), *(Un)settling the Neolithic*, 32–37. Oxford: Oxbow Books.

Milner, N. 2007. Fading star. *British Archaeology* 96, 10–14.

Milner, N. 2010. *Star Carr: An excavation to inform future management discussions. Project Design.* University of York: unpublished report. DOI: https://doi.org/10.5284/1041580.

Milner, N. 2011. *Star Carr revisited: A management strategy to support the proposed excavation of the Early Mesolithic occupation site in the Vale of Pickering, North Yorkshire.* University of York: unpublished report. DOI: https://doi.org/10.5284/1041580.

Milner, N., Conneller, C., Elliott, B., Koon, H., Panter, I., Penkman, K., Taylor, B. & Taylor, M. 2011. From riches to rags: organic deterioration at Star Carr. *Journal of Archaeological Science* 38, 2818–2832. DOI: https://doi.org/10.1016/j.jas.2011.02.015.

Milner, N., Taylor, B., Bamforth, M., Conneller, C., Elliott, B., High, K., Knight, B. & Taylor, M. 2013a. *Assessment report for Star Carr: Excavations 2013.* University of York: unpublished report. DOI: https://doi.org/10.5284/1041580.

Milner, N., Saul, H. & Elliott, B. 2013b. *Star Carr archives project.* York: Archaeology Data Service. DOI: https://doi.org/10.5284/1019856.

Milner, N., Taylor, B., Conneller, C. & Schadla-Hall, T. 2013c. *Star Carr: Life in Britain after the Ice Age.* York: Council for British Archaeology. DOI: https://doi.org/10.11141/AfA1.

Milner, N., Bamforth, M., Knight, B., Conneller, C., Taylor, B., Panter, I., Elliott, B., Little, A., Croft, S., Taylor, M., Craig, O. Rowley, C., French, C. 2014. *Assessment report for Star Carr: Excavations 2014.* University of York: unpublished report. DOI: https://doi.org/10.5284/1041580.

Milner, N., Bamforth, M., Beale, G., Carty, J. C., Chatzipanagis, K., Croft, S., Conneller, C., Elliot, B., Fitton, L. C., Knight, B., Kröger, R., Little, A., Needham, A., Robson, H. K., Rowley, C. C. A. & Taylor, B. 2016. A unique engraved shale pendant from the site of Star Carr: the oldest Mesolithic art in Britain. *Internet Archaeology* 40. DOI: https://doi.org/10.11141/ia.40.8.

Mithen, S. (ed.). 2000. *Hunter-gatherer landscape archaeology: The Southern Hebrides Mesolithic project 1988–1998.* Cambridge: McDonald Institute Monographs.

Mithen, S. 2011. *After the ice: A global human history, 20,000–5000 BC.* London: Weidenfeld & Nicolson.

Møhl, U. 1980. Elsdyrskeletterne fra Skottemarke og Farvbo. Skik og brug ved borealtidens jagter. *Aarbøger for Nordisk Oldkyndighed og Historie* 1978, 5–32.

Moore, K. M., Murray, M. L. & Schoeninger, M. J. 1989. Dietary reconstruction from bones treated with preservatives. *Journal of Archaeological Science* 16, 437–446. DOI: https://doi.org/10.1016/0305-4403(89)90018-6.

Morris, M. G. 2002. True weevils (part 1), Coleoptera Curculionoidea (Subfamilies Raymondionyminae to Smicronychinae), *Handbooks for the identification of British insects* 5 (17b). London: Royal Entomological Society.

Morris, M. G. 2008. True weevils (part 2), (Coleoptera: Curculionidae Ceutorhynchinae), *Handbooks for the identification of British insects* 5 (17c). Shrewsbury: Royal Entomological Society/Field Studies Council.

Morris, M. G. 2012. True weevils (part 3), (Coleoptera: Curculioninae, Baridinae, Orobitinae), *Handbooks for the identification of British insects* 5 (17d). Shrewsbury: Royal Entomological Society/Field Studies Council.

Moyne de Morgues, L. 1875. *Narrative of Le Moyne: An artist who accompanied the French expedition to Florida under Laudonnièr (1564).* Boston: Osgood & Co.

Murphy, C. P. 1986. *Thin section preparation of soils and sediments.* Berkhamsted: AB Academic.

Münnich, K. O. 1957. Heidelberg natural radiocarbon measurements I. *Science* 126, 194–199. DOI: https://doi.org/10.1126/science.126.3266.194.

Museum of London Archaeology Service. 1994. *Archaeological site manual. 3rd edition.* London: Museum of London.

Myers, A. 1989. Reliable and maintainable technological strategies in the Mesolithic of mainland Britain. In R. Torrence (ed.), *Time, energy and stone tools*, 78–91. Cambridge: Cambridge University Press.

Myrhøj, H. M. & Willemoes, A. 1997. Strandingsgods fra ældre stenalder. In L. Pedersen, A. Fischer & B. Aaby (eds.), *The Danish Storebælt since the Ice Age – man, sea and forest*, 157–166. Copenhagen: A/S Storebælt Fixed Link in co-operation with Kalundborg Regional Museum, the National Forest and Nature Agency the Ministry of Environment and Energy, and the National Museum of Denmark.

Nadeau, M. J., Schleicher, M., Grootes, P. M., Eerlenkeuser, H., Gottdang, A., Mous, D. J. W., Sarnthein J. M. & Willkomm, H. 1997. The Leibniz-Labor AMS facility at the Christian-Albrechts University, Kiel, Germany. *Nuclear Instruments & Methods in Physics Research B* 123, 22–30.

Nadeau, M. J., Grootes, P. M., Schleicher, M., Hasselberg, P., Rieck, A. & Bitterling, M. 1998. Sample throughput and data quality at the Leibniz-Labor AMS facility. *Radiocarbon* 40, 239–245. DOI: https://doi.org/10.1017/S0033822200018105.

Nash, G. 2012. Mechanisms of production and exchange: Early prehistoric perforated bead production and use in southwest Wales. *Time and Mind: The Journal of Archaeology, Consciousness and Culture* 5(1), 73–84. DOI: https://doi.org/10.2752/175169712X13195388365036.

Nau, B. 2004. *Guide to shieldbugs of the British Isles*. Shrewsbury: Field Studies Council.

Needham, A. 2007. *Star Carr soils analysis.* University of York: unpublished report.

Noe-Nygaard, N. 1973. The Vig bull: New information of the final hunt. *Bulletin of the Geological Society of Denmark* 22, 244–248.

Noe-Nygaard, N. 1975. Two shoulder blades with healed lesions from Star Carr. *Proceedings of the Prehistoric Society, 41,* 10-16. DOI: https://doi.org/10.1017/S0079497X00010872.

Noe-Nygaard, N. 1977. Butchering and marrow fracturing as a taphonomic factor in archaeological deposits. *Paleobiology* 3, 218–237. DOI: https://doi.org/10.1017/S0094837300005285.

Noe-Nygaard, N. 1983. A new find of brown bear (*ursus arctos*) from Star Carr and other finds in the late glacial and post glacial of Britain and Denmark. *Journal of Archaeological Science* 10, 317–325. DOI: https://doi.org/10.1016/0305-4403(83)90069-9.

Noe-Nygaard, N. 1988. δ13C-values of dog bones reveal the nature of changes in man's food resources at the Mesolithic-Neolithic transition, Denmark. *Chemical Geology (Isotope Geoscience Section)* 73, 87–96. DOI: https://doi.org/10.1016/0168-9622(88)90023-1.

Noe-Nygaard, N. 1995. *Ecological, sedimentary, and geochemical evolution of the late-glacial to postglacial Åmose lacustrine basin, Denmark.* Oslo: Scandinavian University Press.

Noe-Nygaard, N., Price, T. D. & Hede, S. U. 2005. Diet of aurochs and early cattle in southern Scandinavia: evidence from 15N and 13C stable isotopes. *Journal of Archaeological Science* 32, 855–871. DOI: https://doi.org/10.1016/j.jas.2005.01.004.

O'Connor, T. P. 1987. On the structure, chemistry and decay of bone, antler and ivory. In K. Starling & D. Watkinson (eds.), *Archaeological bone, antler and ivory: Proceedings of a conference held by UKIC archaeology section, December 1984*, 6–8. London: United Kingdom Institute for Conservation.

O'Connor, T. P. 2000. *The archaeology of animal bone*. Texas: A&M University Press.

Oonk, S., Slomp, C. P. & Huisman, D. J. 2009. Geochemistry as an aid in archaeological prospection and site interpretation: Current issues and research directions. *Archaeological Prospection* 16(1), 35–51. DOI: https://doi.org/10.1002/arp.344.

Oosten, J. 1992. Representing the spirits: The masks of the Alaskan Inuit. In J. Coote (ed.), *Anthropology, art and aesthetics*, 113–134. Oxford: Clarendon Press.

O'Regan, H. J., Lamb, A. L. & Wilkinson, D. M. 2016. The missing mushrooms: Searching for fungi in ancient human dietary analysis. *Journal of Archaeological Science* 75, 139–143. DOI: https://doi.org/10.1016/j.jas.2016.09.009.

Oshibkina, S. V. 1983. *Mesolit Basseyna Sukhony i Vostochnogo Prionezhia.* Moscow: Navka.

Oshibkina, S. V. 2007. Colonisation of the Russian European North in the Boreal period. In M. Masojć, T. Płonka, B. Ginter & S. K. Kozłowski (eds.), *Contributions to the Central European Stone Age*, 79–88. Wrocław: Uniwersytet Wrocławski Instytut Archeologii.

Otlet, R. L., Walker, A. J., Hewson, A. D. & Burleigh, R. 1980. 14C interlaboratory comparison in the UK: Experiment design, preparation, and preliminary results. *Radiocarbon* 22, 936–946. DOI: https://doi.org/10.1017/S0033822200010341.

Out, W. A., Vermeeren, C. & Hänninen, K. 2013. Branch age and diameter: Useful criteria for recognising woodland management in the present and past? *Journal of Archaeological Science* 40(11), 4083–4097. DOI: https://doi.org/10.1016/j.jas.2013.05.004.

Overton, N. J. 2014. *Memorable meetings in the Mesolithic: Tracing the biography of human-nonhuman relationships in the Kennet and Colne Valleys with social zooarchaeology*. PhD, University of Manchester.

Overton, N. J. 2016. More than skin deep: reconsidering isolated remains of 'fur bearing species' in the British and European Mesolithic. *Cambridge Archaeology Journal* 26(4), 561–578. DOI: https://doi.org/10.1017/S0959774316000391.

Overton, N. J. Forthcoming. Hunting beyond red deer: Exploring species patterning in Early Mesolithic faunal assemblages in Britain and northwest Europe. *Papers presented at the Ninth International Conference on the Mesolithic in Europe, Belgrade 2015.*

Overton, N. J. & Hamilakis, Y. 2013. A manifesto for a social zooarchaeology. Swans and other beings in the Mesolithic. *Archaeological Dialogues* 20(2), 111–136. DOI: https://doi.org/10.1017/S1380203813000159.

Overton, N. J. & Taylor, B. Forthcoming. Humans in the environment: Plants, animals and landscapes. *Journal of World Prehistory.*

Pales, L and Garcia, C. 1981a. *Atlas ostéologique pour servir à l'identification des mammifères du Quaternaire. II. Tête, rachis, ceintures scapulaire et pelvienne, membres: carnivores, homme.* Paris: Editions du Central National de la Recherche Scientifique.

Pales, L and Garcia, C. 1981b. *Atlas ostéologique pour servir à l'identification des mammifères du Quaternaire. II. Tête, rachis, ceintures scapulaire et pelvienne, membres: herbivores.* Paris: Editions du Central National de la Recherche Scientifique.

Pales, L and Lambert, C. 1971a. *Atlas ostéologique pour servir à l'identification des mammifères du Quaternaire. I. Les membres: carnivores.* Paris: Editions du Central National de la Recherche Scientifique.

Pales, L and Lambert, C. 1971b. *Atlas ostéologique pour servir à l'identification des mammifères du Quaternaire. I. Les membres: herbivores.* Paris: Editions du Central National de la Recherche Scientifique.

Palmer, A. P., Matthews, I. P., Candy, I., Blockley, S. P. E., Macleod, A., Darvill, C. M., Milner, N., Conneller, C. & Taylor, B. 2015. The evolution of Palaeolake Flixton and the environmental context of Star Carr, north-east Yorkshire: Stratigraphy and sedimentology of the Last Glacial-Interglacial Transition (LGIT) lacustrine sequences. *Proceedings of the Geologists' Association* 126, 50–59. DOI: https://doi.org/10.1016/j.pgeola.2014.10.002.

Patrick, W. H. & Mahaptra, I. C. 1968. Transformation and availability to rice of nitrogen and phosphorus in waterlogged soils. *Advances in Agronomy* 20, 323–359. DOI: https://doi.org/10.1016/S0065-2113(08)60860-3.

Pearsall, D. M. 1982. Phytolith analysis: Applications of a new paleoethnobotanical technique in archaeology. *American Anthropologist* 84(4), 862–871. DOI: https://doi.org/10.1525/aa.1982.84.4.02a00100.

Pearsall, D. M. 2010. *Paleoethnobotony: a handbook of procedures.* California: Left Coast Press Inc.

Pedersen, K. B. & Brinch Petersen, E. In press. Preboreal Elk Rituals at Lundby Mose, Skottemarke and Favrbo. In M. Sørensen & K. B. Pedersen (eds.), *Problems in Palaeolithic and Mesolithic research. Arkæologiske studier, Volume 12.* Copenhagen: University of Copenhagen.

Pedersen, M. A. 2011. *Not quite shamans: Spirit worlds and political lives in northern Mongolia.* New York: Cornell University Press.

Pedersen, R. L. 2014. *Finds handling process – at the Fehmarn Belt excavations.* Åbne Samlinger. Unpublished report. [Online]. Available at: http://aabne-samlinger.dk/media/497737/mlf_fundhaandtering_eng.pdf [Last accessed 15 September 2017].

Peintner, U. & Pöder, R. 2000. Ethnomycological remarks on the iceman's fungi. In S. Bortenschlager & K. Oeggl (eds.), *The iceman and his natural environment, palaeobotanical results*, 143–150. Vienna: Springer.

Pennacchio, M., Jefferson, L. V. & Havens, K. 2010. *Uses and abuses of plant-derived smoke: Its ethnobotany as hallucinogen, perfume, incense, and medicine.* Oxford: Oxford University Press.

Perdaen, Y., Sergant, J. & Crombé, P. 2004. *Early Mesolithic landscape-use and site-use in northwestern Belgium: The evidence from Verrebroek "Dok"*, 11–18. Oxford: BAR International Series S1302.

Pernet, H. 1992. *Ritual masks: Deceptions and revelations.* Columbia: University of South Carolina Press.

Pestle, W. J., Crowley, B. E. & Weirauch, M. T. 2014. Quantifying inter-laboratory variability in isotope analysis of ancient skeletal remains. *PLoS ONE* 9(7), e102844. DOI: https://doi.org/10.1371/journal.pone.0102844.

Peterson, S. E. 2009. *Retrieval of materials with water separation machines. INSTAP archaeological excavation manual 1.* Philadelphia: INSTAP Academic Press.

Philippsen, B. 2013. The freshwater reservoir effect in radiocarbon dating. *Heritage Science* 1, 24. DOI: https://doi.org/10.1186/2050-7445-1-24.

Phillips, R. 1981. *Mushrooms and other fungi of Great Britain and Europe: The most comprehensively illustrated book on the subject this century*. London: Pan Books Ltd.

Pinder, L. C. V. 1986. Biology of freshwater Chironomidae. *Annual Review of Entomology* 31, 1–23. DOI: https://doi.org/10.1146/annurev.en.31.010186.000245.

Piperno D. R. 2006. *Phytoliths: a comprehensive guide for archaeologists and palaeoecologists*. New York: Altamira Press.

Pitts, M. W. 1979. Hides and antlers: A new look at the gatherer-hunter site at Star Carr, North Yorkshire, England. *World Archaeology* 11(1), 32–42. DOI: https://doi.org/10.1080/00438243.1979.9979748.

Pitts, M. W. & Jacobi, R. M. 1979. Some aspects of change in flaked stone industries of the Mesolithic and Neolithic in southern Britain. *Journal of Archaeological Science* 6(2), 163–177. DOI: https://doi.org/10.1016/0305-4403(79)90060-8.

Pizzorno, A. 2010. The mask: An essay. *International Political Anthropology* 3(1), 5–28.

Pöder, R., Pümpel, T. & Peintner, U. 1994. The ice man. *The Mycologist* 8(1), 44. DOI: https://doi.org/10.1016/S0269-915X(09)80688-5.

Pollock, D. 1995. Masks and the semiotics of identity. *Journal of the Royal Anthropological Institute* 1(3), 581–597. DOI: https://doi.org/10.2307/3034576.

Pomstra, D. & van Gijn, A. 2013. The reconstruction of a Late-Neolithic house. *Bulletin of Primitive Technology* 45, 45–54.

Powers, A. H. 1992. Great expectations: A short historical review of European phytolith systematics. In G. Rapp & S. C. Mulholland (eds.), *Phytolith systematics*, 15–35. New York: Plenum Press.

Powers-Jones, A. H. 1994. The use of phytolith analysis in the interpretation of archaeological deposits: An Outer Hebridean example. In R. A. Luff & P. Rowley-Conwy (eds.), *Whither environmental archaeology*, 41–49. Oxford: Oxbow Books.

Powlesland, D., Lyall, J., Hopkinson, G., Donoghue, D., Beck, M., Harte, A. & Stott, D. 2006. Beneath the sand – remote sensing, archaeology, aggregates and sustainability: A case study from Heslerton, the Vale of Pickering, North Yorkshire, UK. *Archaeological Prospection* 13, 291–299. DOI: https://doi.org/10.1002/arp.297.

Preston, C. D. & Croft, J. M. 1997. *Aquatic plants in Britain and Ireland*. Harley Books: Colchester.

Price, T. D. 1982. Willow tales and dog smoke. *Quarterly Review of Archaeology* 3, 1–4. DOI: https://doi.org/10.2307/279653.

Price, T. D. & Gebauer, A. B. 2005. *Smakkerup Huse. A Late Mesolithic coastal site in northwest Zealand, Denmark*. Aarhus: Aarhus University Press.

Prior, R. 1968. *The roe deer of Cranbourne Chase*. Oxford: Oxford University Press.

Pryor, F. 1991. *Flag Fen: Prehistoric fenland centre*. Avon: English Heritage.

Purdue, J. R. 1983. Epiphyseal closure in white-tailed deer. *Journal of Wildlife Management* 47(4), 1207–1213. DOI: https://doi.org/10.2307/3808195.

Rackham, O. 1977. Neolithic woodland management in the Somerset Levels: Garvin's, Walton Heath and Rowland's tracks. *Somerset Levels Papers* 3, 65–71.

Rackham, O. 2006. *Woodlands*. London: Collins.

Radley, J. 1969. A note on four Maglemosian bone points from Brandesburton, and a flint site at Brigham, Yorkshire. *Journal of the Royal Society of Antiquaries of Ireland* 49(2), 377–378. DOI: https://doi.org/10.1017/S0003581500053841.

Radley, J. & Mellars, P. A. 1964. A Mesolithic structure at Deepcar, Yorkshire, England and the affinities of its associated flint industries. *Proceedings of the Prehistoric Society* 30, 1–24. DOI: https://doi.org/10.1017/S0079497X00015024.

Ramsbottom, J. 1923. *Handbook of the larger British fungi*. London: The Trustees Of The British Museum.

Rankine W. F. 1949. Pebbles of non-local rock from Mesolithic chipping floors. *Proceedings of the Prehistoric Society* 15, 188–90. DOI: https://doi.org/10.1017/S0079497X00019319.

Rankine, W. F. 1956. *The Mesolithic of southern England*. Surrey: Surrey Archaeological Society 4.

Rapp, G. & Mulholland, S. C. (eds.). 1992. *Phytolith systematics*. New York: Plenum Press.

Ray, D. J. 1967. *Eskimo masks: Art and ceremony*. Seattle: University of Washington Press.

Regert, M., Nicolas, G., Oreste, D., Cren-Olivé, C. & Rolando, C. 2003. Structural characterization of lipid constituents from natural substances preserved in archaeological environments. *Measurement Science and Technology* 14(9), 1620–1630. DOI: https://doi.org/10.1088/0957-0233/14/9/313.

Regnell, M., Gaillard, M., Bartholin, T. S. & Karsten, P. 1995. Reconstruction of environment and history of plant use during the Late Mesolithic (Ertebølle culture) at the inland settlement of Bökeberg III, Southern Sweden. *Vegetation History and Archaeobotany* 4, 67–91. DOI: https://doi.org/10.1007/BF00206916.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P., Bronk Ramsey, C., Buck, C. E., Cheng, H., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M. & Plicht, J. van der. 2013. Intcal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4), 1869–1887. DOI: https://doi.org/10.2458/azu_js_rc.55.16947.

Reynier, M. 2005. *Early Mesolithic Britain. Origins, development and directions*. Oxford: Archaeopress (British Archaeological Reports, British Series 393).

Rich, S., Watts, R. & Momber, G. 2016. Mesolithic woodworking, experimental archaeology and underwater heritage in Hampshire and the Isle of Wight. *Mesolithic Miscellany* 24(1), 3–12.

Richards, M. P. & Hedges, R. E. M. 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* 26, 717–722. DOI: https://doi.org/10.1006/jasc.1998.0387.

Richter, J. 1982. Faunal remains from Ulkestrup Lyng Øst: A hunter's dwelling place. In K. Andersen, S. Jorgensen & J. Richter (eds.), *Maglemose hytterne ved Ulkestrup Lyng*, 141–177. Copenhagen: Kongelige Nordiske Oldskriftselskab Volume 7.

Rimantiené, R. 1979. *Sventoji. Narvos kulturos gyvenvietes*. Vilnius: Lietuvos TSR Mokslu Akademijos Istorijos Institutas.

Rimantiené, R. 2005. *Die Steinzeitfischer an der Ostseelagune in Latauen. Forschungen in Sventoji und Butingé*. Vilnius: Litauisches Nationalmuseum.

Roberts, A. J., Barton, R. N. E. & Evans, J. G. 1998. The Early Mesolithic mastic radiocarbon dating and analysis of organic residues from Thatcham III, Star Carr and Lackford Heath. In N. M. Ashton, F. Healy & P. B. Pettie (eds.), *Stone Age archaeology: Essays in honour of John Wymer*, 185–192. Oxford: Oxbow Books.

Robson, H. K. 2016. New ichthyoarchaeological data from the Mesolithic lakeshore settlement site of Friesack IV. In N. Benecke, B. Gramsch & S. Jans (eds.), *Subsistenz und Umwelt der Feuchtbodenstation Friesack 4 im Havelland. Ergebnisse der naturwissenschaftlichen Untersuchungen,* 160–177. Brandenburg: Arbeitsberichte zur Bodendenkmalpflege in Brandenburg 29.

Robson, H. K., Little, A., Jones, A. K. G., Blockley, S., Candy, I., Matthews, I., Palmer, A., Schreve, D., Tong, E., Pomstra, D., Fletcher, L., Hausmann, N., Taylor, B., Conneller, C. & Milner, N. 2016. Scales of analysis: Evidence of fish and fish processing at Star Carr. *Journal of Archaeological Science: Reports*. DOI: https://doi.org/10.1016/j.jasrep.2016.02.009.

Rodwell, J. S. 1995. *British plant communities, Volume 4: Aquatic communities, swamps and tall herb fens*. Cambridge: Cambridge University Press.

Rosendahl, G., Beinhauera, K-W., Löscher, M., Kreipl, K., Walter, R. & Rosendahl, W. 2006. Le plus vieil arc du monde? Une pièce intéressante en provenance de Mannheim, Allemagne. *L'anthropologie* 110, 371–382. DOI: https://doi.org/10.1016/j.anthro.2006.06.008.

Rovner, I. 1983. Plant opal phytolith analysis: Major advances in archaeobotanical research. *Advances in Archaeological Method and Theory* 6, 225–266. DOI: https://doi.org/10.1016/B978-0-12-003106-1.50011-0.

Rowley, C. C. A. Forthcoming. *Early Mesolithic lifeways at Flixton Island: Integrating scientific applications for the study of ephemeral sites*. PhD Thesis, University of York.

Rowley-Conwy. P. 1998. Faunal remains and antler artefacts. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*, 99–107. Cambridge: McDonald Institute for Archaeological Research.

Rowley-Conwy, P. 2010. From Great Bog to Sedge Fen: A note on Grahame Clark's interpretation of Star Carr in its landscape context. In A. Marciniak, & J. Coles (eds.), *Grahame Clark and his Legacy,* 68–84. Newcastle upon Tyne: Cambridge Scholars.

Rozanski, K. 1991. *Report on the International Atomic Energy Agency consultants' group meeting on C-14 reference materials for radiocarbon laboratories, February 18–20, 1991, Vienna, Austria*. IAEA, Vienna: unpublished report.

Rozanski, K., Stichler, W., Gonfiantini, R., Scott, E. M., Beukens, R. P., Kromer, B. & Plicht, J. van der. 1992. The IAEA ^{14}C intercomparison exercise 1990. *Radiocarbon* 34, 506–519. DOI: https://doi.org/10.1017/S0033822200063761.

Rozanski, K., Araguás-Araguás, L. & Gonfiantini, R. 1993. Isotopic patterns in modern global precipitation. In P. K. Swart, K. C. Lohmann, J. McKenzie & S. Savin (eds.), *Climate change in continental isotopic records*, 1–36. Washington, DC: AGU Geophysical Monograph Series 78.

Rozoy, C. & Rozoy, J-G. 2004. *Les camps mesolithiques du Tillet: Analyses typologique, typometrique, structurelle et spatiale.* Paris: Société Préhistorique Française.

Rust, A. 1943. *Die alt- und mittelsteinzeitlichen Funde von Stellmoor.* Neumünster: Wachholtz.

Rysgaard, K., Rasmussen, K. F. & Riede, F. 2016. Mesolitiske bosættelser ved Gudenåsystemets søer og åer. *Kuml* 65, 55–77.

Sands, R. 1997. *Prehistoric woodworking: the analysis and interpretation of Bronze and Iron Age toolmarks.* London: Institute of Archaeology, University College London.

Sanz, C., Morgan. D. & Gulick, S. 2004. New insights into chimpanzees, tools, and termites from the Congo Basin. *The American Naturalist* 164(5), 567–81. DOI: https://doi.org/10.1086/424803.

Sarauw, G. F. L. 1903. *En stenalders boplads i Maglemose ved Mullerup: sammenholdt med beslægtede fund.* Copenhagen: H.H. Thieles Bogtrykkeri.

Savchenko, S, Lillie M. C., Zhilin, M. G., Budd, C. E. 2015. New AMS dating of bone and antler weapons from the Shigir collections housed in the Sverdlovsk Regional Museum, Urals, Russia. *Proceedings of the Prehistoric Society* 81, 265–81. DOI: https://doi.org/10.1017/ppr.2015.16.

Scarre, C. 2013. *The human past: World prehistory and the development of human societies*. London: Thames & Hudson.

Schadla-Hall, R. T. 1988. The early post-glacial in eastern Yorkshire. In T. Manby (ed.), *Archaeology in eastern Yorkshire. Essays presented to T. C. M. Brewster*, 25–34. Sheffield: J.R. Collis.

Schmölcke, U. 2016. Die Säugetierfunde vom präboreal- und borealzeitlichen Fundplatz Friesack 4 in Brandenburg-gewidmet dem Andenken an Lothar Teichert. In N. Benecke, B. Gramsch & S. Jahns (eds.), *Subsistenz und Umwelt der Feuchtbodenstation Friesack 4 im Havelland. Ergebnisse der naturwissenschaftlichen Untersuchungen.* Brandenburg: Arbeitsberichte zur Bodendenkmalpflege in Brandenburg 29.

Schoch, H., Bruns, M., Münnich, K. O. & Münnich, A. 1980. A multi-counter system for high precision carbon-14 measurements. *Radiocarbon* 22, 442–447. DOI: https://doi.org/10.1017/S0033822200009747.

Schuldt, E. 1961. *Hohen Viecheln: Ein mittelsteinzeitlicher Wohnplatz in Mecklenburg*. Berlin: Schriften der Sektion für Vor- und Frühgeschichte, Band 10. Berlin: Akademie-Verlag.

Schulting, R. 2005. '…Pursuing a rabbit in Burrington Combe': New research on the Early Mesolithic burial cave of Aveline's Hole. *Proceedings of the University of Bristol Spelaeological Society* 23(3), 171–216.

Schulting, R. & Richards, M. 2000. The use of stable isotopes in studies of subsistence and seasonality in the British Mesolithic. In R. Young (ed.), *Mesolithic lifeways: Current research from Britain and Ireland*, 55–65. Leicester: University of Leicester Press.

Schulting, R. & Richards, M. 2002a. Dogs, ducks, deer and diet: New stable isotope evidence on Early Mesolithic dogs from the Vale of Pickering, north-east England. *Journal of Archaeological Science* 29, 327–333. DOI: https://doi.org/10.1006/jasc.2002.0707.

Schulting, R. & Richards, M. 2002b. Finding the coastal Mesolithic in southwest Britain: AMS dates and stable isotope results on human remains from Caldey Island, South Wales. *Antiquity* 76(294), 1011–1025. DOI: https://doi.org/10.1017/S0003598X00091821.

Schulting, R. & Richards, M. 2009. Dogs, divers, deer and diet. Stable isotope results from Star Carr and a response to Dark. *Journal of Archaeological Science* 36, 498–503. DOI: https://doi.org/10.1016/j.jas.2008.09.035.

Schulting, R., Fibiger, L., Macphail, R., McLaughlin, R., Murray, E., Price, C. & Walker, E. A. 2013. Mesolithic and Neolithic Human Remains from Foxhole Cave, Gower, South Wales. *The Antiquaries Journal* 93, 1–23. DOI: https://doi.org/10.1017/S000358151300019X.

Schwabedissen, H. 1960. Die Ausgrabungen in Satruper Moor. *Offa* 16, 5–28.

Schwantes, G., Gripp, K. & Beyle, M. 1925. Der frühmesolithische Wohnplatz von Duvensee (vorläufiger Bericht). *Prähistorische Zeitschrift* 16, 173–177.

Schwarzel, K., Renger, M., Sauerbrey, R. & Wessolek, G. 2002. Soil characteristics of peat soils. *Journal of Plant Nutrition and Soil Science* 165, 479–486. DOI: https://doi.org/10.1002/1522-2624(200208)165:4<479::AID-JPLN479>3.0.CO;2-8.

Schweingruber, F. H. 1982. *Anatomy of European woods. 2nd edition.* Stuttgart: Paul Haupt.

Schweingruber, F. H. 1990. *Anatomy of European woods. 3rd edition.* Stuttgart: Paul Haupt.

Schwertmann, U. & Cornell, R. M. 2000. *Iron oxides in the laboratory: Preparation and characterization. 2nd edition.* Weinheim: Wiley-VCH.

Scott, A. C. 2010. Charcoal recognition, taphonomy and uses in palaeoenvironmental analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291(1), 11–39. DOI: https://doi.org/10.1016/j.palaeo.2009.12.012.

Scott, E. M. 2003. The Third International Radiocarbon Intercomparison (TIRI) and the Fourth International Radiocarbon Intercomparison (FIRI) 1990–2002: Results, analyses, and conclusions, *Radiocarbon* 45, 135–408. DOI: https://doi.org/10.1017/S0033822200032574.

Scott, E. M., Aitchison, T. C., Harkness, D. D., Cook, G. T. & Baxter, M. S. 1990. An overview of all three stages of the International Radiocarbon Intercomparison. *Radiocarbon* 32, 309–319. DOI: https://doi.org/10.1017/S0033822200012935.

Scott, E. M., Cook, G. T., Naysmith, P., Bryant, C. & O'Donnell, D. 2007. A report on phase 1 of the 5th International Radiocarbon Intercomparison (VIRI). *Radiocarbon* 49, 409–426. DOI: https://doi.org/10.1017/S003382220004234X.

Scott, E. M., Cook, G. T. & Naysmith, P. 2010a. A report on Phase 2 of the Fifth International Radiocarbon Intercomparison (VIRI). *Radiocarbon* 52, 846–858. DOI: https://doi.org/10.1017/S0033822200045938.

Scott, E. M., Cook, G. T. and Naysmith, P. 2010b. The Fifth Radiocarbon Intercomparison (VIRI): An assessment of laboratory performance in stage 3. *Radiocarbon* 52, 859–865. DOI: https://doi.org/10.1017/S003382220004594X.

Scotter, G. W. 1963. Effects of forest fires on soil properties in Northern Saskatchewan. *The Forestry Chronicle* 39(4), 412–421. DOI: https://doi.org/10.5558/tfc39412-4.

Sergant, J. Crombé, P. and Perdaen, Y. 2006. The 'invisible' hearths: a contribution to the discernment of Mesolithic non-structured surface hearths. *Journal of Archaeological Science,* 33(7), 999–1007. DOI: https://doi.org/10.1016/j.jas.2005.11.011.

Severinghaus, C. W. 1949. Tooth development and wear as a criteria of age in white-tailed deer. *The Journal of Wildlife Management* 13(2), 195–216. DOI: https://doi.org/10.2307/3796089.

Shennan, I., Bradley, S., Milne, G., Brooks, A., Bassett, S. & Hamilton, S. 2006. Relative sea-level changes, glacial isostatic modelling and ice-sheet reconstructions from the British Isles since the Last Glacial Maximum. *Journal of Quaternary Science* 21(6), 585–599. DOI: https://doi.org/10.1002/jqs.1049.

Shipman, P. 1981. Applications of scanning electron microscopy to taphonomic problems. In A. M. E. Cantwell, J. B. Griffin & N. A. Rothschild (eds.), *The research potential of anthropological museum collections*, 357–385. New York: Annals of the New York Academy of Sciences 376.

Sier, M. M., Cohen, K. M., Kooistra, L., Kubiak-Martens, L., Moree, J. M., Niekus, M., Peeters, J. H. M., Schiltmans, D. E. A., Verbaas, A., Verbruggen, F., Vos, P. C. & Zeiler, J. T. 2014. *Twenty metres deep! The Mesolithic period at the site Yangtze Harbour in the Rotterdam Maasvlakte, the Netherlands*. Early Holocene landscape development and habitation. Paper presented at XVII World UISPP Congress 2014. 1–7 September 2014. Burgos.

Silver, I. A. 1969. The aging of domestic animals. In D. Brothwell & E. S. Higgs (eds.), *Science in Archaeology*, 250–268. London: Thames and Hudson.

Skaarup, J. 1983. *Submarine stenalderbopladser I det sydfynske Øhavn.* Antikvariske Studier, 6, 137–161.

Skaarup, J. 1995. Hunting the hunters and fishers of the Mesolithic: Twenty years of research on the sea floor of Funen, Denmark. In A. Fischer (ed.), *Man and sea in the Mesolithic*, 379–401. Oxford: Oxbow Books.

Skaarup, J. & Grøn, O. 2004. *Møllegabet II. A submerged Mesolithic settlement in southern Denmark.* Oxford: British Archaeological Reports International Series S1328.

Skriver, C. & Borup, P. 2012. Fjordbundens Skatte. *Skalk* 4, 3–7.

Smith, O., Momber, G., Bates, R., Garwood, P., Fitch, S., Pallen, M., Gaffney, V. and Allaby, R. G. 2015. Sedimentary DNA from a submerged site reveals wheat in the British Isles 8000 years ago. *Science* 347(6225), 998–1001. DOI: https://doi.org/10.1126/science.1261278.

Society of Museum Archaeologists. 1993. *Selection, retention and dispersal of archaeological collections: Guidelines for use in England, Wales and Northern Ireland. 1st edition.* London: Society of Museum Archaeologists.

Sørensen, S. A. 1987. A Maglemosian hut at Lavringe Mose, Zealand. *Journal of Danish Archaeology* 6(1), 53–62. DOI: https://doi.org/10.1080/0108464X.1987.10589976.

Sørensen, S. A. 2017. Denmark's largest Stone Age excavation. *Mesolithic Miscellany* 24(2), 3–10.

Southwood, T. R. E. & Leston, D. 1959. *Land and water bugs of the British Isles.* London: Warne.

Speth, J. D. 2010. *The paleoanthropology and archaeology of big-game hunting: Protein, fat, or politics?* New York: Springer.

Spurk, M., Friedrich, M., Hofmann, J., Remmele, S., Frenzel, B., Leuschner, H. H. & Kromer, B. 1998. Revisions and extension of the Hohenheim oak and pine chronologies: New evidence about the timing of the Younger Dryas/Preboreal transition. *Radiocarbon* 40(3), 1107–1116. DOI: https://doi.org/10.1017/S0033822200019159.

Stace, C. 2010. *New flora of the British Isles. 3rd edition.* Cambridge: Cambridge University Press.

Stanford, G. 1947. *Potassium fixation in soils as affected by type of clay mineral, moisture conditions, and concentration of other ions*. PhD, Iowa State College.

Steinbergs, A., Iismaa, O., Freney, J. R. & Barrow, N. J. 1962. Determination of total sulphur in soil and plant material. *Analytical Chimica Acta* 27, 158–164. DOI: https://doi.org/10.1016/S0003-2670(00)88469-X.

Stevens, R. E. & Hedges, R. E. M. 2004. Carbon and nitrogen stable isotope analysis of northwest European horse bone and tooth collagen, 40,000 BP-present: Palaeoclimatic interpretations. *Quaternary Science Reviews* 23, 977–991. DOI: https://doi.org/10.1016/j.quascirev.2003.06.024.

Stevens, R. E., Lister, A. M. & Hedges, R. E. M. 2006. Predicting diet, trophic level and palaeoecology from bone stable isotope analysis: A comparative study of five red deer populations. *Oecologia* 149, 12–21. DOI: https://doi.org/10.1007/s00442-006-0416-1.

Stewart, H. 1984. *Cedar: Tree of life to the Northwest Coast Indians.* Seattle: University of Washington Press.

Stonehouse, W. P. B. 1992. Two Early Mesolithic sites in the Central Pennines. *Yorkshire Archaeological Journal* 64, 1–15.

Stoops, G. 2003. *Guidelines for analysis and description of soil and regolith thin sections. Madison.* Wisconsin: Soil Science Society of America.

Strachey, W. 1953. *The historie of travaile into Virginia Britania (1612).* London: The Hakluyt Society.

Street, M. 1991. Bedburg-Königshoven: a Pre-Boreal Mesolithic site in the Lower Rhineland, Germany. In N. Barton, A. J. Roberts & D. A. Roe (eds.), *The Late Glacial in north-west Europe: human adaptation and environmental change at the end of the Pleistocene*, 256–270. London: Council for British Archaeology Research Report.

Street, M. J. 1993. *Analysis of Late Palaeolithic and Mesolithic faunal assemblages in the northern Rhineland, Germany.* PhD, University of Birmingham.

Street, M. & Wild, M. 2015. Technological aspects of two Mesolithic red deer "antler frontlets" from the German Rhineland. In N. Ashton & C. Harris (eds.), *No stone unturned: Papers in honour of Roger Jacobi*, 209–221. London: British Museum.

Stuiver, M. & Polach, H. A. 1977. Reporting of 14C data. *Radiocarbon* 19, 355–363. DOI: https://doi.org/10.1017/S0033822200003672.

Stuiver, M. & Reimer, P. J. 1993. Extended 14C database and revised CALIB 3.0 14C age calibration program. *Radiocarbon* 35, 215–230. DOI: https://doi.org/10.1017/S0033822200013904.

Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, F. G., Plicht, J. van der & Spurk, M. 1998. INTCAL98 radiocarbon age calibration, 24,000–0 cal BP. *Radiocarbon* 40, 1041–1084. DOI: https://doi.org/10.1017/S0033822200019123.

Svensson, L., Mullarney, K., Zetterstrom, D. & Grant, P. J. 2008. *Collins bird guide: The most complete guide to the birds of Britain and Europe. 2nd edition.* New York: HarperCollins Publishers Ltd.

Taborin, Y. 2004. *Language sans parole: La parure aux temps Préhistoriques*. Paris: La Maison des Roches.

Tauber, H. 1971. Danske kulstof-14 dateringer af arkæologiske prøver III. *Aarbøger for Nordisk Oldkyndighed og Historie* 1970, 120–42.

Taylor, B. 2007. Recent excavations at Star Carr, North Yorkshire. *Mesolithic Miscellany* 18(2), 12–17, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtZXNvbGl0aGljbWlzY2VsbGFueExxneDo2Y2JjYmYzYWIxMDc2YzA5 [Last accessed 15 September 2017].

Taylor, B. 2012. *The occupation of wetland landscapes during the British Mesolithic: Case studies from the Vale of Pickering.* PhD, University of Manchester.

Taylor, B. & Gray-Jones, A. 2009. Definitely a pit, possibly a house? Recent excavations at Flixton School House Farm in the Vale of Pickering. *Mesolithic Miscellany* 20(2), 21–6, https://docs.google.com/viewer?a=

v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtZXNvbGl0aGljbWlzY2VsbGFueXxneDo3MjVmODc5NmI5ZjY0OTFg1 [Last accessed 15 September 2017].

Taylor, B., Elliott, B., Conneller, C., Milner, N., Bayliss, A., Knight, B. & Bamforth, M. 2017. Resolving the Issue of Artefact Deposition at Star Carr. *Proceedings of the Prehistoric Society* 83, 23–42. DOI: https://doi.org/10.1017/ppr.2017.8.

Taylor, M. 1998a. Wood and bark from the enclosure ditch. In F. M. M. Pryor (ed.), *Etton: excavations at a Neolithic causewayed enclosure near Maxey, Cambridgeshire, 1982–87*, 115–159. London: English Heritage Archaeological Reports 18.

Taylor, M. 1998b. Identification of the wood and evidence for human working. In P. Mellars & P. Dark (eds.), *Star Carr in context: New archaeological and palaeoecological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*, 52–63. Cambridge: McDonald Institute for Archaeological Research.

Taylor, M. 2001. The wood. In F. M. M. Pryor (ed.), *The Flag Fen basin: Archaeology and environment of a fenland landscape*, 167–228. London: English Heritage Archaeological Reports.

Taylor, M. 2010. Big trees and monumental timbers. In F. M. M. Pryor & M. Bamforth (eds.), *Flag Fen, Peterborough: Excavation and research 1995–2007*, 90–97. Oxford: Oxbow.

Taylor, M. 2011. Waterlogged wood. In G. Momber, D. Tomalin, R. Scaife, J. Satchell & J. Gillespie (eds.), *Mesolithic occupation at Bouldnor Cliff and the submerged prehistoric landscapes of the Solent*, 85–89. York: Council of British Archaeology Research Report 164.

Taylor, M. & Bamforth, M. 2013. *Waterlogged wood analysis report, Carlisle northern development road, Carlisle*. Unpublished archive report 2012_61_WFR.

Taylor, M. & Bradley, P. 2007. Woodworking at the longbarrow. In J. Harding & F. Healy (eds.), *The Raunds Area Project: A Neolithic and Bronze Age landscape in Northamptonshire*, 80–81. London: English Heritage.

Tesch, F. W. 2003. *The eel.* Oxford: Blackwell Publishing.

Théry-Parisot, I., Chabal, L. & Chrzavzez, J. 2010. Anthracology and taphonomy, from wood gathering to charcoal analysis. A review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291(1), 142–153. DOI: https://doi.org/10.1016/j.palaeo.2009.09.016.

Thomassen, B. 2014. *Liminality and the Modern. Living Through the In-Between,* Farnham: Ashgate.

Thompson, D. F. 1964. Some wood and stone implements of the Bindibu tribe of Central Western Australia. *Proceedings of the Prehistoric Society* 30, 400–422. DOI: https://doi.org/10.1017/S0079497X00015188.

Tolan-Smith, C. & Bonsall, C. 1999. Stone age studies in the British Isles: The impact of accelerator dating. *Mémoires de la Société préhistorique française* 26, 249–257.

Tringham, R., Cooper, G., Odell, G., Voytek, B. & Whitman, A. 1974. Experimentation in the formation of edge damage: A new approach to lithic analysis. *Journal of Field Archaeology* 1, 171–196. DOI: https://doi.org/10.1179/jfa.1974.1.1-2.171.

Troels-Smith J. 1955. Karakterisering af løsejordater (Characterisation of unconsolidated sediments) *Danmarks Geologiske Undersøgelse, Series IV*, 3, 73.

Troels-Smith, J. 1960. En elmetræs-bue fra Aamosen og andre træsager fra tidlig-neolitisk tid. En foreløbig meddelelse. *Aarbøger for Nordisk Oldkyndighed og Historie* 1959, 91–145.

Troels-Smith, J. & Fischer, A. 1992. En gravestok fra bosættelsesområde IIa. In A. Fischer (ed.), *Stenalderbopladser ved Lindholm i Nyborg Fjord*, 64–69. Hørsholm: Miljøministeriet, Skov- og Naturstyrelsen.

Tsartsidou, G., Lev-Yadun, S., Efstratiou, N. & Weiner, S. 2009. Use of space in a Neolithic village in Greece (Makri): Phytolith analysis and comparison of phytolith assemblages from an ethnographic setting in the same area. *Journal of Archaeological Science* 36(10), 2342–2352. DOI: https://doi.org/10.1016/j.jas.2009.06.017.

Turner, N. J. 1998. *Plant technology of first peoples in British Columbia. 2nd edition.* Vancouver: UBC Press.

Turner, N. J. 2004. *Plants of Haida Gwaii: Xaadaa Gwaay gud gina k̓aws (Skidegate); Xaadaa Gwaayee guu giin k̓aws (Massett).* British Columbia: Sono NIS Press.

Turner, N. J., Thompson, L. C., Thompson, M. T. & York, A. Z. 1990. *Thompson ethnobotany: Knowledge and usage of plants by the Thompson Indians of British Columbia.* Victoria: Royal British Columbia Museum.

Turner-Walker, G. 2009. Degradation pathways and conservation strategies for ancient bone from wet anoxic sites. In H. D. J. Huisman & K. Strætkvern (eds.), *Proceedings of the 10th Triennial Meeting of the ICOM-CC*

Working Group for Wet Organic Archaeological Materials, 659–675. Lyngby: Department of Conservation, National Museum of Denmark.

Tusenius, M. 1986. *The study of charcoal from some southern African archaeological contexts.* Master's dissertation, University of Stellenbosch.

Uchiyama, J., Clutton-Brock, J. & Rowley-Conwy, P. Forthcoming. The faunal remains from Seamer Carr. In P. Lane & R. T. Schadla-Hall (eds.), *Hunter-gatherers in the landscape: Investigations of the Early Mesolithic in the Vale of Pickering, North Yorkshire. 1976–2000.*

Usher, G. 1974. *A dictionary of plants used by man.* London: Constable.

Vahur, S., Kriiska, A. & Leito, I. 2011. Investigation of the adhesive residue on the flint insert and the adhesive lump found from the Pulli Early Mesolithic settlement site (Estonia) by Micro-ATR-FT-IR Spectroscopy. *Estonian Journal of Archaeology* 15(1), 3–17. DOI: https://doi.org/10.3176/arch.2011.1.01.

Van der Merwe, N. J. & Medina, E. 1991. The canopy effect, carbon isotope ratios and foodwebs in Amazonia. *Journal of Archaeological Science* 18, 249–259. DOI: https://doi.org/10.1016/0305-4403(91)90064-V.

Van de Noort, R., Ellis, S., Taylor, M. & Weir, D. 1995. Preservation of archaeological sites. In R. van de Noort & S. Ellis (eds.), *Wetland heritage of Holderness – an archaeological survey. 1st edition.* Kingston-upon-Hull: Humber Wetlands Project.

van Gijn, A. 1990. *The wear and tear of flint: Principles of functional analysis applied to Dutch Neolithic assemblages.* Leiden: Analecta praehistorica Leidensia.

van Gijn, A. 2007. The use of bone and antler tools: Two examples from the Late Mesolithic in the Dutch Coastal Zone. In C. Gates St-Pierre and R. Walker (eds.), *Bones as tools: Current methods and interpretations in worked bone studies*, 79–90. Oxford: British Archaeological Reports International Series 1622.

van Gijn, A. & Little, A. 2016. Tools, use-wear and experimentation: Extracting plants from stone and bone. In K. Hardy & L. Kubiak-Martens (eds.), *Wild harvest: Plants and people in the pre-agricultural and non-agricultural world*, 135–53. Oxford: Oxbow Books.

Vankina, L. V. 1970. *Torfianikovaia stoianika Sarnate.* Riga: Zinatne.

van Klinken, G. J. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26, 687–695. DOI: https://doi.org/10.1006/jasc.1998.0385.

Vitebsky, P. 2006. *The reindeer people: Living with animals and spirits in Siberia.* Boston: Houghton Mifflin.

Vogt, E. 1949. The birch as a source of raw material during the Stone Age. *Proceedings of the Prehistoric Society* 15, 50–51. DOI: https://doi.org/10.1017/S0079497X00019186.

von den Driesch, A. 1976. *A guide to the measurement of animal bones from archaeological sites.* Harvard: Peabody Museum of Archaeology and Ethnology.

Voruz, J. 1984. *Outillage osseux et dynamisme industriel dans le Néolithique jurassien.* Lausanne: Bibliothèque Historique Vaudoise.

Vyncke, K., Degryse, P., Vassilieva, E. & Waelkens, M. 2011. Identifying domestic functional areas. Chemical analysis of floor sediments at the Classical-Hellenistic settlement at Düzen Tepe (SW Turkey). *Journal of Archaeological Science* 38(9), 2274–2292. DOI: https://doi.org/10.1016/j.jas.2011.03.034.

Waddington, C. (ed.). 2007. *Mesolithic settlement in the North Sea basin: A case study from Howick, north-east England.* Oxford: Oxbow Books.

Walker, D. & Godwin, H. 1954. Lake stratigraphy, pollen-analysis and vegetational history. In. J. G. D. Clark (ed.), *Excavations at Star Carr*, 25–69. Cambridge: Cambridge University Press.

Walker, I. R. & Cwynar, L. C. 2006. Midges and palaeotemperature reconstruction – the North American experience. *Quaternary Science Reviews* 25, 1911–1925. DOI: https://doi.org/10.1016/j.quascirev.2006.01.014.

Ward, G. K. & Wilson, S. R. 1978. Procedures for comparing and combining radiocarbon age determinations: a critique. *Archaeometry* 20, 19–31. DOI: https://doi.org/10.1111/j.1475-4754.1978.tb00208.x.

Warren, G. 2003. Life in the trees: Mesolithic people and the woods of Ireland. *Archaeology Ireland* 17(3), 20–23.

Warren, G. 2006. Technology. In G. Warren & C. Conneller (eds.), *Mesolithic Britain and Ireland*, 13–33. Stroud: Tempus.

Warren, G., Davis, S., McClatchie, M. & Sands, R. 2014. The potential role of humans in structuring the wooded landscapes of Mesolithic Ireland: A review of data and discussion of approaches. *Vegetation History and Archaeobotany* 23(5), 629–646. DOI: https://doi.org/10.1007/s00334-013-0417-z.

Weems, J. B. 1903. Chemistry of clays. *Iowa Geological Survey Annual Report* 14, 319–346.

Weiner, S. 2010. *Microarchaeology: Beyond the visible archaeological record.* New York: Cambridge University Press.

Wentink, K. 2006. *Ceci n'est pas une hache. Neolithic depositions in the Northern Netherlands.* Leiden: Leiden University.

Westerby, E. 1927. *Stenalderbopladser ved Klampenborg. Nogle bidrag til studiet af den Mesolitiske periode.* Copenhagen: H. H. Thieles Bogtrykkeri.

Wetmore, R. 1975. *First on the land: the North Carolina Indians.* Winston-Salem: John Blair.

Wheeler, A. 1978. Why were there no fish remains at Star Carr? *Journal of Archaeological Science* 5(1), 85–89. DOI: https://doi.org/10.1016/0305-4403(78)90020-1.

White, R. 1997. Substantial acts: From materials to meaning in Upper Palaeolithic representations. In M. Conkey, O. Soffer, D. Stratmann & N. Jablonski (eds.), *Beyond art: Pleistocene image and symbol.* 93-123San Francisco: California Academy of Sciences.

Whittle, A., Healy, F. & Bayliss, A. 2011. *Gathering time: Dating the early Neolithic enclosures of southern Britain and Ireland.* Oxford: Oxbow Books.

Wickham-Jones, C. R., Clarke, P. A. and Barlow, A. 1986. A Project in Experimental Archaeology: Avasjo 1982. *Review of Scottish Culture*, 2, 97–104.

Wild, M. 2014. *Funktionelle Analyse an zwei perforierten Hirschschädeln vom frühmesolithischen Fundplatz Bedburg-Königshoven.* Mainz: Johannes Gutenberg-Universität Mainz.

Williams, J., Fell, V., Graham, K., Simpson, P., Collins, M., Koon, H. & Griffin, R. 2006. Re-watering of the Iron Age causeway at Fiskerton, England. In H. Karrs & R. M. van Heeringen (eds.), *Preserving archaeological remains in situ: Proceedings of the 3rd conference, 7–9 December 2006*, 181–198. Amsterdam: Institute for Geo and Bioarchaeology, VU University.

Willis, E. H., Tauber, H. & Münnich, K. O. 1960. Variations in the atmospheric radiocarbon concentration over the past 1300 years. *Radiocarbon* 2, 1–4. DOI: https://doi.org/10.1017/S1061592X00020548.

Wilson, C. A., Cresser, M. S. & Davidson, D. A. 2008. Multi-element soil analysis: An assessment of its potential as an aid to archaeological interpretation. *Journal of Archaeological Science* 35, 412–24. DOI: https://doi.org/10.1016/j.jas.2007.04.00.

Wilson, M., Stewart, A., Biedermann, R., Nickel, H. & Niedringhaus, R. 2015. *The planthoppers and leafhoppers of Britain and Ireland. Identification keys to all families and genera and all British and Irish species not recorded from Germany. Cicadina, Supplement 2.* Scheeßel: WABV.

Witsen, N. & Boddaert, P. 1705. Noord en oost Tartaryen: Behelzende eene beschryving van verscheidene Tartersche en Nabuurige gewesten in de noorder en oostelykste deelen van Azien en Europa. Amsterdam: M. Schalekamp.

Wohler-Geske, A., Moschner, C., Gellerich, A., Militz, H., Greef, J. & Hartung, E. 2016. Provenances and properties of thatching reed (*Phragmites australis*). *Landbauforschung Volkenrode* 66, 1–10. DOI: https://doi.org/10.3220/LBF1457686750000.

Wood, C. J. & Smith, E. G. 1978. Lithostratigraphical classification of the chalk in North Yorkshire, Humberside and Lincolnshire. *Proceedings of the Yorkshire Geological Society* 42, 263–287. DOI: https://doi.org/10.1144/pygs.42.2.263.

Wood, T. 2001. Bryozoans. In J. Thorpe & A. Covich (eds.), *Ecology and classification of North American freshwater invertebrates. 2nd edition*, 505–523. London: Elsevier.

Wylie, A. 2002. *Thinking with things: Essays in the philosophy of archaeology.* Berkeley, Los Angeles: University of California Press.

Wymer, J. 1962. Excavations at the Maglemosian sites at Thatcham, Berkshire, England. *Proceedings of the Prehistoric Society* 28, 329–361. DOI: https://doi.org/10.1017/S0079497X00015759.

Wymer, J., Jacobi, R. & Rose, J. 1975. Late Devensian and Early Flandrian barbed points from Sproughton, Suffolk. *Proceedings of the Prehistoric Society* 41, 235–241. DOI: https://doi.org/10.1017/S0079497X00011014.

Zabilska-Kunek, M. 2014. *Środowiskowe i kulturowe uwarunkowania rybołówstwa ludów wybrzeży Bałtyku w V-IV tysiącleciu przed Chrystusem na przykładzie osady w Dąbkach, stan. 9 (gm. Darłowo).* Rzeszów: Collectio Archaeologica Ressoviensis XXXII, Fundacja Rzeszowskiego Ośrodka Archeologicznego, Instytut Archeologii Uniwersytetu Rzeszowskiego.

Zabilska-Kunek, M., Makowiecki, D. & Kabaciński, J. 2015. Mesolithic fishery in the Polish Lowland. Fish remains from the Site 7 at Krzyż Wielkopolski, Poland. *Environmental Archaeology.* DOI: https://doi.org/10.1179/1749631415Y.0000000015.

Zhang, J., Lu, H., Sun, G., Flad, R., Wu, N., Huan, X., He, K. & Wang, Y. 2016. Phytoliths reveal the earliest fine reedy textile in China at the Tianluoshan site. *Scientific Reports* 6, 18664. DOI: https://doi.org/10.1038/srep18664.

Zhao, Y., Sayer, C. D., Birks, H. H., Hughes, M. & Peglar, S. M. 2006. Spatial representation of aquatic vegetation by macrofossils and pollen in a small and shallow lake. *Journal of Palaeolimnology* 35, 335–350. DOI: https://doi.org/10.1007/s10933-005-1336-5.

Zhilin, M. G. 1997. Artifacts made of animals' teeth and jaws in the Mesolithic of Eastern Europe. In M. Pearce & M. Tosi (eds.), *Papers from the European Association of Archaeologists Third Annual Meeting at Ravenna, Volume I: Pre- and protohistory*, 26–31. Ravenna: British Archaeological Reports 717, 1998.

Zvelebil, M. 1993. Concepts of time and presencing the Mesolithic. *Archaeological Review from Cambridge* 12(2), 51–70.

Zylawyj, S. 1986. Palaeostream bed study. [Microfiche]. In D. Powlesland (ed.), *Excavations at Heslerton, North Yorkshire 1978-82. The Archaeological Journal 143*, M2/11–17.

Index

Star Carr is one of the most important Mesolithic sites in Europe. It was discovered in the late 1940s by John Moore and then excavated by Grahame Clark from 1949-1951, becoming famous in the archaeological world for the wealth of rare organic remains uncovered including barbed antler points and antler headdresses. However, since the original excavations there has been much debate about how the site was used: was it a residential base camp, a hunting camp or even a ritual site?

From 2003-2015, excavations directed by Conneller, Milner and Taylor aimed to answer these questions. This work has demonstrated that the site is much larger and more complex than ever imagined and was in use for around 800 years. The excavations show that Mesolithic groups were highly invested in this place: there is evidence for a number of structures on the dryland (the oldest evidence for 'houses' in Britain), three large wooden platforms along the edge of the lake, and the deposition of rare artefacts into the lake edge, including more antler headdresses and a unique, engraved shale pendant. People continued to occupy the site despite changes in climate over this period. The main results of our work are contained in two volumes: the first provides an interpretation of the site, and the second provides detail on specific areas of research.

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